# Agroforestry systems associated with natural regeneration: alternatives practiced by family-farmers of Tomé-Açu, Pará

## *Sistemas agroflorestais associados à regeneração natural: alternativas praticadas por agricultores familiares de Tomé-Açu, Pará*

Mário M. Oliveira Neto [1]

Livia de F. Navegantes Alves [2]

Gustavo Schwartz [3]

[1] *Master's Degree in Family Farming and Sustainable Development, Federal University of Pará, Belém, PA, Brazil*
*E-mail: marioneto.eng@hotmail.com*

[2] *PhD in Agroecosystems, Full Professor, Amazon Institute of Family Agriculture Federal University of Pará, Belém, PA, Brazil*
*E-mail: lnavegantes@ufpa.br*

[3] *PhD in Ecology and Forest Management, Researcher, Brazilian Agricultural Research Corporation (Embrapa), Belém, PA, Brazil*
*E-mail: gustavo.schwartz@embrapa.br*

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## ABSTRACT

The objective of this article was to analyze the benefits of Agroforestry Systems (AFSs) association with natural regeneration promoted by family farmers of Tomé-Açu, Pará, Brazil. Based on 46 previous interviews with family farmers, 12 of them were selected due to the presence of AFSs with different levels of tree species diversity, in which richness and diversity of tree species were taken into account. In addition, the measurement of the floristic variables was carried out. Results showed that 17% of the AFSs have natural regeneration corridors. This type of AFS has high species richness and diversity (Shannon-Weaner = 2.5), and its main characteristic is the presence of regeneration corridors of secondary forests. Therefore, farmers make production and forest regeneration compatible, and: a) maintain in their AFSs environmental services provided by regenerated secondary forests, b) ensure food security for their families, and c) they may have financial incomes from selling AFS products.

**Keywords:** Species richness. Species diversity. Floristics. Amazon.

*RESUMO*

*O objetivo deste artigo foi analisar os benefícios da associação de Sistemas Agroflorestais (SAFs) com a regeneração natural promovida por agricultores familiares em Tomé-Açu, Pará. Com base em 46 questionários com agricultores familiares, 12 deles foram selecionados por apresentarem SAFs com diferentes níveis de diversidade de espécies arbóreas, nos quais foram consideradas a riqueza e a diversidade dessas espécies. Foi realizada a mensuração dessas variáveis florísticas, os resultados mostraram que 17% dos SAFs possuem corredores de regeneração natural. Esse tipo de SAF possui alta riqueza e diversidade de espécies (Shannon-Weaner: 2,5) e sua principal característica é a presença de corredores de regeneração de floresta secundária. Dessa forma, os agricultores compatibilizam produção e regeneração florestal, e assim: a) mantêm em seus SAFs os serviços ambientais prestados por florestas secundárias, b) garantem segurança alimentar para suas famílias, e c) podem obter renda com a venda de produtos do SAF.*

*Palavras-chave: Riqueza de espécies. Diversidade de espécies. Florística. Amazônia.*

## 1 INTRODUCTION

The increasing demand for sustainable production systems has highlighted Agroforestry Systems (AFSs), reinforcing the conservationist capacity of this kind of system. Currently, the environmentalist scientific community assumes the paradigm that the integration of crop and tree species in the same area can increase economic profitability. In opposition to monoculture, it can bring environmental advantages to rural properties. However, there is an intrinsic diversity of AFSs, whose characteristics vary according to the type of its establishment. Nair (1993) classifies AFSs in terms of environmental and socioeconomic aspects, dividing them into four categories: a) Commercial business AFS, b) Commercial AFS by small farmers, c) Subsistence AFS (small and medium agroforestry backyards), and d) Enriched fallow. Carneiro and Navegantes-Alves (2019) also describe four types of AFS, based on the context of family-farming in Northeastern Pará state, Brazil. Nonetheless, the authors consider the number of species used in the system.

Regarding the variability of AFS types, both to local specificities and indicators considered, it is essential to have classifications as precise and objective as possible. Thus, when studying systems adopted by family farmers, such classifications are essential, employing an approach that includes variables related to economic returns, promotion of social well-being and environmental protection (SILVA, 2013).

