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Sustainability of Bean-Producing Farms in Municipalities of Granma Province

Luis Jesús Escalona Cruz[1], Licet Chávez Suárez[2], Rosa Isabel Zamora Torres[3], Bismar Tamayo Fuentes[4], Raulienkis Rojas Guerra[5], Yeilin Pompa Sutil[6], Aylín María Soler Castellanos[7] & Alexander Álvarez Fonseca[8]

[1]ORCID https://orcid.org/0000-0003-2796-1437, The Jorge Dimitrov Agricultural Research Institute, Research and Environmental Division, Bayamo, Granma, Cuba, [2]ORCID https://orcid.org/0000-0002-7837-2168, The Jorge Dimitrov Agricultural Research Institute, Research and Environmental Division, Bayamo, Granma, Cuba, [3]ORCID https://orcid.org/0000-0001-9523-5395, The Jorge Dimitrov Agricultural Research Institute, Research and Environmental Division, Bayamo, Bayamo, Granma, Cuba, [4]ORCID https://orcid.org/0009-0001-9458-8137, The Jorge Dimitrov Agricultural Research Institute, Research and Environmental Division, Bayamo, Granma, Cuba, [5]ORCID https://orcid.org/0000-0002-2640-0067, The Jorge Dimitrov Agricultural Research Institute, Research and Environmental Division, Bayamo, Granma, Cuba, [6]ORCID https://orcid.org/0009-0003-2262-5669, The Jorge Dimitrov Agricultural Research Institute, Research and Environmental Division, Bayamo, Granma, Cuba, [7]ORCID https://orcid.org/0000-0002-5615-7192, The Jorge Dimitrov Agricultural Research Institute, Research and Environmental Division, Bayamo, Granma, Cuba, [8]ORCID https://orcid.org/0000-0002-5218-445X, The Jorge Dimitrov Agricultural Research Institute, Research and Environmental Division, Bayamo, Granma, Cuba.

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Contributor’s email: ljescalonac1968@gmail.com

Abstract

Context: In bean cultivation, effective sustainable practices must be implemented, such as the efficient use of external inputs, agroecological practices, and soil management and conservation, accompanied by the consolidation of value chains where better management skills are observed.
Aim: The purpose of the research was to evaluate the sustainability of farms dedicated to bean production in municipalities of the Granma Province.
Methods: The research was based on the principles of Participatory Action Research, based on the integration of multicriteria analysis methods and tools for the study and evaluation of sustainability. To obtain the necessary information and analyze the dimensions (economic, ecological, and sociocultural), exploratory tours and informal interviews, observations and measurements were combined, and adaptation was done. Subsequently, the value of each index (ecological, economic, and social) and the General Sustainability Index (GSI) were calculated.
Results: In the ecological dimension, 5 farms presented an index higher than 0.7; the farms "La América" and "El Porvenir" showed lower indices. Similar results were observed in the economic dimension, with the greatest difficulties in indicators related to the use, generation, and maximum utilization of the system's energy. In the social dimension, all farms were above the sustainability threshold of 0.5. The GSI corresponds to the ecological, economic, and social dimensions of the analyzed farms.
Conclusions: The evaluated sustainability indicators show more favorable values in farms that implement a greater number of agroecological practices and knowledge that impact bean production. The farm "La Victoria" presents the highest GSI due to the implemented agroecological activities, better soil management and conservation, energy production and use, and scientific discussions.

Keywords: *Agroecology, general sustainability index, farm, agriculture.*

Introduction

The human right to food and food security, amidst a context of economic, environmental, and energy crisis, implies the need to subject conventional agricultural systems to profound transformations through the application of agriculture with an ecosystem approach, capable of sustainably increasing productivity and resilience (FAO/OCDE, 2019).

In such a situation, agroecology is considered a necessary practice that reorients agricultural systems towards greater productivity and sustainability, and guarantees the resilience of agroecosystems to climate change (Mier et al., 2018; Altieri & Nicholls, 2020a).

In the case of Cuba, sustainable practices are essential to respond to new demands and comprehensive food sovereignty. In particular, good practices are required in grain production since beans (*Phaseolus vulgaris*), along with rice and tubers, constitute a preferred food in the daily diet and are one of the basic protein elements that form it (Pacheco et al., 2016).

