Agroforest Syst (2020) 94:173–183
https://doi.org/10.1007/s10457-019-00381-9

Assessment of silvopasture systems in the northern Peruvian Amazon

Dante Pizarro · Héctor Vásquez · Wilmer Bernal · Eduardo Fuentes · Julio Alegre · Miguel S. Castillo · Carlos Gómez

Received: 22 October 2018 / Accepted: 12 March 2019 / Published online: 18 March 2019

Abstract Animal-agriculture is an important economic activity in the northern Peruvian Amazon Regions of Amazonas and San Martín but it has resulted in significant changes in land-use over time. Managed silvopasture systems have potential to improve degraded grasslands. However, to date, there is limited information about silvopasture systems in these regions, which limits an understanding of the potential of silvopasture systems to provide ecosystem services. Therefore, the objectives of this study were to identify and assess prevalent silvopasture systems as an initial and complementary step to study biological and economic responses in these systems. Land managers were surveyed in the three livestock-producing areas of Molinopampa ($n = 130$), Huayabamba ($n = 89$), and Moyobamba ($n = 70$). Our results indicate that raising cattle activities in these regions occur mainly in production units with area < 10 ha. Predominant silvopasture designs consisted of trees in live fences and scattered trees. Understory forage is mainly monoculture grass grazed by dual-purpose cattle breeds. The common denominators of the types of trees utilized in these systems are trees pruned to obtain firewood, followed by timber trees, followed by fruit trees. Cattle management consisted mainly of continuous stocking, followed by rotational stocking utilizing a rope, and also utilization of electric fencing for rotational stocking. Our data indicates that silvopasture systems in the Amazonas and San Martín regions of Peru occurred spontaneously and benefits and tradeoffs of implementing silvopastures remain largely unknown among producers.

Keywords Peru · Amazonas San Martin · Assessment

D. Pizarro · E. Fuentes · J. Alegre · C. Gómez (✉)
Universidad Nacional Agraria La Molina (UNALM), Lima, Peru
e-mail: cagomez@lamolina.edu.pe

H. Vásquez · W. Bernal
Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas (UNTRM), Chachapoyas, Peru

M. S. Castillo (✉)
Department of Crop and Soil Science, North Carolina State University, Raleigh 27695, USA
e-mail: mscastil@ncsu.edu

Introduction

Agroforesty systems cover between 200 and 357 Mha in Latin America, including 14–26 Mha in Central America, and 88–315 Mha in South America. Commercial silvopasture systems and shaded tree-crop systems [i.e. coffee (*Coffea* spp.) and cacao (*Theobroma cacao* L.)] are the most prominent agroforestry examples in the region (Sommariba et al. 2012). The Peruvian Amazon region is the second largest forest area of the total Amazon Basin accounting for approximately 11% of total Amazon Basin (74 million ha) (Ichikawa et al. 2014). In the Peruvian Amazon, 77% of the population is exclusively dedicated to agricultural activities, out of which 32 and 21% of the population in the northern Peruvian departments of Amazonas and San Martín, respectively, own cattle (INEI 2015). Raising cattle in the rural areas of Amazonas and San Martín departments is an economically important activity; however, this activity has resulted in significant changes in land-use over time, mainly due to deforestation and utilization of wood for timber, fire, and charcoal, and subsequent establishment of tree-less pastures to feed cattle. By 2015, there were about 10 million ha deforested in the Peruvian Amazon, with San Martín and Amazonas departments accounting for the largest deforested area during the 2010-2014 period (MINAM 2015).

Implementation of silvopasture sytems (SPS) in Latin America has occurred empirically and it has been based mainly on the spontaneous integration of livestock with different forest species (Murgueitio 2009). Designs utilized for SPS include: scattered trees in paddocks, trees in alleys, live fences, and SPS with management of plant succession and cutting and hauling systems (Murgueitio et al. 2012; Alegre et al. 2012). In recent years, work on SPS in the Peruvian humid tropics of Yurimaguas, Loreto, has focused on utilization of *Bactris gasipaes* and *Centrosema macrocarpum* as protein banks, recovery of overgrazed areas, and identification of appropriate grazing management and rotationally stocking rates by implementing electric fencing (Arévalo et al. 1998). In the areas of Pucallpa, work on SPS has focused on adaptation of trees and shrubs (Clavo and Chávez 2017). To date, there is limited information about the prevalent SPS across the northern Peruvian Amazon. Lack of published information describing SPS, and the benefits and tradeoffs of SPS systems, can be a potential stumbling block in the adoption of SPS (Orefice et al. 2017).

Managed SPS, that is, the intentional integration of trees and forages grown together and integrated with grazing animals, are considered a sustainable agroforestry practice based on estimates of biodiversity, economic returns, and environmental quality (Karki et al. 2013). Specific documented benefits of SPS include: provision of shade which can modify distribution patterns of grazing livestock (Karki and Goodman 2010), increased N cycling with arboreal legumes (Apolinário et al. 2015, 2016), altered microclimate and mitigation of heat stress for grazing livestock (Karki and Goodman 2015), increased total ecosystem carbon compared to native rangeland (Sollenberger et al., 2019); and diversification of earnings to landowners through facilitating the sale of forest products, such as fuelwood, and agricultural products such as milk and cheese from livestock production (Cotta 2017). In addition, recent research reports from work conducted in USA suggest that SPS may have potential to reduce soil greenhouse emissions by virtue of gas emissions being lower in soils covered with trees than soils with crop and margin canopy cover (Franzluebbers et al. 2017) and that SPS may also have potential to support greater animal responses (Pent and Fike 2018). Research reports from Latin America pointed out mitigation of greenhouse gas emission and C sequestration in SPS when livestock is fed forages with greater digestibility and tannin concentrations (Montgnini et al. 2013; Villanueva et al. 2018).

