Sustainability evaluation of sheep production in the páramo ecosystem of Cerrito Santander municipality, Colombia

Evaluación de la sostenibilidad de la producción ovina en el ecosistema de páramo del municipio Cerrito Santander, Colombia

Avaliação da sustentabilidade da produção ovina no ecossistema páramo no município de Cerrito Santander, Colombia

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Abstract

The preservation of natural resources and the production of enough food to meet the demands of a growing human population will be one of the most important challenges that the world will have to face in the coming years, hence the need to promote the sustainable use of the resources. The objective of this research was to evaluate the sustainability of the sheep production system in the páramo ecosystem, municipality of Cerrito-Santander, Colombia. A survey was applied to 15 sheep farmers, allowing the characterization of the production system and the georeferencing of farms. This information was analyzed by applying descriptive statistics, using SPSS software, version 24, this allowed to present the most relevant aspects of sheep production in the sector. Participatory workshops were held with the producers, to select and evaluate the sustainability indicators of sheep production systems in the páramo area, which were visualized by a biogram or spider web graph. Finally, strategic guidelines were formulated to respond to the critical points of sheep production. Most producers prefer the commercialization of wool and the use of the animal's discarded stages to obtain economic income from the sale of meat. Critical points (food supplements, type of state support received, use of veterinary services and use of energy sources) and favorable points (cost of raw materials, food security and water sources) were evidenced for the economic, social and environmental dimensions. It is necessary to focus attention on the critical points and apply the strategic guidelines, since together with the favorable points they will allow generation and establishment of more sustainable sheep production systems.

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Resumen

La preservación de los recursos naturales y la producción de alimentos suficientes para satisfacer las demandas de una población humana en crecimiento será uno de los retos más importantes que el mundo tendrá que enfrentar en los próximos años, de allí la necesidad de fomentar el uso sostenible de los recursos. El objetivo de este trabajo fue evaluar la sostenibilidad del sistema ovino en el ecosistema de páramo, municipio de Cerrito-Santander, Colombia. Se aplicó un cuestionario a 15 ovinocultores, permitiendo realizar la caracterización del sistema de producción y la georreferenciación de los predios. Esta información se analizó aplicando estadística descriptiva mediante el software SPSS, versión 24. Se efectuaron talleres participativos con los productores, para seleccionar y evaluar los indicadores de sostenibilidad de los sistemas productivos ovinos en zona de páramo, los cuales fueron visualizados por medio de un biograma o gr*á*fico de telaraña. Finalmente se formularon lineamientos estratégicos para responder a los puntos críticos de la producción ovina. La mayoría de los productores le apuesta a la comercialización de lana y a aprovechar las etapas de descarte del animal para obtener ingresos económicos por la venta de carne. Se evidenciaron puntos críticos (suplementos alimenticios, tipo de apoyo estatal recibido, uso de servicios veterinarios y uso de fuentes de energía) y favorables (costo materias primas, seguridad alimentaria y fuentes de agua). Es necesario centrar la atención sobre los puntos críticos y aplicar los lineamientos estratégicos, ya que junto con los puntos favorables permitirá generar y establecer sistemas productivos ovinos más sostenibles.

Palabras clave: caracterización, indicadores, ovinocultura, nudos críticos.

Resumo

A preservação dos recursos naturais e a produção de alimentos suficientes para atender as demandas de uma população humana crescente será um dos desafios mais importantes que o mundo terá que enfrentar nos próximos anos, daí a necessidade de promover o uso sustentável dos recursos. O objetivo deste trabalho foi avaliar a sustentabilidade do sistema ovino no ecossistema páramo, município de Cerrito-Santander, Colômbia. Foi aplicado um inquérito a 15 criadores de ovinos, permitindo a caracterização do sistema de produção e o georreferenciamento das explorações. Essas informações foram analisadas por meio da aplicação de estatística descritiva, apresentando os aspectos mais relevantes da produção de ovinos no setor, utilizando o software SPSS, versão 24. Foram realizadas oficinas participativas com os produtores, para selecionar e avaliar os indicadores de sustentabilidade dos sistemas de produção de ovinos na área do páramo, que foram visualizados por meio de um biograma ou gráfico de teia de aranha. Por fim, foram formuladas diretrizes estratégicas para responder aos pontos críticos da produção ovina. A maioria dos produtores aposta na comercialização da lã e aproveita as etapas de descarte do animal para obter uma renda econômica com a venda da carne. Pontos críticos (suplementos alimentares, tipo de apoio estatal recebido, uso de serviços veterinários e uso de fontes de energia) e pontos favoráveis (custo de matérias-primas, segurança alimentar e fontes hídricas) foram evidenciados para a dimensão econômica, social e ambiental. É necessário focar a atenção nos pontos críticos e aplicar as diretrizes estratégicas, pois juntamente com os pontos favoráveis permitirá a geração e implantação de sistemas de produção ovina mais sustentáveis.

