# Barriers and strategies for scaling up livestock agroforestry systems in the Colombian amazon piedmont

***Barreras y estrategias para el escalamiento de la agroforestería pecuaria en el piedemonte amazónico colombiano***

***Barreiras e estratégias para a expansão da agrofloresta pecuária no piedemonte amazônico colombiano***


Antonio Solarte[1*]; Adrián Rico[2]; Catalina Zapata[3]; Julián Chará[2]; Enrique Murgueitio[2].

[1]*The Nature Conservancy- Sustainable Production Systems Program. - TNC, Colombia*

[2]*Centro para la Investigación en Sistemas Sostenibles de Producción Agropecuaria – CIPAV, Cali, Colombia.*

[3]*Independant Consultant.*



***To cite this article:***

Solarte A, Rico A, Zapata C, Chará J, Murgueitio E. Barriers and strategies for scaling up livestock agroforestry systems in the Colombian amazon piedmont. Rev Colomb Cienc Pecu 2025; 38(1):46–64. https://doi.org/10.17533/udea.rccp.v38n1a5



**Abstract**

**Background:** Silvopastoral systems (SPS) are sustainable livestock production systems with multiple benefits. Nevertheless, its adoption has been limited. **Objective:** To identify the barriers encountered by farmers to adopt SPS, considering the perceptions of producers and the strategies to promote its adoption as a tool for sustainable cattle ranching in the Amazonian foothills of Caquetá province, Colombia. **Methods:** Experts on sustainable cattle ranching from public and private organizations implementing projects in Caquetá were called to contribute to participatory rural appraisal workshops and focus groups. In these workshops also participated producers from the south of the province with three to five years of experience in establishment SPS, and producers from north of the province who were just starting with SPS. **Results:** The experts recognized 13 practices promoted by institutions for sustainable cattle ranching. These alternatives were categorized into pasture management, livestock agroforestry, conservation, and renewable energy systems. They also identified 21 barriers that limit the adoption of these alternatives, which were grouped into skills and knowledge, social, economic, environmental, and technical and operational barriers. The cattle farmers prioritized and established the advantages and disadvantages of the four main SPS. In response to the barriers, 22 scaling-up strategies were identified and classified into five categories contributing to promote the adoption of SPS. **Conclusions:** Organizations promoting sustainable practices for cattle ranching and farmers in the Caquetá foothills recognize the importance of SPS, but there are still barriers related to knowledge, implementation costs, environmental, and cultural conditions that need to be addressed to increase its adoption.



**Keywords**: *barriers; cattle; livestock agroforestry; livestock reconversion; silvopastoral system; sustainable livestock; sustainable practices; sustainable production; sustainability; technology adoption.*

*Received: March 10, 2024. Accepted: May 24, 2024*



***Corresponding author.** Carrera 7 # 71. Torre B, Piso 13 Bogotá, Colombia. Tel.: +57 3206959213. E-mail: antonio@fun.cipav.org.co; antonio.solarte@tnc.org

**Resumen**

**Antecedentes:** Los sistemas silvopastoriles (SPS) son una opción para la producción sostenible y reconversión ganadera. Sin embargo, a pesar de sus múltiples beneficios, su adopción ha sido limitada. **Objetivo:** Identificar las barreras que dificultan la adopción de los SPS según las percepciones de los productores, así como las estrategias para escalar la agroforestería pecuaria como herramienta de reconversión de la ganadería en el piedemonte amazónico del departamento del Caquetá. **Métodos:** Se realizaron talleres de diagnóstico participativo y grupos focales con profesionales expertos de organizaciones públicas y privadas relacionadas con proyectos que promueven la ganadería sostenible en la provincia de Caquetá. En esos talleres también participaron productores del sur de la provincia con experiencia de tres a cinco años en el establecimiento de SPS, y productores del norte de la provincia que apenas se iniciaban en los SPS. **Resultados:** Los profesionales agropecuarios reconocieron 13 prácticas que promueven las instituciones para la reconversión ganadera, que fueron categorizadas en: manejo de la pastura, agroforestería pecuaria, conservación, y energías renovables. Asimismo, identificaron 21 barreras que limitan su adopción, las cuales fueron agrupadas así: desconocimiento, social, económico, ambiental, y técnico y operacional. En cuanto a los ganaderos, ellos priorizaron y establecieron ventajas y desventajas de cuatro SSP. Respondiendo a las barreras de adopción, se reconocieron 22 estrategias de escalamiento para promover la adopción de los SSP. **Conclusión:** Los ganaderos e instituciones que promueven prácticas sostenibles para la reconversión ganadera en el piedemonte del Caquetá reconocen la importancia de los SPS pero que aún existen barreras relacionadas con el conocimiento, costos de implementación, condiciones ambientales y culturales que deben ser abordadas para aumentar la adopción.

**Palabras clave:** *adopción de tecnología; agroforestería pecuaria; barreras; escalamiento; ganado; ganadería sostenible; prácticas sostenibles; producción sustentable; reconversión ganadera; sistemas silvopastoriles; sostenibilidad.*

**Resumo**

**Antecedentes:** Os sistemas silvopastoris (SPS) são uma opção para a produção sustentável e conversão de gado, mas embora os seus múltiplos benefícios tenham sido demonstrados, a sua adopção tem sido limitada. **Objetivo:** Identificar as barreiras à adopção das SPS, de acordo com as percepções dos produtores e estratégias para a expansão da agroflorestação pecuária como instrumento para a reconversão da pecuária no sopé amazónico do departamento de Caquetá. **Métodos:** Profissionais de organizações públicas e privadas relacionadas com projectos que promovem a pecuária sustentável na província de Caquetá foram convidados para workshops de diagnóstico participativo e grupos focais, bem como produtores dos municípios do sul da província com 3 a 5 anos de experiência no estabelecimento de SPS, e produtores do norte da província que estavam a iniciar-se no SPS. **Resultados:** Os profissionais agrícolas reconheceram 13 práticas promovidas por instituições de conversão de gado, que foram categorizadas em gestão de pastagens, agroflorestação de gado, conservação e energias renováveis. Identificaram também 21 barreiras que limitam a sua adopção, as quais foram agrupadas em falta de conhecimento, barreiras sociais, económicas, ambientais e técnicas e operacionais. Quanto aos criadores de gado, eles dão prioridade e estabelecem as vantagens e desvantagens de quatro SPS. Em resposta às barreiras à adopção, foram identificadas 22 estratégias de escalonamento para promover a adopção de SSP. **Conclusão:** As instituições que promovem práticas sustentáveis para a reconversão pecuária nos contrafortes de Caquetá e os criadores de gado reconhecem a importância dos sistemas silvopastoris, mas que ainda existem barreiras relacionadas com o conhecimento, custos de implementação, condições ambientais e culturais que precisam de ser abordadas para aumentar a adopção.