In this perspective, with the objective of "looking over the shoulders" (GEERTZ, 1989) of family farmers in Tomé-Açu, Pará state, Brazil, in this work, agroforestry practices from the family farmers perspective are analyzed, as well as perceptions and empirical understanding. Thus, this work came across different types of AFSs, which one called attention: the AFS with natural regeneration corridors, which is highly diversified in terms of floristics and farmers' economic satisfaction.

From these perceptions, synergy is possible in an AFS that, besides providing economic resilience for family farmers, can bypass the use of a few species as in a monoculture, being an alternative system with sustainable production practices. Therefore, the objective of this article was to analyze the benefits of the association of AFSs with natural regeneration promoted by family farmers of Tomé-Açu.

## 2 MATERIAL AND METHODS

### 2.1 STUDY SITE

The study was carried out in the municipality of Tomé-Açu, located in Northeastern Pará state, Brazil (Figure 1). This study site was selected for two reasons: 1) the existence of a long and well-known experience with agroforestry systems (AFSs), ensuring a historical perspective of knowledge and perceptions of farmers on the integration of trees in productive activities; 2) the AFSs presence in Tomé-Açu and surrounding municipalities, enabling a diversity of perceptions regarding the uses and functions of the species in the systems.


**Figure 1 |** Location of the municipality of Tomé-Açu, Northeastern of Pará state, Brazilian Amazon.

*Source: Authors.*

The municipality of Tomé-Açu is 200 km distant from Belém (Figure 1), the state capital, and has an area of 5,145.36 km² (IBGE, 2016). Its population is 62,854 (IBGE 2018), with 56% living in urban areas and 44% in rural areas (IBGE, 2016).

Tomé-Açu has a unique characteristic of colonization compared to other municipalities of Pará since it was composed of Japanese people. The first Japanese immigrants arrived in the 1920s, being the pioneer in settlements of Japanese families in the Amazon. The arrival of these immigrants resulted from an agreement between Brazil and Japan regarding the immigration policy (TAFNER JR; SILVA, 2011). Motivated by precarious conditions in Japan after the First World War, Japanese peasants sought land to develop their agricultural production (YAMADA; GHOLZ, 2002). Moreover, when Japanese immigration began in the Amazon, preconceived ideas prevailed, such as paradise, the green territory with indigenous populations, the world's lung, among many other representations (PIZARRO, 2012).

In the first years of colonization, the immigrants implemented horticulture, mainly of black pepper (*Piper nigrum* L.), supported by the Brazilian government, making possible technological advances

and launching Pará as the largest black pepper producer in the country. However, with the decline of the black pepper cycle due to the fusariosis disease from the 1970s onwards, farmers sought new production alternatives (BOLFE; BATISTELLA, 2012).

From this event, Japanese farmers realized that dependence on a single species in agriculture involved significant financial risks because of crop losses to diseases and market variations. Thus, they started to include tree species in the degraded plantings of black pepper to shade cocoa (*Theobroma cacao* L.) plantings. This originated a new production system that combined annual and perennial agricultural species with tree species, characterizing an AFS (YAMADA; GHOLZ, 2002).

## 2.2 SAMPLING

In Tomé-Açu, AFSs are widely cultivated by business farmers (usually associated with the Japanese) and family members. Given the complexity of studying all types of AFS, the present research focused on a commercial AFS cultivated by family farmers.

Article 3 from Law No. 11,326, of July 24, 2006, defines a family farmer as "the owner of an area up to four fiscal modules, using only family labour, with a minimum percentage of family income from economic activities from his rural property and with family members managing it" (BRASIL, 2006).

Even though this concept defines a family farmer, it does not represent the different expressions and peculiarities that family farmers present. Hence, the term family-farming is assumed parallel to that of the peasantry. For Chayanov (1974), it is a family-based economy represented by an economic system with logic, with different specificities and motivations from eminently capitalist-based agriculture.

Many reasons justify the choice of focus on this social category. First, it is an essential protagonist of local development, for being, at the same time, the landowner and responsible for the work, as well as the bearer of a cultural tradition, which in Amazonia usually corresponds to a particular and intrinsic relationship with nature (POMPEU; KATO; ALMEIDA, 2017; WANDERLEY, 1996).

Based on 46 previous interviews with family farmers, 12 rural family properties with AFS involving heterogeneity of farming practices were selected. Floristic surveys were carried out in these rural properties, including richness and diversity, as described below.