Palabras-chave: caracterização, indicadores, ovinocultura, ponto crítico.

Introduction

One of the most important challenges that the world will have to face in the coming years is related to the preservation of natural resources and the production of enough food to meet the demands of a growing human population (Contreras, 2021). The United Nations Organization (UN, 2018), states that by 2030, sustainable consumption and production consist of promoting the efficient use of resources, energy and the construction of environmental friendly infrastructure.

For a long time, some countries have developed environmental, economic and social indicators, since they have served as the basis for future research, where it is intended to achieve that balance between each and every one of the factors that influence sustainability, creating a synergistic and binding environment for all sectors (Quiroga, 2001). Sustainable agriculture refers to the need to minimize the degradation of agricultural land, while maximizing production. Thus, different activities are considered, such as soil, water and crop management, biodiversity conservation, food supply and raw materials. (Martínez-Castillo, 2009).

The management of sheep production systems varies according to the agricultural region in which they are developed and involves multiple factors associated with the animal's management and with the environment where the activity is carried out. (Dutruel and De Caro, 2019). Thus, the environmental component is one of the most important factors, since a balance must be sought between the use of water, land and waste management, as in the case of greenhouse gas emissions (caused by these ruminants), in order to contribute to the sustainability of agricultural production. (Pulido, *et al*., 2018). However, it should be noted, that production systems based on grazing are more sustainable than those based on having large numbers of animals in stables, because the presence of pastures and in some cases trees, allows carbon sequestration produced by animals. (Contreras *et a*l., 2019; Chávez-Espinoza *et al*., 2022).

In recent years, sheep production conditions have changed substantially, influenced by factors such as climate risk, new approaches to animal health and welfare, the crisis of raw materials and/or the perception that consumers have of the livestock (Chávez-Espinoza *et al.,* 2022; Avendaño and Navarro, 2020).

The municipality of Cerrito Santander is not an exempt from these problems that are generated in livestock production systems in páramo areas, since sheep production systems are mainly made up of small and medium-sized producers who have traditionally focused on extensive management, without grazing control, genetic and sanitary component, reflecting low zootechnical indexes, and generating environmental problems, mainly due to the ignorance of the impact that this activity is generating on the agroecosystem. However, from the municipal government, this productive sector is promoted by a development plan, with an economic, social and environmental approach, through the implementation of strategies and programs to overcome the problems of the rural population, seeking to improve the working, productive and competitive conditions that will lead to an environment of growth and well-being (Alcaldía Municipal, 2020).

Nevertheless, it is important to carry out more in-depth studies to identify and evaluate the strengths and weaknesses of the sustainability of each production system (economic, social and environmental), thus facilitating the adoption of changes or the most appropriate corrective measures according to the problems detected. Given the foregoing, it was proposed to evaluate the sheep production system in the Páramo ecosystem in the municipality of Cerrito, Santander, Colombia; In order to achieve this objective, it was necessary to 1) Characterize the sheep production system by applying a holistic approach that seeks to address the reality of sheep farmers, in the páramo ecosystem of the Cerrito Santander municipality, from different areas (Sarandón, 2021). 2) Evaluate the dimensions and critical points through the selected sustainability variables and 3) Formulate strategies for sheep production in the páramo ecosystem of the Cerrito Santander municipality, Colombia.

