Tropical Grasslands-Forrajes Tropicales (2022) Vol. 10(2):78–88
doi: 10.17138/TGFT(10)78-88

Review Article

A review of silvopastoral systems in the Peruvian Amazon region

Revisión de sistemas silvopastoriles en la Amazonia peruana

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Abstract

Livestock in the Peruvian Amazon region is mostly produced in areas considered degraded pasturelands and associated with deforestation. Silvopastoral systems (SPS) are an alternative for sustainable livestock production. This article aims to provide information about progress in the development of SPS in the Peruvian Amazon region during the last 2 decades and opportunities to develop it further at the national level. The geographical characteristics and climatic conditions of the Peruvian Amazon are described, followed by a review of the experiences with SPS in the 5 most relevant departments of the region. Constraints for implementation of SPS practices in the country and the current initiatives at regional and national level to promote and develop more sustainable livestock production in the region are presented. There is a large variation in SPS practiced along the different departments of the Amazon region. It is imperative that the Peruvian Government continues promoting SPS for recovering degraded lands through generating enabling conditions for farmers to adopt and/or scale up SPS.

Keywords: Agroforestry, livestock, sustainable production, tropics.

Resumen

La actividad ganadera en la región amazónica peruana se realiza mayormente en áreas de pasturas degradadas asociadas con actividades de deforestación. Los sistemas silvopastoriles (SSP) son una alternativa de producción ganadera sostenible. El presente artículo de revisión tiene como objetivo brindar información sobre los avances en el desarrollo de SSP en la Amazonia peruana durante las últimas dos décadas y las oportunidades para desarrollarlo más a nivel nacional. En este atículo se describen las características geográficas y condiciones climáticas de la Amazonia peruana, seguidas por la revisión de las experiencias sobre SSP en los cinco departamentos más importantes de la Amazonia peruana. Asimismo, se presentan las limitaciones para la implementación de prácticas silvopastoriles en el país y las iniciativas actuales (a nivel regional y nacional) para promover y desarrollar una producción ganadera más sostenible en la región. Los resultados muestran alta variación en los SSP practicados en los departamentos de la región amazónica. Es imperativo que el Gobierno peruano continúe promoviendo los SSP para recuperar tierras degradadas, generando al mismo tiempo las condiciones para motivar a los ganaderos a adoptar o masificar los SSP.

Palabras clave: Agroforestería, ganadería, producción sustentable, trópico.

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Introduction

Peru has 5.2 million cattle, which represents an increase of 14.7% in comparison to 1994 (INEI 2012). These are mostly owned by small-scale farmers using 353,458 hectares of native pastures for livestock in the Amazon region. Only 21% of all producers belong to farmers' associations. The lack of a strong cooperative system reduces options for farmers to access credit and new technologies required for recovering degraded pastures, as well as for sharing the costs of technical support (CDP 2018). Nearly 17% (887,299) of cattle are concentrated in the Amazon region, where cattle are raised in fragmented forest areas, covered by early successional forests (locally called purma), or in abandoned deforested lands covered by native grasses such as *Axonopus* spp. and *Paspalum* spp. (Meza López et al. 2007).

Traditional animal production systems in the Amazon region are based on monocultures of grasses, with seasonal variation in forage availability, lack of fertilization and inadequate grazing management, resulting in high rates of land degradation and soil erosion. Cattle production is based on low capital investment and is viewed by farmers as a low-risk activity compared with crops that are subject to price volatility. However, poor land management has led to overall low productivity, low economic feasibility, vulnerability and extensification of livestock systems and rural poverty and malnutrition, increasing the need for farmers to continue deforesting while trying to benefit from the temporal higher fertility of recently open land. Loreto, Ucayali, Madre de Dios, San Martín and Huánuco are the 5 departments located in the Amazon region that are more affected by deforestation (Figure 1), representing 86% of the national forest loss (355,555 ha) during the period 2010–2014. The land area of livestock farms in the Amazon region is on average 25.4 ha/farm, with a herd size of 10.6 animals/farm, production per lactating cow of 4.1 kg milk/d, and an average carcass weight per beef animal (more than 2 years of age) of 134.3 kg (INEI 2012).