Managed SPS could play a particularly important role in the Amazon Basin to improve degraded grasslands, while also favoring the competitiveness of the agricultural and forestry production chains of the Amazon Basin, preventing spontaneous and indiscriminate deforestation, favoring the adaptation and mitigation of producers to the effects of climate change, and favoring the environmental and economic sustainability of the area. Implementation of SPS and recovery of degraded soils in the Peruvian Amazon are expected to contribute to reduction of greenhouse grass emissions by about 30% by the year 2030 (INDC 2015). Information on SPS is needed to better understand the potential of SPS in these regions to provide ecosystem services. Therefore, the primary objectives of this study were to identify and assess prevalent SPS in the Amazonas and San Martín political regions of the northern Peruvian Amazon as an initial and complementary step to study biological and economical (Chizmar et al. 2018) responses.

Methods

Study area and community characteristics

The study was conducted in the Regions of Amazonas and San Martín. Specifically, data were collected in the three livestock-producing areas of: Molinopampa and Huayabamba which are located in the Amazonas Region, and Moyobamba which is located in the Region of San Martín (Fig. 1); hereafter refer to as Molinopampa, Huayabamba, and Moyobamba. Elevation, rainfall, and Holdridge's life zone

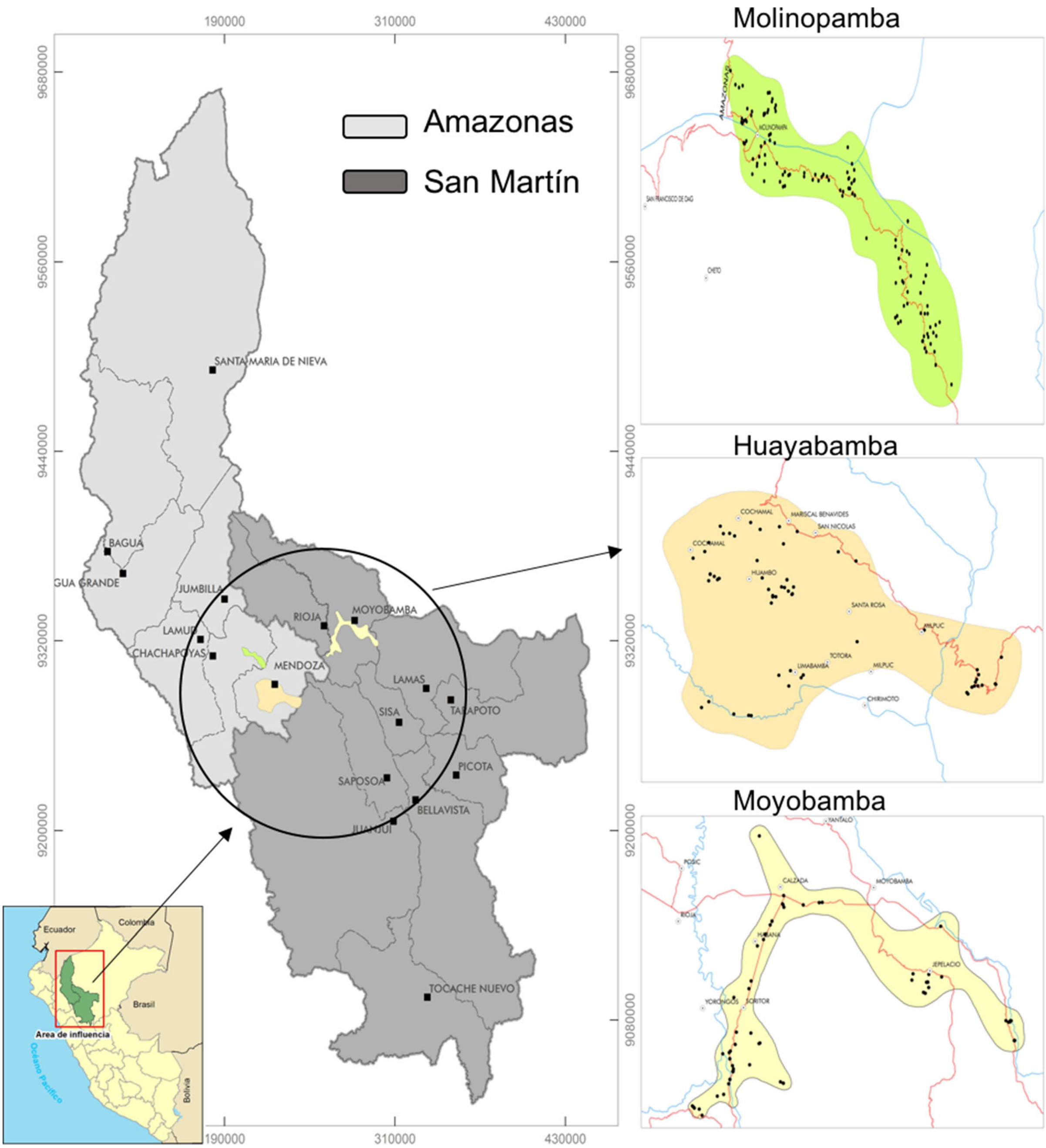

Fig. 1 Location of surveyed areas. Black dots within highlighted areas show the specific location of surveyed farms