In beans, climate change adaptation policies are an important element in designing a policy of productive transformation through value chains. Additionally, there is a need for increased agricultural yields, the introduction of new varieties with higher productive potential and better seasonal distribution, reduction of post-harvest losses, a better focus on demand, aspects related to nutrition, and scientific-technical services to extend the results of science and innovation (García & Anaya, 2020).

The ultimate goal is the development of resilient farms capable of facing any kind of change—climatic, market, or political—and creatively absorbing the transformation without losing their identity (Casimiro, 2016; Molina et al., 2017).

Globally, various tools have been employed to conduct research that translates to the sustainable development of agricultural systems. Currently, participatory techniques have been adopted, aimed at transforming agroecosystems from a holistic socio-economic and agroecological perspective, considering community participation as the protagonist of the development process (Silva & Ramírez, 2017; Vázquez & Chia, 2020; Nicholls & Altieri, 2021). In practice, these studies cover diverse lines that relate aspects such as equity, independence from external inputs, technological alternatives, productivity, profitability, and economic stability; with environmental aspects such as diversity and the impact of techniques on the environment (Altieri & Nicholls, 2020b; Bjørn et al., 2020; Bezner et al., 2022; Maldonado et al., 2023).

The aim of this paper was to evaluate the sustainability of farms dedicated to bean production in municipalities of the Granma Province.

Materials and methods

The research was conducted in 7 agricultural systems identified by the same number of farms, located in 4 municipalities of the Granma Province: Jiguaní, Bayamo, Bartolomé Masó, and Guisa (Table 1).

Table 1. Agricultural systems involved in the evaluation of sustainability

Farm Name	CCS	Municipality	Coordinates	
			Latitude	Longitude
1. El Porvenir	William Soler	Jiguaní	20.336512	76.414630
2. La Dichosa	Anselmo Aldana	Bayamo	20.360113	76.666996
3. San Nicolás	Ignacio Pérez	Bayamo	20.320858	76.583942
4. Matos	José Martí	Bayamo	20.290591	76.794957
5. Tierra Honda	Vicente Pérez	Bartolomé Masó	20.183332	76.910608
6. La América	Vicente Pérez	Bartolomé Masó	20.179420	76.914296
7. La Victoria	Braulio Curuneaux	Guisa	20.264819	76.530955

The municipalities where the study was conducted are affected by climate change. Precipitations take place at a late stage, causing drought and facilitating the occurrence of forest fires, increasing anthropogenic activity and temperatures, with less or more abundant rain outside their season, resulting in significant modifications to local flora and fauna.

All farmers involved were asked for their consent to participate in the research and were informed about the importance of the information they could provide for the development of the study.

The work methodology was based on the principles of Participatory Action Research (PAR) and designed by integrating multicriteria analysis methods and tools for studying and evaluating sustainability, as proposed by Masera & López (2000); Sepúlveda (2002); Albicette et al. (2009).

To obtain the necessary information and analyze each farm in its dimensions (economic, ecological, and sociocultural), various tools were combined such as exploratory tours and informal interviews, observations and measurements, and adaptation, according to the experience acquired in the Local Agricultural Innovation Program (PIAL) project, a pre-designed questionnaire proposed by Leyva et al.

(1999) and used by Silva & Ramírez (2017), where key aspects of bean cultivation were also considered.

Indicators composed of different variables associated with the dimensions of sustainability were applied.

Given that the selected variables have different units of measurement (percentages, monetary values, indices, qualitative data), which do not allow direct comparison between them, a standardized scale (value judgment) was constructed to represent the value they have in relation to the desirable situation, defining maximum and minimum conditions and taking into account the main characteristics and particularities of the area. This scale, like the questionnaire, was adapted according to the experience gathered in the PIAL project. A 1-10 scoring was assigned, relating to sustainability levels for each variable. The standardized scale allowed organizing all information and converting different values into a homogeneous value. The numerical value of the variables was assigned through an interactive process with the participation of the facilitators and stakeholders involved in the research. The value of the variables corresponds to the value judgment assigned in the value scale.

The value of sustainability indicators was calculated through the sum of the variables that make up each indicator:

$$\boldsymbol{VI} = \frac{\sum_{1}^{S}(\boldsymbol{VV})}{\boldsymbol{S}}$$

Where S is the number of variables that make up each indicator.