Peru expects to increase its per capita consumption of milk and beef by 37 and 19% respectively, while reducing imports of these goods by 2027 (Minagri 2017). If livestock productivity is not improved to attain this goal, then it would imply increasing the national herd size and potentially, also increasing deforestation in the Amazon region. To prevent this situation, Peru designed The National Livestock Farming Development Plan in 2017 (Minagri 2017). The 5 mainstays included in the plan are adequate management of natural resources, increasing competitiveness, enhancing value addition to livestock products, improving coverage of services for accessing markets and strengthening producers' capabilities. This context provides opportunities to implement silvopastoral systems (SPS), defined as the intentional integration and management of grass, livestock and trees, as a means to achieve sustainable livestock production and farm income diversification. In addition, implementation of SPS has potential to provide environmental benefits, with the rehabilitation of 353,458 hectares of degraded pastures in the Amazon region of Peru already completed, plus the commitment of the Peruvian Government to plant 119,000 hectares to SPS by 2030 for reducing carbon emissions in the framework of The Nationally Determined Contributions (NDC). Although SPS has been used for decades and its value to allow continued use of cleared land and reduce deforestation documented (Loconto et al. 2019), its development in Peru is still a novel approach compared with other countries of Latin America.

Characteristics of the Peruvian Amazon region

The Peruvian Amazon region covers approximately 78.5 million ha. Geographically, it is located between 0°2' and 14°30' S and 68°39' and 79°29' W (Figure 1). The Peruvian Amazon consists of 2 distinct ecoregions: the lowland tropics (*Selva baja*) of the Amazon basin and the intermediate tropics (*Ceja de Selva*) on the foothills (Klarén 2017). The lowland humid tropics is the largest ecoregion in Peru, found between 80 and 1,000 meters above sea level (masl). The region has an average temperature of 31 °C, high relative humidity (higher than 75%), and a yearly rainfall of approximately 1,000 mm. The intermediate tropics is the ecoregion that extends into the eastern foothills of the Andes, between 1,000 and 3,800 masl, with an average temperature of 22 °C, average relative humidity of 75%, and yearly rainfall of approximately 2,600 mm to 4,000 mm. (Minagri 2020). These eastern slopes of the Andes are home to a diverse variety of fauna and flora because of the different altitudes and climates within the region (Pulgar Vidal 1979). Loreto (47.8%), Ucayali (13.4%), Madre de Dios (10.8%), San Martín (6.2%) and Amazonas (4.7%) are the 5 departments that represents 83% of the total Peruvian Amazon region (Minam 2015). Elevation, rainfall, evapotranspiration and temperature determine the tree species and pastures to be considered for the design of SPS.

