REVISTA
SOCIEDAD CIENTÍFICA DEL PARAGUAY

ISSN 0379-9123 • e-ISSN 2617-4731
Volumen 29 Número 02 • julio-diciembre 2024 Doi: http://dx.doi.org/10.32480/rscp.2024.29.2.116 Páginas de 01 a 16
Recibido: 22/05/2024 • Aceptado: 20/09/2024
Editor Responsable: Luis Dávalos Dávalos.
Sociedad Científica del Paraguay, Asunción, Paraguay

Original Article
Artículo Original

FARMERS' AND OTHER STRATEGIC ACTORS' PERSPECTIVES ON IMPLEMENTING AGROFORESTRY MODELS IN PARAGUAY

PERSPECTIVAS DE LOS AGRICULTORES Y OTROS ACTORES ESTRATÉGICOS SOBRE LA IMPLEMENTACIÓN DE MODELOS AGROFORESTALES EN PARAGUAY

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Cómo citar este artículo:
Insfrán Ortíz, A.; Rey Benayas, J. M. y Soto, C. Farmers' and other strategic actors' perspectives on implementing agroforestry models in Paraguay. Rev. Soc. cient. Parag. 2024;29(2):01-16

ABSTRACT
The opinion of farmers and other agents involved in agroforestry systems is little studied in Paraguay. This article analyzed the predisposition of farmers to apply agroforestry models in Yerba mate (*Ilex paraguariensis A. St-Hil*) farms in the municipality of Carlos Antonio López, Paraguay. Relatively simple surveys were conducted with 62 farmers from two communities in the municipality and interviews were conducted with 20 strategic stakeholders representing institutions. The quantitative data were analysed with logistic regression in Rstudio and the qualitative data with Atlas.ti v. 9 with the inductive approach of grounded theory in the Emergence Index and exploratory theorizing. It was found that the predisposition of farmers to apply agroforestry is a function of educational level, land tenure and farm size. Regarding motivations, the higher the educational level of the farmers, the higher the predisposition to apply agroforestry. The strategic actors have pointed out that agroforestry in Paraguay is marginal and limited to isolated cases, the near absence of public policies, incipient research, the absence of financing mechanisms, and the pressure of mechanised agriculture. It is concluded that agroforestry is applicable in farms with *Ilex paraguariensis A. St-Hil* cultivation and essentially obeys pragmatic motivations, with factors that must be overcome.
Keywords: Agroforestry; adoption; *Ilex paraguariensis*; agroecological restoration; motivations.

RESUMEN
La opinión de los agricultores y otros agentes involucrados en sistemas agroforestales está poco estudiada en Paraguay. En este artículo se analizó la predisposición de los agricultores a aplicar modelos agroforestales en fincas de Yerba mate (*Ilex paraguariensis A. St-Hil*), en el municipio de Carlos Antonio López, Paraguay. Se realizaron encuestas relativamente sencillas a 62 agricultores de dos comunidades del municipio y entrevistas a 20 actores estratégicos representantes de instituciones. Los datos cuantitativos fueron analizados con regresión logística en Rstudio y los cualitativos con Atlas.ti v. 9 con el enfoque inductivo de teoría fundamentada en el Índice de Emergencia y teorización exploratoria. Se constató que la predisposición de los agricultores a aplicar

la agrosilvicultura está en función del nivel educativo, la tenencia de la tierra y el tamaño de la explotación. En cuanto a las motivaciones, cuanto mayor es el nivel educativo de los agricultores, mayor es la predisposición para aplicar la agrosilvicultura. Los actores estratégicos han señalado que la agroforestería en Paraguay es marginal y se limita a casos aislados, la casi ausencia de políticas públicas, la incipiente investigación, la ausencia de mecanismos de financiamiento y la presión de la agricultura mecanizada. Se concluye que la agroforestería es aplicable en fincas con cultivo de *Ilex paraguariensis A. St-Hil* y obedece esencialmente a motivaciones pragmáticas, con factores que deben ser superados.
Palabras clave: Agroforestería, adopción, *Ilex paraguariensis A. St-Hil*, motivaciones, restauración agroecológica.

INTRODUCTION

Conventional agricultural systems currently pose one of the main threats to the environment and global sustainability[1]. Faced with this reality, a paradigm shift in agricultural production systems is needed, especially one that focuses on agroecological transformation, which centres the recovery of biodiversity and the functionality of agroecosystems[2]. Agroforestry is an agricultural production alternative that can contribute to this agroecological transformation[3]. The practice of combining trees or shrubs and crops or grasses on the same farm[4] is receiving widespread recognition as a sustainable land management system among farming communities[5], and as a model for restoring ecosystem services[6].

As particular socio-economic contexts require the need to design restoration goals alongside local people[7], numerous publications have recognised the importance of both human[8] and social[9] dimensions to ensure the success of ecological restoration. Setting goals for ecological restoration is argued to be contingent on people's attitudes[10,11,8,12,13]. Attitude refers to the learned predisposition to respond consistently in a favourable, neutral, or unfavourable way to an object, activity, concept, or symbol[14,15]. Attitude is a behavioural indicator which can have positive or negative implications and high or low intensity. The attitudes of different individuals and social groups, which should be interpreted as symptoms rather than facts[16], can determine the success of any restoration initiative.