All 46 questionnaires proved to be sufficient to attain the saturation point when the information is repeated after a certain number of dialogues. The "snowball" tool was used to assist both in the selection criteria of the 46 interviewees and the 12 rural properties where floristic measurements were taken. For Vinuto (2014, p. 204), this sampling tool is "a process of permanent information collection, which seeks to take advantage of the social networks of the identified interviewees to provide the researcher an increasing set of potential contacts, where the process can be finished from the saturation point criterion".

Even belonging to the same AFS type (commercial and made by family farmers), after applying the questionnaire to family farmers and the floristic measurement, the 12 sampled AFSs presented differences in richness, floristic diversity, and spatial arrangement. So, for a better understanding of results, the AFSs sampled were divided into three groups: a) AFS with an arrangement including Amazonian species, b) AFS with natural regeneration corridors, and c) AFS with random natural regeneration. The first group corresponds to the broadest and most comprehensive AFS typology, conducted under the scope of the research project, of which this article is part of, entitled REFLORAMAZ (Forest recovery by family-farmers in the Eastern Amazon), aiming to improve the balance between environmental benefits and socioeconomic factors in forest recovery. This type corresponds to the most traditional arrangement of AFS in the Amazon, consisting mainly of commercial species native to the region, with rapid economic returns.

It is known that the 12 systems selected may not be a representative sample of the numerous AFS experiences undertaken in Tomé-Açu. Many farmers having AFS with natural regeneration corridors were not found, so sampling was reduced to the number of systems to be more equitable in their respective classes. Furthermore, this choice is also justified because researchers may have taken more time to observe and settle with farmers and their practices and not simply have collected the data and processed them in the office.

The central research point was decided to highlight the peculiarities and differences among AFSs with natural regeneration since they presented the most incredible richness and floristic diversity. Therefore, two schematic sketches were prepared to highlight the spatial differences between AFS arrangements, with and without natural regeneration corridors.

The minimum age to select a given AFSs to conduct the floristic survey was 12 years of establishment. All live planted, and spontaneous tree individuals in the system with a minimum diameter of 5 cm at breast height (1.30 m from the ground) were identified and quantified. When sampling perennial species, such as cocoa and cupuaçu (*Theobroma grandiflorum* (Willd. ex Spreng.) K. Schum.), the number of individuals per sample plot was counted (VIANA; DUBOIS; ANDERSON, 1996).

The tree species inventory was based on adapting the methodology suggested by Vieira *et al.* (2018). Thus, five rectangular units of 625 m² (5 m x 25 m) per hectare were established, with the addition of one plot for each additional hectare in the AFS, always following the east-west direction. For example: 1 ha = 5 inventoried plots, 2 ha = 6 inventoried plots, 3 ha = 7 inventoried plots and further on. Large border zones with neighbouring vegetation were discarded.

Firstly, the identification of tree species present in AFSs had a parabotanist and farmers who indicated the cultivated plants and their associated local names. Then, with doubts in the field, samples were taken for later identification in the IAN herbarium of Embrapa Amazônia Oriental in Belém, following the APG IV system.

Calculations of species richness and species diversity were based on the abundance of individuals and frequency of species using Microsoft Excel software (MAGURRAN, 1988).

To characterize socioeconomic variables, questionnaires were applied to 12 family farmers, eight with Amazonian species arrangement, two with natural regeneration corridors, and two with random natural regeneration. Questionnaires were previously elaborated according to the criteria of Mann and Velho (1969), which reports basic steps to perform research and collect original data.

Data on the families and rural properties and their agricultural surroundings were collected from the questionnaires, with questions grouped into social, economic, technical, and ecological themes. Nevertheless, the focus was on the AFSs, collecting data on floristic diversity, management, establishment, technical assistance, motivations, and incentives.

Questionnaire questions were divided into direct and closed questions. In direct questions, farmers answered questions in their way. In closed questions, there were pre-established alternatives to be chosen.

The degree of satisfaction was estimated by assessing farmers' and spouses' income with their AFSs (VEENHOVEN, 1994, 2008). Farmers indicated their economic satisfaction using the following numerical scale: 3: High satisfaction; 2: Medium satisfaction; 1: Low satisfaction; and 0: Dissatisfied.

A "summary infographic" was prepared using Microsoft Excel and PowerPoint software, producing a broader view of the factors linked to the proposed AFS types. It put together the significant aspects from an ecological and socioeconomic point of view that influence the balance of AFSs.