Materials and methods

Study population

The research was carried out in the area of the Almorzadero páramo at the Cerrito municipality, which is located in the eastern part of Santander department, located to the Northeast of the García Rovira Province and approximately 22 km from the city of Malaga, capital of the province; 188 km from Bucaramanga, capital of the Department, and 390 km from the city of Bogotá, capital of the country. It is located at an altitude of 2,500 meters above sea level, at 73° and 0.3 minutes east longitude, 6° and 0.1 minutes north longitude.

A satellite image was developed with the help of the mobile application "GPS coordinate", which allowed a map preparation and also find the satellite location in Google Earth of each of the properties at the páramo agroecosystem. These farms were delimited with a perimeter of 51.25 km and a total area of 120.87 km^2 (figure 1).

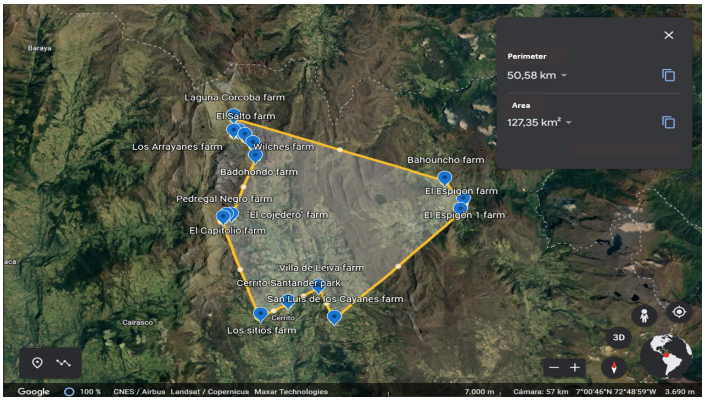

Figure 1. Location of Cerrito municipality in Santander and in Colombia.

Data collection techniques

Using a participatory action methodology, a questionnaire was applied to 15 sheep farmers selected by intentional non-probabilistic sampling, in which three dimensions were taken into account: economic, social and environmental. Questionnaire was validated by two experts in the area of animal husbandry and productive projects.

Then, with the participation of sheep farmers, sustainability variables were selected, through a participatory workshop and application of diagnostic tools, under a focus group technique, which seeks to collect data through a semi-structured group survey that revolves around around a theme proposed by the researcher (Rodas and Pacheco, 2020).

Data analysis techniques

Univariate statistical techniques: frequency distribution and measures of central tendency (according to the nature of the data) were used through the SPSS V24 program, which allowed the initial characterization of the sheep production system to be carried out.

Before the sustainability evaluation, sheep farmers selected by consensus the variables that they considered most important, and then, they proceeded to rank them and these results were represented in a biogram or spider web graph, which shows a multidimensional diagram with the representation of the respective indices, and indicate the "state" of the agricultural production systems, since each radius (axis) represents a calculation indicator. The diagram was made using Excel 365 V16 program. In this case, each radius had a maximum value of 10, so each indicator ranged from 0 to 10, which were assigned in consensus by the producers during the development of the workshops (Barrantes *et al.,* 2018). In this way, according to the shaded area in the graph, it was possible to identify indicators in collapse (values less than 2), in a critical situation (between 2 and 4), unstable (between 4 and 6), stable (between 6 and 8) and optimal situation (between 8 and 10). Finally, strategic guidelines were proposed to respond to the critical points of sustainability in these systems.

Results y discusion

Figure 2 shows the "veredas" or villages located in the páramo ecosystem, False Corral is the one that predominates with the greatest number of sheep production systems in the Mortiño sector, followed by Tierra Negra sector, which its heights above sea level range from 2,865 to 4,150 meters, this implies a strong adaptation and resilience of the sheep species to climatic and altitude conditions (Petryna and Bayer, 2011).

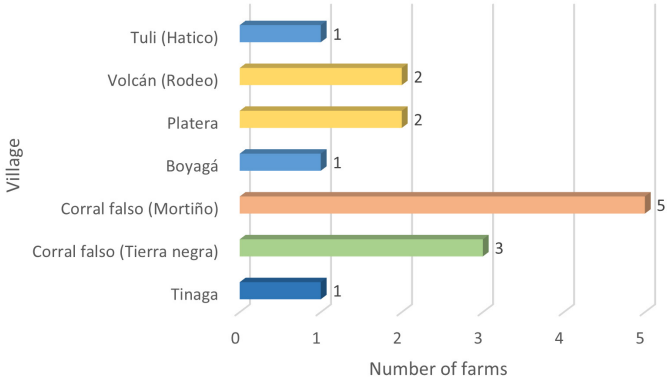

Figure 2. Number of farms or properties by each villages in the Cerrito municipality, department of Santander.