**Palavras-chave:** *adoção de tecnologia; agroflorestação; aumento de escala; barreiras; gado; pecuária sustentável; práticas sustentáveis; produção sustentável; reconversão pecuária; sistemas silvopastoris; sustentabilidade.*

## Introduction

Caquetá province, in the Amazon piedmont of Colombia (South America) occupies 18.64% of the Colombian territory in this basin (Salazar and Riaño, 2016). According to the Rural Agricultural Planning Unit of Colombia (UPRA) there are many conflicts in this province due to land overuse since most of the territory has a conservation vocation and only 1% is suitable for agriculture, 0.1% for livestock, 0.003% for forestry, and 3.6% for agroforestry (Jiménez, 2019).

This province is an important player in the Colombian dairy sector with 2,198,256 cattle heads (7.5% of the national inventory) in 20,737 dual-purpose farms, and an estimated production of 1,914,057 Liters of milk per day (Torrijos, 2022). Dairy farming is the main sector of Caquetá's economy (Fajardo *et al.*, 2014). Unfortunately, the province undergoes a high deforestation trend (Murad and Pearse, 2018) due to the establishment of new pastures (Navas, 2010; Cabrera, 2022).

In recent years, livestock agroforestry has been considered a suitable option for cattle production as it offers advantages for the conversion of extensive livestock farming towards more efficient and productive systems which contribute to biodiversity conservation, reduction of greenhouse gas emissions, and adaptation to climate change, under proper animal welfare (Broom *et al.*, 2013; Murgueitio *et al.*, 2013; Buitrago *et al.*, 2018).

Despite the advantages of SPS, its adoption in the region has been slow and influenced by several barriers. According to several researchers, SPS adoption is limited by producer perceptions, lack of knowledge, lack of technical assistance, capital limitations, and producer uncertainty about the management of systems of greater complexity and risks, among other factors (Clavero and Suárez, 2006; Zepeda *et al.*, 2016; Lee *et al.*, 2020; Vargas-de la Mora *et al.*, 2021; Salcedo *et al.*, 2022). Caquetá province is a good example of this limited SPS implementation (Solarte *et al.*, 2022).

According to Pannell *et al.* (2006), adoption of agricultural innovations is a dynamic learning process related to innovation and to personal, social, cultural, and economic factors.

The objective of this study was to identify barriers to SPS adoption for the entire livestock system and for specific farms, according to producer perceptions. Additionally, to identify strategies for scaling up livestock-agroforestry alternatives.

## Materials and Methods

### *Location*

Caquetá province is in southern Colombia, northeast of the Amazon basin, in the transition area between the Andes, the Amazon, and the southeastern plains (Centro Nacional de Memoria Histórica, 2013). The left bank of Caquetá River serves as boundary to the south and separates it from Putumayo and Amazonas provinces. It limits to the north with Meta and Guaviare provinces; to the east, with Vaupés and Amazonas provinces; and to the west with Huila and Cauca provinces. It is located between 00° 42' 17" south latitude and 02° 04' 13" north latitude, and 74° 18' 39" and 79° 19' 35" west longitude of Greenwich meridian (SINCHI, 2017).

The study was conducted between 2019 and 2021 through participatory rural workshops in face-to-face and virtual focus groups, with participation of professionals and producers from six municipalities (Albania, Belén de los Andaquíes, Morelia, El Doncello, El Paujil, and La Montañita). Qualitative information collected in the workshops and participatory diagnostic exercises was systematized and analyzed to identify main trends.

### *Characteristics of farmers*

Farmers participating in this study owned a family farm averaging 56.62 Ha. They had an average of 49 cattle heads and milked 12 cows to produce 5.15 L/cow/day (Table 1). All farms were of dual-purpose type (production of milk and calves). Milking was carried out with the


https://doi.org/10.17533/udea.rccp.v38n1a5

presence of the calf. Paddocks were divided with electric fences, separating three groups of animals: i) milking cows, ii) breeding cows, and iii) calves until weaning.

**Table 1.** Farmer description of south and north of Caquetá.

| Zone | Farm size (Ha) | Heads of cattle | Heads of cattle range | | Lactating cows | Milk production (L/cow/ day) |
|---|---|---|---|---|---|---|
| | | | Min | Max | | |
| South | 59.4 | 51 | 5 | 163 | 11 | 4.8 |
| North | 54 | 47 | 8 | 145 | 14 | 5.35 |

*Sustainable livestock practices and barriers for the adoption of silvopastoral systems*

Identification of elements promoted by the institutions for livestock conversion was carried out through a workshop with a focus group of 12 professionals from local and national institutions involved in academia, research, international cooperation, training, technical assistance, and/or agricultural extension. This group also identified the barriers present in Caquetá that limit greater adoption of SPS as a practice to promote livestock conversion in the region.

*Barriers limiting the adoption of silvopastoral arrangements in the region*

Four participatory workshops were conducted with focus-group farmers (Escobar and Bonilla-Jiménez, 2017; Geilfus, 2009) in municipalities of South (Albania, Belén and Morelia) and North (La Montañita, El Paujil, and El Doncello) to identify perceived advantages and disadvantages favoring or hindering the adoption of specific SPS arrangements,

The first group (46 farmers; southern Caquetá) had three to five years of experience in SPS implementation and management, while the second group (50 farmers; northern Caquetá) was at the initial stage participating in the co-design process of SPS which included technical talks and knowledge-exchange visits with other farmers. Both groups of farmers (experienced and inexperienced in SPS) were referred by research and development organizations experienced in implementing SPS projects in the region. The invitation was made to a larger number of producers; however, the working groups were constituted with those individuals who attended the meetings in person.

With *Focus group one*, semi-structured dialogues were held to address guiding questions on learning and operational difficulties for the implementation and management of SPS; classification and influence-dependence and double-entry matrices were used to compare and prioritize the SPS (Geilfus, 2009).

With *Focus group two*, the World Cafe methodology (Hurley and Brown, 2016) was applied to promote participation and dialogue on knowledge and experience on the most common SPS types in the region using guiding questions to analyze advantages and limitations. Five sub-stations were established, each referring to a particular SPS in which visual materials (poster-type) were placed to facilitate the dialogue. Each sub-station was led by a host who promoted participation of each subgroup, wrote cards with the ideas expressed on advantages and disadvantages of the four SPS types, and complemented them with the opinions of the other four subgroups rotating through the different stations until the circuit was completed.

A matrix was made with the workshop results in each group to highlight the barriers limiting the adoption of SPS and determine similarities and/or identify other barriers. Subsequently, the terms for each identified barrier and type of SPS design were compared and unified for their respective grouping.

*Strategies to promote the scaling up of SPS adoption.*

Strategies to promote the scaling up of SPS were identified through a virtual workshop with a focus group of 41 professionals made up of agricultural extensionists, researchers, and qualified professionals linked to sustainable cattle ranching projects. The workshop was conducted virtually using ZOOM and the MURAL collaborative work platform to promote participation and collect information. This methodology presented and validated the five categories of barriers for implementing SPS previously listed by the first focus group workshops. For each category, the following question served as a guide to identify strategies: How to overcome the barriers to SPS adoption related to each previously identified category? The answers were recorded on cards on a whiteboard and grouped together in a participatory way under the guidance of the moderator to eliminate duplication. In the office phase, the strategies were drafted considering the key words quoted by the workshop participants.