Table 1 Site description

Region	District	Holdrige's life zone	Altitude (m.a.s.l.)	Annual rainfall (mm)
Amazonas	Molinopampa	Dry forest lower montane tropical	2200–2600	910
	Huayabamba	Moisture forest premontane tropical	1500–2000	1010
San Martín	Moyobamba	Wet forest premontane tropical	830–1040	1305

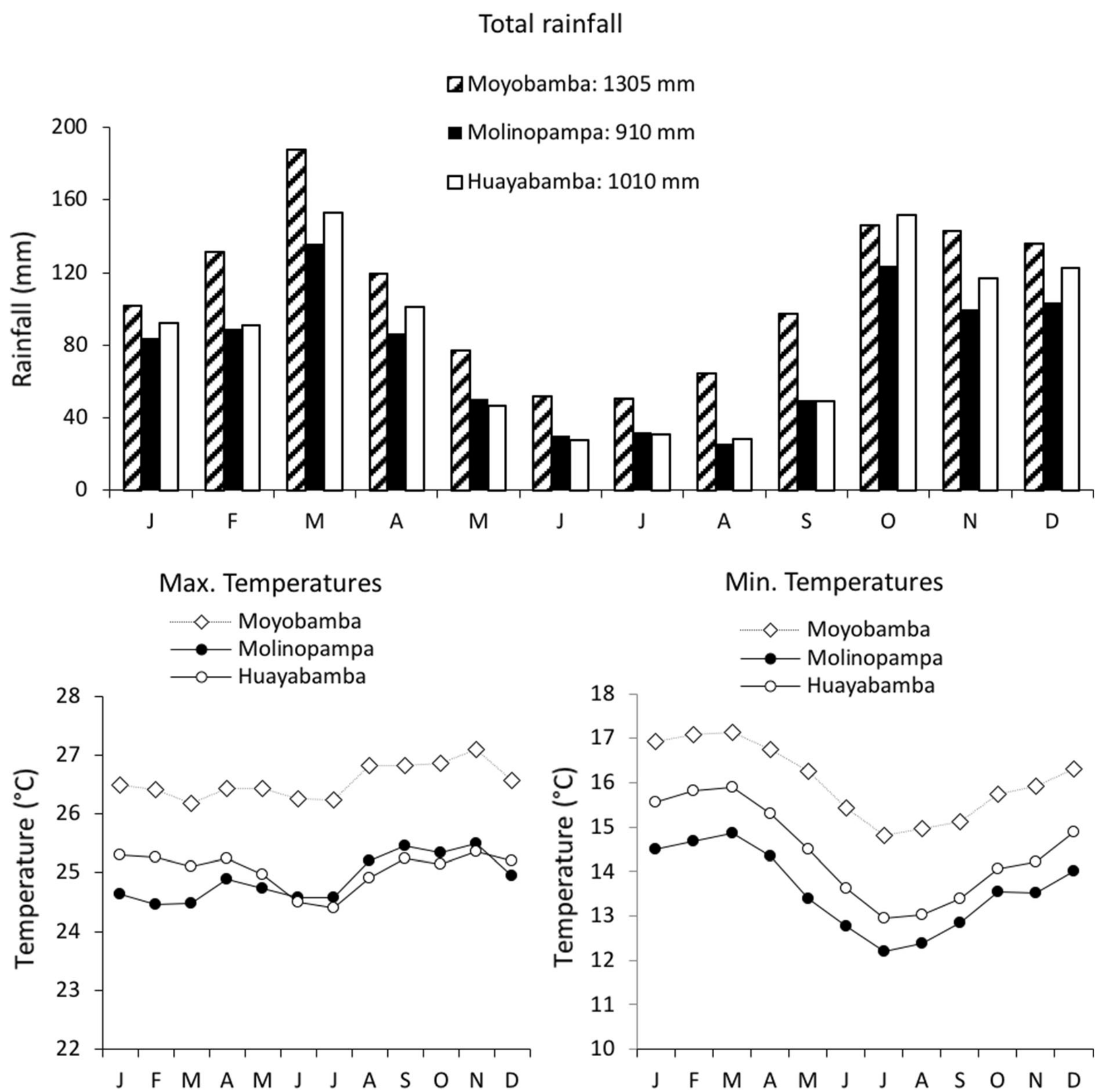

Fig. 2 Long-term (10-year) average total and monthly rainfall, and average max. and min. temperatures

classification data for each location are presented in Table 1. Long-term (10-year) monthly rainfall and temperatures are presented in Fig. 2 (Lavado et al. 2016). In general, environmental conditions are more similar between Molinopampa and Huayabamba, compared to Moyobamba which has greater overall rainfall and temperatures.