For proper calculation of the VI value, it must be between 0 and 1; a value equal to 1 is the most desired and will indicate the sustainability of the indicator.

The value of each index (ecological, economic, and social) and the General Sustainability Index (GSI) of the studied agricultural systems was calculated using the formula:

$$\boldsymbol{GSI} = \frac{\sum_{1}^{n}(\boldsymbol{VI})}{\boldsymbol{VMI} * \boldsymbol{N}}$$

Rating scale of indicators

Range	Quantitative Assessment	Level of Sustainability
0 - 0.29	Very bad state	Unsustainable
0.3 - 0.49	Bad state	Potentially unsustainable
0.5 - 0.69	Average state	Moderately sustainable
0.7 - 0.89	Good state	Partially sustainable
0.9 - 1	Very good state	Sustainable

All data obtained were processed and analyzed using Excel software (2010).

Results and discussion

The farms showed particularities in sustainability indicators.

Overall, 62.5% of the people in the studied agroecosystems are within the working age range (18-65 years) and represent the actors who most significantly influence productive processes. This data indicated a high availability of human resources, considering that 56.25% work on the farms, 37.5% full-time and 18.75% part-time. It was observed that 37.0% of the women participate in agro-productive activities and decision-making on the farms. Some 85.7% of the producers hired labor, 66.6% permanently and the rest during periods of need such as planting and harvesting.

Meanwhile, 57.1% demonstrated a high level of knowledge about agroecology, corresponding with their innovative capacity and experimentation, as well as the level of socialization and knowledge exchange in territorial workshops and national and international events.

Moreover, 100% of the farm areas have water available for irrigation, though only 85.7% have irrigation systems. Additionally, in 42.8% of them, competition between human consumption and agricultural irrigation was observed, which intensified in the last dry period where the water level in wells was low.

There are differences among farms in terms of total area, temporary crop area, permanent crop area, grazing area, forestry area, and predominant soil type (Table 2).

Table 2. Distribution, use of total area and predominant soil type of the farms

Land Use (ha)	Farms						
	El Porvenir, Jiguaní	La Dichosa, Bayamo	San Nicolás, Bayamo	Matos, Bayamo	Tierra Honda, B. Maso	La América, B. Maso	La Victoria, Guisa
Total area	9.52	3	2.96	35.6	36	3	2.44
Temporary Crops	4.5	2.3	2.89	10.2	23	1.5	1.2
Permanent Crops	1.7	0.4	0	0	1.25	0	0.25
Family Garden	0.12	0	0	0.4	0.5	0	
Grazing	0	0.2	0	22	10	0	
Forestry	3	0	0	1	1	0	0.25
Cultivable fallow areas	0	0	0	0	0	0	
Non-cultivable fallow areas	0	0	0	0	0	1.47	0.44
Home and Surroundings	0.2	0.1	0.07	2	0.25	0.03	0.3
Type of soil:	Brown	Brown	Fersialitic	Brown and fluvisols	Brown	Fluvisols	Brown

Four farms, 57.1%, have three or fewer hectares. Only three farms, 42.8%, combined cropping and livestock production; two of them, with the largest areas, have sufficient grazing area. This is beneficial as it allows for better use of the productive area and establishes better integration among the different species present. This allows for better use of available resources and nutrient recycling, which in turn improves economic efficiency.

According to Bover & Suárez (2020), the development of integrated agriculture-livestock systems generates synergies that enhance the productive capacities of these systems, besides reducing vulnerability to agricultural pests, decreasing dependence on external inputs and capital requirements, and increasing land use efficiency.

In most areas, 71.4%, brown soils prevailed, with one farm presenting fersialitic soils and another fluvisols according to Hernández et al. (2015). Furthermore, 85.7% of the farms have flat topography with good productivity and no limitations for crops.

The crops managed by farmers differed from one farm to another, influenced by the specific characteristics of each agroecosystem, the specialization, and their preferences (Fig. 1). 1). The most common crops among them are directly related to local dietary customs and income generation.

