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Empowering Amazonian Communities: The Importance of Participatory Planning and Local Knowledge in Agroforest Systems

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Abstract
Agroforestry systems (AFS) represent an alternative production method for family farmers, allowing for the optimization of land use through product diversity and income generation. Considering that the socioeconomic condition of floodplain communities is based on extractive economies and that the implementation of intercropped crops should be done in a participatory and constructive manner, this work aims to report an experience emphasizing the steps and main tools adopted in the planning and establishment of an AFS. The fieldwork was conducted in the community of Ipaupixuna, in the floodplain region of Lake Maicá, municipality of Santarém, Pará, Brazil. The actions of this work were concentrated between February and October 2019, as part of the research project "Floodplains and Riverbanks of the Lower Amazon." The main tools used in this work were a systemic approach with the community of Ipaupixuna, which sought to understand the environment and its interactions, through various stages such as mapping, workshops, interviews, planning, area preparation, and logistical organization for implementation. The actions and results of the project showed that participatory planning and community knowledge are crucial for the successful establishment of an AFS in communities. It was concluded that the community embraced the intercropping project and showed interest and collaboration in the activities carried out. This work reinforces the need to consider resources and tools for the necessary mapping and development of appropriate agroforestry designs for producers in similar initiatives.

Keywords
Family farming — Traditional communities — Product diversity — Income generation — Floodplain

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1. Introduction

Forests are valued for the variety of products and benefits they provide, both for subsistence and commercialization. However, in the Amazon region, these forests and their resources have been under pressure from production systems based on livestock, extensive agriculture and logging. These production systems do not align with the adaptive reality of the Amazon, causing small farmers to seek alternative approaches for production and the recovery of degraded areas (Júnior et al., 2009).

The valuing of forest resources and increased efficiency of agricultural systems through agroforestry systems (AFS) positively impact the socioeconomic context of families by improving productivity and quality of life and promoting conservation and sustainability of traditional land use systems in floodplain areas (Gama & Bentes-Gama, 2009). For family farming, AFS represents a choice for a new perspective on land use patterns, and this system continues to seek ways to strengthen productive units, taking into consideration economic performance (Ferreira et al., 2014).

In the search for alternatives for cultivation and land use that align with environmental conservation principles, numerous publications (Miccolis et al., 2016, Kitamura, 2003, Júnior & Yared, 1991; Nair, 2011, Monteih, Ong & Corlett, 1991) emphasize that agroforestry systems (AFS) could be a sustainable model due to their resemblance to natural vegetation formations, their performance in biogeochemical cycles, and their role in carbon stock

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maintenance. AFS has also gained attention for its provision of environmental services and benefits for agriculture (Mangabeira, Tosto & Romeiro, 2011) and as a strategy for replacing or complementing monocultures.

AFS can be defined as a set of techniques that intentionally combine forest species with crops in the same area, with or without the presence of animals (Silva, 2013). They are listed as directly aligned with the Millennium Development Goals, such as achieving food security and promoting sustainable agriculture (UN, 2023); they are considered an excellent strategy for the production of goods and services (Dubois & Castro, 1996) and contribute to rural family income (Bentes-Gama et al., 2005, Arco-Verde & Amaro, 2015; Cardozo et al., 2015).

In the construction of a body of knowledge, the articulation between scientific knowledge and traditional and popular knowledge should be capable of guiding the conversion of conventional production systems (monocultures intensive in non-renewable energy and capital) into diversified, resilient, and self-sufficient systems that make it possible to use natural resources correctly for food production (Udry & Araújo, 2012).

The traditional ecological knowledge present in rural communities is of great importance in any intervention strategy in rural environments. From this knowledge, the basis for effective diagnosis and planning should emerge in the design of production systems that simultaneously guarantee the survival of people living in and from rural areas and conserve the resource base for the future (Donazzolo, Balem & Silveira, 2012).