Molinopampa en Huayabamba are connected by the Rodriguez de Mendoza road and Moyobamba by the Fernando Belaunde Terry road, both are main roads within the Amazonas and San Martin regions, respectively. Table 2 presents the total population, population growth rate, and median yearly income of the three communities. The Amazonas region area is 1.7 Mha and one of the most marginalized political regions of Perú with higher levels of poverty and malnutrition. The San Martín Region area is 5.1 Mha and this region is characterized by a population influx in search of active jobs from the neighboring regions (Banco Central de Reserva del Perú 2008).

Sample size and data collection

A survey was designed to collect qualitative and quantitative information from livestock managers in order to identify and assess SPS. The survey was written in Spanish language and consisted of open-ended questions. One person per location, for a total of three people, conducted the surveys from June to July 2016. The survey's method of administration consisted of site visits followed by oral interviews on the same day and at the farm-sites. The interviews were conducted in Spanish language and by personnel who were native Spanish speakers. Questions were read to the interviewees and their responses were recorded by the interviewer in hard-copy survey formats. The group of interviewers are part of a team collaborators from Universidad Nacional Agraria La Molina, El Porvenir Research Station (INIA), the Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas, and North Carolina State University (NCSU), who have been collaborating for the past 5 years with private landowners to better understand the dynamics of applied agroforestry systems (Gómez 2017). A total of 289 interviews were completed; sample sizes were n = 130 for Molinopampa, n = 89 for Huayabamba, and n = 70 for Moyobamba. The sample was acquired by randomly selecting livestock production sites that displayed silvopasture systems accessible by roads (Fig. 1), and based on the availability and willingness of the landowners to provide information. A specific site qualified as silvopasture system if, at the time of the visit, the interviewer observed livestock actively grazing understory forage in association with trees, or areas with grass-trees associations that were part of a grazing rotation were identified. For Huayabamba, it is estimated that there exist approximately 6468 production-units and 778 for Molinopampa. We could not obtain an accurate estimate of production-units for Moyobamba. Participation was voluntary and participants did not receive any economic incentive for their participation. The responses were coded and tabulated in Excel by one person. Based on the tabulated results, the responses were grouped into categories by a single researcher. Results were analyzed using descriptive statistics using JMP software (SAS Institute 2017) and are presented by location.

Results

Average total farm area size was predominantly lower than 10 ha in Molinopampa (61%), while it was more evenly distributed between sizes < 10 ha and 10–30 ha for Huayabamba (43 and 42%, respectively) and Moyobamba (47 and 35%, respectively) (Table 3). Less than 18% of surveyed farms among the three locations had land areas greater than 30 ha. Producers retained land ownership of 85% of all surveyed farms. Areas categorized as SPS were

Table 2 Total population (2015), growth rate, and media yearly income for the three locations surveyed

Region	Location	Population	Growth rate from 2010 to 2015 (%)	Average yearly income ($)
Amazonas	Molinopampa	2740	0.7	1677
	Huayabamba	5603	1.5	
San Martin	Moyobamba	61,310	2.6	2013

Source: INEI (2014)

Table 3 General characteristics of silvopasture systems (SPS) in the Regions of Amazonas and San Martín

Item	Region/location		
	Amazonas		San Martín
	Molinopampa (n = 130) (%)	Huayabamba (n = 89) (%)	Moyobamba (n = 70) (%)
Average total area (ha)			
< 10	61	43	47
10–30	28	42	35
> 30	11	16	18
Area of SPS (ha)			
< 1	55	49	70
1–5	36	22	21
> 5	8	28	9
Age of SPS (year)			
< 5	27	16	9
5–20	67	47	87
> 20	6	37	4
SPS design			
Tress in live fences and windbreaks	40	47	53
Trees in alleys	12	3	1
Scattered trees	47	49	46
Herd size (#)			
< 10	58	54	69
10–20	18	24	23
> 20	24	22	8
Stocking method			
Continuous	58	72	97
Rotational-rope	28	27	3
Rotational-electric fence	14	1	0
Main expansion activity			
Slash and burn	94	77	6
Buy new land	5	19	26
Rent/mortgage	1	4	68
Producer retains land ownership	85	91	97

predominantly ≤ 5 ha for approximately 91% of surveyed farms in both Molinopampa and Moyobamba, with the exception of Huayabamba were approximately 28% of the surveyed farms had SPS in areas > 20 ha (Table 3).

The predominant SPS designs, for at least 87% of all of surveyed farms among all locations, were scattered trees and tress in live fences. Table 4 shows the most prevalent planted trees for each location and their uses such us timber, firewood, and fruit trees. Tree-pruning to obtain firewood was a consistent common denominator for utilization of trees among the three locations. The type of trees utilized in SPS where more similar between Huayabamba and Moyobamba compared to Molinopampa.