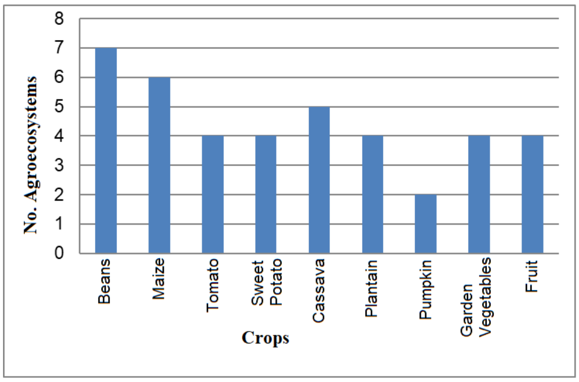

Fig. 1. Farmer-managed crops

The ecological dimension differed among the farms. A total of 5 farms had an index higher than 0.7: La Dichosa, San Nicolás, and Matos in Bayamo; Tierra Honda in Bartolomé Maso; and La Victoria in Guisa. In El Porvenir, Jiguaní, the index was 0.59, and in La América, in the municipality of Bartolomé Maso, it was 0.48.

Five farms (71.4%) were involved in research and innovation projects: La Dichosa, San Nicolás, and Matos in Bayamo; Tierra Honda in Bartolomé Maso; and La Victoria in Guisa. Particularly, the farms in Bayamo and Guisa municipalities were trusted samples of the Local Agricultural Innovation Project (PIAL) and have systematized important results.

Biological diversity varies among the studied farms depending on the number of species and individuals of crops and animals managed (Table 3).

Table 3. Biological diversity of farms in four municipalities of the Granma province

Farm Name	Municipality	Number of Species	
		Crops	Animals
El Porvenir	Jiguaní	7	3
La Dichosa	Bayamo	11	6
San Nicolás	Bayamo	10	3
Matos	Bayamo	14	7
Tierra Honda	B. Masó	12	4
La América	B. Masó	4	-
La Victoria	Guisa	9	6

In the managed crops, short-cycle species like grains prevailed. Beans (*Phaseolus vulgaris* and *Vigna* spp.) were present in 100% of the farms, followed by corn (*Zea mays*) in 85.7%. Among tubers, cassava (*Manihot esculenta*) stood out in 71.4%, followed by sweet potatoes (*Ipomoea batatas*) and plantains (*Musa* spp.) with 57.1% each. Furthermore, 71.4% of the farms planted tomatoes (*Solanum lycopersicum*) and other vegetables.

One farm, La América, did not manage animal production. In the remaining farms, the managed animal species included cattle (*Bos taurus*) and chickens, roosters, and chicks (*Gallus gallus domesticus*) in all farms, followed by pigs (*Sus scrofa domestica*) in 85.7%. Then came sheep (*Ovis aries*) in 71.4% and Creole and Pekin ducks (*Cairina moschata* and *Anas platyrhynchos domesticus*) in 42.8%. In two farms

Only three farms (42.8%) combined agricultural and livestock production. Two of them, with the largest areas (Matos and Tierra Honda), had sufficient grazing area, which is beneficial as it allows for better utilization of productive area and integration among different species.

Fig. 2. Satellite view of the Tierra Honda farm in Bartolomé Maso Source: Google maps.

This enables better use of available resources and nutrient recycling, improving economic efficiency.

According to Funes (2015), the development of integrated agriculture-livestock systems balances the energy benefits from animal and plant production, achieving greater efficiency and productivity, meeting the nutritional, existential, and functional needs of humans. Casimiro et al. (2020) noted the importance of farm economies sustaining a variety of options to be less vulnerable to external shocks, whether climatic or market-related.

The most frequently used agroecological practices included animal traction, application of organic fertilizers, mainly compost and cattle manure, crop rotation, planting against the slope, hedges, and the use and management of bioproducts like efficient microorganisms, *Trichoderma sp*., *Rhizobium sp*., and FitoMas-E, and rational water use.

Farmers indicated the use of polyculture or intercropping, although monocropping is more commonly practiced. According to Bezner et al. (2019), crop rotation and polycultures are developed to stimulate natural soil fertility, control pests, restore productive capacity, and achieve greater equivalent land use, thus potentially increasing yields in most economically important crops. As Altieri & Nichols (2020a) expressed, traditional intercropping and agroforestry systems mimic natural processes, and their sustainability lies in the ecological models they follow.

La Victoria farm stood out with a high degree of soil management and conservation specialization.

Fig. 3. Satellite view of La Victoria farm showing terraces made from living vetiver barriers (*Vetiveria zizanioides*, Lin.) Source: Google maps.