## 3 RESULTS AND DISCUSSION

Amongst the 12 AFSs where forest measurements were conducted, four had the highest levels of richness and Shannon-Weaner (H') diversity index (average H'=2.4), resulting from the integration of natural regeneration in the system. The other systems were composed of a few species (average H'=1.5), generally dominated by two or three commercial fruit trees. Besides having pre-defined planting spacing and dependence on external inputs, these agroforestry systems (AFSs) were also classified as "agronomic", due to their conventional line system, with little flexibility in spatial design and addressing their plantings to the market in a general perspective (MILLER, 2009). There is absolutely no intention to devalue the "agronomic" AFS, as it is understood that such crops should enable a process of increasing capitalization in favour of farmers, especially in Tomé-Açu, producing a favourable economy among them (DUBOIS, 2013; YAMADA; GHOLZ, 2002). However, this kind of system already has widespread techniques, and, in general, it does not bring novelties to the discussion of this article. Consequently, this analysis focused on discussing the AFSs that integrated natural regeneration.

Therefore, it is known that the natural regeneration present in the AFS increased values of species richness and diversity (Figure 2). Two patterns were found in these four AFSs with natural regeneration corridors and AFSs with random natural regeneration. The main difference between the two AFS models was the spatial arrangement of natural regeneration (Figures 2 and 3).

### 3.1 AGROFORESTRY SYSTEM WITH NATURAL REGENERATION CORRIDORS

The AFS model with natural regeneration corridors had exclusive lines for regeneration within the system. Two farmers presented this practice of intensifying natural regeneration in corridors. They maintained rectangular lines of 5 to 10 m in width that followed the whole length of the AFS, in which the farmer leaves the vegetation to regenerate naturally (Figure 2).

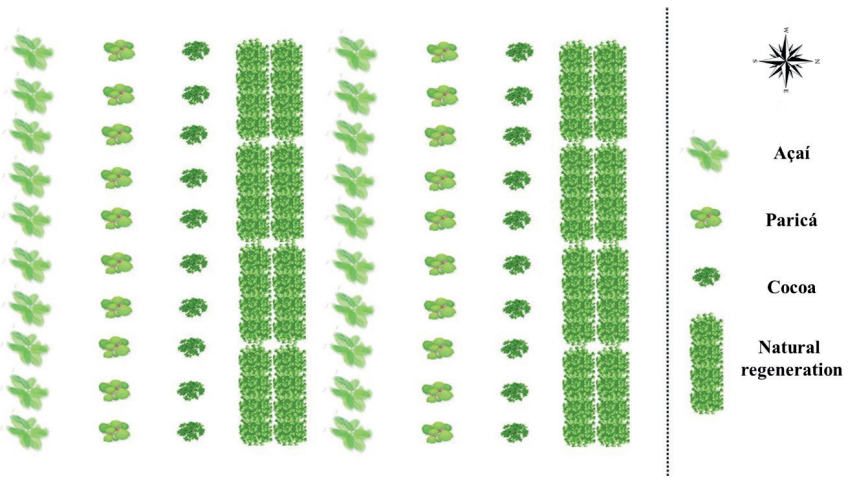


**Figure 2 |** Model of agroforestry systems with natural regeneration corridors, municipality of Tomé-Açu, Pará state, Brazil, 2019.

*Source: Authors.*

When questioned on the left corridors inside the AFS, one of the farmers commented: "*I have left some lines of "capoeira" (secondary forest) in the middle of the site because it was a very stony terrain and there was not much production*" (BJ, 73 years old, family-farmer in Tomé-Açu, who has been working with AFS for 50 years, originally from Mocajuba – PA). This means that these natural regeneration corridors came out in the farmer's perception as inappropriate areas for agricultural production or fragile areas within the AFSs, allowing natural regeneration inside intentionally.

Knowledge of the land to be cultivated is one of the specificities of family farmers. For Ploeg (2014), family-farming has control over the primary resources, which, besides land, include animals, crops, genetic material, the house, buildings, machinery and, in a systemic way, the knowledge that specifies how these resources can be used and combined.

