Agroforest Syst (2024) 98:1273–1282
https://doi.org/10.1007/s10457-023-00944-x

Silvopastoral systems in the Upper Atlantic Forest of Argentina: what type of farms adopt them and how?

C. C. Gelabert · N. I. Gasparri · S. E. de Bargas · D. H. Chifarelli · T. N. Rojas · P. M. Mac Donagh · G. A. Zurita

Received: 27 June 2023 / Accepted: 17 December 2023 / Published online: 17 January 2024

Abstract Despite silvopastoral systems' environmental and production benefits, their adoption in forest ecosystems has been moderated. Identifying a silvopastoral farm typology combining farm size and management practices can help explore the constraints to their adoption and guide technical support initiatives. We investigated farms adopting silvopastoral systems in the Upper Atlantic Forest of Argentina and whether their management practices are related to the farms structural characteristics. We analysed 60 surveys that covered 3428 ha under silvopastoral management. First, we group the farms according to size and land use using the factor analysis mixed data and group with hierarchical clustering. Second, we performed two correspondence analyses with variables related to management practices in the silvopastoral area to explore the relationship between the practice management adopted and the cluster farm. Our results summarised the variability of farms and management practices in three groups: Specialist silvopastoral farms, Agricultural farms with silvopastoral management and forest plantation, and Livestock farms with silvopastoral management sectors. Specialist silvopastoral farms adopted most of the technical recommendations for this land use. Despite this work contributions, some information gaps still need to be addressed to have an integrated vision of how silvopastoral systems in the

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10457-023-00944-x.

C. C. Gelabert (✉)
CONICET, Universidad Nacional de Misiones, Facultad de Ciencias Forestales, Eldorado, Argentina
e-mail: ceciliagelabert@gmail.com

C. C. Gelabert
Universidad de Buenos Aires, Facultad de Agronomía. Departamento de Economía, Desarrollo y Planeamiento Agrícola, Cátedra de Sistemas Agroalimentarios, Buenos Aires, Argentina

C. C. Gelabert · N. I. Gasparri · T. N. Rojas
Instituto de Ecología Regional, CONICET - Universidad Nacional de Tucumán, Yerba Buena, Argentina

N. I. Gasparri
Facultad de Ciencias Naturales e IML, Universidad Nacional de Tucumán, San Miguel de Tucumán, Argentina

S. E. de Bargas
Universidad de Buenos Aires, Facultad de Agronomía. Departamento de Producción Animal, Cátedra de Producciones Animales Alternativas, Buenos Aires, Argentina

D. H. Chifarelli · P. M. Mac Donagh · G. A. Zurita
Universidad Nacional de Misiones, Facultad de Ciencias Forestales, Eldorado, Argentina

D. H. Chifarelli
Instituto Nacional de Tecnología Agropecuaria, Centro Regional Misiones, Estación Experimental Agropecuaria Montecarlo, Agencia de Extensión Rural Eldorado, Eldorado, Argentina

G. A. Zurita
Instituto de Biología Subtropical, CONICET - Universidad Nacional de Misiones, Puerto Iguazú, Argentina

Upper Atlantic Forest of Argentina can be adopted in an extended manner.

Keywords Land systems · Agroforestry systems · Sustainable livestock management · Farms typology · Technology adoption

Introduction

Silvopastoral systems have recently been promoted in forest ecosystems as a sustainable alternative to traditional cattle ranching (Murgueitio et al. 2011; Broom et al. 2013; Lerner et al. 2017; Jose and Dollinger 2019). These systems combine trees, fodder, and livestock in the same area, and contribute to biodiversity conservation, increase carbon storage, and improve the water cycle (Rivera et al. 2013; Gómez-Cifuentes et al. 2019, 2020; Bosi et al. 2020). In contrast, traditional cattle ranching implies the complete replacement of the native forest with full-sun pasture, which has led to land degradation and biodiversity loss in tropical and subtropical forests (Rivera et al. 2013; Jose and Dollinger 2019). In addition, silvopastoral systems improve animal welfare and increase livestock productivity (Broom et al. 2013; Montagnini et al. 2015). Despite silvopastoral systems' environmental and productive benefits, their adoption in forest ecosystems has been moderate, and the reasons for their low adoption are still poorly understood (Pattanayak et al. 2003; Mercer 2004; Kiptot et al. 2007).

Previous studies have identified initial investment costs, management complexity, risk, and uncertainty as limiting factors for adopting silvopastoral systems (Pattanayak et al. 2003; Murgueitio et al. 2011). However, their adoption has been observed across farms under different scales and productive orientations (Frey et al. 2012a, b; Frey and Comer 2018). Identifying a silvopastoral farm typology can help summarise these variabilities and guide technical support initiatives. There are different methodological approaches to the construction of typologies, the most widespread being those based on structural variables of the farms (e.g., size) (Alvarez et al. 2018; Tittonell et al. 2020). Alternative, less-used approaches are functional typologies that aim to capture farmers' decision-making in each context (Tittonell et al. 2020).