This productive space is recognized in Cuba as a Farm Initiated in Sustainable Land Management by the Country Partnership Program on Sustainable Land Management and the Environmental Agency of CITMA. It is located in the Soil Polygon of the Guisa municipality, with significant organic matter production. Arteaga et al. (2020) observed that the application of soil conservation measures on the "La

Esperanza" livestock farm in Cumanayagua municipality, Cienfuegos province, prevented the loss of 10.2 t/ha/year of soil and allowed the retention of 168, 294, and 295 kg/ha of P_2O_5, K_2O, and organic matter respectively, improving soil fertility and increasing yields of cassava, corn, tomatoes, beans, and sweet potatoes by more than 20-36%.

These results are similar to those reported by Lezcano et al. (2021) in the characterization of the agro-productive situation of a small farm in Matanzas and observed by Terry (2023) when evaluating the effect of the application of good agricultural practices in increasing productivity on three farms in Jaruco municipality in Mayabeque province.

Regarding the economic dimension, in El Porvenir, La Dichosa, La América, and La Victoria, farmers declared moderate incomes; whereas in Matos and Tierra Honda farms, they reported high incomes.

In El Porvenir and La América, moderate incomes are justified by insufficient levels of economic stability, economic efficiency, productivity, cost-benefit ratio, need for external inputs, and low use of alternative inputs, with own equipment and machinery leading to average yields in their crops, and average values of 0.53 and 0.41, at and below the sustainability threshold, respectively.

However, La Dichosa and La Victoria, despite declaring moderate incomes, showed values of 0.61 and 0.76, above the sustainability threshold, with better economic stability, economic efficiency, productivity, cost-benefit ratio, less dependence on external inputs, and use of alternative inputs. La Dichosa has an uninstalled 400 L biogas digester due to lack of advice. La Victoria has the same kind of equipment, generating energy, though not efficiently, the leachate is mainly used in organic matter production with crop residues; moderate incomes may be related to the average yields presented in the crops.

The remaining farms San Nicolás, Juan Eduardo Matos, and Tierra Honda enjoyed high incomes, consistent with their economic stability, economic efficiency, productivity, cost-benefit ratio, less dependence on external inputs, and use of alternative inputs. The sustainability values in this dimension were 0.61, 0.65, and 0.60, respectively. They presented high production yields, considering the prevailing conditions in the country: Matos farm 3.0 t/ha^{-1} of corn, 1.5 t/ha^{-1} of beans, and 19.0 t/ha^{-1} of cassava; similarly, the producers of San Nicolás farms reported 3.0 t/ha^{-1} of corn, 20.0 t/ha^{-1} of tomatoes, although 0.8 t/ha^{-1} of beans and Tierra Honda more than 3.0 t/ha^{-1} of corn, 1.4 t/ha^{-1} of beans, and more than 15.0 t/ha^{-1} of cassava. In Cuba, according to ONEI (2022), corn yields were 1.89 t/ha^{-1}, beans 0.86 t/ha^{-1}, and tomatoes 11.02 t/ha^{-1}.

All producers use intermediaries to sell their productions, justified by the need for quick economic benefits, as compliance with commercialization through contracts tends to delay. Arias & Contrera (2023) stated that the delay in payments to producers remains unresolved, although measures have been taken, and there are periods when the delays have been reduced. Currently, this problem persists, resulting in producers being demotivated to increase production and seeking other avenues that yield more benefits for selling agricultural products, even if they are not always within the legal framework.

Regarding the economic dimension, the greatest difficulties are present in indicators related to the use, generation, and maximum utilization of the system's energy. Casimiro et al. (2020) observed in a farm with a fully agroecological design and management that 50% of the energy used for agricultural production and family reproduction comes from endogenous resources, and only 25% of the necessary inputs come from outside. Miranda et al. (2021) noted that these indicators weaken the dimension and the system itself, and if corrected, they would optimize the farms' sustainability levels.

In terms of the social dimension, all farms were above the sustainability threshold of 0.5. The farms La Dichosa, San Nicolás, Matos, Tierra Honda, and La Victoria stand out with average values above 0.8. The farms El Porvenir and La América show the lowest values, with 0.65 and 0.54, respectively.