The most prevalent forage species growing in SPS by regions are listed in Table 5. Forages grown in SPS of Molinopampa are primarily cool-season C_3-photosynthetic pathway plants, with the exception of 'Kikuyo' grass (*Pennisetum* clandestinum). 'Kikuyo' grass is a C_4-photosynthetic grass well adapted to cool-season weather conditions (Marais 2001; Crush and Rowarth 2007). Molinopampa was the only location where surveyed farms reported clovers

Table 4 Most prevalent planted trees for silvopasture systems

Family	Genus, species	Common name	Region/location			Uses
			Amazonas		San Martín	
			Molinopampa	Huayabamba	Moyobamba	
Betulaceae	*Alnus acuminata*	Aliso	x			b
Cupressaceae	*Cupressus macrocarpa*	Cipres	x			a, b
Pinaceae	*Pinus patula*	Pino	x			a, b
Arecaceae	*Ceroxylon quindiuense*	Pona	x			b
Salicaceae	*Salix* sp.	Alamo		x		b
Fabaceae	*Inga edulis*	Guaba		x	x	b, c
Myrtaceae	*Eucalyptus* sp.	Eucalipto		x	x	a, b
Fabaceae	*Ormosia coccinea*	Guayruro		x	x	b
Myrtaceae	*Psidium* sp.	Guayaba		x	x	b, c
Lauraceae	*Ocotea quixos*	Ishpingo		x		a, b
Fabaceae	*Cedrelinga catenaeformis*	Tornillo			x	a, b
Rhamnaceae	*Colubrina glandulosa*	Shaina			x	a, b
Anacardiaceae	*Mangifera indica*	Mango			x	b, c

(a) Timber, (b) pruning for firewood, (c) fruit tree

Table 5 Predominant forage species in silvopasture systems

Family	Genus, species	Common name	Region/location			Photosynthetic pathway
			Amazonas		San Martín	
			Molinopampa	Huayabamba	Moyobamba	
Fabaceae	*Trifolium pratense*	Trébol rojo	x			C_3
Fabaceae	*Trifolium repens*	Trébol blanco	x			C_3
Poaceae	*Dactylis glomerata*	Ovillo	x			C_3
Poaceae	*Lolium multiflorum*	Ryegrass	x			C_3
Poaceae	*Pennisetum clandestinum*	Kikuyo	x			C_3
Poaceae	*Phalaris arundinacea*	Phalaris	x			C_3
Poaceae	*Setaria sphacelata*	Nicarion	x	x		C_4
Poaceae	*Brachiaria mutica*	Mutica		x		C_4
Poaceae	*Pennisetum purpureum*	King grass morado		x		C_4
Poaceae	*Pennisetum* sp.	Elefante		x		C_4
Poaceae	*Digitaria Decumbens*	Pangola		x	x	C_4
Poaceae	*Brachiaria brizantha*	Brizantha		x	x	C_4
Fabaceae	*Arachis pintoi*	Maní forragero		x	x	C_3
Fabaceae	*Pueraria phaseoloides*	Kutzú		x	x	C_3
Poaceae	*Brachiaria decumbens*	Decumbens			x	C_4
Poaceae	*Axonopus compressus*	Torourco			x	C_4
Poaceae	*Paspalum dilatatum*	Pasto de agua			x	C_4

growing in mixtures with grasses in SPS. In contrast, for Huayabamba and Moyobamba, C_4- grasses dominated the list of forages in SPS with several species in the genus *Brachiaria* and *Pennisetum*.

Herd size distribution per farm among the three categories was similar between Molinopampa and Huayabamba. At least half of all surveyed farms among the three locations had a total herd size lower than 10 animals. For Molinopampa and Huayabamba, herd sizes between 10 and 20 and > 20 were approximately equal distributed percentages; however, Moyobamba had the lowest percentage of farms in the > 20 herd size category and the highest percentage of farms for the < 10 herd size category (Table 3). The predominant stocking method for livestock management among locations is continuous stocking, followed by rotational stocking.

For Molinopampa, 81% of surveyed farms reported growing livestock breed Brown Swiss, followed by Simmental and the Criollo. For Huayabamba, predominant livestock breeds were Simmental (44%), followed by hybrid-mixes among several breeds (29%). For Moyobamba, predominant livestock types were hybrid-mixes (36%) followed by Brown Swiss (34%). Brown Swiss and Simmental cattle are dual-purpose breeds for milk and meat production (Andersen et al. 1977; Monsón et al. 2004).

The results indicated that expansion activities for Molinopamba and Huayabamba were more similar with slash and burn as the predominant expansion plan, followed by buying new land, and followed by rent/mortgage land. However, for Moyobamba in the San Martín Region, the opposite trend for expansion plans was reported by farmers.

Discussion

Smallholding, i.e. < 10 ha, is the primary land ownership-type of agricultural production units in the regions Amazonas and San Martin in Peru. Land ownership and amount of area per production unit are important factors to consider for programs that intent to provide incentives, such as payments for ecosystem (environmental) services, for forest management, or for establishment of silvopastures, and where integration of trees have the potential to help sequester carbon specially in degraded pastures (Montagnini and Nair 2004). Calle et al. (2013) indicated that government incentives are usually inadequate for small and medium holders that lack organization structure and because access to those incentives entails stringent requirements, complex paperwork, and high costs that only that only the larger enterprises can meet.

Scattered tree design was the predominant design of SPS, followed by trees in live fences and windbreaks. Scattered tree design is the result of selective tree thinning and pruning, for wood for fire or construction, from original tree-only plantations. In contrast, trees in live fences were intentionally planted as a strategy to delineate paddocks, to provide shade to the grazing livestock, and probably more importantly, as a strategy to mark property rights among land owners. Across locations, less than 30% of the interviewees indicated to have some knowledge about SPS's benefits and tradeoffs and less than 15% indicated that they have received some type of training about developing SPS. Consequently, SPS in the areas of Amazonas and San Martín have occurred spontaneously and benefits and tradeoffs of implementing SPS remain largely unknown among producers.