## Results

*Sustainable practices and barriers to SPF adoption*

The workshop with the first group of professionals identified 13 sustainable livestock practices promoted by their institutions for livestock conversion, which were grouped into four categories. Pasture management was considered a cross-cutting practice combined with the others. Six types of livestock-agroforestry arrangements have been implemented in the region as alternative production systems. Use of renewable energies and conservation of forests and water resources (including wetlands) were identified as complementary actions (Table 2).

Likewise, this first focus group recorded 21 barriers to SPS adoption, classified into the following categories: social, economic, environmental, capacities and knowledge, and technical and operational (Table 3).

Among the barriers, the most relevant were related to lack of knowledge on the alternatives, low access to economic resources, and deficient technical assistance, followed by availability of seeds, inputs, machinery, and skilled labor for implementing sustainable practices.

*Barriers limiting the adoption of SPS in the region.*

Farmers in the south of the province (group 1) conducted an exercise to prioritize the SPS implemented in their farms. Farmers at Albania and Belén municipalities managed six types of systems, of which they prioritized four, in the following order: 1) Scattered trees in pastures (STP); 2) Trees in strips with subsistence crops (TSS); 3) Divisions with trees in strips (DTS); and 4) Mixed fodder banks (MFB).

**Table 2.** Practices promoted by institutions for sustainable livestock production in Caquetá.

| | |
|---|---|
| **Pasture management** | Improved grassland planting and management |
| | Rotational grazing |
| **Livestock agroforestry** | Live fences |
| | Silvopastoral systems with native species |
| | Silvopastoral systems based on plant succession |
| | Silvopastoral systems for free grazing |
| | Agrosilvopastoral strips |
| | Mixed fodder banks |
| **Conservation** | Forest and wetland conservation agreements |
| | Connectivity corridors |
| **Renewable energy** | Solar panels |
| | Biodigesters |
| | Wood-saving stoves |


https://doi.org/10.17533/udea.rccp.v38n1a5

**Table 3.** Barriers and strategies for scaling-up the adoption of silvopastoral systems.

| Categories | Adoption barriers | Strategies for scaling – up |
|---|---|---|
| Skills and knowledge | 1. Lack of knowledge on sustainable livestock models for the region. | 1. Knowledge management: access, systematization, transfer, and dissemination. |
| | 2. Lack of local capacity building for technicians and producers. | 2. Capacity building: technical assistants, extensionists, producers, labor, women, and youth. |
| | 3. Lack of technical assistants trained in sustainable livestock production. | 3. Exchange and training programs |
| | 4. Deficient technical assistance and agricultural extension system. | |
| Social | 5. Resistance to change | 4. Development of regional and local sustainable livestock programs and policies. |
| | 6. Lack of family consensus about changes in land uses and livestock practices. | 5. Inter-institutional coordination |
| | 7. Change in social behavior | 6. Work on generational replacement |
| | | 7. Gender: inclusion of women and youth |
| Economic | 8. Low availability of economic resources for implementation of sustainable practices. | 9. Diversification with SPS: fruits - timber – subsistence crops, other minor species. |
| | 9. Lack of financing for the development of silvopastoral systems. | 10. Undertakings for SPS: mechanization, plant material, planting, electric fences, livestock aqueducts, and others. |
| | 10. Low flexibility of credit schemes | 11. Special products for differentiated markets |
| | | 12. Value chain approach – linkages |
| | | 13. Economic incentives - environmental markets |
| | | 14. Credits and special lines of credit |
| Environmental | 11. Agroecological and climatic characteristics of the region | 15. Land use planning |
| | 12. Degradation processes in pastures | 16. Ecosystem conservation and restoration |
| | 13. Availability of water sources | 17. Research – monitoring |
| | 14. Availability of area for ecological exchange when projects require conservation areas. | |
| Technical and operational | 15. Requirements for the protection of forestry material. | 18. Establishment of productive-reproductive records. |
| | 16. Scarcity of equipment and machinery | 19. Establishment of production costs |
| | 17. Inadequate management of native plant species. | 20. Management, administrative and financial management. |
| | 18. Low availability of forest material in nurseries | 21. Specialized technical assistance |
| | 19. Distance for transport and installation | 22. Establishment of good farming practices |
| | 20. Low availability of shade-tolerant grass materials. | 23. Inclusion of animal welfare practices |
| | 21. Shortage of labor | |

On the other hand, farmers in Morelia municipality prioritized three systems, in the following order: 1) Mixed fodder banks; 2) Scattered trees in pastures; and 3) Divisions with trees in strips.

These results respond to the dynamics, own experience with each design (time and type of management) and socioeconomic and cultural characteristics of each region. Producers in Albania and Belén are closer to markets and municipal capitals and have greater access to projects compared to those in Morelia, who are in more remote areas and prefer systems that support food security with low implementation costs, suggesting a strong influence of this contextual factors when selecting or adopting a certain type of SPS arrangement.

According to the prioritization and perception of the two groups of farmers in the north and south of Caquetá, advantages and disadvantages were established for the four most representative SPS arrangements in the last 15 years: 1. Scattered trees in pastures (STP); 2. Live fences (LF); 3. Tree divisions in agro-silvopastoral strips (AS); and 4. Mixed fodder banks (MFB).

The main arrangements (Table 4 and Figure 1) were STP established with trees and/or shrubs already present in the pasture, through selective cutting and/or pruning of the vegetation to reduce density, thus allowing for proper development of the pastures by diminishing competition for light and nutrients.

**Table 4.** Farmer perception of SPS arrangements composed of scattered trees in pastures (STP).

| Advantages | Disadvantages |
|---|---|
| 1. Cost of establishment | 1. Difficult mechanization for pasture establishment |
| 2. Uses native species that guarantee adaptation with less tree mortality. | 2. Requires knowledge to select and manage tree species |
| 3. Immediate availability of shade for animal welfare | 3. Requires management for shade regulation (pruning and thinning). |
| 4. Creates biological corridors, providing habitat and food for wildlife. | 4. Difficult to implement in pastures with low natural regeneration of tree species. |
| 5. Provides organic matter to the soil | 5. More suitable for large farms |
| 6. Improves soil and controls erosion in hillside areas | 6. Difficult for cattle handling |
| 7. Some tree species can be used for timber and firewood | 7. Does not allow the shade to be evenly distributed throughout the paddock. |
| 8. Source of animal food with native species that support browsing or provide fruit. | |

**Figure 1.** Scattered trees on pastures (STP) in farms located in Caquetá.


https://doi.org/10.17533/udea.rccp.v38n1a5

Live fences (Table 5 and Figure 2) are a type of SPS in which multi-purpose trees (shade, habitat, wildlife food, firewood, timber, or fruit) are planted in a linear arrangement by establishing seedlings or large stakes along boundaries or in paddock divisions. Distance between trees ranges from 3 to 10 meters, distributed in a single line or more (2 to 4 species in the case of multi-strata fences). Trees are protected in their first two years with electric fences and are planted in areas where there is already an established pasture.