Most restoration projects are motivated, at least in part, by the desire to restore species, ecosystems, or ecosystem processes altered by human activities[17]. Key considerations for the implementation of restoration actions include financial incentives and the education and professional training of farmers[18]. Additionally, there may be a need to compensate for damages, provide economic benefits, reconnect with cultural/spiritual values, and comply with legislation[17]. Conceptually, from the neoclassical economics perspective, there is a tendency towards the monetisation and commodification of ecosystem services[19]. In this article, the subject matter is approached from (a) the attitudes shown by farmers towards the agroforestry model, its multiple tangible values or use values[20], and intangible or non-use values[21]; and (b) the opinion of other strategic actors linked to agroforestry in Paraguay, specifically within academia, government agencies, non-governmental organisations, and private companies. To this end, the various useful properties of agroforestry systems (AFSs) are analysed from a perspective that guides application of agroecological principles on rural farms in Paraguay. This perspective is rooted in the historical context which is defined by local knowledge and culture[22].

Agroforestry, from an ecological restoration perspective, satisfies social values [11] and responds to part of the rationale for ecosystem restoration[23,24]. Ceccon[25] pointed out that the recovery of ecosystem services may depend on strategies other than those promoted in the principles of the International Society for Ecological Restoration, as ecological restoration must contemplate interdisciplinarity and cooperation with the affected social group, as well as engaging in a necessary dialogue with local groups[26].

The usual pattern of yerba mate (*Ilex paraguariensis A. St-Hil*) cultivation in eastern Paraguay is in monocultures sometimes associated with annual crops; in a few cases it is combined with other tree species. Fundación Moisés Bertoni considers Yerba mate as a productive and sustainable element that contributes to the maintenance of forests and the reestablishment of biological corridors[27]. The extent to which this crop is socially accepted and recognised as a native tree species has not been investigated. There is a need to understand how individual farmer attitudes are influenced by characteristics such as age, education, social status, and estate dominance status, among others[28]. The objectives of this study are 1) to analyse the relationship between the adoption of agroforestry models on farms and

the characteristics of farmers, their families, and the farms themselves; and 2) to explore the opinions of strategic institutional actors on current agroforestry practices in Paraguay to gather insights on the limitations and opportunities for the application of agroforestry in the region. We asked 1) What characteristics of farmers are relevant for the application of the agroforestry model in yerba mate cultivation; and 2) What are their motivations for deciding to implement the agroforestry model on their farms? Crucially, individual initiatives for farmers require a framework for action that involves other strategic actors linked to the agricultural sector. From this perspective, we also asked 3) how is the application of agroforestry systems in Paraguay perceived in academia, government agencies, civil society organisations and the private business sector? The starting hypotheses are that: (H_1) the level of interest in implementing agroforestry models in yerba mate farms depends on the form of land tenure, and farms with land titles tend to apply the agroforestry system more; (H_2) the degree to which farmers are motivated to apply agroforestry is mostly related to the farmers' age, as older people value biodiversity more than younger people; and, (H_3) in the opinion of institutional actors, the biggest constraint for the implementation of agroforestry systems is the high initial investment required.

The importance of this research lies in its potential to better understand the adoption of agroforestry on farms. The results obtained will help to guide agricultural development policies and strategies that promote sustainable practices and measures aimed at restoring biodiversity and ecosystem services in rural area.

MATERIALS AND METHODS

Research design and sampling

This study used a mixed (quantitative and qualitative) approach as this facilitates a more comprehensive understanding of the problem studied and strengthens the credibility of the findings[29,30]. The research design was non-probabilistic. We conducted 1) farmer surveys using a quantitative approach and 2) interviews with strategic institutional actors considered to be key informants for agroforestry development in Paraguay using a qualitative approach. The latter was exploratory and hermeneutic, i.e. based on an interpretative framework without prior judgements that could produce subjective distortions about the phenomenon studied. This was complemented by grounding theory which helped the emergence of a new theoretical model[31,32,33].

1) Farmers' Surveys. The sampling was targeted and included all farms with yerba mate cultivation in the study area (Figure 1), located in the municipality of Carlos A. López (department of Itapúa, Paraguay), close to the agroforestry experimental units[34]. The surveys included a total of sixty-two farmers located in similar agro-bioclimatic conditions. All farms are of the family farming typology[35,36,37]. These farmers are distributed in two lines drawn along East-West country roads: the first follows the route from the Caacupe-mi neighbourhood towards the urban area km 8 (line A-B); the second line starts from the urban area km 8 towards the Paraná River up to the San Isidro neighbourhood (line C-D; Figure 1). In both cases, farms on both sides of the route were included. All farmers surveyed had previously visited the experimental agroforestry units with thirty plots of conventional, agroecological and traditional schemes indicated above. They visited in groups of three to five farmers to gauge their interest. The surveys were conducted on the individual farms of each farmer in November and December 2021.

Each survey collected key data on the farmer (gender, age, level of education), the family (number of children), and the farm (land tenure, size, area under yerba mate cultivation and area of forest). The information was recorded as follows:

1) gender = 1 for men and 0 for women; 2) age of respondent in years; 3) number of children; 4) educational level based on studies = 1 for Basic, 2 for Secondary, 3 for University, and 4 for Postgraduate; 5) form of land tenure = rented, rightful title under management, or titled; 6) farm size in total hectares; remaining forest area in hectares; and 7) yerba mate cultivation area in hectares (Table S1). This information, coded prior to statistical analysis of the data, was carefully analysed to identify patterns and trends to help understand the factors influencing motivations for the adoption of agroforestry.