The Atlantic Forest (Brazil, Paraguay, and Argentina) is one of the most diverse and threatened ecosystems in the world (Myers et al. 2000). Argentina preserves one of the most continuous remnants of the Upper Atlantic Forest (13,062 km^2) (Ribeiro et al. 2009; Izquierdo et al. 2011). Since the 1990s, silvopastoral systems have been promoted as a low-impact alternative to conventional cattle ranching in the Upper Atlantic Forest of Argentina (Fassola et al. 2009; Lacorte et al. 2016). Recent studies found higher biodiversity in silvopastoral systems compared to full-sun pastures (Giménez Gómez et al. 2020; Gómez-Cifuentes et al. 2020; Guerra Alonso et al. 2022). Furthermore, a previous study analyzed the relative technical efficiency between different farmers decision-making (i.e., silvopastoral, full-sun pasture, and forestry) on the farm and identified a higher technical efficiency of silvopastoral management than full-sun pasture (Frey et al. 2012a). Another study compared the perception of different adopters of silvopastoral systems (i.e., scale and type according to primary production) and their variation over time to identify factors that could affect the continuity of their adoption (Frey et al. 2012b). In this manuscript, we developed a typology that combines the productive characteristics of the farms and the practices they adopt for silvopastoral management, which could contribute to the design of intervention strategies according to the type of farm.

Methodology

Study area

We conducted this study in the Upper Atlantic Forest of Argentina (Misiones) (Fig. 1). The climate is subtropical, with an isometric rainfall regime. Annual rainfall varies between 1000 and 1800 mm (IPEC 2015). The mean annual temperature is 21 °C with minor seasonal variation (IPEC 2015). The predominant order of soils is ultisols, followed by alfisols and oxisols (IPEC 2015).

Livestock production in the Upper Atlantic Forest of Argentina covers an area of approximately 2749.3 km^2, representing 13% of the provincial agricultural area with 354,062 head of cattle (INDEC-CNA 2021). Beef cattle production is mainly for family consumption (90%), and only 10% of cattle farms have a commercial profile (INDEC-CNA 2021). Farms with a commercial profile developed complete cycle cattle farming (49%), cattle breeding (31%), feeder cattle (12%), and cattle rebreeding

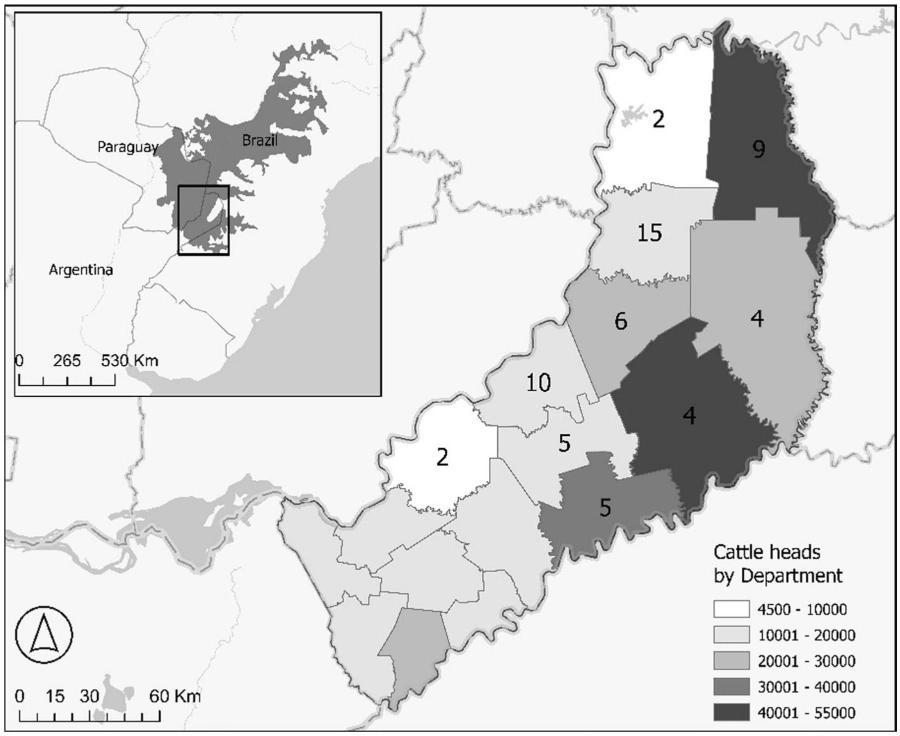

Fig. 1 Study area in the Upper Atlantic Forest of Argentina. The numbers on the map indicate the number of farms surveyed per department. Number of the head of cattle by the department according to the National Agricultural Census 2018 (INDEC-CNA 2021)

(5%) (INDEC-CNA 2021). Between 2002 and 2018, the area devoted to producing annual and perennial fodder decreased by 57%, from 79,559 ha in 2002 (INDEC-CNA 2007) to 45,230 ha in 2018 (INDEC-CNA 2021). This decrease was accompanied by a 1% increase in the head of cattle in the province over the same period, indicating an intensification of the activity. The average stocking rate is 1.3 head/ha (INDEC-CNA 2021). The cattle farms use various breeds, such as Zebu, British (mainly Hereford), Creole, and their crosses (i.e., Braford and Brangus).