The SPS arrangements called "Strip tree divisions" involve planting improved pastures, lines of trees spaced every 3 to 4 meters, and implementing a livestock aqueduct. The trees allow to divide the paddock for establishing rotational grazing and are protected with electric fencing on each side, with strips of 2.5 to 3 meters wide.

When plant species for family food security or forage for minor animal species are incorporated into the strips, the system is called "Agro-silvopastoral strips" (Table 6 and Figure 3). It is a special type of SPS that -in addition to tree, livestock, and pasture components- incorporates a crop component. The strips usually include multi-purpose trees, banana plants, cassava, fruit trees, corn, and beans, and/or tall forage species. This system favors tree development by reducing competition with grass. Trees also take advantage of residual fertilizer from the crops.

**Table 5.** Farmer perception of live fences (LF).

| Advantages | Disadvantages |
|---|---|
| 1. Reduced costs of paddock divisions and maintenance of fences. | 1. High initial investment, represented by posts and wire for tree protection. |
| 2. Monetary income from timber sales | 2. Requires special training for pruning and tree management |
| 3. Improves soil conditions by nutrient cycling | |
| 4. The shade provides animal welfare | |
| 5. Grazing areas and pasture growth are not affected | |
| 6. Serves as windbreaks | |
| 7. It is multipurpose: wood, fodder, organic matter, and food for fauna. | |

**Figure 2.** Live fences (LF) in Caquetá farms.


https://doi.org/10.17533/udea.rccp.v38n1a5

**Table 6.** Farmer perception of tree divisions in Agro-silvopastoral strips (AS).

| Advantages | Disadvantages |
|---|---|
| 1. Contributes to household food security | 1. Requires planning for tree planting and harvesting |
| 2. Human welfare | 2. High demand of time for management and care |
| 3. Animal welfare, food for minor species | 3. High initial cost (fence, fertilization, wire, aqueduct, alleys). |
| 4. Soil recovery by providing organic matter and nitrogen-fixing legumes. | |
| 5. Generates corridors for seed dispersion by fauna | |
| 6. Generates shade and feeding options for livestock | |
| 7. Diversification of production | |
| 8. Maximum land yield (trees for shade and food production). | |
| 9. Additional income from subsistence crops (banana, cassava, fruit trees). | |
| 10. Low costs of weed control | |

**Figure 3.** Tree-divisions in Agro-silvopastoral strips (AS) in Caquetá farms.

Mixed fodder banks (MFB) is a type of SPS (Table 7) that generally occupy areas between 0.1 and 0.5 ha in which herbaceous, arboreal, and shrub species of high nutritional value are associated and planted intensively (5 to 10,000 plants/ha). They produce biomass of high protein quality for high-quality fodder, which is then cut, transported, chopped and supplied fresh or in silage to ruminant and/or monogastric species. According to producer preferences, leguminous trees, multipurpose trees, fruit trees, and palms are included, as well as plant species for family food security, such as banana, cassava, corn, beans, and pineapple.

*Strategies to promote scaling up of SPS adoption.*

The second focus group of professionals identified 22 strategies to promote greater adoption of SPS, responding to the classification of previously identified barriers to adoption (Table 2).

In the *Skills and knowledge* category, the study identified a need to work on capacity building and knowledge management, from access to mass dissemination of information and experiences already existing in the region. Likewise, there is a need for training in this area, from technicians to cattle-raising families.

**Table 7.** Farmer perception of Mixed fodder banks (MFB).

| Advantages | Disadvantages |
|---|---|
| 1. High production of quality forage per unit of area | 1. High demand for management in times of high rainfall |
| 2. Availability of forage for silage at critical times | 2. High requirement in terms of number of fodder species and fertilization. |
| 3. Alternative for feeding minor species | 3. Negative perception of some producers toward new alternatives. |
| 4. Improves milk quality | 4. High labor requirements |
| 5. Increased and/or sustained milk and meat production | 5. High investment for establishment and management, maintenance, infrastructure, and equipment. |
| 6. Possibility to include in the arrangement of subsistence crops for family food security. | 6. High demand on time, management, and care |
| 7. Allows using manure generated in the barn as fertilizer | |
| 8. Possibility of stabling the animals and increasing the farms' stocking rate. | |
| 9. Reduction in the use of concentrates | |

**Figure 4.** Mixed fodder banks (MFB) of farms in Caquetá.

Regarding *Knowledge* factors of SPS, participants mentioned that producers require adequate training according to socio-cultural conditions, with community governance workshops on water resources, theoretical and practical in-farm workshops following a producer-to-producer training strategy with links to courses taught by the *Colombian service for learning agency* (SENA Emprende Rural, SER) program, which provides training and support to develop productive units with a focus on sustainability.

Dissemination of information and research results can be shared through radio programs, newsletters, or events such as field days, in-farm exchanges called *Innovation laboratories*, models, or demonstration farms.

Technical assistance should be provided by agricultural extensionists on sustainable livestock farming and ecological restoration. Universities and SENA should participate in training through field schools with a *Learning-by-doing* approach on topics related to sustainable cattle ranching. This technical assistance must have long-term support (more than five years) and be defined and financed by instances such as the regional extension service plan known as *Plan Departamental de Extensión Agropecuaria* (PDEA).


https://doi.org/10.17533/udea.rccp.v38n1a5

Regarding *Social aspects*, specific policies and programs should be developed to promote sustainable livestock farming, generating spaces to strengthen both generational replacement and the inclusion of women and youngsters. To reduce resistance to change, it is necessary to train producers through the exchange of experiences and knowledge, showing economic results through field schools and establishing transition plans to more sustainable production systems. Additionally, it is necessary to develop participatory processes in both research and extension and anthropological or sociological studies that allow for a better understanding of the factors associated with adoption and resistance to change.

In terms of *Economy*, SPS provide an opportunity to diversify income by including other activities associated with livestock farming. Nevertheless, it is necessary to strengthen the enterprises that provide inputs and services associated with the establishment and management of the SPS. A value chain approach is needed to reach markets with differentiated products and access to special lines of credit and incentives considering the environmental contribution of these systems. Credits should recognize the environmental contribution made by farmers, with incentives and/or low and soft interest rates with adequate grace periods to cushion the high investment and the first years of implementation and transition.

In the *Environmental* area, there is a need for comprehensive land use planning of the entire farm, including not only production but also conservation and/or restoration of ecologically important areas within the property and the landscape.