Characterization of Sheep Production System

Social dimension

The 93 % of respondents are male and their average age is 47±12 years. 47 % of the farms can be reached by road and the rest by tertiary roads and bridle paths, because the accesses to the farms cannot be intervened due toit is a protected páramo area. It stands out that 60 % of the sheep farmers are owners of their houses, the average number

of people who share the house is approximately 4. The school level of the majority is primary and secondary (67 %), affiliated to the Potential Identification System Beneficiaries of Social Programs of Colombia (SISBEN), classified in levels I and II. The source of income comes from agricultural and livestock activities (66 %); 93 % state that they have not received any support from entities or organizations. An advantage of the production systems in the study area is that most of them are owners of their farms, so they take care of animal welfare and the environment where they live as an integral approach to the production system. The level of schooling observed is important when it comes to developing income-generating activities.

Economic dimensión

Most of the production systems (74 %) of the Cerrito sheep farmers developed a mixed production activity (table 1), that is, they combine several production purposes such as wool, meat and breeding. Likewise, it was observed that the sheep breeds that are handled the most are Romney marsh, Hampshire and Moro, which are characteristic of this moorland area because they are resilient to the climate and also provide wool and meat, as well as for sale as breeding stock, contributing to the food security of the área; by tradition, they carry out this activity in the different stages of the species, generating meat for sale and consumption, and wool that they market for further processing.

Table 1. Production systems in Cerrito municipality.

Tipe of productive system	Frecuency	%	Acumulative %
Mixed (Wool, Meat, Breed)	11	74	74
Double Purpose	2	13	87
Integral	2	13	100
Total	15		100

The average farm size of the sheep farmers was registered in 47±53 ha, however, this variability is an indication that more than half of these producers have small extensions of land, consistent information with the fact that 53 % of the participants have less than 32 sheep/farm, 20 % have between 45 and 60 animals and only the remaining (27 %) have more than 150 sheep/farm with a maximum of 398 animals (table 2). Likewise, it is highlighted that a large extension of each property is used for livestock based on natural pastures.

In this sense, it was observed that natural pastures area predominates, data consistent with (Aristizábal, 2019), who states that most of the mountainous areas of the national territory are suitable for raising sheep and goats. On the other hand, it was observed that the existence of improved pastures is reduced or minimal due to the climatic and agroecological conditions of the páramo sector, likewise, because of the traditional culture that they maintain in the sheep activity of the región, sheep production in this region is combined with other livestock species and some agricultural activities, contributing to the food security of families and the territory (table 2).

Environmental dimension

In this dimension, the availability and use of water resources was addressed, observing that four out of five sheep farmers have the culture of managing water reserves for human consumption, only few producers are supplied by the aqueduct. The streams are the main source of water in the majority of sheep farms, giving domestic use as human and animal consumption, including during the summer periods. As a second alternative they have springs, wells and "Jagüeyes" or superficial water reservoirs that are used mainly for animal management (table 3). 80 % of the producers implement different mechanisms to conserve and preserve the water sources that are used for animal consumption.

Table 2. Distribution of land use for properties in the municipality of Cerrito.

Land use	Average area (ha)
Total	47 ± 53
Natural pastures	19 ± 16
Improved pastures	5 ± 4
Livestock	24 ± 14
Others species	10 ± 9
Crops	7 ± 9
Conservation	17 ± 10

Table 3. Sources of water used by sheep farmers in Cerrito municipality for human and animal consumption and for agricultural activities.