Considering that the socio-economic condition of the floodplain communities is based on an extractive economy and that the implementation of mixed-cropping systems should be carried out in a participatory and constructive manner, this work aims to report an experience emphasizing the stages and main tools adopted in the planning and introduction of an agroforestry system (AFS), focusing on the area of the Ipaupixuna Community, in the influence region of the floodplain of Lake Maicá, in the municipality of Santarém, Pará.

2. Material and Methods

2.1 Study area

The actions were concentrated in the period from February to October 2019, followed by an interruption due to the COVID-19 pandemic and the subsequent resumption of in-person activities in March 2022. The project was developed in the Ipaupixuna community, in the municipality of Santarém, which, according to the Köppen climate classification, is of the Am type, with annual precipitation ranging from 1,900 to 2,200 mm and an average annual temperature of 25 to 27 ℃ (Alvares et al., 2013).

The municipality of Santarém has a large part of its territory located mainly on the right bank of the Tapajós River, in regions known as Planalto Santareno and Bacia do Rio Moju (Rodrigues & Santos, 2001). According to this publication, the soils of the municipality (scale 1:100,000) are predominantly typical dystrophic yellow latosols (medium and very clayey texture), typical dystrophic yellow argisols (medium and clayey texture), and haplic gleisols.

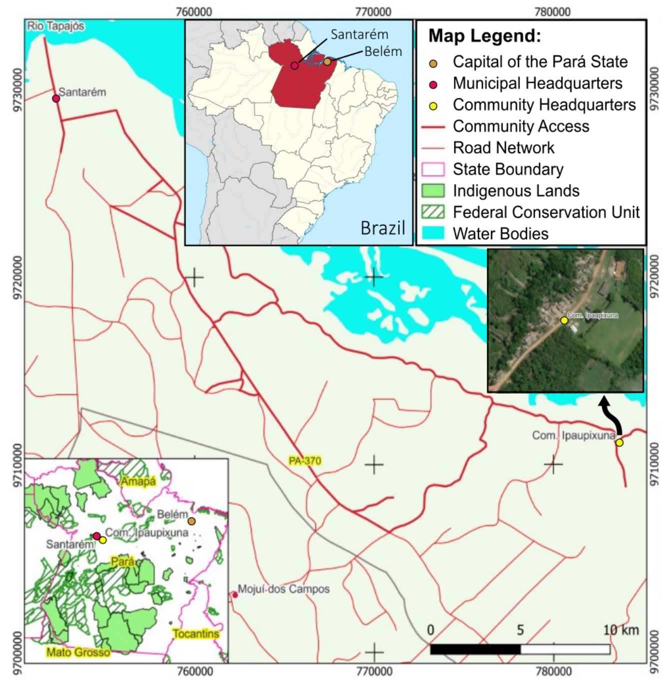

Figure 1. Location of the community of Ipaupixuna, Santarém, Pará. Created by Everton Cristo Almeida (2022).

The vegetation cover of Santarém municipality and region is composed of four distinct forest formations: sub-perennial equatorial forest and sub-perennial equatorial cerrado, on uplands; and floodplain equatorial hygrophytic forest and hygrophytic equatorial floodplain grasslands, in flooded areas (Rodrigues & Santos, 2001).

The residents of Ipaupixuna self-declared as indigenous in 2009 (Santos; Oliveira; Sousa, 2021), identifying themselves, along with three other communities, as Munduruku indigenous people of Planalto. However, the process of territory demarcation has not been consolidated yet and is currently in the identification phase in the judiciary (Isa, 2022). The community of Ipaupixuna includes 206 indigenous individuals divided into 66 families, making it the most populous among the other villages (De Oliveira, 2021). The main access road to the community is the PA-370 highway (Figure 1).