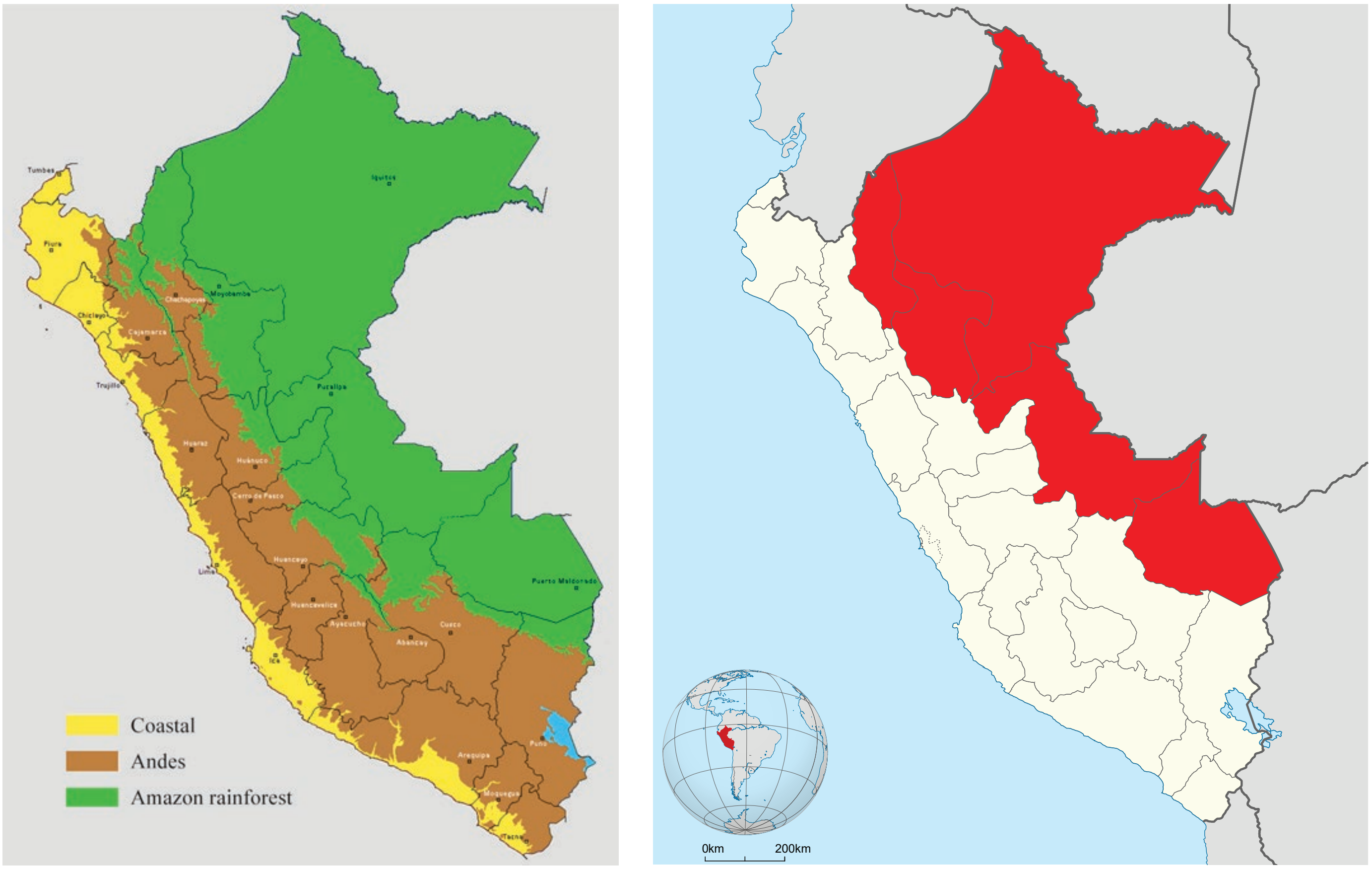

Figure 1. Map of the Peruvian Amazon (left) and the 5 departments with the largest geographical extent of forest (right in red). Source: Mauricio Lucioni (CC BY-SA 4.0) and Guillermo Romero (CC BY-SA 3.0).

SPS technologies available in 5 departments in the Peruvian Amazon

Loreto

Loreto department is located in the lowland tropics of Peru and has an area of 37.5 million ha. SPS in Yurimaguas province are one of the main options for recovering degraded lands using grass-legume mixtures (Arevalo et al. 1998). Livestock production is predominantly for beef. Land degradation is caused mainly by poor grazing management leading to overgrazing. Long-term changes in soil physical properties and surface soil compaction are the main effects of overgrazing (Alegre and Lara 1991). SPS of bracharia (*Urochloa* spp.) and peach palm (*Bactris gasipaes*), planted at a 5 × 5 m distance, with *Centrosema macrocarpum* used as a cover crop as a protein bank for beef, resulted in improved soil fertility and reduced soil compaction under adequate grazing management (Alegre et al. 2012). Livestock were rotationally grazed between 2 paddocks, with 14-days grazing and 14-days rest, and with a stocking rate of 3 livestock units (TLU)/ha. The average live weight gain (LWG) was 445 g/animal/d during the 4 years of the study. Such LWG is substantially greater than the one obtained under traditional grazing systems used by farmers in the area (380 g/animal/d). Current research work is focused on recovering degraded brachiaria (*Urochloa brizantha*) pastures by fertilizing with 40 kg P/ha plus overseeding of *Centrosema* (Alegre et al. 2017). After full establishment of the pasture, fast-growing native trees were planted at a density of 3 × 3 m. The trees include capirona (*Calycophyllum spruceanum*), bolaina (*Guazuma crinita*) and marupa (*Simarouba amara*). Five years after planting, the tree stand was thinned to a density of 6 × 6 m. Grazing started at the beginning of the sixth year using rotational stocking at a stocking rate of 3 TLU/ha, based on previous experience. The carbon stocks for different land uses systems were also evaluated in Yurimaguas. The average carbon stock of a 10-year-old peach palm plantation with *C. macrocarpum* was 55 t/ha with a flux of 5.5 t C/ha/y, and in a 10-year multistrata system with *Centrosema* was 59 t/ha with a flux of 5.9 t C/ha/y (Alegre et al. 2004; Palm et al. 2002).