On the other hand, forestry has a long history and tradition in the Upper Atlantic Forest of Argentina. Since the 1970s, active policies have promoted tree plantations (mainly *Pinus spp*.), developing a solid forestry cluster. Plantation forestry accounts for 56% of the cultivated area of the province (INDEC-CNA 2021). The primary forestry industry is pulpwood, which represents 46% of the national production (IPEC 2020).

Sampling and data collection instrument

We focused on farms adopting silvopastoral management in the study area (Fig. 1). We selected farms in a non-probabilistic way using the snowball method through consultations with local livestock associations and rural extension services (Hernández-Sampieri et al. 2010). We use this method because, currently, there is no record of the total number of farms that have adopted silvopastoral management. However, a previous estimate suggested that 20,000 ha are under silvopastoral management in the region (Frey et al. 2012a). Whereas this estimation is old, there is the most updated value publisher. The surface devoted to this activity has probably changed. We conducted 62 anonymous surveys in ten departments in the province. We had to discard two surveys because we identified errors in the data collection, so these 60 surveys covered 3428 ha under silvopastoral management (Fig. 1).

We designed a survey with closed questions, some with multiple-choice answers. We reviewed the survey with two technical advisors of silvopastoral systems and conducted a pilot test with one silvopastoral farmer. We included the data collected in the pilot test in the analysis. We did four field trips to survey with collaborators between June 2019 and March 2022. We used between 30 and 45 min to do the survey.

Table 1 Variables defined for silvopastoral farmers interviews in the Upper Atlantic Forest of Argentina

	Variable	Variable unit
1	Productive area	Hectares
2	Ratio full-sun pasture/productive area	Percentage
3	Ratio silvopastoral systems area/productive area	Percentage
4	Ratio forestry plantations without cattle use/productive area	Percentage
5	Agricultural production	Yes/No
6	Type of cattle activity	Cattle breeding
		Cattle rebreeding
		Feeder cattle
		Full-cycle farming
		Own consumption
7	Head	Bellies/ha/head/ha
8	The primary motivation for adopting a silvopastoral system	Productive diversification
		Productive intensification
		Technical promotion
		Shade for cattle
		Protection of pasture from winter frost
		Environmental conservation
9	Technical advice on silvopastoral management	Yes/No
10	Years of experience in silvopastoral management	Less than 15 years
		More than 15 years
11	Forest species	Pine hybrid[1]
		Pine[2] and eucalyptus[3]
12	Planting pattern	Single or double lines
		Regular
13	Initial planting density	Low density (less than 500 pl/ha)
		Medium density (500–1000 pl/ha)
		High density (more than1000 pl/ha)
14	Number of thinning	0
		1
		2
		3 or more
15	Final pruning height	Do not prune
		Pruning to 4 m
		Pruning above 4 m
16	Cattle management type	Pasture without supplement
		Pasture with supplement
17	Type of grazing	Continuous grazing
		Rotational grazing
18	Alternates with full-sun pasture	Yes
		No
19	Fodder reserves	Yes
		No

[1]*Pinus elliottii var. Elliottii x Pinus caribaea var. Hondurensis*

[2]*Pinus elliottii or Pinus taeda*

[3]*Eucalyptus grandis*

The survey consists of four sets of questions (Table 1). One set relates to farm size and general land use (variable from 1 to 5). The second set relates to cattle activity (variable from 6 to 7). The third set relates to motivation, technical support, and years of experience in silvopastoral management (variable from 8 to 10). The primary motivation for adopting a silvopastoral system (variable 8) is a closed question with multiple choices. Finally, another set relates specifically to silvopastoral management (variable from 11 to 19). We defined the questions on management based on a review of technical documentation, scientific literature, and expert consultation (Frey et al. 2012b; Lacorte et al. 2016, Esquivel 2022). The categorical responses to these variables were defined based on the adoption or non-adoption of the recommended practices. The recommended practices are those that contribute to reducing the shade generated by the forest component to the pasture (i.e., hybrid pine, plant in single or double lines, low and medium initial planting densities, thinning) and to improve the forage balance (i.e., rotational grazing, supplementation, creation of forage reserves) (Lacorte et al. 2016; Esquivel 2022).

Data analysis

First, we performed a descriptive analysis of the sample. We considered the total productive area and the area by type of use (i.e., silvopastoral area, full-sun pasture area, forestry area). We include if farms do agriculture and the type of cattle activity. Finally, we asked about the motivation for its implementation, whether they had received technical advice, and years of experience in silvopastoral management (Table 1, variable from 1 to 10).