Uses		Source	Frecuency	(%)
Preservation/conservation of water sources		Yes	12	80
		No	3	20
Domestic use		Aqueduct	2	14
		River ravine	9	60
		River source	2	13
		Well	2	13
Animal use		River ravine	11	73
		Superficial water reservoirs	3	20
		River ravine and Superficial water reservoirs	1	7
Summer use	Animals	River ravine	5	34
		River source	5	33
		Well	5	33
	Irrigation	River ravine	5	33
		River source	3	20
		Well	3	20
		Did not answer	4	27

Participatory identification of variables for the sustainability evaluation

In the meetings with focus groups, a consensus was reached together with the sheep farmers to determine the variables regarding the three dimensions addressed

The sustainability evaluation in these three dimensions allowed to approach the sheep production system from a holistic and integral perspective and not only from the productive aspects or parameters. This is how sustainability contemplates aspects of social order that involve variables of the producer and his family, while the environmental variable focuses on the rational use of available natural resources. These two variables have a direct impact and are

related to the economic dimension that is based on the indicators of the production process.

Table 4. Dimensions and variables of sustainability.

Dimension	Variable	
Economical	Natural mating (NM)	Record of information (RI)
	Animal Supplements (AS)	Mixed production system de (MPS)
	Raw material costs for animal feed (RMC)	
Social	Type of support received (TSR)	Use of veterinary services (UVS)
	Schooling grade (SG)	Home ownership (HO)
	Food safety (FS)	
Ambiental	Water sources (WS)	Use of energy sources (UES)
	Soil conservation practices (SCP)	Soil management-land use (SMLU)

Sustainability evaluation

Despite the fact, that different studies have been developed to evaluate the sustainability of sheep production systems, a consensus has not been generated in order to establishes a set of indicators for universal use; Therefore, the use of indicators as a part of a multicriteria analysis allows quantifying the different aspects related to the productive systems (Vargas *et al*., 2022).

Figure 3 shows the spider web graph for the economic dimension. Five variables were evaluated for this dimension and it was possible general observe an optimal behavior for the development in this dimensión, since most of the variables are in a state named "stable" (RI, MPS, NM) and "optimal" (RMC). However, it is important to pay attention to the food supplement variable (AS) that is in a "critical" state, then a critical problem or knot is being evidenced for the economic dimension in these productive systems.

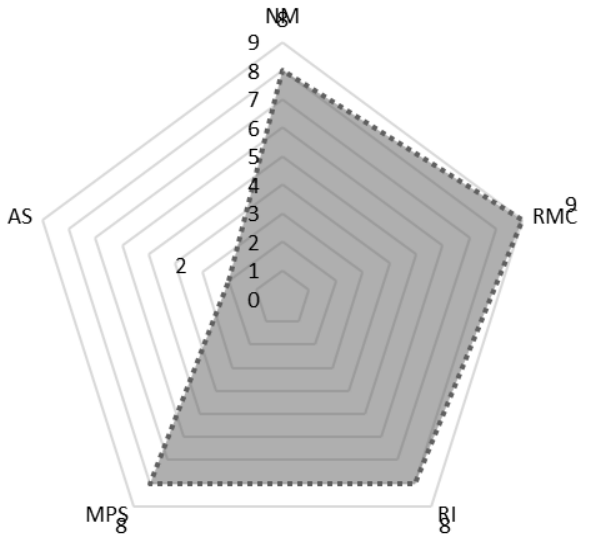

Figure 3. Spider web graph for the economic dimension. NM: natural mating; AS: animal supplements; RMC: raw materials costs for animal feeding; RI: record of information; MPS: mixed production system.

Velázquez (2019), evaluated sustainability of three sheep production systems, indicating that the processes of productive diversification and marketing are essential in the economic dimension of the productive unit. The record of information is a key tool that allows the producer to make the correct decision-making by generating indicators that lead to constant monitoring, evaluation and feedback of the productive system. At the financial level, accounting records will allow the producer to have solid foundations that direct him to estimate real production costs and determine the profit margin of the production system.

In the social dimension, five variables were evaluated (figure 4) and it was possible to observe that most of the variables are in a critical state named "unstable" (SG) and "collapse" (UVS, TSR). The use of veterinary medicines becomes a limitation for many of these production systems due to the high costs its represent, becoming a problema, that in the long term can lead to health problems for the animals and finally to economic losses that affect family income of these producers. The type of support received by the producers is limited, although, they have the help of goverment entities for the provision of veterinary services, such as the UMATA (Municipal Units of Agricultural Technical Assistance), the long distances between their properties and the municipal head mean that they do not go to them, taking as a solution to implement all kinds of of empirical maneuvers to treat and save their cattle.