Ucayali

Ucayali department is located in the lowland tropics with an area of 10.5 million ha. Livestock production systems are predominantly extensive and semi-extensive low-input systems, causing significant deforestation threats. Most livestock farms are used for beef production with a lower proportion for dairy. In both cases productivity is limited because of inadequate management, which has led to pasture degradation, soil erosion and a high presence of invasive weed species. Vela et al. (2010) developed a baseline of SPS initiatives in Ucayali, observing different designs of SPS (scattered trees in pastures, forage banks, live fences and windbreaks). Among the farmers' reasons for implementing SPS were the introduction of trees to complement cultivated pastures (50% of farmers), improvement of the nutritional quality of native pastures (19%), system diversification (13%), recovering degraded land for pastures or crops (13%) and improvement of soil-plant-animal system sustainability (5%). Farmers also reported the main benefits of SPS as better management of their current production system (46% of farmers), increased knowledge about crop-livestock-tree farming (34%), increased property value (8%), enhanced income (8%), and the introduction of new production systems (4%). Primary forest trees such as *Amburana cearensis*, *Ceiba samauma*, *Swietenia macrophylla*, *Aspidosperma macrocarpon* and *Dipteryx odorata* together with secondary forest trees such as *Calycophyllum spruceanum*, *Simarouba amara*, *Guazuma crinita*, *Handroanthus serratifolius*, *Terminalia oblongata*, *Erythrina* spp, *Inga edulis*, *Ficus insipida*, *Inga* spp., *Gmelina arborea*, *Jatropha curcas*, *Crescentia cujete*, *Schizolobium parahyba* and *Vitex pseudolea* were incorporated in the SPS by farmers (Riesco et al. 1995; Clavo et al. 2006; Vela et al. 2019). These trees were used for shade for cattle, firewood, timber, fruits and medicinal products. Clavo and Fernandez-Baca (1999) suggested the importance of natural regeneration as an alternative to planting trees for the establishment of SPS in Ucayali. Among the native tree species considered were *Cordia ucayalensis*, *Ochroma pyramidale*, *H. serratifolius* and *Trema micrantha* due to their frequency (42 plants/ha), survival rate (86%), non-interference with planted tree species and potential economic value.

Vela et al. (2019) reported the performance of a multistrata SPS prototype in Ucayali department based on pastures (*Urochloa dictyoneura*), shrubs and forage trees (*C. cujete*, *Cratylia argentea*, *Erythrina berteroana* and *Leucaena leucocephala*), short-cycle trees (*S. amara*) and long-cycle trees (*D. odorata*), compared with a monoculture plot of *U. dictyoneura* grazed by Holstein × Gyr cows. Results obtained showed positive effects of SPS, including improved soil physical and chemical characteristics, increased macrofauna, lower temperature (32.5 vs. 35.4 °C), an average daily milk production of 5.0 kg/animal/d at a stocking rate of 5 TLU/ha and a potential carbon sequestration equivalent to 133 t C/ha. These results suggest that there is a wide diversity of shrubs and tree species that can be used for fodder, wood, live fences and other uses. Currently, the average carrying capacity of this SPS is 2.5 TLU/ha. In terms of carbon sequestration in Ucayali, an evaluation of a SPS production based on a 30-year rubber (*Hevea brasilienses*) plantation with kudzu (*Neustanthus phaseoloides*) produced an average carbon stock of above and below ground biomass of 152.6 t C/ha. Similarly, legumes and grasses grazed within the trees increased the carbon stocks by 2–5 t C/ha (Alegre et al. 2004; Palm et al. 2002). Callo et al. (2002) reported a difference of 22.5 t C/ha of carbon stock in a SPS based on scattered trees and pasture on degraded land in Ucayali, demonstrating the potential environmental contribution of SPS in this department.

Madre de Dios

Madre de Dios department is in southeastern Peru, on the border with Bolivia and Brazil, and is mostly in the lowland tropics. It has an area of 8.5 million ha. This department is considered the capital of Peruvian biodiversity because it hosts more than fifteen protected areas. Livestock production is mainly beef cattle in the provinces of Tambopata and Tahuamanu. A baseline study conducted by the Ministry of Agriculture (Minagri 2019a) reported that livestock farms have an average 67 ha of cultivated pasture supporting predominantly Brown Swiss x Zebu crossbred animals. The report by Minagri (2019b) also identified low soil fertility and acidity as constraints and recommended the application of phosphoric rock and agricultural dolomite prior to planting cultivated pastures. SPS present in the area are based on timber and fruit trees such as *I. edulis*, *G. crinita*, *C. spruceanum*, *Guazuma ulmifolia*, *Gliricidia sepium*, *B. gasipaes*, *Dipteryx micrantha*, *G. arborea* and *Cedrela odorata*, in association with different genotypes of *Urochloa*. Minagri is currently promoting the implementation of SPS in Madre de Dios as an alternative for sustainable land use against illegal mining activities and deforestation. They are supporting the establishment of 600 hectares of trees (*G. crinita* and *D. micrantha*) in live fences associated with cultivated grasses, using a pasture planting density of 4 kg seeds/ha of *Urochloa*. Additionally, Minagri is encouraging the establishment of high-density protein banks for improving livestock production, prioritizing the use of *L. leucocephala* and *C. macrocarpum*.