Regarding *Technical and operational aspects*, the need for a more managerial and administrative approach was emphasized, including records, production costs, and permanent specialized technical assistance to improve livestock practices and animal welfare. These practices should be accompanied by conservation of biodiversity and ecosystem services for water sources, forests, and native species. Emphasis should be made on finding funding through environmental incentives and animal welfare with differentiated prices in special markets. Knowledge is required on the tree species to be implemented in the SPS and SASP programs for different purposes: commercial, conservation, restoration, adaptation and/or mitigation of climate change.

## Discussion

Livestock agroforestry and the different SPS types have been fundamental for sustainable livestock in Colombia in the last two decades (Murgueitio, 2000; Mahecha, 2003). In Caquetá, these alternatives are on the agenda of public and private organizations including the academic, research, international cooperation, training, and agricultural extension sectors (Solarte *et al.*, 2022). We identified that, beyond pasture and SPS management, ecosystem conservation and renewable energies are also important topics for the local stakeholders.

Knowledge and training are important factors to promote adoption. Pannell *et al.* (2006), defines adoption as a dynamic learning process with a series of phases for the producer: 1) Awareness of the problem or opportunity; 2) Non-experimental evaluation, which involves gathering information to support a decision; 3) Evaluation in small-scale trials, which contributes to decision making and skills development; 4) Adoption, as part of a continuous, gradual and stepwise process; 5) Review and adjustment, for scaling up the innovation; 6) Non-adoption or de-adoption, in case the results do not favor the objectives sought by the producer or a more promising innovation appears.

We identified a lack of knowledge on SPS, lack of technical support, and insufficient training of extensionists as the main barriers for SPS adoption. Other studies reported similar results on limitations related to knowledge (Bussoni *et al.*, 2015; Zapata *et al.*, 2015; Flores-González *et al.*, 2019). In addition, low quality of information and communication and low level


https://doi.org/10.17533/udea.rccp.v38n1a5

of schooling have also been reported as barriers for SPS adoption (Garbach *et al.*, 2012; Ramírez *et al.*, 2012). According to Sandino *et al.* (2023), organizations that promote agroforestry play a positive role in its adoption, and the knowledge gaps that can prevent adoption are reduced through SPS training.

In a study conducted to define adopter profiles in Caquetá, Sandoval *et al.* (2021) reported that there is a learning curve necessary for adoption; it starts with improved pastures, passes through STP and MFB, and finally reaches more complex systems such as pasture divisions with trees and agrosilvopastoral strips. This was also clearly identified by producers in the present study. As SPS disadvantages, they included the need of knowledge about forestry practices, and the management of plant succession and shade for the tree species used.

Resistance to change and lack of family consensus were reported in the present study as barriers to SPS adoption. These are cultural barriers related to beliefs and perceptions of farmers concerning reduced growth of grasses under trees, the time required to establish trees, and deeply rooted technological packages based on the use of grasses that farmers are reluctant to replace by more complex systems (Clavero and Suárez, 2006; Mahecha, 2003). In addition, generational replacement was identified as a limiting factor for adoption due to low motivation and lack of interest of youngsters to continue working on the livestock industry as their parents age, which makes it difficult to develop changes towards SPS (Rizo-Cavarría *et al.*, 2022).

Lee *et al.* (2020) reported that the long-term investment required to obtain benefits and the perceived high complexity are the main barriers to SPS adoption in Cundinamarca province (Colombia); high initial investment, low labor availability, and lack of financing (credit) were the economic barriers identified by farmers. These factors influence the design and type of system to be implemented. Similar results were reported by Dagang and Nair (2003), Mahecha (2003), Pagiola *et al.* (2005), Useche *et al.* (2011), Frey *et al.* (2012), and Opdenbosch and Hansson (2022). The costs of seedlings, herbicides and amendments, the investment payback period, the lack of financing, and low family income are considered adoption barriers. Additional factors that limit adoption are the degree of intermediation to sell the products, and the lack of public policies aimed to promote these practices (Zepeda *et al.*, 2016).

Farm size was also considered by farmers as a factor that could constrain the adoption of sustainable practices in the local context, as land availability limits the establishment of conservation agreements or ecological swaps required by some projects or credit schemes to promote SPS. Various studies have also reported farm size as a factor affecting the probability of adoption (Clavero and Suárez, 2006; Bussoni *et al.*, 2015; Etshekape *et al.*, 2018).

Complementary to the homogeneous farm management approach, a study was recently published by Castro *et al.* (2024) in which land use at the paddock level was used as the unit of analysis given that silvopastoral projects carry out reconversion in small areas of the farms. Results show that the main factors associated with high levels of SPS adoption at the paddock level are gender, resources and knowledge. The study also pointed out the following policy recommendations for scaling up SPS in the Colombian Amazon: (1) Promote paddock division and implement diverse management strategies to facilitate transition to SPS adoption; (2) Reach out to ranchers who have not yet participated in SPS projects and enable them to invest in low-emissions livestock production; (3) Target female heads of households in scaling-up efforts; (4) Recognize and communicate the broader benefits of SPS beyond productive and financial benefits.

Moving from traditional extensive livestock systems based on naturalized or improved grasses to systems that incorporate a tree component and more efficient grazing management implies changes in the normal routines of the producer, which increases the demand for knowledge, technical resources, inputs, and labor.

According to Alvarado *et al.* (2022), common drivers of SPS adoption include variables related to experience (years of current agricultural, and livestock experience), showing a significant negative relationship with adoption; meaning that more experience decreases the probability of adoption. Therefore, if the negative relationship between experience and SSP adoption in Caquetá is a result of traditional paradigms, addressing them could generate substantial increases in adoption rates. Adoption of SPS is favored when it does not represent a problem for the producer in terms of access to inputs, plant management, support, or increased vulnerability to climatic events (Vargas-de la Mora *et al.*, 2021).

Complexity for implementing SPS as a potential barrier due to its intensive management can generate technical difficulties for farmers not familiar with the system including greater availability of water to make paddock divisions (Dagang and Nair, 2003; Ramírez *et al.*, 2012; Amare *et al.*, 2019). In the present study, the disadvantages identified by producers are related to the high costs of land preparation, seedlings, fencing materials, among other inputs, and a greater demand for labor.

The present study identified a series of strategies that can contribute to scaling up SPS in Caquetá (Table 2). In this regard, Calle *et al.* (2013) reported five key elements for a SPS scaling-up strategy: 1. Establishment of pilot farms for research, training, and peer-to-peer technology transfer; 2. Capacity building, including students, producers, field workers, researchers, technicians, extensionists, and policymakers; 3. Development of pilot projects, including environmental incentives, technical assistance, subsidized credits, and differentiated SPS products; 4. Legitimacy and institutional recognition of the positive results of the pilots as a strategy to gain political support; and 5. Development of large-scale projects applying lessons learned from the pilots. Farms and pilot projects facilitate this learning process by bringing innovation closer to the producer. As mentioned above, one of the most widely used scaling-up strategies is the implementation of pilot projects, which consider several scaling-up drivers.