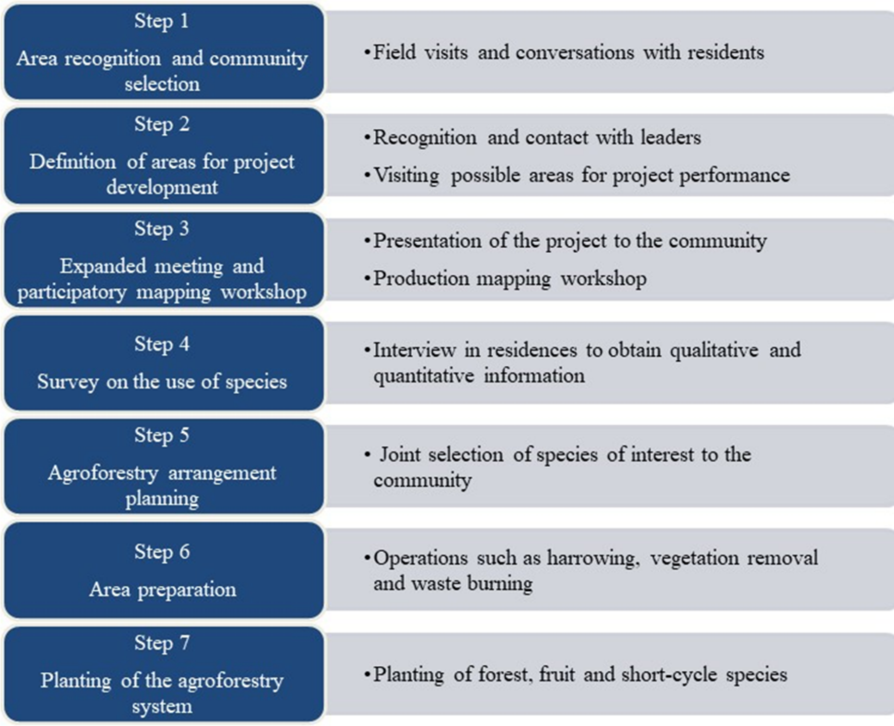

Figure 2. Flowchart representing the methodological stages carried out for the implementation of agroforestry systems, depicting the continuous process involved from area recognition and community selection to project development definitions, meetings and participation mapping, species survival and use, agroforestry arrangement planning, preparation of planting area, and agroforestry planting. This comprehensive flowchart highlights the interconnected nature of these steps and underscores the holistic approach required for the successful establishment and management of an agroforestry project.

2.2 Context and Background of the Project

The project was developed as part of the research initiatives of the "Várzeas e Ribeiras do Baixo Amazonas" Research Project, which involved a network of research activities in two floodplain regions (mouth of the Nhamundá River and its surroundings and the Amazon River floodplain), funded by the Amazon Foundation for Support to Studies and Research (FAPESPA).

The project was structured to achieve the goals of capacity building, implementation, and management of a consortium system, aligned with the traditional practices of family farmers in the community. Initially, the implementation of three agroforestry systems (AFSs) in contiguous areas was planned, with different types of soil preparation (area 1 - Vegetation cutting and burning; area 2 - Mechanized preparation with vegetation removal and tractor plowing; and area 3 - Opening of lines in secondary vegetation for enrichment planting), thus constituting three treatments to address the research/extension interface character of the project.

However, by the end of March 2020, in light of the Coronavirus/COVID-19 pandemic, in-person activities were suspended (Article 7 of IN 02 of March 20, 2020), resulting in a 24-month interruption of the project. As a result, only the first agroforestry arrangement (Area 1 - Vegetation cutting and burning) was implemented in the field. For the mechanically prepared area (area 2), the process was limited to soil preparation without the planting of perennial species. As for area 3 (enrichment planting in secondary vegetation), only the demarcation of the area was carried out, without opening the planned lines for planting.

Therefore, it is important to note that the results and lessons learned presented in this document are limited to the introduction of a single agroforestry arrangement (area 1 - Vegetation cutting and burning). This document covers the phases of mapping, planning, and planting the agroforestry arrangement. After this period, the activities were interrupted due to the pandemic, as both the University and the Community were unable to collect data on the monitoring and survival of the introduced species at the site.

3. Results and Discussion

A systemic approach was adopted in working with the community of Ipaupixuna, aiming to understand the environment and its interactions. The study consisted of several stages (Figure 2), starting from community familiarization to the introduction of agroforestry systems in the community, including mapping, workshops, interviews, planning, area preparation, and logistical organization.