It is a strategy different from the agribusiness, which homogenizes the area regardless of its productive incapacity and different from what the farmer said "*very stony terrain*", with dependence on agrochemicals agricultural machinery, to the detriment of the conservation and optimization of the land's endogenous resources (ALTIERI; NICHOLLS, 2020).

## 3.2 AGROFORESTRY SYSTEM WITH RANDOM NATURAL REGENERATION

The disadvantage of the AFS with random natural regeneration, concerning the productive aspect, is the randomness of how spontaneous arboreal individuals may be arranged in the system. As the opposite of the AFS with natural regeneration corridors, this AFS does not have an isolated area to develop naturally occurring species (Figure 3). Farmers who have AFS with this feature reported not initially planning to let natural regeneration participate in the system. Before the AFS establishment, farmers carefully analyzed the arrangement and floristic composition, selecting the species according to the agroforestry practices of the neighbours and the market demands.

When questioned for the reason of such species, which were not planted by them and were part of their AFS, one of the farmers commented: "*I have left many weeds in the middle of the cocoa plantation, but I had not cut them, I have let them grow, while I had been planting and harvesting*" (BR, 74 years old, family-farmer in Tomé-Açu, who has been working with AFS for 53 years, originally from Baião – PA). Another farmer replied: "*the farmer suffers a lot, the goods are not worth the money, so I got demotivated and started leaving the field*" (JR, 32 years old, family-farmer in Tomé-Açu, who has worked with AFS for 15 years, originally from Tomé-Açu - PA).

These farmers have a source of income outside agriculture. They are civil servants of the Tomé-Açu city hall and, according to them, have good incomes. Therefore, they go to the field "once in a while," and, logically, the two farmers dedicate little time to maintaining their systems. Thus, the yield tends to be low, and, thus, their economic satisfaction with the AFS is low.

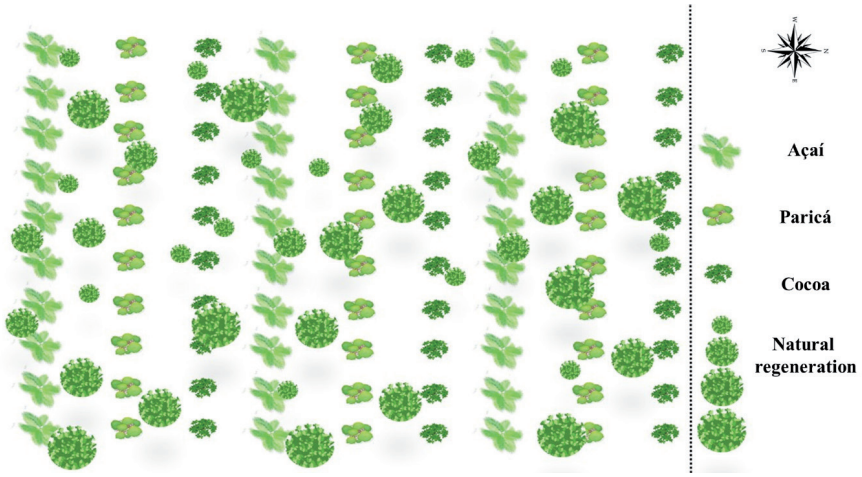


**Figure 3 |** Model of agroforestry systems with random natural regeneration, municipality of Tomé-Açu, Pará state, Brazil, 2019.

*Source: Authors.*

## 3.3 SOCIOECONOMIC QUESTIONS

The decision-making process of allowing or not the natural regeneration was an attribute of the farmer and his family, following what systemic theories applied to agricultural studies indicate, which identifies the man as a "pilot" of his practices (OSTY, 1978; SEBILLOTTE, 1974). These decisions were based on the combination of two aspects: the farmer's knowledge of the ecosystem of his rural property and his socioeconomic situation. Hence, the spatial organization of the natural regeneration corridors was based on knowledge of the biophysical environment and the requirements of the planted species. The other type of AFS, with natural regeneration dispersed in the system, occurred in the face of labour limitation combined with higher financial stability from outside the system.

The high richness and floristic diversity of the AFSs did not depend only on the farmer interventions, is also linked to the ecological succession of the environment where the AFS is placed. It is related to the species' structural changes and to the processes of the floristic community over time, which advances to a certain point defined as the climax (ODUM, 2004). At the end of a successional process, the composition and frequency of tree species, as well as the biomass of the secondary forest, will depend mainly on the availability of seed bank and seedlings in the soil, the proximity of forest fragments rich in propagules and the availability of fauna for seed dispersal (CHAZDON, 2012; POORTER, 2016).