To group the farms according to size and land use (variable from 1 to 5), we first conducted an ordering analysis using the factor analysis mixed data (FAMD) technique (Pagès 2004). The FAMD method allows us to study data by combining continuous and categorical variables and reducing the number of variables. Then, we selected the first two dimensions from this analysis to perform a hierarchical clustering on principal components to classify the farms. This method uses the unweighted pair group method with arithmetic means as the grouping technique (UPGMA). The default partitioning level in the hierarchical tree is the level with the highest relative inertia loss. We performed this analysis in R Studio software (version 4.2.2., FactorMineR package) (Lê et al. 2008). The analysis was performed on a dataset of 60 farms after discarding missing values.

We performed two correspondence analyses (CA) to explore the relationship between the groups formed on the hierarchical clustering and the management practices adopted (Table 1, variables from 11 to 19). In the first case, we linked groups with practices related to forest management (variables 11 to 15) and, in the second case, with cattle management (variables 16 to 19). This analysis only included 49 farms with a commercial production orientation. We excluded farms identified as own-consumption orientation because they do not provide complete information about management practices (11 farms). We analysed this in R Studio software (version 4.2.2., FactorMineR package) (Lê et al. 2008). Finally, we constructed the typology based on cluster classification and correspondence analysis.

Results

Description of the surveyed farms

The average size of the farms surveyed was 174 ha, with a minimum of 8 ha and a maximum of 1430 ha. Farms showed different scales of production, 35% representing 21 cases of less than 50 ha, 25% representing 15 cases of between 50.1 and 100 ha, and 35% representing 21 cases of between 100.1 and 500 ha; only 5% representing 3 cases of had more than 500 ha. Farms surveyed devote more than 50% of the productive area to cattle ranching. Cattle grazing area under silvopastoral management varies among surveyed farms. About half of the cases under study (33 farms) have less than 50% of the area under silvopastoral management. In contrast, 11 cases under study occupy between 50% and 75% of their area, and the remaining cases occupy more than 75% of the area under this management. The farms also practice agriculture and forestry, although the latter activity is more common in those with an area greater than 100 ha.

Most surveyed farms produce cattle for the market (49 farms) and very few for family consumption

(11 farms). The most frequent cattle activities are: 1) breeding (with the sale of calves at weaning for rearing and fattening) and 2) complete cycle (breeding and fattening for slaughter sale). The average stocking rate is one head/ha in total cattle area (i.e., silvopastoral area and full-sun pasture). In terms of time since the adoption of silvopastoral, 24 cases under study have more than 15 years of experience, while the rest have less than 15 years. Regarding technical support, half of the cases under study have received technical advice on silvopastoral management.

Finally, regarding motivations to adopt silvopastoral practices, half of the cases under study indicated that technical promotion was the main reason and the motivation to adopt was related to diversification and intensification of production; 7 cases under study for the benefits related to livestock activity, such as providing shade for livestock or protection of pasture of winter frost, and 5 cases under study because they consider it an environmental conservation practice.

Construction of typologies

The FAMD based on farm size and land use (variable from 1 to 5) explained 62% of the sample variation in the first two axes. The first axis explained 32% of the variance. It was mainly associated with the ratio of full-sun pasture/productive area. The second axis explained 30% and was associated with forest area/productive area and agricultural production (Fig. 2) (Supplementary Table 1, 2, and 3). Then, the hierarchical clustering on principal components based on the first two axes of the FAMD classified farms into three groups (Fig. 2) (Supplementary Table 4, 5, and 6).

The CA shows no dependence between forest management (rows) and farm classification (columns) (chi-square = 15.6 and p-value = 0.97). The CA explained 100% of the sample variation in the two components. The first axis explained 79.5% of the variance. In comparison, the second axis explained 20.5% (Fig. 3a). In the first component, the variables that explain most of the variation in