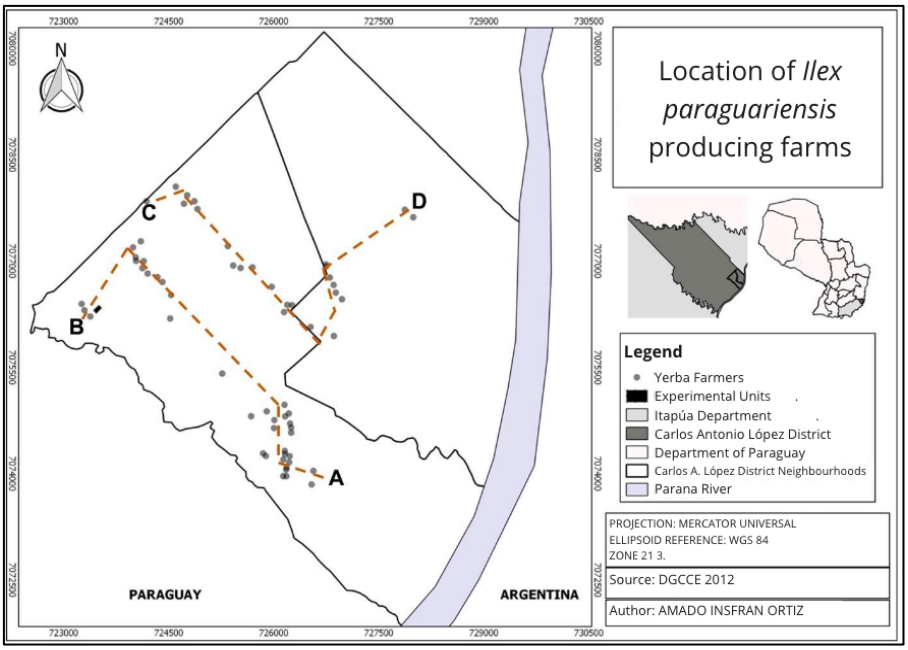

Figure 1. *Location (grey dots) of the farms of the surveyed yerba mate farmers (n = 62), in the neighbourhoods of Caacupemí (A-B) and San Isidro (C-D) in the municipality of Carlos A. López (Itapúa, Paraguay)*

The surveys considered two dimensions linked to farmers' attitudes related to (a) local implementation (coded as dimension "e") and (b) motivations (coded as dimension "f"). Local application is the willingness of farmers to apply the agroforestry model on their farms. For this purpose, a set of ten statements referring to the agroforestry system visited were developed as follows: "it is applicable on my farm", "I would like to apply it in the yerba mate plot", "I am willing to purchase seedlings", "I am willing to purchase supplies", "I am interested in training on the subject", "I am willing to buy equipment", "I am interested in learning about its benefits", "I am interested in restoring native trees", "I am interested in showing it to my neighbours", and "I can allocate an area of my farm for this purpose".

Motivations are the general reasons that would help the farmer implement the agroforestry model on his farm. Ten statements were developed with motivation response options grouped according to Clewel and Aronson[38]: technocratic motivations to "respond to a municipal plan promoting agroforestry" and "meet legal requirements"; biotic motivations "to reintroduce tree species to plots" and "create a wildlife habitat"; heuristic motivations "to improve soil quality" and "cope with extreme droughts"; idealistic motivations "to promote environmental education" and "provide jobs for local youth"; and pragmatic motivations "to provide firewood for the house" and "to provide shade for rest on the farm".

Each farmer surveyed responded to each of the statements following a summative categorical rating scale from 0 to 5, adapted from Likert[39] to measure attitudes[40,41,16]. According to this scale, values tending to 5 (five) denote a favourable predisposition to affirmation and those tending to 1 (one) an unfavourable predisposition. The scale was constructed based on a series of items reflecting a positive or negative attitude towards a stimulus or referent represented by the implementation of agroforestry systems on their farms. Each statement was structured with six response alternatives: 5) = strongly agree, 4) = agree, 3) = indifferent, 2) = disagree, 1) = strongly disagree and nr) = no response. The non-response option is recommended to be used in the scale [42] and conceptually it is a "*failure to obtain response in the units of analysis (of a population or sample) for various reasons such as absence of a person in the household, refusal, empty households, non-return of the questionnaire, omission of one or more entries in a questionnaire, etc*."[43]. In this study option nr refers to the omission response. The responses measured the individual farmers' willingness to apply agroforestry models in particular social contexts. All statements made were positive towards the application of the agroforestry model to safeguard consistency in the relationship of the responses.

2) Interviews with strategic institutional actors. The selection of respondents was made according to their field of work and was based on the credibility of the actors given their professional background[31]. The sample included 20 respondents distributed equally in five institutional sectors: a) academic, comprising researchers from the National University of Asunción; b) governmental, comprising professionals working in ministries with functions linked to agricultural activities; c) private, aimed at professionals working in agricultural companies; d) non-governmental organisations, with professionals responsible for agroforestry projects; e) private, aimed at professionals working in agricultural companies; and f) non-governmental organisation, aimed at professionals responsible for agricultural projects (Table S2). The literature was used to formulate structured questions that served as a starting point for the interviews and observations[32]. A structured questionnaire with three blocks of open-ended questions was used to allow the respondents to answer freely, following a logical sequence. The first part of the questionnaire focused on the respondent's opinion about agroforestry in the country with the question "What is your opinion on the current state of agroforestry in Paraguay (Q1)?" This was followed by the question on whether the ecoregions of Paraguay offer the right conditions for the application of agroforestry (Q2). The third block focused on agroforestry experiences with the question "How do you evaluate the implementation of known cases of agroforestry in the country?" (Q3). The interviews were conducted by email between September and November 2022.

Data analysis

We must distinguish between two sets of analyses, those of the quantitative data from the farmer surveys and those of the qualitative data from the strategic stakeholder interviews.

(1) Surveys with farmers. Nine percent of the quantitative data from the farmer motivation surveys had gaps (i.e. "nr" -- non-response). No active corrections were made to fill these data; on the contrary, these values were omitted during the analysis to avoid distortions in the interpretation of the results. The cleaned data, excluding the "nr" values, were organised in a database designed for analysis in the RStudio environment [44]. The confidence analysis of the data, measured through Cronbach's alpha coefficient, revealed an overall value of 0.95, indicating a significant and high internal consistency in the responses to the survey questions and among the variables assessed.