Farmers at El Porvenir and La América showed low values in four indicators: gender equity, innovative capacity and experimentation, and access to training. Additionally, in the latter farm, no jobs are generated like the rest, and the farmer lacks solid agricultural knowledge. In the first case, the producer lives alone, and in both cases, the woman enjoys the benefits of the farm but does not participate in decision-making or productive processes.

In the rest of the farms, family members, mainly women (37.0%), participate in decision-making and are involved in productive processes. The farm La Dichosa stands out, where the woman actively participates in all farm-related activities, decision-making, experience exchanges, participation in national workshops, and other projects like PIAL. However, Díaz et al. (2021) pointed out that there is still a need to increase female presence in the agricultural sector by applying the gender approach in local development. Arévalo et al. (2022) stated that cooperative women face difficulties accessing information, work, resources, and production benefits. For example, in the selection and acceptance process for different activities, from job postings considered "masculine," men are privileged, identifying stereotyped practices that masculinize the work by considering job demands, such as in seedbeds and not in harvesting.

The General Sustainability Index (GSI) aligns with the ecological, economic, and social dimensions of the analyzed farms (Fig. 4).

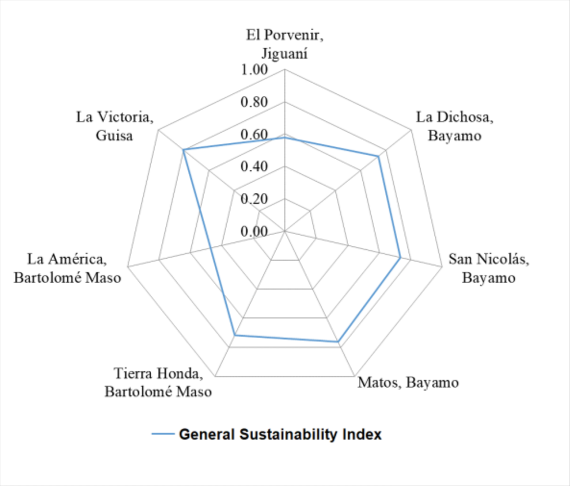

Fig. 4. General sustainability index of the seven studied farms

According to these results and the quantitative valuation scale ranges, La América is potentially unsustainable, El Porvenir is moderately sustainable, and La Dichosa, San Nicolás, Matos, Tierra Honda, and La Victoria farms fall into the partially sustainable category.

Casimiro et al. (2020) indicated that the capacity for technological change, innovation, experimentation, and exploration can favor new strategies for agroecosystem design and management and enhance the transition process.

Similarly, Miranda et al. (2021) concluded that farms achieved better sustainability levels as a result of implemented agroecological activities, presenting better functionality and conditions to respond to anthropic pressures and climate change.

It is necessary to continue transitioning the studied farms to alternative production models based on cycles that adapt to local conditions and promote agricultural practices that mobilize various ecological processes and provide a greater variety of available genetic resources, as referred by Bover & Suárez (2020), Mason et al. (2021), and Maldonado et al. (2023). According to Wezel et al. (2020) and Nicholls & Altieri (2021), developing self-sufficient, diversified, and economically viable agroecosystems is required, with crop and livestock systems designed and managed with locally adapted technologies, within farmers' possibilities, requiring contextual and transdisciplinary innovation processes.

Conclusions

The evaluated sustainability indicators show more favorable values in farms that implement a greater number of agroecological practices and knowledge impacting bean production.

La Victoria farm presents the highest General Sustainability Index due to implemented agroecological activities, better soil management and conservation, energy production and use, and knowledge exchange.

Author contribution statement

Luis J. Escalona Cruz: Led the research, participated in designing work protocols, managed bibliography, prepared the template, and managed article publication.

Licet Chávez Suárez: Participated in designing the research, diagnosing the farms, and correcting the article.

Rosa Isabel Zamora Torre: Participated in diagnosing the farms and classifying biological species.

Bismar Tamayo Fuentes: Participated in diagnosing the farms, classifying biological species, and searching for bibliography.

Raulienkis Rojas Guerra: Participated in diagnosing the farms and interviewing producers.

Yeilin Pompa Sutil: Participated in designing the research, diagnosing the farms, and interviewing producers.

Aylín María Soler Castellanos: Participated in diagnosing the farms and interviewing producers.

Alexander Álvarez Fonseca: Participated in designing the research and designing interviews.

Conflict of interest statement

Not declared.

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