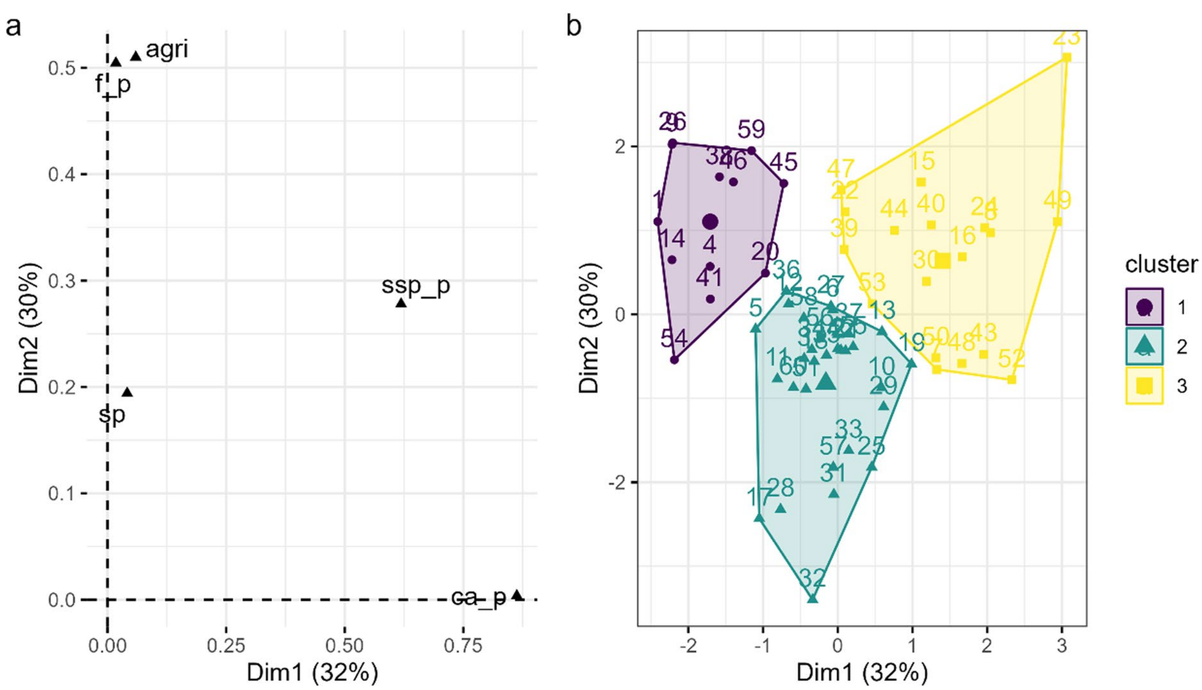

Fig. 2 Cluster farms according to size and land use in the Upper Atlantic Forest of Argentina. **a** FAMD and **b** hierarchical cluster on FAMD analysis output. Legend: sp: productive area, ca_p: full-sun pasture area/productive area, f_p: forestry plantations without cattle area/productive area, ssp_p: silvopastoral systems area/productive area, agri: agricultural production

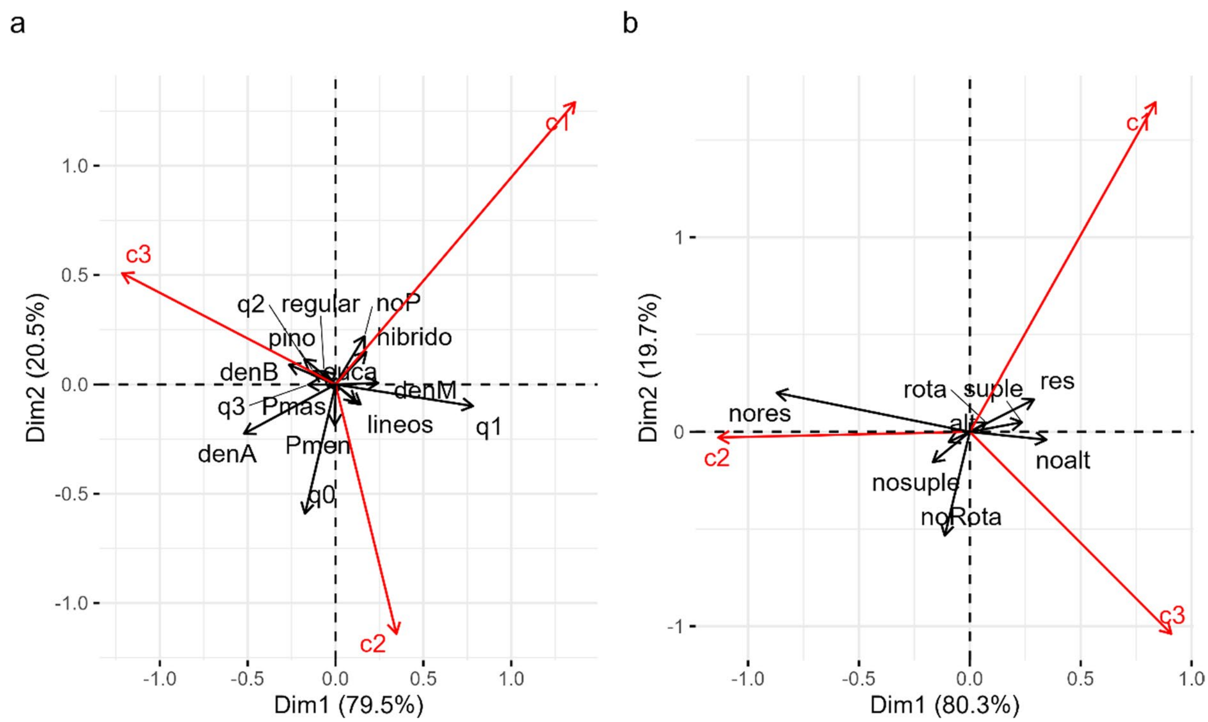

Fig. 3 Correspondence analysis between management in the silvopastoral area and farm classification in the Upper Atlantic Forest of Argentina. **a** Forest management practices. **b** Cattle livestock management practices. Legend: In black practice management: euca: eucalyptus, pino: pine, hibrido: hybrid pine, denB: low density, denM: medium density, denA: high density, noP: do not prune, Pmas: pruning to over 4 m, Pmenos: pruning to 4 m, q0: not thinning operations, q1: 1 thinning operation, q2: 2 thinning operations, q3: 3 or more thinning operations, supple: with supplementation, no supple: without supplementation, rota: rotational grazing, no rota: continuous grazing, alterna: alternates with full-sun pasture area, no alterna: no alternates with full-sun pasture area, res: use fodder reserves, nores:no use fodder reserves. Farm cluster in red