Velázquez (2019), mentions that the social sustainability of sheep production systems represents a great impact on the quality of life of both the producer and the people related to this economic sector. This is how, knowledge transfer activities and incentives are fundamental in order to lead to the improvement of the productive processes themselves.

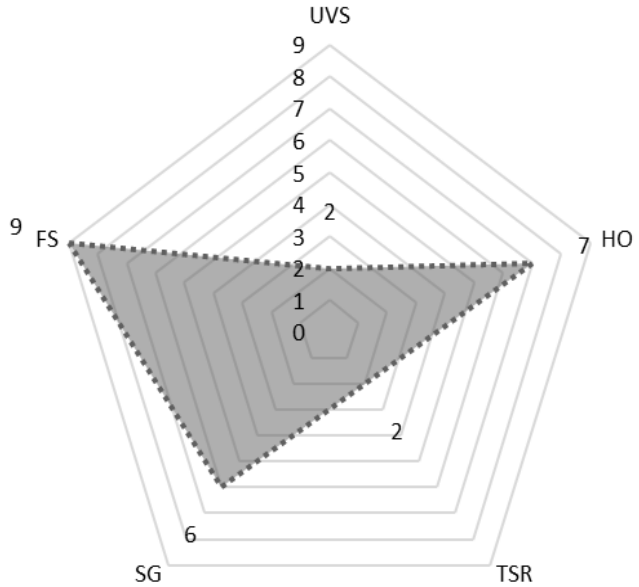

Figure 4. Spider web graph for the social dimensión. UVS: Use of veterinary services; HO: Home ownership; TSR: type of support received; SG: Schooling grade, FS: food safety.

There were four variables for the environmental dimension (figure 5), one of them in a critical state named "unstable" (UES). The current state of the variable related to the use of energy sources places it in a condition that shows the limited access that sheep farmers have to this, especially those that represent an environmental benefit (solar energy, wind energy, hydraulic power, etc.).

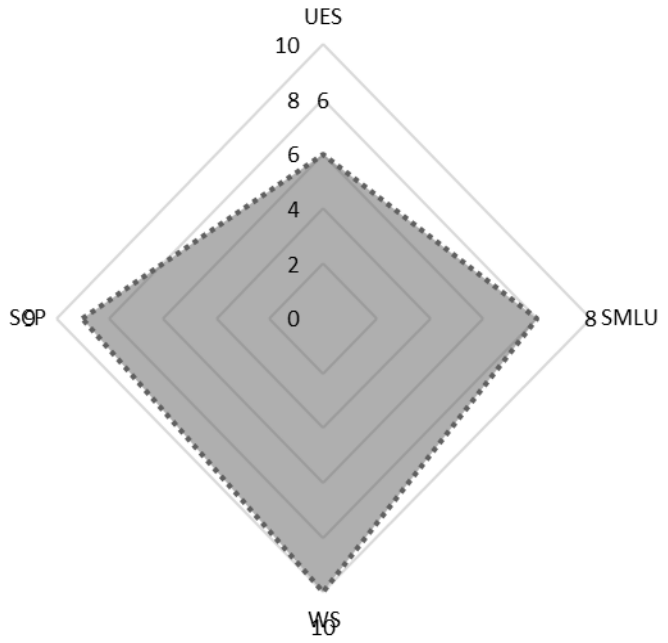

Figure 5. Spider web graph for the environmental dimensión. UES: use of energy sources; SMLU: Soil management-land use; WS: water fsources, SCP; soil conservation practices.

The environmental dimension (EnD) is especially oriented to the process of management and conservation of resources such as water sources and soil (Velázquez, 2019). Alternative energy sources are necessary especially for small and medium farmers that lead to optimize the use of resources and therefore to improve the profit margin.

Finally, figure 6 shows the index obtained for each dimension, showing that the economic (ED) and environmental dimensions are generally in an optimal state, while the social dimension (SD) is in a state of instability in the production systems. Thus, it is important to focus attention on the variables of the SD since, in order to advance towards the development of sustainable sheep production systems, it is necessary to improve the aspects involved into the viability and permanence of sheep producers (Chiappe, 2001).