In reviewing the descriptive results, a clear pattern was evident in the average rating levels of dimensions "e" (local application) and "f" (motivations). It was observed that the average ratings were generally concentrated towards the higher values. All questions in dimension "e" resulted in average values above the median of the group responses (Figure S1). Similarly, for dimension "f", the average values were generally above the median, except for question f48 (Figure S2). This revealed that, in general, typical responses focused only on scales 4 (agree) and 5 (strongly agree). This result prompted the simplification of the statistical analysis by recategorizing all variable responses into two scales.

Consequently, the initial response variable (average rating on each dimension e0 and f0) was transformed by dichotomising the variable into the values 0 and 1, where zero represents "agree" and one means "strongly agree".
To classify each average response into the dimensions "e" (e_0) and "f" (f_0), the median value of these average responses (e0_median and f0_median, respectively) was calculated. These two values were used as a threshold or reference, above which the average responses were separated into the two categories. Specifically, the logic of "If e0 <= e0_median, then y = 'Agree'; otherwise, y = 'Strongly agree'" was followed. This transformation allowed for simplified interpretation of responses and subsequent hypothesis testing. Given the nature of the data from the ordinal Likert scale, a logistic linear regression analysis was conducted to verify the hypotheses.

(2) Interviews with strategic actors. The analysis of the qualitative data from the stakeholder interviews used an exploratory, inductive grounded theory approach, allowing concepts and ideas to emerge from the data[31,45]. The approach therefore makes it possible to "discover theories, concepts, propositions and hypotheses directly from data, rather than from a priori assumptions or theoretical frameworks of reference"[46]. The steps for data analysis were:

a) Open coding: responses were processed using free or open coding as defined by Strauss and Corbin[32]. The code, words, or short phrases, is a construct generated by the researchers to symbolise data[45]. This stage

required a general analysis and a detailed analysis. Firstly, an extensive coding of the interview transcripts was conducted in search of relevant ideas and themes, concluding when the discussion between authors did not result in any major disagreements about the emerging themes. Subsequently, in a second coding, the codes (themes) were listed to merge or eliminate those that were redundant or signified the same idea. The coding provided the Grounding (Gr), which represents the number of coded citations or number of citations in the document. A detailed line-by-line and paragraph-by-paragraph analysis of the interview transcripts was employed using Atlas.ti version 9 software[46].

b) Axial coding. As coding occurs around the axis of a category and links codes according to their properties and dimensions[32], the codes are related to each other in order to reveal the density of interactions. The relationships considered between the codes were: "Contradicts to;" "Is the cause of;" "Is part of;" and "Is associated with."

c) Calculation of the Emergence Index (EI). The emerging categories, which respond to the research objectives, were obtained by adding the grounding of each code with the density. The simple average of the sum of the EIs was determined from the total of the codes identified; the codes with a value above the average represent the most relevant emerging categories. In this way, the grounding of the identified codes is visualised on the basis of the number of citations of these codes in the imagination of the actors interviewed. For this purpose, the grounding table document was used and from this, the Sankey diagram was created to illustrate the result.

d) Exploratory theorisation. Although the objective of the research was not to develop a theory, which implies discovering the abstract categories and the relationships between them in order to understand the how and why of the phenomenon analysed[47], an exploratory analysis was carried out that allows for the discussion of the results and provides ideas that could serve as a basis for the theorisation of the phenomenon analysed, i.e. agroforestry in Paraguay. The co-occurrences of the exploratory theorisation were presented through the theoretical Sankey diagram.

RESULTS

Farmers' willingness to implement agroforestry systems

The results of the farmer surveys (n = 62) reflected interest in implementing agroforestry on their farms. Farmers' responses indicated an average tendency to agree (29.2%) and strongly agree (27.1%). The sums of "agree" and "strongly agree" responses were given especially in the favourable predisposition to recover trees of native species (82%), the applicability of agroforestry on the farm (79%), the interest in training to implement agroforestry schemes (79%), and to allocate an area of their farms for the agroforestry model (68%). However, farmers' willingness was reduced when the implementation of the agroforestry model implied covering the costs of equipment, inputs, and seedlings from their side (Figure 2, Table S3).

Farmers' responses showed discrepancies in terms of motivations. There was a higher level of agreement in motivations related to interest in having firewood in the house and shade on the farm for resting (98.4% in both cases). (94.7%). However, responses to the option of establishing a municipal restoration plan that would motivate the implementation of agroforestry models on their farms tended towards "disagree" and "totally disagree" (-82.2%);

Figure 3, Table S4).Interest in replanting trees on their plots (96.7%) and the perception that agroforestry could be a way of coping with extreme droughts was also high.