The conservation of forest fragments within the rural property was essential for establishing AFSs with natural regeneration corridors. The two farmers with this kind of system also have primary forest fragments in their properties, helping maintain great species diversity inside their AFSs. When questioned about their reason for maintaining their "*pristine forest*" in their properties, since most of the farmers deforested their lands in the past, the response of one was: "*this is the only good that I can leave to my children and grandchildren: the forest*" (BJ, 73 years old, family-farmer in Tomé-Açu, who has been working with AFS for 50 years, originally from Mocajuba – PA; and GA, 70 years old, family-farmer in Tomé-Açu, who has been working with AFS for 45 years, originally from Cametá – PA). This statement can be analyzed from two perspectives, as suggested by Woortmann (2009). Firstly, from the economic point of view, these trees work as an "investment" for the family; in case of crisis, trees can be sold, and the money can be used for the home's needs. Secondly, from the memorial perspective, it is a way of a given ascendant to be remembered in the landscape, mainly when "he/she will no longer be there".

In other words, to allow the development of natural regeneration corridors in AFS is also a moral issue for these two farmers. The AFS with Amazonian species arrangement, commonly used in the region, does not resemble primary forest as much as the type of system they are applying. It is as if the AFS with natural regeneration corridors referred to the forest they aim to conserve, whether for economic or memorial reasons. Another vital factor in increasing the richness and floristic diversity of the AFS is the farmer's permission to let the secondary forest regenerate naturally. This can also be an individual issue, based on the historical labour relationship between the farmer and the secondary forest for food generation through the slash-and-burn system in fallow areas. Such a system is formed by agriculture units of traditional populations in the Brazilian tropics (MARTINS, 2005).

On the other hand, the other two farmers who have AFS with random natural regeneration have two characteristics in common: they do not have primary forest fragments within their land, and the Tomé-Açu city hall employs them. Both farmers were satisfied with their wages. Although they have AFSs with the highest floristic richness and diversity levels, they did not have this type of system on their original purpose. On the contrary, they reported that they wanted to work more in their AFS areas, but the extra-family workload and the AFSs maintenance that "the bush took over" make the work challenging and demotivate them with the activity.

## 3.4 FLORISTIC DIVERSITY OF AFSS

The following discussions were driven by how the farmers allocated natural regeneration in AFSs. Social and economic aspects and the richness and floristic diversity were the main variables influenced by this process.

The Shannon-Weaner (H') index was similar in both types of AFS. The AFS with random natural regeneration numbers 09 and 11 presented H' = 2.4 and 2.6 respectively, while the AFS with natural regeneration corridors 10 and 12 presented H' = 2.4 and 2.7 respectively (Figure 4). Although the diversity values were similar, the AFS with random natural regeneration was negatively impacted in fruit productivity due to the randomness of the regeneration growth in the middle of the system. On the other hand, AFS with corridors allocates natural regeneration in specific places to decrease competition between commercial and regeneration species. These values were much higher than the AFS with the arrangement of Amazonian species, which had an average of H' = 1.5. Such low diversity is explained by the predominance of commercial fruit species, such as cocoa, cupuaçu, and açaí (*Euterpe oleracea* Mart.).

In ecological terms, the maintenance of pollination processes and the control of natural pests, which critically depend on native biodiversity, are present in the two AFSs types (Figure 4) focused on this study (VIEIRA; GARDNER, 2012). Furthermore, young natural regeneration, with less than 20 years old, has high rates of biomass accumulation and, consequently, provides an essential environmental service in capturing atmospheric carbon (ELIAS *et al.*, 2019).

When the regeneration is older than 20 years, it can also provide ecosystem products and services similar to those provided by primary forests (SCHWARTZ *et al.*, 2015). These services may include the conservation of water, soil, nutrients, biodiversity, and landscape (CHAZDON; GUARIGUATA, 2016; TEIXEIRA *et al.*, 2020). In addition, according to Altieri (1999), incorporating trees and shrubs in crop fields can increase the systems' structural heterogeneity and improve the soil processes responsible for accumulating organic matter and soil fertility.