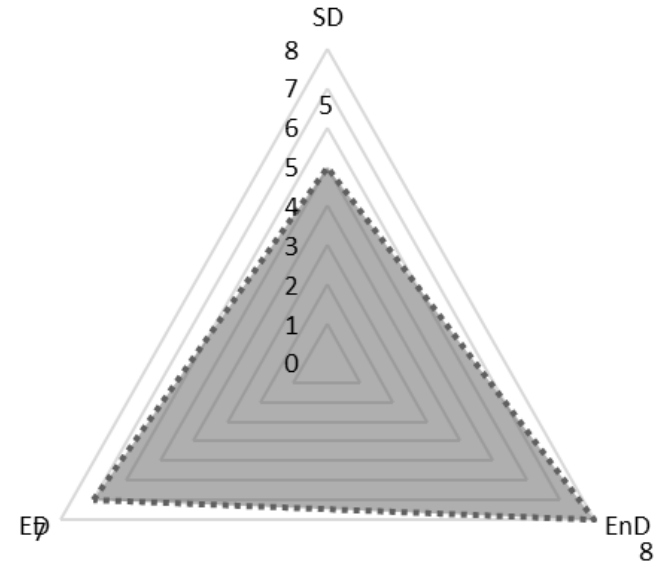

Figure 6. Web plots for economic dimension (ED), social dimension (SD) and environmental dimension (EnD).

Strategic guidelines for sustainable sheep production

In the environmental dimension, something very important to note is that sheep are able to survive in a wide variety of climates and environments and enhance agricultural production in both developed and underdeveloped regions of the world (Redden and Thorne, 2020). So a sustainable future for sheep and goat production is perceived by promoting the utilization of grasses and forages, grazed in situ, using resources such as hill land that cannot sustain other productive enterprises (McCoard *et al.,* 2019)

In the economic dimension, it is proposed to have sheep breeders according to genetic plan (meat and wool); the implementation of artificial insemination protocols and early weaning to stimulate early estrus in ewes; crossbreeding strategies in search of productivity and added value; stabilization of the flow of ewes (inflows = outflows); among others strategies. A significant contribution that makes visible the problems that the Agricultural and Rural Sector is going through, is strictly related to the lack of profitability in most productive activities, and at a greater disadvantage for small and medium producers. Therefore, it is proposed to develop productive projects through the association of sheep farmers to bring resources to the community in order to promote the improvement of productivity and competitiveness of regional production.

Finally, the social dimension includes training to farmers on the implementation of sanitary, nutritional and management plans with the participation of the family nucleus; certification in good livestock and animal welfare practices; and the promotion of rural tourism, ecotourism and adventure tourism as a way to bring communities closer together through activities of coexistence and interaction in all social, cultural and productive expressions of daily life.

Conclusions

Characterization showed a low schooling grade and a lack of support received from state entities for sheep farmers, a situation that leads to a lack of technification in the production systems and has an impact on the momentum of the production chain. On the other hand, most producers focus on marketing wool and taking advantage of the animal's discard stages to obtain economic income from the sale of meat. Optimal production parameters obtained in the breeding system is related to the availability of water, which is obtained from water sources such as streams. However, given the limited availability of water resources, producers resort to using wells and superficial water reservoirs in the soil.

The evaluation of the sustainability of sheep systems made it possible to establish their critical points. In this case, critical points were identified for the economic dimension (feed supplements and animal housing systems), the social dimension (type of government support received and use of veterinary services) and the environmental dimension (use of energy sources).

It was also possible to establish the favorable points for the sustainability of production systems in the economic dimension (cost of raw materials), social dimension (food security) and environmental dimension (soil conservation practices and water sources), showing that sheep production in páramo agroecosystems is viable to generate food security, taking into account the care of water sources and soil conservation, while improving the quality of life and living conditions of families. In this way, this system of small livestock production is a significant item for small and medium-sized producers, contributing to social, economic and environmental development.

It is necessary to focus attention on the critical points mentioned above and apply the strategic guidelines generated for each of them, since, together with the favorable points, they will make possible to generate and establish more sustainable sheep production systems.

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