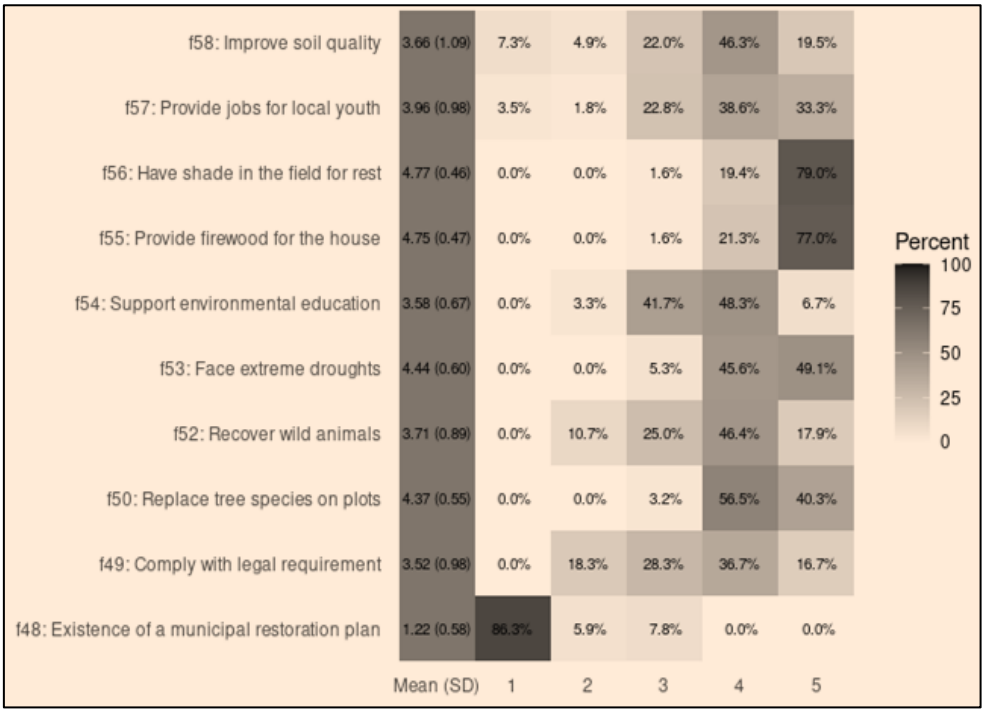

***Figure 2**. Responses denoting farmers' interest in implementing agroforestry models on their farms, estimated according to the Likert scale: 5) = strongly agree, 4) = agree, 3) = indifferent, 2) = disagree and 1) = strongly disagree*

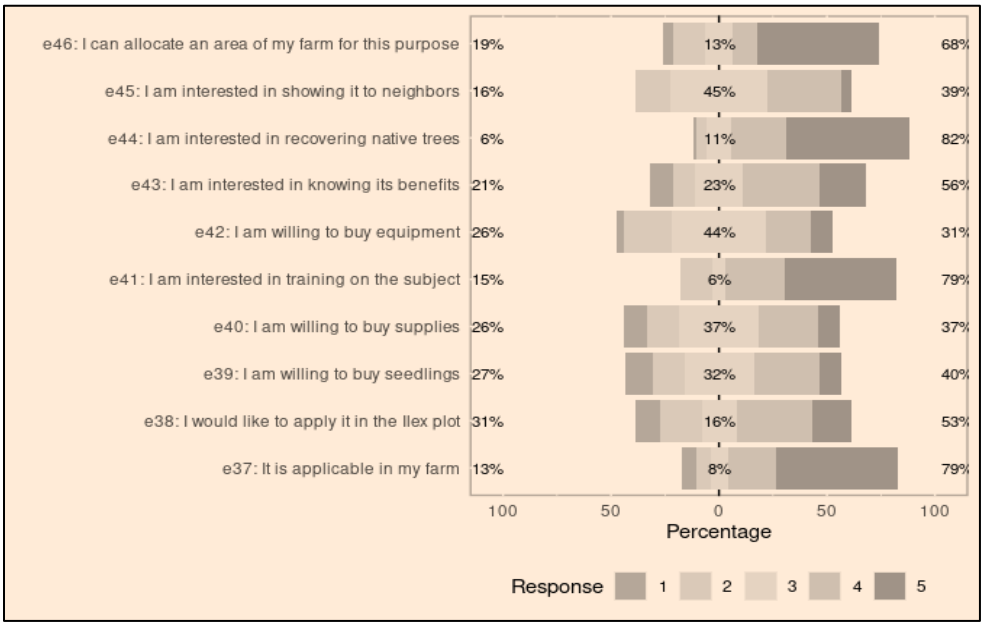

***Figure 3**. Responses expressing farmers' motivations for implementing agroforestry models on their farms, according to the Likert scale: 5) = strongly agree, 4) = agree, 3) = indifferent, 2) = disagree and 1) = strongly disagree}*

The logistic regression model used to analyse these dimensions revealed prominent patterns. Educational level (p = 0.015), land tenure form (p = 0.025), and farm size (p = 0.037) were the statistically significant variables in the logistic linear regressions that explained farmers' interest in implementing agroforestry systems. In the case of motivations, the only statistically significant variable was educational level (p = 0.03; Table 1).

	Interest in implementation (dimension "e")				Motivations for implementation (dimension "f")			
Variable	Estimate	Std. Error	z value	Pr(>|z|)	Estimate	Std. Error	z value	Pr(>|z|)
	-9.7071	4.0678	- 2.386	**0.0170***	-2.1964	1.3747	-1.598	0.1101
Neighbourhood	-1.8200	1.2105	-1.504	0.1327	-0.5599	0.6941	-0.807	0.4199
Age, 40-59 years	3.6082	2.1343	1.691	0.0909.	0.9948	0.9835	1.012	0.3118
Age, >60 years	3.5508	2.3214	1.530	0.1261	-0.8260	1.2096	-0.683	0.4947
Number of children	1.0850	1.4594	0.743	0.4572	-0.2280	0.9277	-0.246	0.8058
Level of education	3.7638	1.5483	2.431	**0.0151***	1.8671	0.8611	2.168	**0.0301***
Land tenure	5.0100	2.2422	2.234	**0.0255***	1.0451	0.8450	1.237	0.2161
Farm size, <5-10ha	3.3350	1.6033	2.080	**0.0375***	1.4493	1.0750	1.348	0.1776
Farm size, >10ha	4.2125	2.0166	2.089	**0.0367***	2.3835	1.4497	1.644	0.1001
Size of remnant forest.	-1.7006	1.6685	-1.019	0.3081	1.5069	0.8879	1.697	**0.0897.**
Size of yerba mate crop	0.4541	1.8470	0.246	0.8058	-1.5579	1.3225	-1.178	0.2388