An experience on scaling up in Caquetá was generated from a small pilot project to an initiative of greater coverage and regional impact in the dairy chain. This project is known as the "Environmentally Sustainable Milk Project". Nestle company and Centro para la Investigación en Sistemas Sostenibles de Producción Agropecuaria (CIPAV) developed it between 2008 and 2011. The project promoted livestock conversion to silvopastoral systems in 13 pilot farms distributed as nuclei of technological diffusion to promote its dissemination. Nestlé paid a premium for milk quality, allowing producers to invest in SPS establishment (Tafur *et al.*, 2011). On a second phase, Nestle and the Inter-American Development Bank (IDB) provided credit for SPS implementation to approximately 130 company associates during two years for establishing and specialized technical assistance (Nestle, 2019).

At the national level, another experience was developed in the Andean region consisting of a multi-scale work named Integrated Silvopastoral Approaches to Ecosystem Management Project. It was conducted between 2003 and 2007 on 110 farms located in La Vieja river basin between Valle del Cauca and Quindío provinces. That project established a payment index for biodiversity and carbon environmental services, plus technical assistance provided for land conservation and promotion of conversion of agricultural and livestock use to sustainable livestock farming with SPS. The experience allowed a later expansion of the scheme to five regions and 4,100 farms in Colombia under the Sustainable Colombian Livestock Project led by the National Federation of Cattle Ranchers (FEDEGAN) between 2010 and 2020 (Chará *et al.*, 2011).

For successful adoption, information must be available not only to the farmer but also to his family and the social environment in which they live as a dynamic learning process to support decision-making (Pannell *et al.*, 2006). Positive effects of producer participation in events and training programs for SPS adoption has been recognized in Colombian studies at the national level (Jara-Rojas *et al.*, 2020) in the coffee-growing region (Calle *et al.*, 2009) and in Caquetá (Sandoval *et al.*, 2021). Additionally, belonging to an association of producers favors the exchange of knowledge and can influence the scaling up and adoption of SPS (Alvarado *et al.*, 2023).

Training professionals and extensionists in livestock agroforestry contributes to improving technical assistance provided to producers since these topics are not always included in university programs (Clavero and Suárez, 2006). Local unions and universities in Caqueta have developed diploma courses to train professionals and producers on sustainable livestock raising, including SPS. The combination of training with long-term technical assistance and institutional support is a determining factor for the successful implementation and adoption of SPS (Zepeda *et al.*, 2016).

Women inclusion and creation of opportunities for the permanence of youngsters contribute to scaling up innovations. There is a great influence of the producer own characteristics, his family, and their closest social environment as sources of information and decision support during the learning process needed for adoption (Pannell *et al.*, 2006). In this regard, Zepeda *et al.* (2016) and Etshekape *et al.* (2018) indicate that family composition, age, lack of permanence of youngsters in the field, and the cultural environment, can influence the adoption and permanence of SPS because they reinforce the perceptions associated with resistance to change. Massification of SPS requires profound cultural and technological changes; thus, it is necessary to provide specialized and suitable technical assistance for successful adoption of these initiatives (Murgueitio, 2009).

Despite the common perception of higher costs for establishing SPS versus traditional extensive management, there is sufficient evidence for better efficiency of land use and sustainability of SPS. These systems provide more benefits than traditional systems, reduce the need for external inputs, and improve soil properties, animal carrying capacity, and productivity (Salas *et al.*, 2013; Osorio-García *et al.*, 2019). This is related to a direct perception of producers on improved income from cattle activity, which can increase confidence to invest in SPS and other good management practices (Salcedo *et al.*, 2022). In addition, livestock agroforestry contributes to diversifying production as it is possible to include multipurpose species and generate additional products, including wood, fruit, fodder, and firewood that can generate additional income and contribute to food security. The system incorporates multiple products, including timber and livestock in the same area, which offers an economic way to combine two activities (Ramírez *et al.*, 2012; Bussoni *et al.*, 2015).

According to the adoption study by Sandoval *et al.* (2021) in Caquetá, as SPS become more complex they increase production per unit area, animal carrying capacity, and improve milk production and quality, thus generating higher profitability. However, generating differentiated markets that recognize the environmental attributes of SPS products is a strategy in need of development. Studying SPS in Caquetá, Rodríguez *et al.* (2022) reported that local and regional economic conditions affect the potential for scaling up sustainable land use systems due to lack of stable and differentiated markets for the products generated by these systems.

At the environmental level, farmers and professionals recognize the value of SPS to generate biological corridors for fauna, and their contribution to protecting water sources, enhancing nutrient cycling, and controlling erosion. Pagiola *et al.* (2005) and Calle *et al.* (2009) argue that SPS improve biodiversity, vegetation cover, water, soil erosion and fertility.

The association among plant species creates different strata that generate shade which improves animal welfare and weed control. Similar results were found by Frey *et al.* (2012) regarding the perception of SPS in Argentina. They mention that cattle help to control shade-tolerant weeds. Other researchers agree, indicating that trees generate a microclimate through shade which reduces heat the stress of livestock; furthermore, heat stress reduction helps to produce forage of high nutritional value in summer, while trees provide shelter for the animals during the winter (Pagiola *et al.*, 2005; Calle *et al.*, 2009; Garbach *et al.*, 2012). The SPS improve farm productivity, diversify products (milk, meat, wood, poles, and firewood), provide shade, improve animal diet, and reduce the use of chemical fertilizers and concentrates, which is evidenced by less use of external inputs. In addition, SPS allow generating environmental services such as carbon sequestration, biodiversity conservation, and protection of water sources (Ibrahim *et al.*, 2006; Murgueitio *et al.*, 2014; Russo, 2015).

There is a consensus among institutions regarding the importance of promoting livestock agroforestry for conversion of livestock farming in the Caquetá piedmont. Nevertheless, there are still barriers related to knowledge, implementation costs, and environmental and cultural conditions which need to be addressed to enable scaling up these systems.

Finally, interventions must balance advantages and disadvantages of some SPS that provide greater benefits but require more skills versus other SPS that may have fewer benefits but can achieve wider adoption with fewer requirements (Bettles *et al.*, 2021).

## Declarations

### *Acknowledgments*

The authors are grateful to the livestock producers at the municipalities of Morelia, Belén, Albania, La Montañita, El Paujil, and El Doncello, and to the teams from the participating institutions, as well as the CIPAV team for their support to conduct the study.

### *Funding*

This study was conducted within the framework of project 18_III_106_COL_A_Sustainable Production Strategies. This project is part of the International Climate Initiative (IKI). The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) also supports this initiative by the German Bundestag.

The United States Agency for International Development (USAID) funded the project "Sustainable management of livestock agro-landscapes in prioritized corridors of the Andean-Amazonian piedmont of Caquetá, to improve connectivity, adaptation to climate change and local economic development" under the Conservation and Governance Program in the Amazon piedmont, developed by the Natural Heritage Fund in partnership with the Center for Research on Sustainable Agricultural Production Systems - CIPAV.

### *Conflicts of interest*

The authors declare they have no conflicts of interest regarding the work presented in this report.