Remaining scattered tree design for SPS could be a considered a success-story in prevention of clear-cut deforestation while transitioning from forest to agriculture use; likewise, the introduction of trees in live-fences. However, it is not clear that producers will maintain current SPS if direct benefits are not realized in the shorter term. Slash and burn was cited as the predominant practice for future expansion plans by producers in Molinopampa and Huayabamba while it was the least likely in Moyobamba. It is not clear the reason for differences in terms of expansion plans among sites; however, the fact that slash and burn continues to be a predominant plan for expansion in Molinopampa and Huayabamba, and that the majority of SPS across locations were < 20 year in age, reflects that scattered-tree SPS are most likely an spontaneous feature in the landscape rather than an intentional strategy practiced in these regions. It is imperative that future research focuses on describing and measuring biological and economic benefits and tradeoffs of SPS systems in these regions.

Continuous stocking is a method of grazing livestock on a specific unit of land where animals have unrestricted and uninterrupted access throughout the time when grazing is allowed (Allen et al. 2011). Continuous stocking was the predominant method of stocking livestock in the regions of Amazonas and San

Martín and this method is generally a characteristic of less intensive farm-management or extensive production systems. Rotational stocking, is a method that utilizes recurring periods of grazing and rest among three or more paddocks (or areas of land) in a grazing management unit throughout the time when grazing is allowed (Allen et al. 2011). Rotational stocking with a rope is typical of small-scale operations where livestock production and animal care is one of the most important daily activities of the farm. Rotational stocking with a rope consists of using a rope to tie the livestock to one end of the rope and with the other end tied to a grounded stake, with the purpose of limiting the grazable area to a few square meters. Once the animals have consumed the forage allocated in the small area, then producers move the rope and ground the stake to a different location. This practice usually occurs at least 3 times per day. Rotational stocking using a rope is the most intensive way of rotational stocking, typical of small-scale farmers that own a limited number of livestock and land, and it requires almost full-day-long attention to livestock to move the animals several times per day; leaving the producers with very little time for other activities during the day. Rotational stocking using electric fence is the least utilized strategy cited for livestock management in these regions; however, it is interesting to note that utilization of electric fencing is increasing in popularity in the region and as an alternative to using a rope for rotational stocking.

Conclusions

Raising cattle is an economically important activity in the rural areas of Amazonas and San Martín Regions of the Peruvian Amazon that occurs mainly in smallholding (< 10 ha) production units. There are a diversity of trees and forages currently utilized in silvopasture systems of the northern Peruvian Amazon. Predominant silvopasture designs consist of trees in live fences and scattered trees, with understory forage grazed by dual-purpose cattle breeds. The common denominators of the types of trees utilized in these systems are trees pruned to obtain firewood, followed by timber trees, followed by fruit trees. Understory forage consisted mainly of monoculture grass species; however, there were a few instances where we identified grass-legume mixtures, especially in the higher altitude areas dominated by C_3 forage species. Cattle management consisted mainly of continuous stocking, followed by rotational stocking utilizing a rope, and also utilization of electric fencing for rotational stocking. Our data suggests that silvopasture systems in the areas of Amazonas and San Martín have occurred spontaneously and benefits and tradeoffs of implementing SPS remain largely unknown among producers. It is imperative that future research work focuses on describing and measuring biological and economic benefits and tradeoffs of SPS systems in these regions so that implementation of new systems and retention of existing SPS be possible.

Acknowledgements The authors express their appreciation to Vivian Calvo for her excellent support during manuscript preparation. Funding for this project was provided by the Programa Nacional de Innovación Agrararia (PNIA) of Peru, Project #2936.

References

Alegre J, Vega R, La Torre B (2012) Manual de manejo de suelos con sistemas silvopastoriles. Proyecto VLIR – UNALM. UNALM. https://doi.org/10.13140/rg.2.2.20163.30245. https://www.researchgate.net/publication/323839651/download. Accessed 3 Sept 2018

Allen VG, Batello C, Berretta EJ, Hodgson J, Kothmann M, Li X, McIvor J, Milne J, Morris C, Peeters A, Sanderson M (2011) An international terminology for grazing lands and grazing animals. Grass Forage Sci 66:2–28

Alonso J (2003) Factores que intervienen en la producción de biomasa durante el manejo del sistema silvopastoril *Leucaena leucocephala* y *Panicum maximum* vc. Likoni. Thesis Dr. Instituto de Ciencia Animal. La Habana, Cuba. p. 68

Andersen BB, Liboriussen T, Kousgaard K, Buchter L (1977) Crossbreeding experiment with beef and dual-purpose sire breeds on danish dairy corw: III. Daily gain, feed conversion and carcass quality of intensively fed young bulls. Livest Product Sci 4:19–29

Apolinário VX, Dubeux JCB Jr, de Lira MA, Ferreira RLC, Mello ACL, dos Santos MVF, Sampaio EVSB, Muir JMP (2015) Tree legumes provide marketable wood and add nitrogen in warm-calimate silvopasture systems. Agron J 107:1915–1921