Signif. código: * = 0.05;. = 0.1

Table 1. *Logistic linear regression coefficient of farmers' interest and motivations in implementing agroforestry models (n = 62). Coefficients with a statistical significance level ≤ 0.1 are indicated in bold.*

Opinions of strategic actors linked to agroforestry in Paraguay

Twenty-two codes were identified from the responses given by the strategic institutional actors interviewed. The grounding values that contributed to the highest Emergence Indices (EI) indicated that agroforestry development in Paraguay is limited to isolated and unsustainable cases (EI = 32); noting the near absence of public policies for agroforestry development (EI = 24); the incipient research on the topic (EI = 21); the absence of financing mechanisms (EI = 20); and the pressures of mechanised agriculture (EI = 20). However, respondents argued that agroforestry is a suitable system for small multifunctional farms (IE = 24) and that it has the capacity to restore biodiversity and ecosystem services (EI = 22) (Table 2).

Code	**Rooting**	**Density**	**EI**
Potentials			
Suitable for small multi-purpose farms	11	13	24
Applicable to all ecoregions of the country	4	11	15
Empirical knowledge	6	10	16
Successful private efforts	5	8	13
Indigenous and small-scale agroforestry culture exists	5	10	15
Restores biodiversity and ecosystem services	12	10	22
Silvopastoralism greater potential for scaling up	8	11	19
Edaphoclimatic advantages	8	7	15
High land equivalent ratio	2	11	13
Constraints			
High initial investment costs	1	8	9
Applied to isolated, non-sustainable cases	11	21	32
Lack of funding mechanisms	8	12	20
Low competitiveness	2	17	19
Weak public institutions	1	9	10
Optional training in formal education	4	6	10
Family labour shortage	1	8	9
Lack of support for farmers	5	12	17
Untrained public officers	1	7	8
Emerging research	9	12	21
Almost non-existent public policy	15	9	24
Pressure from extensive farming as a limiting factor	10	10	20
Requirements for technical expertise	1	10	11
Total			362
Average			16

Table 2*. Identified codes, Rooting, Density and Emergence Index (EI) values obtained from twenty interviews with strategic institutional actors (respondents)*

The number of citations coded from the responses of the strategic actors interviewed followed the decreasing order (a) government agencies (Gr = 41), (b) academics (Gr = 37), and (c) non-governmental agencies and private sector (Gr = 27). Roots with higher relative frequencies indicated that for government agencies agroforestry is considered suitable for small multifunctional farms (15%); there is an absence of funding mechanisms; public policies are almost absent; and agroforestry restores biodiversity and ecosystem services (12.5% respectively). Academics highlighted the near absence of public policies (13.9%), and that agroforestry is applied in isolated and unsustainable cases (11.1%). NGOs pointed out that research is incipient in the field of agroforestry; agroforestry restores biodiversity and ecosystem services (both 14.8%); and that public policies on agroforestry are almost absent (11.11%). For the private sector, the most repeated response was that there are soil and climatic advantages for agroforestry (18.5%); there have been successful efforts within the private sector (11.1%); it is applied to isolated and unsustainable cases (11.1%); and the pressure from extensive agriculture is a constraint (11,1%) (Figure 4, Table S5).

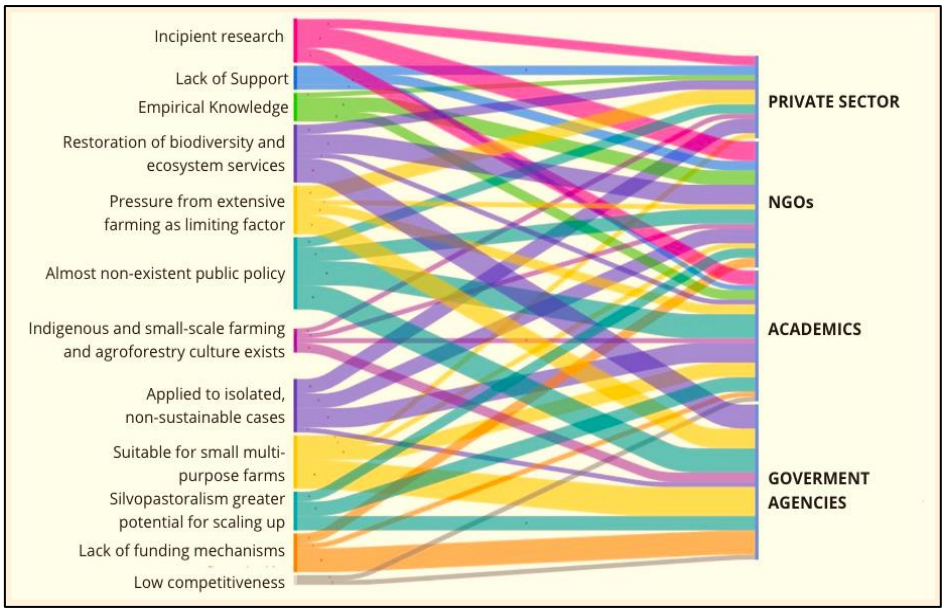

Figure 4. *Sankey diagram of emerging agroforestry codes (responses) in Paraguay according to the strategic actors interviewed*

Emergent findings from the exploratory analysis

The Sankey Diagram showed the interaction between the set of responses given by the institutional actor respondents, where the predominance of a certain sector or affirmation of sectors was not visualised. The co-occurrence analysis showed the strongest interactions were between the absence of funding mechanisms and the lack of support for farmers. However, although agroforestry is suitable for small multi-purpose farms it is strongly and positively associated with isolated and unsustainable cases (Figure 5).