### *Author contributions*

Conceptualization: Antonio Solarte, Catalina Zapata. Methodology: Antonio Solarte, Catalina Zapata, Adrián Rico. Systematization and analysis: Antonio Solarte, Adrián Rico, Catalina Zapata. Writing - draft manuscript: Antonio Solarte, Adrián Rico. Writing - editing: Julián Chará, Antonio Solarte and Enrique Murgueitio. Fundraising: Julián Chará, Catalina Zapata and Antonio Solarte. Supervision: Julián Chará and Catalina Zapata.

### *Use of artificial intelligence (AI)*

No AI or AI-assisted technologies were used during the preparation of this work.

## References

Amare D, Wondie M, Mekuria W, Darr D. Agroforestry of smallholder farmers in Ethiopia: practices and benefits. Small-scale Forestry 2019; 18(1):39–6. https://doi.org/10.1007/s11842-018-9405-6

Alvarado C, Barnes AP, Sepúlveda I, Garratt M, Thompson J, Escobar-Tello. Examining factors for the adoption of silvopastoral agroforestry in the Colombian Amazon. Sci Rep 2023; 13(12252). https://doi.org/10.1038/s41598-023-39038-0

Alvarado C, Barnes AP, Sepúlveda I, Garratt M, Thompson J, Escobar-Tello. Transitioning to silvopastoral forestry. Testing the common drivers of farmer adoption in the Colombian Amazon. Res Sq 2022; 1–17. https://doi.org/10.21203/rs.3.rs-2404072/v1

Bettles J, Battisti D, Cook-Patton S, Kroeger T, Spector J, Wolff N, Masuda Y. Agroforestry and non-state actors: a review. For Policy Econ 2021; 130(102538). https://doi.org/10.1016/j.forpol.2021.102538

Broom DM, Galindo FA, Murgueitio E. Sustainable, efficient livestock production with high biodiversity and good welfare for animals. Proc Biol Sci 2013; 280(1771). https://doi.org/10.1098/rspb.2013.2025

Buitrago ME, Ospina LA, Narváez W. Sistemas silvopastoriles: alternativa en la mitigación y adaptación de la producción bovina al cambio climático. Bol Cient Mus Hist Nat Univ Caldas 2018; 22(1):31–42. https://doi.org/10.17151/bccm.2018.22.1.2

Bussoni A, Juan C, Fernández E, Boscana M, Cubbage F, Bentancur O. Integrated beef and wood production in Uruguay: potential and limitations. Agroforest Syst 2015; 89(6):1107–1118. https://doi.org/10.1007/s10457-015-9839-1

Cabrera E. Actualización de Cifras de Monitoreo de La Superficie de Bosque – Año 2021. Instituto de Hidrología, Meteorología y Estudios Ambientales-IDEAM, Ministerio de Ambiente y Desarrollo Sostenible 2022:23. http://documentacion.ideam.gov.co/openbiblio/bvirtual/023983/SMByC.pdf

Calle A, Montagnini F, Zuluaga AF. Farmer's perceptions of silvopastoral system promotion in Quindío, Colombia. Bois For Trop 2009; 300(2):79–94.

Calle Z, Murgueitio E, Chará J, Molina CH, Zuluaga AF, Calle A. A. Strategy for scaling-up intensive silvopastoral systems in Colombia. J Sustain For 2013; 32(7):677–693. https://doi.org/10.1080/10549811.2013.817338

Castro A, Buritica A, Holmann F, Ngaiwi M, Quintero M, Solarte A, González, C. Unlocking sustainable livestock production potential through paddock division and gender inclusivity. Res Sq 2024; 1–29. https://doi.org/10.21203/rs.3.rs-3592285/v1

Centro Nacional de Memoria Histórica. Caquetá: conflicto y memoria. 1st ed.; 2013.

Clavero T, Suárez J. Limitaciones en la adopción de los sistemas silvopastoriles en Latinoamérica. Pastos y Forrajes 2006; 29(3):1–6.

Dagang ABK, Nair PK. Silvopastoral research and adoption in Central America: recent findings and recommendations for future directions. Agroforest Syst 2003; 59(2):149–155. https://doi.org/10.1023/A:1026394019808

Escobar J, Bonilla-Jimenez FI. Grupos focales: una guía conceptual y metodológica. Cuadernos Hispanoamericanos de Psicología 2011; 9(1):51–67.

Etshekape PG, Atangana AR, Khasa DP. Tree planting in urban and peri-urban of Kinshasa: survey of factors facilitating agroforestry adoption. Urban For Urban Green 2018; 30:12–23. https://doi.org/10.1016/j.ufug.2017.12.015

Fajardo MY, Facundo G. Costos de conversión en los procesos de producción de ganadería tradicional al sistema silvopastoril en fincas ganaderas del Municipio de Florencia, Morelia y Belén del Departamento del Caquetá. FACCEA 2014a; 4(1):30–40.

Flores-González A, Jiménez-Ferrer G, Castillo-Santiago M, De Oña CR, Covaleda S. Good livestock practices: adoption of technologies in the rio perlas gorge, Ocosingo, Chiapas Mexico. Trop Subtrop Agroecosystems 2019; 22(1):87–96. http://dx.doi.org/10.56369/tsaes.2670

Frey GE, Fassola HE, Pachas AN, Perceptions of silvopasture systems among adopters in northeast Argentina. Agric Syst 2012; 105(1): 21–32. https://doi.org/10.1016/j.agsy.2011.09.001

Garbach K, Lubell M, DeClerck FAJ. Payment for ecosystem services: the roles of positive incentives and information sharing in stimulating adoption of silvopastoral conservation practices. Agric Ecosyst Environ 2012; 156:27–36. https://doi.org/10.1016/j.agee.2012.04.017

Geilfus F. 80 Herramientas para el desarrollo participativo: diagnóstico, planificación, monitoreo evaluación. Instituto Interamericano de Cooperacion para la Agricultura (IICA) 2009. https://repositorio.iica.int/handle/11324/4129

Hurley T, Brown J. Conversational leadership: thinking together for a change. The Systems Thinker 2016; 20(9):2–7.

Ibrahim M, Villanueva C, Casasola F, Rojas J. Sistemas silvopastoriles como una herramienta para el mejoramiento de la productividad y restauración de la integridad ecológica de paisajes ganaderos. Pastos y Forrajes 2006; 29(4).

Jara-Rojas R, Russy S, Roco L, Fleming-Muñoz D, Engler A. Factors affecting the adoption of agroforestry practices: insights from silvopastoral systems of Colombia. Forests 2020; 11(6). https://doi.org/10.3390/f11060648

Jiménez JG. Ordenamiento productivo y social de la propiedad en la Amazonia: casos Caquetá y Guaviare estrategias y desarrollo. Instituto Amazónico de Investigaciones Científicas SINCHI; 2019.