the dataset are the number of thinning (one thinning) and the planting density (high, medium, and low density). In the second component, the variables that most explain the variation in the dataset are do not-thinning, planting density (high density), and the species planted (hybrid pine).

In the case of cattle management, the CA shows a significant marginal dependence between practices (rows) and farm classification (columns) (chi-square = 22.2 and p-value = 0.07). The CA explained 100% of the sample variation in the two components. The first axis explained 80% of the variance. In comparison, the second axis explained 20% (Fig. 3b). In the first component, the variable that explains most of the variation in the dataset is the lack of forage reserves. In the second component, the variables that explain most of the variation in the dataset are the implementation of rotational grazing, preparation of forage reserves, and supplementation or no supplementation. The farms in clusters 1, 2, and 3 can relate to the analysed cattle management practices.

Table 2 shows the typology created by the productive diversification of the farms with silvopastoral management and their most representative management practices.

Discussion and conclusion

We developed a typology summarising the variability of farms that adopt silvopastoral management and their practices based on the analysis of 60 surveys. Our results identify three types of farms: Specialist silvopastoral farms (T1), Agricultural farms with silvopastoral management and forest plantation (T2),

Table 2 Type of farms and silvopastoral management in Upper Atlantic Forest of Argentina

Group	Farm description	Forest management	Cattle management
Specialist silvopastoral farms (T1)	A high proportion of the area is under silvopastoral management	While no clear pattern exists in forest management, hybrid pine is the most frequent species and does not implant at high density	Rotational grazing and use of fodder reserves
Agricultural farm with silvopastoral management and forest plantation (T2)	It carries out agriculture. It has 27% of the area under silvopastoral management, and 15% under forest management	No clear pattern exists in forest management	No use of fodder reserves
Livestock farms with silvopastoral management sectors (T3)	Cattle farming is based on full-sun pasture (more than 64%), and 27% of the area is under silvopastoral management	While there is no clear pattern in forest management, pine (not hybrid genetic) is the most frequent species, and the initial planting density is low	Do not alternate grazing in the silvopastoral area

and Livestock farms with silvopastoral management sectors (T3) (Table 2). The typologies developed to differ from previous studies because they highlight the relative area under silvopastoral use over the productive area. In contrast, previous characterisations grouped farms according to size without distinguishing the area under this management (Frey et al. 2012a, b). Typologies identifying the relationship between silvopastoral area and productive area can help as a baseline for analysing adoption processes. According to Kiptot et al. (2007), the analysis of the adoption of agroforestry systems is usually approached as either adoption or non-adoption by farmers. However, since these are long production cycles, it is necessary to understand the adoption process and its influencing factors, such as resource endowments, risk and uncertainty of the new technologies, market incentives, and farmers preferences (Mercer 2004) to identify whether the farms are transitioning towards specialisation, are testing the technology, or have decided to discontinue silvopastoral management even if they still retain the forestry component (Kiptot et al. 2007).

The range of the productive area of the farms surveyed differs from those surveyed in previous works. We surveyed a minimum of 8 ha and a maximum of 1430 ha with an average of 174 ha, while previous work in the region varied between 15 and 14,000 ha with an average of 4090 ha (Frey et al. 2012a, b). The difference concerning the maximum value would be associated with the difference in the study area since we only surveyed farms in the Upper Atlantic Forest of Argentina. For the main productive activity, the sample included farms that carried out livestock, crops, and forest plantations without silvopastoral use. Unlike Frey et al. (2012b), we did not distinguish between annual and perennial crops. However, we included the relative area between different use decisions.

When we explored the characteristics of the farm with the recommended forest management, we did not find a significant relationship. However, we did obtain a significant relationship for cattle management. Although correspondence analysis could not link typologies with forest management practices, Type 1 and Type 3 management patterns exhibit differential management. The specialist silvopastoral farms (T1) use hybrid pine, which reduces the number of intermediate operations (thinning and pruning) and facilitates pasture management (Lacorte et al. 2016; Esquivel 2022). The livestock farms with silvopastoral management (T3) use pine (not hybrid genetic) with low initial planting density. Species selection and planting density are key aspects to reduce the shading of the pastures and affect their production (Lacorte et al. 2016; Esquivel 2022), one of the main disadvantages farmers perceive (Frey et al. 2012b).

