

CONTRIBUTION OF CUMARU AND CASSAVA TO THE ECONOMIC VIABILITY OF AGROFORESTRY SYSTEMS IN THE EASTERN AMAZON

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Abstract: Agroforestry systems (AFS) are composed of arrangements of species that allow for different productive strategies and augment the economy in rural properties and communities, such as in agrarian reform settlements, mainly in the Brazilian Amazon. In the cultivated spaces, it is possible to plan the staggering of production, as the system can consider plant and animal species to provide combinations of food, raw materials, and environmental services. In this work, the economic viability of two species in Agroforestry Systems in the Sustainable Development Project (SDP) Paraíso in Alenquer, in the state of Pará, was evaluated. Data were collected for the period from 2018 to 2021,

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calculating the following variables: revenues, costs/expenses, profit/loss, payback period, Net Present Value (NPV), Equivalent Annual Value (EAV), and Internal Rate of Return (IRR). All analyses were carried out considering this five-year time frame, showing that the highest profitability of cassava occurs in operations with scale for the production of flour, as well as gains from the sale of tonka bean or cumaru (*Dipteryx odorata*). The AFS are economically viable with high profitability in most productive arrangements. The low investment, flour sales strategies, and the high demand for tonka beans allow the producers to recoup investments in less than 8 months.

Keywords: Agroextractivists. Agroforestry systems. Settlement Territories.

Introduction

The last five years in Brazil were characterized by the substantial loss of natural resources in important biomes throughout the national territory, especially in the Amazon (Chen and Dirmeyer, 2020; Ruiz-Vásquez et al., 2020). This influences the precipitable water in tropical South America and the ocean-atmosphere system. The factors arising from deforestation may be associated, for example, with the expansion of commercial agriculture and livestock, land speculation, infrastructure works, logging, and mining (Aleixo and Arima Junior, 2022). As of 2020, public lands, including Conservation Units and indigenous lands, have been suffering from the intensification of illegal occupation by land grabbers, prospectors, and loggers, causing severe degradation in the environment (Alves and Diniz, 2022).

The opening of new areas by disorderly occupation constitutes a paradox from an economic point of view, as these lands contribute little to economic development because of the low productivity and reduced quality of pastures for livestock expansion in the region (Rajão et al., 2020).

To mitigate the impacts caused by deforestation and areas in significant process of degradation, strategies have been developed to reduce food insecurity and poverty in the countryside. For example,

the use of Agroforestry Systems (AFS) that adopt agroecological principles increases and diversifies production, boosting the local economy (Altieri and Nicholls, 2017; Palma et al., 2020; Wolpert et al., 2022). In addition to economic benefits, AFS bring ecological benefits that optimize land use and also contribute to sustainable development globally (Wilson and Lovell, 2016). These productive arrangements comply with environmental and forestry legislation. According to the Forestry Code, they can be used for maintenance and recomposition of the legal reserve area, and as it is considered a low impact activity, it can also be used to recover permanent preservation areas when the requirements of the law are respected.

In accordance with the adoption of these strategies and perspectives, the agrarian reform settlements in Brazil are designated as ‘key territories’ for the implementation of this sustainable production system. Among the settlements contemplated by the national land policy, the Sustainable Development Projects (SDP) are included, which were standardized by Incra Ordinance No. 477/99 and regulated by Incra Ordinance No. 1.032 of October 25, 2003. It consists of a differentiated settlement model based on environmental conservation as the basis for development, where farmers assume the leading role in the sustainable use of natural resources (Brasil, 2000).

This settlement modality includes environmentally differentiated activities in productive processes, targeting the public as traditional populations. The land title is granted collectively while issues related to the selection of beneficiaries, infrastructure, roads, water, and energy, as well as access to credit such as the National Program for Strengthening Family Agriculture - Pronaf, are carried out by the National Institute of Colonization and Agrarian Reform – Incra (Antonacci, 2018).

According to INCRA (2017), there were 2,421 families settled in 12 land reform projects in the municipality of Alenquer, west of the state of Pará, occupying an area of 376,978.00 hectares. The Sustainable Development Project - Paraíso has the capacity to settle 800 families in an area of 260,824.74 hectares.

However, the adoption of an agroforestry system, by itself, cannot guarantee the success of family agricultural production. It is necessary to measure these benefits and promote periodic

evaluations, aiming to measure whether this system is productive and viable from an economic, financial, and environmental point of view. The analyses of these investments involve the use of techniques and methodologies that compare revenues, costs, and expenses of the system, enabling a more assertive decision-making on the undertaking of actions (Rezende and Oliveira, 2013).