These steps constitute the main outcome of the work, as they demonstrate the demands that needed to be addressed and the necessary mobilization to culminate in the introduction of agroforestry planting. In the state of

Figure 3. Study photographs. Part A) first option offered for the installation of the agroforestry system by representatives of the community. Part B) Participatory mapping workshop in the community. Part C) Marking of the planting area and digging of planting holes and planting of fruit trees and forest species in an agroforestry system in the community. All pictures were taken in the Community of Ipaupixuna, Santarém, Pará.

Pará, public policy instruments such as the State Policy on Agroecology and Biodiversity, the State Plan Amazon Now (Semas, 2020), and the State Policy on Climate Change (Legis-PA, 2020) have encouraged the integration of agroforestry systems (AFSs) into agriculture.

Despite the high expectations associated with this type of cultivation, there are difficulties in diffusion and dissemination (Mangabeira, Tosto & Romeiro, 2011), area management (Almeida & May, 2016), appropriate financing, product commercialization, production flow, and industrialization (Silva, 2013; Nicodemo & Melotto, 2013; Canuto, 2017), as well as a lack of specialized technical assistance, which results in a high abandonment rate of AFSs (Silva, 2013). Therefore, it is important to demonstrate the phases or steps completed in this work as a way to disseminate the progress made within the community and highlight the relevance of prioritizing community involvement and participation in the process.

Step 1. Recognition of areas and selection of the Community

The first step in this process involved visiting potential areas for the project's implementation (January/2019), starting from the Maicá neighborhood (urban area of Santarém), passing through the Castela and Miritituba communities, to assess the productive potential of these communities and identify possible areas for the implementation of an agroforestry system (AFS). Based on this activity, the community of Ipaupixuna was selected for the project's development, following an expression of interest by local leaders.

Step 2. Definition of areas for project development

After receiving a positive indication from the leaders of the Ipaupixuna community for project development, two additional visits were made (February/2019), involving staff and students from the Federal University of Western Pará (UFOPA) and local leaders. This step was important to assess the possibilities and align interests among the stakeholders involved in the proposal, and it proved to be a crucial phase in building the collective proposal. Figure 3-A shows images taken during a visit to the community and its leaders, as well as the field conditions of the first option indicated by the residents as the location for the implementation of the AFS.

The subsequent visit was necessary to assess the conditions of a second option for the implementation of the AFS as well as to engage in dialogues with community leaders and members to determine the activities that needed to be carried out for the preparation of the area and planting of species.

Step 3. Expanded Meeting and Participatory Mapping Workshop

The next step, which took place in October 2019, involved the presentation of the project and the experiment proposal to the members of the Ipaupixuna community. During this occasion, a workshop was also conducted with the community members to determine the species to be cultivated in the agroforestry system (AFS) as well as the timeline for implementing the activities (Figure 3-B). During this meeting, previous cultivation experiences and the farmers' perception of AFS were gathered to identify the main species that could be part of the agroforestry arrangement to be developed by the project.

Involving the community in the selection of species is an important process, as participatory planning of agroforestry systems (AFS) incorporates the aspirations of

Table 1. Characteristics of the plant species used at the agroforest systems by residents of the indigenous community of Ipaupixuna, Santarém, Pará.