The correspondence analysis could link typologies with cattle management practices. Type 1 implements rotation and uses fodder reserves to improve the forage balance and reduce the risk of one of the main perceived disadvantages by farmers (Frey et al. 2012b). Type 3 does not use the silvopastoral area for grassing; so, in connection with low density, it can be inferred that this area is used for shade and reduced heat stress of cattle in association with one of the advantages perceived by farmers and previously identified by Frey et al. (2012b).

Agricultural farms with silvopastoral management and forest plantation are the most diversified type (T2). Although productive diversification was one of the main motivations for adopting silvopastoral management, it ceases to be so (Frey et al. 2012b). For this typology, no management pattern could be identified beyond the statistical significance of the analysis.

Despite the contributions of this work, there are still information gaps that are a priority to have a comprehensive view of how silvopastoral systems are adopted in the Upper Atlantic Forest of Argentina. Mercer (2004) stresses the importance of analysing farmers' perception of risk and uncertainty in agroforestry systems, as it is higher when compared to adopting innovations in annual crops. Kiptot et al. (2007) point out the need to identify different categories associated with the adoption process, such as testing, adoption, discontinuation, and re-adoption. The lines that both authors propose can be addressed through qualitative methodologies (i.e., interviews) that allow for exploring cultural variables involved in the adoption decision. Finally, it is a priority to have an updated estimate of the area under the use of silvopastoral systems to analyse their evolution over time.

Acknowledgements This work was supported by the Universidad Nacional de Misiones (16/F158-PI). C.C. Gelabert was supported by a Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) postdoctoral fellowship. Ahuvit Trumper improved the map.

Author contributions Conceptualization: CCG, NIG, SED, DHC, PMMD; Survey design: CCG, DHC; Field Work: CCG, DHC; Data Curation: CCG, SED, PMMD; Data analysis: CCG, TNR; Writing original draft: CCG, NIG, GAZ; Writing-review and editing: All authors; Grants administration: DHC. All authors read and approved the final manuscript.

Funding This work was supported by the Universidad Nacional de Misiones (16/F158-PI). C. C. Gelabert was supported by a Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) postdoctoral fellowship.

Declarations

Conflict of interest The authors have no conflicts of interest to declare relevant to this article content.

References

Alvarez S, Timler CJ, Michalscheck M, Paas W, Descheemaeker K, Tittonell P, Andersson JA, Groot JCJ (2018) Capturing farm diversity with hypothesis-based typologies: an innovative methodological framework for farming system typology development. PLoS ONE. https://doi.org/10.1371/journal.pone.0194757

Bosi C, Pezzopane JRM, Sentelhas PC (2020) Soil water availability in a full sun pasture and in a silvopastoral system with eucalyptus. Agrofor Syst. https://doi.org/10.1007/s10457-019-00402-7

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

Esquivel JI (2022) Sistemas silvopastoriles en el Nordeste de Argentina. In: Sharry SE, Stevaniy RA, Galarco SP (eds) Sistemas Agroforestales en Argenitna. Libros de Cátedra, UNLP, La Plata, pp 208–228

Fassola HE, Lacorte SM, Pachas AN, Goldfarb MC, Esquivel J, Colcombet L, Crechi EH, Keller A, Barth SR (2009) Los sistemas silvopastoriles en la región subtropical del NE argentino. XIII Congreso Forestal Mundial

Frey GE, Fassola HE, Pachas AN, Colcombet L, Lacorte SM, Renkow M, Perez O, Cubbage FW (2012a) A within-farm efficiency comparison of silvopasture systems with conventional pasture and forestry in northeast Argentina. Land Econ. https://doi.org/10.3368/le.88.4.639

Frey GE, Fassola HE, Pachas AN, Colcombet L, Lacorte SM, Pérez O, Renkow M, Warren ST, Cubbage FW (2012b) Perceptions of silvopasture systems among adopters in northeast Argentina. Agric Syst. https://doi.org/10.1016/j.agsy.2011.09.001

Frey GE, Comer MM (2018) Annotated bibliography on the impacts of size and scale of silvopasture in the Southeastern USA. General Technical Report-Southern Research Station, USDA Forest Service, (SRS-e230).