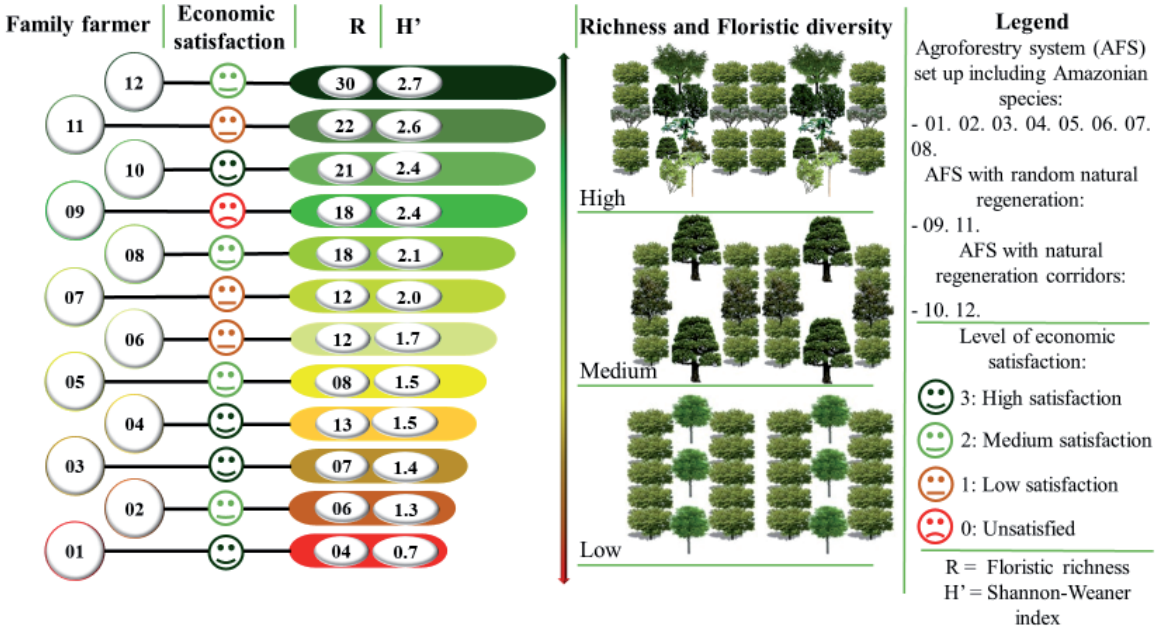


**Figure 4 |** Infographic with the relationship between the Shannon-Weaner index and the farmers' economic satisfaction according to different agroforestry systems in the municipality of Tomé-Açu, Pará, Brazil, 2019.

*Source: Authors.*

Due to that, the AFS with natural regeneration corridors favoured the farmers' economic satisfaction more than the other system types (Figure 4). Competition for light, water and nutrients between commercial and spontaneous species was lower in the AFS with natural regeneration corridors. Whether each plant is in its proper place, the demand for light, water, and nutrients is optimized, and it can significantly reduce competition (NAIR, 1993). For example, the AFS stratification, where each species occupies a floor in the system according to its needs, is a strategy to reduce competition for light among plants. The species that demand more light (pioneers) can occupy the canopy, and the others (non-pioneers), such as cocoa, which are not high demanding on light, occupy lower strata of the AFS.

The floristic composition of the initial natural regeneration is dominated mainly by pioneer species (CHAZDON, 2014; DOS SANTOS; FERREIRA, 2020; SCHWARTZ et al., 2013). This is the main problem of the AFS with random natural regeneration because the pioneer species require more light and grow faster, making the AFS canopy dominated by these species, reducing growth chances for individuals of commercial purposes. On the other hand, the AFS with natural regeneration corridors has specific bands for pioneer species, reducing and even nullifying the competition between these species and the commercial ones.

## 3.5 BALANCE POSSIBILITIES OF AFS WITH NATURAL REGENERATION CORRIDORS

Besides presenting the lowest floristic richness and diversity values, farmers who work with AFS set up with Amazonian species were also the most economically satisfied. Only 25% had low satisfaction, while the others had medium or high satisfaction with their AFSs.

The most economically dissatisfied farmers were those who have AFS with random natural regeneration, which only favoured the systems richness and floristic diversity. On the contrary, the organization of natural regeneration in corridors increased the economic satisfaction (medium and high) and the highest levels of biodiversity (Figure 4).