San Martín

San Martin department is located mainly in the intermediate tropics (*Ceja de Selva*) and covers an area of 4.9 million ha. Pizarro et al. (2020) reported that, on average, farm size is less than 10 ha with 35% of the farms having between 10 and 30 ha and approximately 81% of the farms having less than 5 ha in SPS. Cattle production is focused on dairy and beef production. In Moyobamba province, most cattle are crossbreds (36%) and Brown Swiss (34%). SPS designs consist mainly of trees in live fences and scattered trees in pastures. The understory forage is mainly grass monoculture grazed by dual-purpose cattle. Trees used in SPS are pruned to obtain firewood, but there are also timber and fruit trees. The most predominant tree species in SPS are *I. edulis*, *Eucalyptus* sp., *Ormosia coccinea*, *Psidium* sp., *Cedrelinga cateniformis*, *Colubrina glandulosa* and *Mangifera indica*. These trees were observed in association with *Digitaria eriantha*, *U. brizantha*, *Arachis pintoi*, *N. phaseoloides*, *U. decumbens*, *Axonopus compressus* and *Paspalum dilatatum*.

Holmann and Lascano (2001) reported that higher stocking rates were possible in farms of San Martin that had pastures of *C. macrocarpum*, *U. decumbens* and *U. brizantha* compared to degraded pastures. Pizarro et al. (2020) evaluated SPS with *Corymbia tolleriana* in live fences and *U. decumbens* and determined the suitable stocking rate as 1.8 TLU/ha/yr and a productivity of 2,200 kg milk/lactation. Alegre et al. (2019) analyzed soil attributes in 3 types of SPS in Moyobamba province and reported on average an acid pH (4.8), high organic matter content (4.3%), low phosphorus (2.36 ppm) and low to medium potassium (114 ppm) levels. In relation to the feeding value of tree foliage in San Martin department, Bernal (2019) reported an in vitro apparent dry matter digestibility (IVADMD) of 56% and 47% for *I. edulis* and *C. tolleriana*, respectively. Godoy et al. (2020) identified byproducts as a complementary source of energy and protein and obtained high to medium IVADMD for broken rice (99.3%), rice polishings (99%), coffee pulp (79.3%), cacao husks (75.5%) and coconut cake (52%).

Amazonas

Amazonas department is also located mainly in the intermediate tropics (*Ceja de Selva*) and covers 3.7 million ha. Pizarro et al. (2020) reported that more than 60% of the farmers surveyed in Amazonas have less than 10 ha of land. SPS are predominant in the southern part of the department and cattle production is predominantly dairy. Alegre et al. (2019) reported the presence of SPS based on associations of *Populus alba*, *I. edulis* and *C. torrelliana* trees with *Urochloa mutica* at 1200 masl and *Pinus patula*, *Cupressus sempervirens*, *Ceroxylon peruvianum* and *Alnus acuminata* trees with *Dactylis glomerata* and *Lolium perenne* pastures at 2400 masl. Vásquez et al. (2020) evaluated the average carbon stock above and below ground for 4 types of SPS; *Alnus acuminata* intercropped with grasses, *Pinus patula* intercropped with grasses, *Cupressus macrocarpa* in live fences and *Ceroxylon quindiuense* as scattered trees in pastures, associated in all the cases with *D. glomerata*, *L. multiflorum* and *Trifolium repens*. The average above-ground biomass (sum of tree, herbaceous and leaf litter) and soil carbon stocks (below-ground biomass) were 179.5 t C/ha for *C. quindiuense* (57.9 from above-ground biomass plus 121.6 from soil), 160.8 t C/ha for *P. patula* (11.7 from above-ground biomass plus 149.1 from soil), 150.1 t C/ha for *C. macrocarpa* (32.8 from above-ground biomass plus 117.2 from soil) and 108.2 t C/ha for *A. acuminata* (6.9 from above-ground biomass plus 101.3 from soil). They also observed high dry matter yields (0.3 kg/m2) and nutritional values (Crude Protein of 16.1% and IVADMD of 66.1%) in pastures of SPS associated with *A. acuminata*. Similarly, Oliva et al. (2018) reported positive effects of the association with *Erythrina edulis*, *A. acuminata* and *Salix babylonica* on the yield and nutritive value of *L. multiflorum* and *T. repens*. In terms of economics, Chizmar (2018) evaluated a SPS model compared to a typical pasture-based cattle system in Amazonas department and observed a higher net present value (992.5 vs. 796.9 $/ha) and benefit-cost ratio (1.16 vs. 1.11) at 4% discount rate for the SPS. However, the establishment costs were higher (1,203.4 vs. 1,197.5 $/ha) and the payback period was longer (4 vs. 3 years).