Giménez Gómez VC, Verdú JR, Zurita GA (2020) Thermal niche helps to explain the ability of dung beetles to exploit disturbed habitats. Sci Rep. https://doi.org/10.1038/s41598-020-70284-8

Gómez-Cifuentes A, Giménez Gómez VC, Moreno CE, Zurita GA (2019) Tree retention in cattle ranching systems partially preserves dung beetle diversity and functional groups in the semideciduous Atlantic forest: the role of microclimate and soil conditions. Basic Appl Ecol. https://doi.org/10.1016/j.baae.2018.10.002

Gómez-Cifuentes A, Vespa N, Semmartín M, Zurita GA (2020) Canopy cover is a key factor to preserve the ecological functions of dung beetles in the southern Atlantic forest. Appl Soil Ecol. https://doi.org/10.1016/j.apsoil.2020.103652

Guerra Alonso CB, Zurita GA, Bellocq MI (2022) Livestock grazing impact differently on the functional diversity of dung beetles depending on the regional context in subtropical forests. Sci Rep. https://doi.org/10.1038/s41598-022-05616-x

Hernández-Sampieri R, Fernández Collado C, Baptista Lucio Mdel P (2010) Metodología de la investigación. Mcgraw-Hill-Interamericana Editores, Mexico

Instituto Provincial de Estadísticas y Censos (IPEC) (2015) Gran Atlas de Misiones https://mega.nz/file/oNl3SCxS#ilShTQXtTePcZ8esM_Z_Kb-OtoQla9spwjuibbMO4yE

Izquierdo AE, Grau HR, Aide TM (2011) Implications of rural-urban migration for conservation of the Atlantic forest and urban growth in Misiones, Argentina (1970–2030). Ambio. https://doi.org/10.1007/s13280-010-0095-3

Jose S, Dollinger J (2019) Silvopasture: a sustainable livestock production system. Agrofor Syst. https://doi.org/10.1007/s10457-019-00366-8

Kiptot E, Hebinck P, Franzel S, Richards P (2007) Adopters, testers or pseudo-adopters? Dynamics of the use of improved tree fallows by farmers in western Kenya. Agric Syst. https://doi.org/10.1016/j.agsy.2007.01.002

Lacorte SM, Barth SR, Colcombet L, Crechi EH, Esquivel JI, Fassola HE, Goldfarb MC, Pezzuti R, Videla D, Winck RÁ (2016) Silvopastoral systems developed in misiones and corrientes, Argentina. In: Peri PL, Dube F, Varella A (eds) Silvopastoral systems in southern south America. Springer, Berlin, pp 117–168

Lê S, Josse J, Husson F (2008) FactoMineR: an R package for multivariate analysis. J Stat Softw. https://doi.org/10.18637/jss.v025.i01

Lerner AM, Zuluaga AF, Chará J, Etter A, Searchinger T (2017) Sustainable cattle ranching in practice: moving from theory to planning in Colombia's livestock sector. Environ Manag. https://doi.org/10.1007/s00267-017-0902-8

Mercer DE (2004) Adoption of agroforestry innovations in the tropics: a review. Agrofor Syst. https://doi.org/10.1023/B:AGFO.0000029007.85754.70

Montagnini F, Somarriba E, Murgueitio E, Fassola H, Eibl B (2015) Sistemas Agroforestales: funciones productivas, socioeconómicas y ambientales. Serie técnica. Informe técnico. CIPAV, CATIE.

Murgueitio E, Calle Z, Uribe F, Calle A, Solorio B (2011) Native trees and shrubs for the productive rehabilitation of tropical cattle ranching lands. For Ecol Manag. https://doi.org/10.1016/j.foreco.2010.09.027

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature. https://doi.org/10.1038/35002501

Instituto Nacional de Estadística y Censos (INDEC) (2007) Censo Nacional Agropecuario (CNA) 2002: resultados definitivos, marzo de 2007. Ministerio de Economía y Producción, Argentina

Instituto Nacional de Estadística y Censos (INDEC) (2021) Censo Nacional Agropecuario (CNA) 2018: resultados definitivos, abril de 2021. Ministerio de Economía, Argentina

Pagès J (2004) Analyse factorielle de donnees mixtes: principe et exemple d'application. Revue De Statistique Appliquée 52(4):93–111

Pattanayak SK, Mercer DE, Sills E, Yang JC (2003) Taking stock of agroforestry adoption studies. Agrofor Syst. https://doi.org/10.1023/A:1024809108210

Instituto Provincial de Estadísticas y Censos (IPEC) (2020). Informe sobre la situación actual del sector foresto industrial de la provincia de Misiones. Diagnóstico y perspectivas para el año 2020. https://ipecmisiones.org/wp-content/uploads/2020/10/IPEC-Misiones-Informe-Situacion-Sector-Foresto-Industrial-de-Misiones-A%C3%B1o-2020.pdf

Ribeiro MC, Metzger JP, Martensen AC, Ponzoni FJ, Hirota MM (2009) The Brazilian Atlantic forest: how much is left, and how is the remaining forest distributed? Implications for conservation. Biol Conserv. https://doi.org/10.1016/j.biocon.2009.02.021

Rivera LF, Armbrecht I, Calle Z (2013) Silvopastoral systems and ant diversity conservation in a cattle-dominated landscape of the Colombian Andes. Agr Ecosyst Environ. https://doi.org/10.1016/j.agee.2013.09.011

Tittonell P, Bruzzone O, Solano-Hernández A, López-Ridaura S, Easdale MH (2020) Functional farm household typologies through archetypal responses to disturbances. Agric Syst. https://doi.org/10.1016/j.agsy.2019.102714