Apolinário VX, Dubeux JCB Jr, de Lira MA, Sampaio EVSB, de Amorin SO, de Miranda e Silva NG, Muir JP (2016) Arboreal legume litter nutrient contribution to a tropical silvopasture. Agron J 108:2478–2484

Arévalo LA, Alegre JC, Bandy DE, Szott LT (1998) The effect of the cattle grazing on soil physical and chemical properties in a silvopastoral system in the Peruvian Amazon. Agrofor Syst 40:109–124

Banco Central de la Reserva del Perú (2008) Informe económico y social Región de San Martín. http://www.bcrp.gob.pe/docs/Proyeccion-Institucional/Encuentros-Regionales/2008/San-Martin/Informe-Economico-Social/IES-San-Martin.pdf. Accessed 3 Sept 2018

Botero R, Russo R (1998) Utilización de árboles y arbustos fijadores de nitrógeno en sistemas sostenibles de producción animal en suelos ácidos tropicales. Conferencia electrónica de la FAO sobre "Agroforesteria para la Producción animal en Latinoamérica"

Calle Z, Murgueitio E, Chará J, Molina CH, Zuluaga AF, Calle A (2013) A strategy for scaling-up intensive silvopastoral systems in Colombia. J Sustain For 32:677–693

Chizmar EJO, Sills E, Abt R, Castillo MS, Cubbage F (2018) A comparative economic assessment of silvopastures systems in the Amazonas Region of Peru and in North Carolina, USA. Master's Thesis, North Carolina State University. https://repository.lib.ncsu.edu/bitstream/handle/1840.20/35059/etd.pdf?sequence=1&isAllowed=y. Accessed 22 Sept. 2018

Clavo M, Chávez J (2017) Caracterización del componente vegetal de los diferentes estratos de un sistema silvopastoril en Ucayali, Perú. I Curso Internacional Ganadería y Agro ecosistemas Tropicales Sostenibles para Enfrentar el Cambio Climático: Sistemas Silvopastoriles

Costa SBM, de Mello ACL, Dubeux JCB Jr, dos Santos MVF, de Lira MA, Oliverisa JTC, Apolinário VXO (2016) Livestock performance in warm-climate silvopastures using tree legumes. Agron J 108:2026–2035

Cotta JN (2017) Revisiting Bora fallow agroforestry in the Peruvian Amazon: Enriching ethnobotanical appraisals of non-timber products through household income quantification. Agrofor Syst 91:17–36

Crush JR, Rowarth JS (2007) The role of C_4 grasses in New Zealand pastoral systems. New Zealand J Agric Res 50:125–137

Franzluebbers AJ, Chappell JC, Shi W, Cubbage FW (2017) Greenhouse gas emissions in an agroforestry system of the southeaster USA. Nutr Cycl Agroecosyst 108:85–100

Galindo W, Murgueitio E (2003) Herramientas de manejo sostenible para la ganadería andina. Manejo Sostenible de los Sistemas Ganaderos Andinos. CIPAV, Cali, pp 19–88

Gómez CA (2017) Sistemas Silvopastoriles: Investigación e Innovación en el caso de Amazonas y San Martín. In: I Curso Internacional Ganadería y Agroecosistemas tropicales sostenibles para enfrentar el cambio climático: Sistemas silvopastoriles. Pucallpa, Peru. Print

Harvey CA, Haber WA (1999) Remnant trees and the conservation of biodiversity in Costa Rican pastures. Agrofor Syst 44:37–68

Holdrige LR (1967) Life zone ecology. Tropical Science Center, San Jose

Ibrahim M, Villanueva C, Casasola F (2007) Sistemas Silvopastoriles como una herramienta para el mejoramiento de la productividad y rehabilitación ecológica de paisajes ganaderos en Centro América. Arch Latinoam Prod Anim 15:74–88

Ichikawa M, Ricse A, Ugarte J, Kobayashi S (2014) Migration patterns and land use by immigrants under a changing frontier society in the Peruvian Amazon. Tropics 23:73–82

Instituto Nacional de Estadística e Informática (INEI) (2014). Estimaciones y Proyecciones de Población 2000 al 2015. Oficina de Gestión de la Información y Estadística. https://proyectos.inei.gob.pe/web/poblacion/. Accessed 15 Oct 2018

Instituto Nacional de Estadística e Informática (INEI) (2015) Panorama económico departamental 2015. https://www.inei.gob.pe/media/MenuRecursivo/boletines/informe-tecnico-n12_panorama-dptal-oct2015.pdf. Accessed 24 Nov 2017

Instituto Nacional de Estadística y Censos (INEC) (2015) VI Censo Nacional Agropecuario: Atlas estadístico agropecuario. San José de Costa Rica

Intended Nationally Determined Contributions (INDC) (2015) Contribución Prevista y Determinada a Nivel Nacional de la República del Perú http://www4.unfccc.int/submissions/INDC/Published%20Documents/Peru/1/iNDC%20Per%C3%BA%20castellano.pdf. Accessed 12 Jul 2017

Karki U, Goodman MS (2010) Cattle distribution and behavior in southern-pine silvopasture versus open-pasture. Agrofor Syst 78:159–168

Karki U, Goodman MS (2015) Microclimate differences between mature loblolly-pine silvopasture and open-pasture. Agrofor Syst 89:319–325