Constraints to the implementation of SPS practices

To achieve the required scale of SPS in Latin America, farmers must have access to inputs, capital and information (Arango et al. 2020). There are 350,000 ha of degraded pastures in the Amazonian region of Peru that could be improved by implementing SPS to increase animal productivity and enhance carbon sequestration, as well as reducing the carbon emissions associated with deforestation and forest degradation. The main constraints for implementing SPS in the region were identified through interactions with relevant actors in Peru.

Technology

While SPS farmer-validated options are available for the Peruvian Amazon region, there is still a need for studies on suitable SPS in other ecosystems in the different departments. Participatory research and workshops with farmers to recover indigenous and local knowledge, together with sharing experiences with Latin American SPS specialists are important to determine which species to include in SPS. Proper selection of species is critical to the success and sustainability of SPS because the costs of introducing tree and shrub species and the time required for their development could be considerable. It is also important to consider the technical and economic feasibility, which are critical for adoption. Oliva et al. (2018) reported that land size, herd size, number of cows in lactation, soil conservation practices, trees available on farms and access to support for planting activities are some of the factors that limit the adoption of SPS technology in the Amazonas department. Lee et al. (2020) identified degraded soil quality as a major limitation to SPS implementation by farmers.

Studies of agroforestry production systems (SPS are a type of agroforestry) in Brazil (Cubbage et al. 2012), Bolivia (Hoch et al. 2012; Jacobi et al. 2017) and Uruguay (Cubbage et al. 2012) all identified fire as a significant threat. Uncontrolled fires used for pasture expansion can move quickly and newly planted trees are vulnerable, especially in agricultural frontier areas along the periphery of the Amazon Rainforest (Hoch et al. 2012).

Experience in designing and testing SPS innovations, as well as demonstration of the rational use of adapted forages, new spatial and temporal arrangements of trees and pastures, improved feeding strategies and the beneficial effects of indigenous tree species in Peruvian SPS are needed for further development of the sector. In all cases, the presence of an efficient value chain for products derived from SPS is required. One important constraint for implementing SPS in the region is the lack of sufficient input providers for seeds, fertilizers, tree seedlings and electric fences. Limited road connectivity and rural road deterioration also limit the movement of extension agents and service providers to farms. Similar problems have been observed for most Latin American countries, where formal grass and legume seed sale systems are underdeveloped, limiting the access to planting material of new pasture varieties (Arango et al. 2020).

Training

Training on silvicultural, agricultural and livestock practices, grazing management, genetic improvement of cattle, environmental impacts of SPS, irrigation practices, farm economic management and marketing is needed for farmers to enable a complete understanding of the potential of SPS. Technical knowledge required for managing a successful SPS is often reported as a concern by farmers. The technical knowledge required for pasture, livestock and forest management are perceived to be major limitations during SPS adoption (Frey et al. 2012). Dairy producers have identified the complexity of new rotational grazing systems (Bussoni et al. 2015), planting, pruning, harvesting of trees and shrubs (Dubeux Junior et al. 2017) and the interruptions of daily operations as barriers to adoption (Bussoni et al. 2015; Dagang and Nair 2003). Participatory extension approaches could be used by extension agents to strengthen farmers' capacities through learning about technical aspects, solving their current problems and at the same time, making action plans for implementing SPS.

Farmers' sociocultural characteristics are an important factor that could significantly affect the training process and SPS implementation. Many livestock producers in Latin America prefer traditional over more technical and sustainable production systems for reasons of simplicity and risk aversion. It is important to understand how livestock producers make decisions on the adoption of technologies or what influenced those decisions. Arango et al. (2020) identified this as a knowledge gap which needs to be addressed to assure a more widespread adoption of strategies such as SPS.