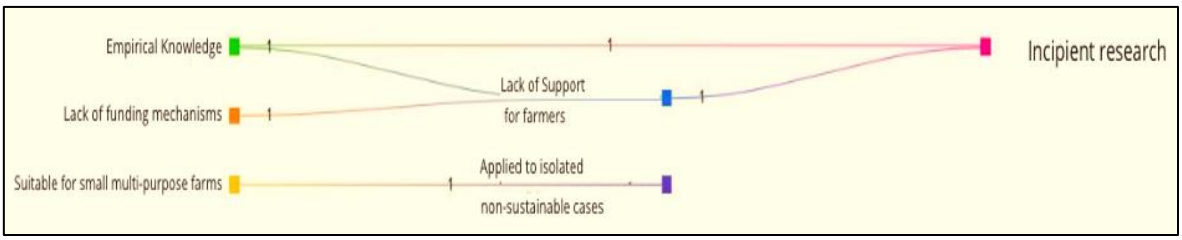

Figure 5. *Sankey diagram and exploratory theorisation from co-occurrence calculation for agroforestry systems in the study region*

The lack of research on agroforestry models in Paraguay reflects a concern regarding the role of academia and research centres in the country. As a result, "knowledge of the potential of agroforestry is not widespread in the country, there is a lack of promotion, but also a lack of documented and published experiences by researchers" (interviewee ACA5-

jp). Although "there are scientific events that deal with the subject, and also many courses that offer knowledge on topics related to the application of agroforestry" (interviewee ACA3-pe), the expected impacts are not observed.

DISCUSSION

This study, based on surveys and interviews, analysed the relationship between the adoption of agroforestry models on farms in Paraguay and the characteristics of farmers, their families, and the farms themselves, and explored the opinion of strategic institutional actors on contemporary agroforestry practices in the country. The results generally support the starting hypotheses.

Replicability of agroforestry systems

The replicability of agroforestry systems will depend on the willingness expressed by farmers. In general, voluntary adoption is low[48]. However, our results point to the latent and favourable predisposition of local farmers to implement agroforestry initiatives in the context studied. Farmers are willing to recover lost native trees, motivated by future uses, as they provide products such as marketable timber, fruits, seeds, and pods that feed humans, livestock, and wildlife[49,50]. In tropical contexts, the contribution of native trees is relevant as they help to conserve water, improve the capacity of the productive system in the face of risks generated by climate variability, and contribute to the sustainability of the productive system[51].

In our research, logistic regression results indicated that agroforestry is applicable on the farms of the farmers surveyed. We hypothesised that interest in the application of agroforestry models on farmers' farms with *Ilex paraguariensis* depends on the form of land tenure and that it is feasible on farms with land titles (H_1). This hypothesis was corroborated by the results. Furthermore, interest in the application of agroforestry models increased with the level of education and farm size of the farmer, a result consistent with other studies[52,53]. According to these authors, a larger farm size, younger and more educated farmers, more visits by technicians, and better market access contribute to greater adoption of agroforestry. However, there are critical factors that influence decision making. In this research, it was observed that when farmers are asked to be responsible for covering the costs of the necessary equipment, inputs, and/or seedlings, the willingness to apply agroforestry models decreases, coinciding with studies by Ramírez et al.[54] in Mexico. In Colombia, infrastructure, data collection and record keeping, environmental awareness, welfare and safety of working groups, and quality control are important determinants in the adoption of agroforestry systems[55]. In Paraguay, institutional fragmentation and international donor intervention are factors that affect the adoption of agroforestry[56].

In terms of farmer's motivations for implementing the agroforestry model on their farm, this research showed that pragmatic motivations, such as the possibility of having firewood in the house and having shade on the farm for resting, were the most frequently expressed. This indicates that, beyond the benefits of agroforestry systems in providing numerous ecosystem services[52,57] and natural capital[58,59], farmers were motivated by pragmatic reasons. In other geographical contexts, simple practices with quick results attract farmers for early adoption[50].

This study has also found that farmers would apply agroforestry systems to replenish tree species on their land to cope with extreme droughts. From these responses it appears that there is concern about the loss of plant biodiversity on farms (biotic motivation); and that this loss is related to drought events (heuristic motivation) which generate uncertainties for farmers. High temperature stress is a major limiting factor for maize yield in China[60] and a cause of tree species mortality in primary forests worldwide[61]. Agroforestry systems are appropriate measures to address these climate change-related impacts[52,62].

We hypothesised that farmers' motivations to apply agroforestry on their farms are related to their age and that older people value on-farm biodiversity more (H_2). This hypothesis was rejected by our results, as the logistic linear regression indicated that farmers' level of education was the determining factor; the higher the educational level of the farmers, the higher the predisposition to apply agroforestry. Other studies confirm this result, as landowners with a higher level of education understand the knowledge underlying the technology and can make better informed

decisions[63,64]. However, in another case, education did not influence the adoption of agroforestry practices, as more educated owners have better off-farm employment opportunities and spend less time on farm management[65].