Popular name*	Scientific Name	Component used	Usage
Abacateiro	*Persea americana* L.	Fruit	Food
Açaizeiro	*Euterpe oleracea* Mart.	Fruit	Food
Andirobeira	*Carapa guianensi* Aubl.	Fruit and trunk	Logging and medicinal
Aquariquarana	*Minquartia guianensis* Aubl.	Trunk	Logging
Arroz	*Oryza sativa* L.	Fruit	Food
Bacabeira	*Oneocarpus mapora* Karsten	Fruit	Food
Bananeira	*Musa* sp.	Fruit	Food
Barbatimão	*Stryphnodendron barbatiman* M.	Bark	Medicinal
Buritizeiro	*Mauritia flexuosa* L.F.	Fruit	Food
Cacaueiro	*Theobroma cacau* L	Fruit	Food
Cajueiro	*Anacardium ocidentale* L.	Fruit	Food
Cana-de-açúcar	*Saccharum officinarum* L.	Stalk	Food
Carazeiro	*Dioscorea alata* L.	Fruit	Food
Castanheira	*Bertholletia excelsa* H.B.K.	Fruit	Food
Cedrorana	*Cedrelinga catenaeformis* Ducke	Trunk	Logging
Cipó-titica	*Heteropsis flexuosa* (H.B.K.) G. S. Bunting	Fiber	Handcrafted
Coqueiro	*Cocos nucifera* L.	Fruit	Food
Cumaruzeiro	*Dipteryx odorata*	Fruit	Food
Cupuaçuzeiro	*Theobroma grandiflorum* (Willd. ex Spreng.) Schum.	Fruit	Food
Feijão	*Vigna unguiculata* (L.) Walp.	Fruit	Food
Goiabeira	*Psidium guajava* L.	Fruit	Food
Goiabinha	*Myrcia tomentosa* (Aubl.) DC.	Fruit	Food
Gravioleira	*Anona muricata* L.	Fruit	Food
Guaruba	*Vochysia maxima* Ducke.	Trunk	Logging
Ingá cipó	*Inga edulis* Mart.	Fruit	Food
Ipê-Amarelo	*Tabebuia serratifolia* Vahl Nich.	Trunk	Logging
Ipê-roxo	*Tabebuia impetiginosa* Martius Ex A. P.	Trunk	Logging
Itaúba	*Mezilaurus itauba*	Trunk	Logging
Jarana	*Holopyxidium jarana* (Huber) Ducke	Trunk	Logging
Jerimum	*Cucurbita* sp	Fruit	Food
Laranjeira	*Citrus aurantium* L.	Fruit	Food
Limoeiro	*Citrus limon* (L.)	Fruit	Food
Maçaranduba	*Manilkara huberi* (Ducke) Standl.	Trunk	Logging
Mamoeiro	*Carica papaya* L.	Fruit	Food
Mandioca	*Manihot esculenta* Crantz	Fruit	Food
Mangueira	*Mangifera* indica L.	Fruit	Food
Maracujazeiro	*Passiflora* sp.	Fruit	Food
Melancia	*Citrullus* sp.	Fruit	Food
Milho	*Zea mays* L.	Fruit	Food
Muiracatiara	*Astronium lecointei* Ducke	Trunk	Logging
Muirapixuna	*Cassia scleroxylon* Ducke	Fruit	Food
Murici do mato	*Byrsonima sericea*	Trunk	Logging
Muruci	*Byrsonima crassifolia* (L.) Rich	Fruit	Food
Pimenta-do-reino	*Piper nigrum* L.	Fruit	Food
Piquiazeiro	*Caryocar villosum* (Aubl.)	Fruit	Food
Plalheira	*Attalea* sp.	Leaf	Provision
Pupunheira	*Bactris gasipaes* Kunth	Fruit	Food
Tangerineira	*Citrus reticulata* Blanco	Fruit	Food
Taperebazeiro	*Spondias mombim* L.	Fruit	Food
Tatajuba	*Bagassa guianensis* Aubl.	Trunk	Logging
Unha de gato	*Uncaria tomentosa* (Willd) DC.	Bark	Food
Uxizeiro	*Endopleura uchi* (Huber) Cuatrec	Fruit	Food

*A common name of most species called/referred to in Brazil. Table source: Adapted from Silva et al. (2022).

the farmers as well as the ecological and socio-economic environment, thereby improving the chances of project success. In this context, it is important to highlight that traditional ecological knowledge is of fundamental importance for biodiversity conservation, as it has been passed down through generations (Norgaard, 1989). Therefore, understanding and incorporating traditional ecological knowledge into practices tends to promote the sustainable use of natural resources and the conservation of biodiversity (Berkes, Folke & Gadgil, 1995).