Another important issue for the Peruvian Government is the ability to offer an adequate extension service to farmers. This includes ensuring the availability of extension agents in the Amazon region and covering their training needs in SPS. Universities of the Amazon region may play a key role by supporting the training of professionals in SPS management.

Incentives

There may be need to provide farmers with incentives to adopt SPS practices, as demonstrated in other countries. A financial mechanism to cover the initial investment and alleviate negative cash flow during the first 5 years of operation is needed to tackle the 2 most important barriers for adoption, which are the lack of capital and the high cost of establishment and management (Calle et al. 2013). Furthermore, as described by Saunders et al. (2016), the costs of establishing and subsequently managing, agroforestry systems are generally higher than those of conventional woodlands and forests because individual trees require protection from livestock, while the forest canopy requires active management to maintain the productivity of the grass sward for grazing and the trees to produce high-quality timber. Unfortunately, private financial entities usually don't offer loans for agriculture because it is vulnerable to extreme climate change and farmer payment defaults. Government financial mechanisms for the implementation of pastoral systems, such as SPS, would give smallholders access to loans with lower interest rates over the medium to long term. Interventions on 104 farms to convert grassland to SPS have been trialed by the Colombian government (Pagiola and Rios 2013; Rivera et al. 2013).

Another constraint is the definition and valorization of the primary ecosystem services that SPS provides. Direct and indirect benefits, including water regulation, biodiversity maintenance and carbon sequestration, are obtained from properly functioning ecosystems (Casasola et al. 2009). Lack of information about ecosystem services, particularly carbon sequestration under specific SPS conditions in the Peruvian Amazon, is a knowledge gap that needs to be filled. There is limited information about differences in greenhouse gas (GHG) emissions and carbon sequestration between SPS and traditional practices of raising cattle on degraded land. One mechanism by which SPS can contribute to the mitigation of GHG emissions is through the reduction of enteric methane emissions from ruminants, due to the consumption of better quality herbaceous, shrub or tree-legume forages containing secondary plant metabolites such as condensed tannins and saponins (Martin et al. 2016). Reports in the literature indicate emission reductions between 5 and 10% when forages containing such secondary metabolites are included in the diet (Molina-Botero et al. 2019). Further studies on enteric methane emissions by herbivores are needed because of the diversity of forages that prevail in the Amazon region of Peru.

Working through cooperatives or associations can also benefit agribusiness as an incentive. In Uruguay, Paraguay and Costa Rica, cooperatives control the dairy chain, providing more profits and lower transaction costs to members. In Nicaragua, Ecuador and Paraguay, small-scale farmers are organized in associations or cooperatives that emphasize a vertical integration organizational model, market articulation and business strategies (FAO 2012). Cooperatives and farmer associations offer the possibility to implement collective voluntary approaches and achieve competitiveness levels similar to those of larger companies (Liendo and Martínez 2011).

Planning and policies

Support to SPS practices is needed from local, regional and national governments together with the engagement of private and public sector key stakeholders. Studies in the Colombian Amazon identified a lack of communication between research institutions, government agencies and non-government organizations (Charry et al. 2018; Clavero and Suárez 2006), often leading to conflicting messages that impact on their credibility and trust. Strengthening institutional capacities of the government to improve their planning and evaluation processes is also necessary.

Effective policies targeting both the demand- and supply- side of cattle value chains are needed to generate market opportunities and increase livestock competitiveness and sustainability in the country. The Peruvian Government should establish clear policies to ensure the sustainable use of degraded areas and the conservation of permanent protected areas. Regions targeted for these interventions should be under specific ecological zoning protocols which are lacking in the country. An emission measurement, report and verification (MRV) system is required for the agricultural sector and could contribute to the promotion of SPS via carbon sequestration. The lack of formal land tenure documentation disincentivizes long-term investments for land. Farmers are reluctant to invest in improved soil quality and structure and improved forage production if they may never realize the benefits of increased dairy cattle productivity from SPS (Tschopp et al. 2020). A study conducted by Pokorny et al. (2021) found that less than 20% of cocoa farmers from San Martín, many of whom keep cattle, held a legal title for the land they occupied, indicating many farmers reluctant to make improvements in their land.

Initiatives of the Peruvian Government to promote silvopastoral systems

The Peruvian Government has defined that the NDC should target a reduction of 30% of GHG emissions by year 2030 (Gobierno del Perú 2018). Such projected GHG reduction considers, among other strategies, the recovery of 119,000 ha of degraded soils via SPS in the Peruvian Amazon. The departments in the Peruvian Amazon region have started developing action plans and related policies for low-emission rural development strategies with potential to be scaled up. However, the initiative is not well articulated at the national level and a lack of a sense of urgency for the protection of forests is perceived.