Karki U, Goodman MS, Sladden SE (2013) Plant-community characteristics of bahiagrass pasture during conversion to longleaf-pine silvopasture. Agrofor Syst 87:600–619

Lavado W, Fernández C, Aybar C, Caycho T, Endara S, Vega F, Huerta A, Acuña A, Obando OF (2016) PISCO: Peruvian Interpolated data of SENAMHI's Climatological and hydrological Observations. Servicio Nacional de Meteorología e Hidrología del Perú. http://ons.snirh.gob.pe/Peru/maproom/Monitoring/Meteorological/PISCO_reporte.pdf. Accessed 15 Dec 2017

Marais JP (2001) Factors affecting the nutritive value of kikuyu grass (*Pennisetum clandestinum*): a review. Tropical Grasslands 35:65–84

Ministerio de la Producción del Perú (2015) Estudio de diagnóstico de crecimiento de la Región Amazonas. http://demi.produce.gob.pe/Content/files/EstRegionales/InformeFinal_Amazonas_PxP.pdf. Accessed 3 Sept 2018

Ministerio del Ambiente (MINAM) (2015) Mapa Estandarizado de Cambio de la Cobertura de Bosque por Deforestación en la Amazonia Peruana. http://demi.produce.gob.pe/Content/files/EstRegionales/InformeFinal_Amazonas_PxP.pdf. Accessed 3 Sept 2018

Monsón F, Sañudo C, Sierra I (2004) Influence of cattle breed and ageing time on textural meat quality. Meat Sci 68:595–602

Montagnini F, Nair PKR (2004) Carbon sequestration: an underexploited environmental benefit of agroforestry systems. Agrofor Syst 61:281–295

Montgnini F, Ibrahim M, Murgueitio ER (2013) Silvopastoral systems and climate change mitigation in Latin America. Bois et Forêts des Tropiques. http://bft.cirad.fr/cd/BFT_316_3-16.pdf. Accessed 22 Oct. 2018

Murgueitio E (2009) Incentivos para los sistemas silvopastoriles en América Latina. In: Avances en Investigación Agropecuaria. Palma García, José Manuel. 13 (1): 3 – 19. ISSN 0188789-0. http://ww.ucol.mx/revaia/anteriores/

PDF%20DE%20REVISTA/2009/ene/1.pdf. Accessed 3 Sept 2018
Murgueitio E, Calle Z, Chará J (2012) Integración de las actividades forestales con la ganadería extensiva sostenible y la restauración del paisaje. Unasylva 63:31–40
Orefice JN, Carroll J (2017) Silvopasture – It's not a load of manure: differentiating between silvopasture and wooded livestock paddocks in the Northeastern United States. J For 115(1):71
Orefice JN, Carroll J, Conroy D, Ketner L (2017) Silvopasture practices and perspectives in the Northeastern United States. Agrofor Syst 91:149–160
Pent GJ, Fike JH (2018) Lamb productivity on stockpiled fescue in honeylocust and black walnut silvopastures. Agrofor Syst. https://doi.org/10.1007/s10457-018-0264-0
Pent GJ, Fike JH, Kim I (2018) Ewe lam vaginal temperatures in hardwood silvopastures. Agrofor Syst. https://doi.org/10.1007/s10457-018-0221-y
Pezo D, Ibrahim M (1998) Sistemas silvopastoriles. 2. ed. Turrialba, CR, proyecto agroforestal CATIE-GTZ. 275 p. (Módulo de enseñanza agroforestal N°2). http://repositorio.bibliotecaorton.catie.ac.cr/bitstream/handle/11554/4025/Sistemas_silvopastoriles.pdf;jsessionid=7C1FA58EC4904367D72AC34E18A06369?sequence=1. Accessed 3 Sept 2018
Rios J (2007). Enfoques Integrales de Producción Ganadera en la Amazonia Peruana. XXX Reunión APPA, Cusco. Arch Latinoam Prod Anim Vol. 15 (Supl 1). http://www.bioline.org.br/pdf?la07060. Accessed 3 Sept 2018
SAS Institute (2017) JMP Pro software. Version 13. SAS Inst., Cary, NC
Sollenberger LE, Kohmann MM, Dubeux Jr JC, Silveira ML (2019) Grassland management affects delivery of regulating and supporting services ecosystems services. Crop Sci J 59:441–459
Sommariba E, Beer J, Alegre-Orihuela J, Andrade HJ, Cerda R, DeClerck F, Detlefsen G, Escalante M, Giraldo LA, Ibrahim M, Krishnamurthy L, Mena-Mosquera VE, Mora-Delgado JR, Orozco L, Scheelje M, Campos JJ (2012) Mainstreaming Agroforestry in Latin America. In: Nair PK, Garrity D (eds) Agroforestry: The Future of Global Land Use, Advances in Agroforestry 9. Springer, Berlin, pp 429–454
Villanueva C, Casasola F, Detlefsen G (2018) Pontencial de los sistemas silvopastoriles en la mitigación al cambio climático y en la generación de multiples beneficios en fincas ganaderas de Costa Rica. Boletín técnico 87. Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Turrialba, Costa Rica. http://repositorio.bibliotecaorton.catie.ac.cr/bitstream/handle/11554/8729/Potencial_de_los_sistemas_silvopastoriles.pdf?sequence=7&isAllowed=y. Accessed 22 Oct. 2018