The AFSs with natural regeneration corridors were more satisfactory for farmers, in ecological and economic terms, and were able to increase their incomes by selling wood species of the secondary forest corridors. For Schwartz *et al.* (2015), commercial softwood species, commonly found in tropical secondary forests, may assume a more relevant role in the timber market due to the decline of high-density tropical primary forest species. Studying the timber potential of a secondary forest, Piazza *et al.* (2017) concluded that a sufficiently large number of regenerating individuals of species with potential for timber production. However, they recommend silvicultural treatments in these ecosystems, especially enrichment planting, as species with no timber potential dominance is high.

The need for silvicultural treatments to increase the productivity of commercial species in secondary forests is commonly found in scientific works (ATONDO-BUENO *et al.*, 2018; PEÑA-CLAROS *et al.*, 2002). Schwartz *et al.* (2015) recommended an innovative silvicultural treatment for secondary forests. The authors suggested opening canopy gaps in the natural regeneration to establish AFSs. According to them, the AFS establishment within the secondary forests is favourable due to these ecosystems' good ecological conditions. These artificially opened canopy gaps provide the necessary light conditions for establishing a specific AFS without harmful interference in the diversity of trees in the secondary forest (SCHWARTZ *et al.*, 2015). The perspective of this silvicultural treatment follows the same logic of the AFS with natural regeneration corridors, but with the process performed in a reverse way. In the AFSs studied here, the secondary forest appears naturally in the middle of the system, with low use of labour. This is different from the AFS proposed in the literature mentioned above, where the canopy's opening is necessary for its establishment.

AFS with natural regeneration corridors is low disseminated among farmers. The specific area distinguishes it for the development of spontaneous species without affecting the ones with commercial interest. The farmer elaborates zoning in part of the system, taking into account less favourable places for agriculture and leaving them for natural regeneration. Next to the regeneration lines, the farmer

produces an intensive AFS. Thus, the farmer: a) Maintains the environmental services of the regenerated secondary forest; b) Contributes to the family's food security (STRATE, 2020); and c) Provides financial income from the sale of products generated by the AFS.

In one way or another, it is clear that the conciliation of these two ecosystems, AFS and secondary forest, made in an adjusted way and their proper place, is beneficial for the AFS ecology (floristic richness and diversity), the social environment, and the economic returns to farmers.

A noteworthy fact is that one AFS model does not compete with the other; however, the farmers' conditions determine the AFS be established. The non-dependence from incomes exclusively from the AFS with random natural regeneration resulted in better socioeconomic factors for the AFS with natural regeneration corridors. Perhaps, if the farmers who have AFS with random natural regeneration depended on incomes exclusively from AFS, i.e., did not have other income sources, they could have more time to work in their rural properties and possibly better manage the system.

The insertion of the family farmers' point of view in this research was essential because several scientific contributions about more sustainable production systems are given. However, they may not be applied to the reality of the farmer. To learn from them, therefore, as stated by Geertz (1989), it is necessary to "look over the shoulders" and value, analyze, and pass on the knowledge acquired through their practice and experience. Hence, AFSs with natural regeneration corridors are strongly recommended for other family farmers who live in situations similar to those presented here.

## 4 CONCLUSION

Agroforestry systems (AFSs) associated with natural regeneration identified in this research enabled the compatibility between agricultural production with high species richness and diversity. Such association between two ways of environmental recovery, generally adopted in different areas, was made possible by maintaining secondary forest regeneration inside the AFS areas. For this, family farmers' unique and exclusive strategies were based on specific spatial distribution, through the allocation of natural regeneration corridors, or on a random distribution, through the maintenance of spontaneous regeneration, dispersed throughout the AFS area.

Thus, the studied AFSs bring the following benefits for agricultural families and society: a) Maintenance of environmental services provided by secondary forests; b) Assurance of food and nutrition security. And c) Incomes from the sale of AFS products. In addition, from the farmers' point of view, these systems enabled their economic satisfaction, which, associated with ecosystem services, enables a conclusion of higher well-being of the involved families.

Therefore, it is demonstrated through the study of concrete and endogenous experiences practised by Amazonian family farmers that there are alternatives to produce and conserve the environment. For that reason, the results of this research are in line with the ideas still questioned, that the incompatibility between agricultural activity and environmental conservation is a false dilemma.

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