A more proactive role of the Peruvian Government through the promotion of payments for ecosystem services (PES) and carbon sequestration is necessary. This would support the use of more sustainable land-use systems, like SPS, compared with competitive and conventional cattle-forage systems (Vosti et al. 2003). Policies promoting PES would be consistent with the ambitions announced by the Peruvian authorities in the NDC to reduce net carbon emissions. PES may also supplement annual income to landowners to raise incomes to comparable levels to income earned in the farming industry, thus ensuring an adequate income to landowners of rural lands (Chizmar et al. 2020).

Since 2018, the Peruvian Government is taking action to promote the adoption of new low-carbon production technologies. The normative and institutional framework that accompanies such an approach is documented in the Climate Change Framework Law, the National Agrarian Policy, the Forestry and Wildlife Law, the National Competitiveness and Productivity Plan, the Guidelines for Green Growth, and the National Livestock Development Plan. The Peruvian Government is also advancing cross-sectoral coordination to orient the identification and implementation of the NDC through the Multisectoral Working Group. This group is non-permanent and has made progress on the identification of measures to achieve NDC aims in the different sectors, but with limited progress on their implementation. Currently, there is lack of a coordination mechanism within the agricultural sector to align the technical, financial and political efforts for implementation of proposed actions to reduce emissions.

The Peruvian Government has started allocating public funding to overcome some of the barriers to transforming the livestock sector in the Amazon region. In 2019, the Ministry of Agriculture, in coordination with regional governments, established 600 hectares of SPS, based on improved pastures associated with native trees in live fences, use of electric fences for rotational grazing and installation of protein banks, to promote sustainable livestock production systems in the provinces of Tambopata and Tahuamanu (Madre de Dios department). This initiative contributes to the NDC goals for mitigating emissions in the agricultural sector. This effort could be considered a first small step to achieve the NDC goals at the National Level in terms of sustainable livestock production. However, rolling out this ambitious plan requires a holistic approach that supports sustainable livestock farming production alongside monitoring deforestation trends in Peru. This plan should involve all stakeholders in the livestock farming supply chain, including producers, local government livestock farming departments, the private sector and the forest and environmental sectors.

The current context of SPS adoption in Peru is similar to other countries in Latin America where animal husbandry has low productivity and competitiveness (Murgueitio et al. 2015). Farmers in Latin America practice a wide variety of SPS including small-scale fodder banks for cut and carry, live fences in Mesoamerica and the Andean mountains, natural regeneration of native trees, establishment of large commercial areas with SPS in Mexico and Colombia, timber-beef production in Argentina, Paraguay and Uruguay and integrated crop-livestock-forestry systems in Brazil. In Colombia, the project 'Mainstreaming biodiversity into sustainable cattle ranching', has promoted the establishment of SPS in 5 regions of this country (Chará et al. 2019). These examples demonstrate that grass monocultures could be replaced by agro-silvopastoral systems, providing sustainability for livestock production in the region.

Conclusions

SPS have the potential to serve as an overall national and regional management strategy to reduce deforestation and recover degraded lands, to improve livestock productivity in a sustainable manner and strengthen resilience of small- and large-scale farms while helping to mitigate emissions. However, SPS research and promotion efforts in the country have been limited. Development of policies and adequate financial incentives are required to enhance the adoption of SPS, along with well-planned strategies for disseminating information, training farmers (using a train-the-trainers approach) and farm managers, supported by the production of training materials highlighting the benefits of implementing SPS. While the benefits of implementing SPS through improved ecosystem services and incomes can be numerous, a dedicated effort needs to be made to fund research and extension activities on SPS. It is imperative that the Peruvian Government continue promoting SPS for rehabilitating degraded lands and achieving the NDC national commitments, at the same time generating better conditions to motivate farmers to adopt or scale up SPS.

Acknowledgments

This research was undertaken as part of the Project N° 016-2019-FONDECYT-BM-INC.INV: 'Climate change and Livestock in Peru: Mitigation and Adaptation'. We are grateful to the National Fund for Scientific, Technological Development and Technological Innovation (Fondecyt) and the World Bank for the financial support for this work.

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(Note of the editors: All hyperlinks were verified 3 May 2022).

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(Received for publication 25 March 2021; accepted 18 April 2022; published 31 May 2022)