Step 4. Survey on Species Use

To further deepen the understanding of species used for agricultural cultivation and extractive purposes in the community of Ipaupixuna, visits were conducted to identify households willing to participate in qualitative and quantitative interviews. The interviews were guided by the following topics: a) social information, such as length of residence and number of inhabitants per household; b) data on the economic activities of the families; and c) inventory of cultivated plants or native vegetation and their respective uses. In this regard, it is worth noting that semi-structured interviews facilitate an open environment for dialogue by allowing the interviewee to express themselves freely without limitations imposed by a questionnaire (Pinheiro et al., 2011).

The interviews were conducted with fourteen (14) families in the community, and the information obtained from this survey was compiled into a scientific document on cultivation and extractivism in the indigenous community of Ipaupixuna (Silva et al., 2022). The study reported that the local dynamics are based on families engaged in agro-extractive activities, where plant species used for food (Table 1), particularly those producing fruits (such as açaí, cupuaçu, and banana), are prominent choices for cultivation and/or extractivism in the community.

Step 5. Agroforestry Arrangement Planning

In this step, plant species were selected, followed by planning the agroforestry arrangement to be introduced in a module of 32 m by 40 m (1,280 m2), the available area for planting in the community. This phase included defining spacing, arrangement, and species to be used, reconciling seed and seedling availability, farmers' aspirations, the ecological succession roles of each species, and project resources. The planned system was configured as a silvicultural-agricultural system where annual crops and perennial crops develop concurrently in time and space.

Species with the potential to compose diversified production systems in the future were listed, taking into consideration their socio-environmental and economic value for greater acceptance by the community. In this regard, the proposition involved the participation and knowledge of the farmers, as well as support from literature related to the topic.

Fruit species such as acerola (*Malpighia emarginata*), banana (*Musa* sp), camu-camu (*Myrciaria dubia*), taperebá (*Spondias mombin*), and ingá (*Inga edulis*) were prioritized for the introduction. Cumaru (*Dipteryx odorata*) was chosen as the main forest species for seed production and was planned with a spacing of 10 x 10 meters. Similarly, African mahogany (*Khaya grandifoliola*) and taperebá were planned with a spacing of 10 x 10 meters, but only on the front and back edges of the planting area. These species, when mature, grow into large trees that could shade other crops excessively if planted in the central area of the agroforestry system (AFS). In the adjacent edges, ingá-cipó (Inga edulis) was chosen, with a single row planted at a spacing of 4 meters, to serve as a nitrogen-fixing species through pruning of its leaves and branches and for fruit production. Banana and camu-camu were intercropped in the same rows, with one seedling every 5 meters. Acerola was planted in a double row with a spacing of 3 x 3 meters. Therefore, the arrangement was planned to be composed of 8 rows, totaling 100 seedlings to be planted.

Step 6. Site preparation for cultivation

The project team, along with a collaborating community member, monitored the demarcation of the experimental area and the subsequent manual clearing of vegetation (November 2019). The vegetation was cut using hand tools and later (after 15 days), a controlled burn of the plant material was conducted. This area required the hiring of two individuals from the community, who worked for six days in an area equivalent to 32 m by 50 m.

Step 7. Planting of the agroforestry system

With the perennial forest and fruit tree seedlings in hand, the planting lines were marked and planting holes were dug for the selected species (Figure 3-C). The activities were carried out in a participatory manner, with the assistance of undergraduate students and representatives from the community.

4. Conclusion

The community has shown adherence to the project and demonstrated interest and collaboration in the activities up to the planting phase of the agroforestry system. This indicates that there may be acceptance of transitioning from traditional farming systems to new modalities of cultivation with the inclusion of tree components. The establishment of agroforestry systems required efforts to carry out all the necessary steps, promoting community involvement in the project construction process, especially in the identification of key species to be included in the planning and subsequently cultivated in the field. This highlights the importance of considering the dynamics and resources required in community-based projects so that all stages can be carried out in a way that makes the implemented system representative of the involved residents.

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