Lee S, Bonatti M, Löhr K, *et al.* Adoption potentials and barriers of silvopastoral system in Colombia: case of Cundinamarca region. Cogent Environmental Sci 2020; 6(1). https://doi.org/10.1080/23311843.2020.1823632

Mahecha L. Importancia de los sistemas silvopastoriles y principales limitantes para su implementación en la ganadería colombiana. Rev Colomb Cienc Pecu 2003; 16(1):11–18.

Murad CA, Pearse J. Landsat study of deforestation in the Amazon region of Colombia: departments of Caquetá and Putumayo. Remote sensing applications. Society and Environment 2018; 11:161–171. https://doi.org/10.1016/j.rsase.2018.07.003

Murgueitio E. Incentivos para los sistemas silvopastoriles en América Latina. AIA 2009; 13(1):3–20.

Murgueitio E. Sistemas agroforestales para la producción ganadera en Colombia. Pastos y Forrajes 2000; 23(3).

Murgueitio E, Chará J, Barahona R, Cuartas C, Naranjo J. Los sistemas silvopastoriles intensivos (SSPi), herramienta de mitigación y adaptación al cambio climático. Trop Subtrop Agroecosystems 2014; 17(3):501–507.

Murgueitio E, Chará JD, Solarte AJ, Uribe F, Zapata C, Rivera JE. Agroforestería Pecuaria y Sistemas Silvopastoriles Intensivos (SSPi) para la adaptación ganadera al cambio climático con sostenibilidad. Rev Colomb Cienc Pecu 2013; 26:313–316. https://doi.org/10.17533/udea.rccp.324845

Navas A. Importancia de los sistemas silvopastoriles en la reducción del estrés calórico en sistemas de producción ganadera tropical. Rev Med Vet 2010; (19):113–122. https://doi.org/10.19052/mv.782

Opdenbosch H, Hansson H. Farmers' willingness to adopt silvopastoral systems: investigating cattle producers' compensation claims and attitudes using a contingent valuation approach. Agroforestry Systems 2022; 97: 133–149. https://doi.org/10.1007/s10457-022-00793-0

Osorio-García AM, Paz L, Howland F, *et al.* Can an innovation platform support a local process of climate-smart agriculture implementation? A case study in Cauca, Colombia. Agroecol Sustain Food Syst 2019; 44(3):378–411. https://doi.org/10.1080/21683565.2019.1629373

Pagiola S, Agostini P, Gobbi J, de-Haan C, Ibrahim M, Murgueitio E, Ramírez E, Rosales M, Ruíz J. Paying for biodiversity conservation services. MRED 2005; 25(3):206–211. https://doi.org/10.1659/0276-4741(2005)025[0206:PFBCS]2.0.CO;2

Pannell DJ, Marshall GR, Barr N, Curtis A, Vanclay F, Wilkinson R. Understanding and promoting adoption of conservation practices by rural landholders. Aust J Exp Agric 2006; 46(11): 1407–1424. https://doi. org/10.1071/EA05037

Ramírez B, Lavelle P, Orjuela J, Villanueva O. Caracterización de fincas ganaderas y adopción de sistemas agroforestales como propuesta de manejo de suelos en Caquetá, Colombia. Rev Colomb Cienc Pecu 2012; 25(3):391–401. https://doi.org/10.17533/udea.rccp.324782

Rizo-Chavarría C, Cascante-Carvajal C, Imbach-Hermida A, Tobar-López D. Perception of livestock farmers on ecosystem services provision in the livestock production activity, Esparza, Costa Rica. Revista Forestal Mesoamericana Kurú 2022; 19 (45):38–46. https://doi.org/10.18845/rfmk.v19i45.6324

Russo R. Reflexiones sobre los sistemas silvopastoriles. Pastos y Forrajes 2015; 38(2) 157–161.

Salas JM, Leos JA, Sagarnaga M, Zavala-Pineda MJ. Adopción de tecnología por productores beneficiarios del progasma de estimulos a la productividad ganadera (PROGAN) en México. Rev Mex Cienc Pecu 2013; 4(2):243–254.

Salazar CA, Riaño E. Perfiles urbanos en la Amazonia colombiana. 1st ed.; 2016.

Salcedo W, Toral J, Pérez E, Piñeiro A, Jiménez G. Level of adoption of silvopastoral techniques in the Sierra Madre de Chiapas, Mexico. Trop Subtrop Agroecosystems 2022; 25(2). http://dx.doi.org/10.56369/tsaes.4001

Sandoval D, Fernández JC, González C, Solarte A, Holmann F, Quintero M, Castro A, Zapata C. Reporte técnico: factores que influyen en la adopción de sistemas silvopastoriles en el piedemonte andino-amazónico del departamento del Caquetá, Colombia. Publicación CIAT No 517. CIAT, CIPAV, Patrimonio Natural 2021. https://hdl.handle.net/10568/116242

SINCHI. División político-administrativa de la Amazonia colombiana. 2017. https://siatac.co/la-amazonia-colombiana/

Rodríguez T, Bonatti M, Löhr K, Lana M, Del Río M, Sieber S. Analyzing influencing factors to scale up agroforestry systems in Colombia: a comparative ex-ante assessment of cacao farming and cattle ranching in two regions. Agroforest Syst 2022; 96:435–446. https://doi.org/10.1007/s10457-022-00730-1

Solarte A, Rico A, Zapata C, Chará J, Murgueitio E. Retos para escalar los sistemas silvopastoriles en Caquetá. DeCarne 2022;58(6):54–57. https://es.calameo.com/read/002033190230a63fc9523

Tafur O, Hurtado E, Murgueitio E, Pedraza G, Gacharna N, Zambrano F, Ortiz L. Leche ambientalmente sostenible. Fundación CIPAV; 2011.

Torrijos R. Cifras de Contexto Ganadero Caquetá 2022. Comité Departamental de Ganaderos del Caquetá 2022. https://issuu.com/rafaeltorrijos/docs/contexto_2022_imp

Useche D, Harvey CA, DeClerck F. Implicaciones sociales, económicas y ecológicas para la implementación de sistemas silvopastoriles como estrategia para la conservación de la biodiversidad en paisajes ganaderos tropicales. Agroforestería Américas 2011; (48):84–93.

Vargas-de la Mora AL, Castillo-Santiago M, Randhir TO, Hernández-Moreno M del C, Cach-Pérez MJ, Camacho-Valdéz V. Conocer para mejorar: factores que influyen en la transición hacia sistemas silvopastoriles en la costa de Chiapas. Trop Subtrop Agroecosystems 2021; 24(3):1–16. http://dx.doi.org/10.56369/tsaes.3689

Zapata C, Robalino J, Solarte A. Influencia del pago por servicios ambientales y otras variables biofísicas y socioeconómicas en la adopción de sistemas silvopastoriles a nivel de finca. LRRD 2015; 27(63).

Zepeda RM, Velasco ME, Nahed J, Hernández A, Martínez JJ. Adopción de sistemas silvopastoriles y contexto sociocultural de los productores: apoyos y limitantes. Rev Mex Cienc Pecu 2016; 7(4):471–488.