Limitations and potentials of the application of agroforestry systems in Paraguay
The most widespread evidence suggests that: the development of agroforestry in Paraguay is confined to *cases that are isolated and unsustainable; research* on the subject *is in its infancy;* there is *a lack of funding mechanisms*; and the *pressure from mechanised farming* prevents the development of agroforestry in the country. The unsustainability pointed out by the interviewees could be due to the near absence of public policies for the development of agroforestry in Paraguay. Although these limitations exist, respondents have argued that agroforestry is suitable for small multifunctional farms and is a strategy to recover biodiversity and ecosystem services. The Emergent Indices resulted in the rejection of the hypothesis (H_3) *"In the opinion of institutional actors, the major constraint for the implementation of agroforestry is the high initial investment cost."*

Agroforestry systems in Paraguay are almost devoid of state support in terms of public policies, and this view is reflected in the suggestions reported by respondents. Firstly, some respondents stated that *"public policies are practically non-existent or not sufficiently accessible to stakeholders or potential implementers of agroforestry projects"* (interviewee ACA5-jp), and that there is *"Almost nothing, with no effective implementation compared to other policies in place for the agricultural sector"* (interviewee ONG1-ji) and that therefore, "*existing state policies prioritise conventional agriculture and livestock farming, and agroforestry takes a back seat, being presented as 'production alternatives' rather than as systems that can be prioritised*" (interviewee OGU1-do). This aspect is relevant and requires harmonisation between current policies and regulatory instruments for forest conservation and restoration[66].

Secondly, at the national level, it is suggested that "*the Ministry of Agriculture and Livestock (MAG) and the National Forestry Institute (INFONA), must have logistical and financial resources for government policies on agroforestry, and provide for payment for environmental services and financial incentives or tax exemptions*" (interviewee ACA1-md). Laws 4241/2010 on the re-establishment of forests protecting watercourses, 3001/2010 on environmental services, 6286/2019 on the defence, restoration, and promotion of peasant family farming, and 7190/2023 on carbon credits are legal instruments in force in Paraguay that provide for agroforestry models to be implemented as measures[67].

Although payments for environmental services in developing countries foresee rewards for agroforestry, they materialise only after farmers provide data on adult trees as a product[68]. At the local scale, extensive monospecific agriculture is advancing at the expense of forests and other legally protected areas and multifunctional farms. In the case of Ilex paraguariensis A. St-Hil, the productive areas are linked to the Atlantic Forest ecoregion in Paraguay. In this respect, "*the Atlantic Forest area in Paraguay has a lot of potential for the application of agroforestry as an environmental safeguard mechanism, but the pressure of soya makes it difficult to develop*" (interviewee OGU2-hc).

Given this reality, *"it is important that diversified peasant family farming be zoned according to where agroforestry has a greater chance of success"* and that *"the country's municipalities declare areas of interest for peasant family farming, implementing agroforestry and agroecological systems"* (interviewee OGU2-hc). This is particularly relevant in areas where "*Agroforestry requires further promotion from local governments and academia, in the search for the best measures to address climate change and the recovery of multifunctional landscapes*" (interviewee OGU3-pp). This is consistent with other studies[69,70]. Municipalities have a crucial role to play in this context, and policy enforcement, farmer training[53] and incentives, are urgent measures[71].

Exploratory theorisation
From the Sankey Diagram it was observed that there was no predominance of a particular sector in the set of emerging responses from institutional actors. This result is congruent with the recommendations of Evans et al[67].

Many cases reported by respondents are in the Atlantic Forest area of Paraguay. This is relevant as, with only 10% of this biome currently remaining, it is important to consider the conservation of the larger remaining fragments and to implement programmes to connect these fragments[72,73] where agroforestry systems are a very valid option.

The incipience of research on agroforestry models is a major constraint to scaling up at the national level. The results of this study refer to geographical areas and should not be generalised. The success factors of agroforestry in crop cultivation of *I. paraguariensis* in Paraguay are still unclear[34], as in the Brazilian cerrado ecosystem, where research on edaphic and biotic factors in agroforestry is also incipient[74].

Therefore, the theory as an ideal model[46], constructed from the results of this study, is the basis for the development of agroforestry in Paraguay based on the strengthening of robust scientific research. This research reflects the shortcomings, strengths and weaknesses of the agroforestry system, and the demystification of ideas or concepts that surround this practice and are barriers to its successful implementation and dissemination.

CONCLUSIONS

The results of this social study provide useful information for the design and implementation of agroforestry projects; and insight into farmers' predispositions and motivations to promote the adoption of agroforestry systems at different scales. Agroforestry is applicable in the farms of farmers with crops of *I. paraguariensis*. This applicability will increase according to the extent to which land tenure is formalised with a land title, the education level attained by farmers, and the size of the farmer's farm. However, this favourable predisposition will be contingent upon the extent to which the costs of implementing agroforestry models are covered by actors external to the farm.
This research has also shown that farmers' main motivations are related to pragmatic considerations, with significant value placed on having firewood in the house and having shade on the farm for resting.

Public policies aimed directly at promoting the growth of the agroforestry sector linked to *Ilex paraguariensis A. St-Hil* are still scarce in Paraguay. However, mention is made of the National Development Plan, the results of which are still awaited. An important recommendation, directed mainly to decision-makers and those responsible for implementing the country's development policies, is the promotion of scientific research to support a National Agroforestry Plan with prospects for sustained implementation over time to achieve long-term results.

Financing statement:	Part of this research was carried out with its own funding and with the support of the Non-Governmental Organization *Fomento de Iniciativas para la Restauración de Ecosistemas del Paraguay (FIRE Paraguay).*
Declaration of conflict of interest:	The authors declare no conflict of interest.
Declaration of authors:	The authors endorse the final version of the article.
Author contributions:	Conceptualization and methodology, AIO, JMRB and CS; data collection, AIO; formal analysis, AIO and CS; validation, AIO, CS, and JMRB; writing— original draft preparation, AIO; writing—review and editing, AIO and JMRB; supervision, JMRB. All authors have read and agreed to the published version of the manuscript.
Acknowledgments:	We thank the Carolina Foundation of Spain and the National University of Asunción for a doctoral scholarship for AIO. To the Ibero-American Science and Technology Program (CYTED) for its support within the framework of the Biocultura Network. We are also grateful to FIRE Paraguay for linking the research with the institutional project "Restoration of Agricultural Areas".

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