Queiroz et al. (2019) reveal that the absence of studies of this nature has made it extremely difficult for farmers to access credit at rural financing agencies, and specifically in the case of the Amazon, studies have been limited to basically dealing with technical, biological, and sociological aspects.

According to Fapespa (2021), cassava production in Alenquer in 2020 reached the level of 154,000 tons, solidifying itself as the main product of temporary farming since the 1990s. With regard to plant extractives, cumaru has assumed an important role in the local economy since the year 2000. From 2017 to 2019, production was 53 tons, and in 2020, 37 tons of almonds were sold.

Considering this potential and the agroextractivist vocation, agroforestry systems are part of alternatives to sustainable production with income generation. This strengthens local and regional development and justifies the importance of this work, which consisted of evaluating the economic viability of agroforestry systems in the field of agriculture family in the Sustainable Development Project (SDP) – Paraíso, Alenquer, Pará, Brazil.

Materials and methods

The work was developed using data collected in the Sustainable Development Project - SDP Paraíso, located in the municipality of Alenquer, state of Pará. In mid-2009, the settled agroextractivists were encouraged by the Institute of Forest and Agricultural Management and Certification – Imaflora, to cultivate tonka bean or cumaru (*Dipteryx odorata*), as well as the species included in agroforestry arrangements combined with agricultural crops such as cassava, beans, lemon, and papaya, among others.

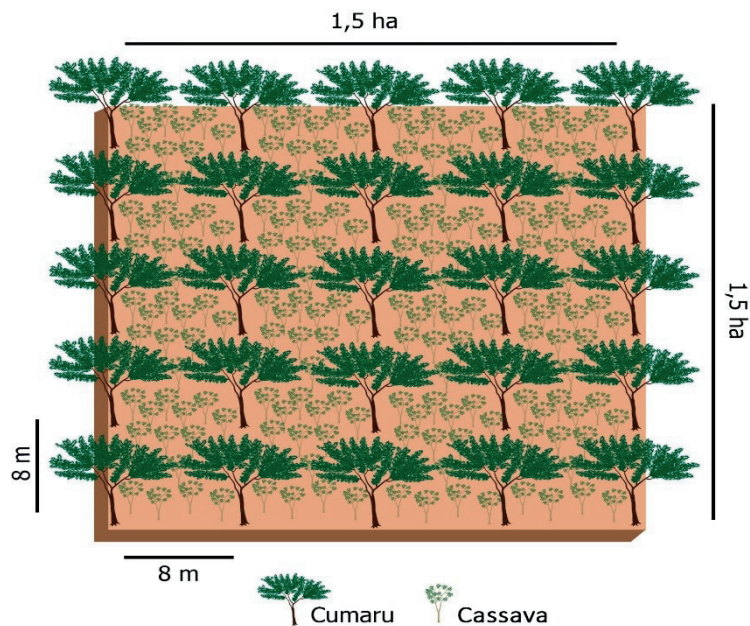
Therefore, in this work, settlers who still cultivate this forest species were selected, identified in three communities. There were two producers in Igarapé Preto, two in São Paulo Community, and two other family-based farmers in Benfica Community, totaling six agroforestry systems.

The level of organization of the agroextractivists who kept notes with data that could be analyzed economically and financially on their rural property was considered as a selection criterion, as indicated by the Association of the Sustainable Development Settlement Project SDP - Paraíso (Aparaí). This criterion was applied to ensure that the information allowed the application of less arbitrary economic analysis methods in the referred AFS.

To support the understanding of the analyzed agroforestry systems, the following description was made:

- The surveyed AFS have floristic composition and diversified arrangements, varying according to the management of each agroextractive family (Fig. 1). The AFS were composed of tonka bean (*Dipteryx odorata*) and cassava (*Manihot esculenta*), occupying a total area of 1.5 hectares. Cumarú was cultivated in standardized areas with spacing of 8 m x 8 m, and approximately 230 trees, intercropped with the cassava crop, planted in approximate spacing of 50 cm x 50 cm with annual cultivation (Fig. 1) lasting in the area for around five years;
- All AFS have the same age and were planted in 2016, however, the study adopted the year 2018 as a base, since the collection of cumarú almonds was started, concomitant with the production of cassava flour;
- It is common in the structure of the AFS that other crops for subsistence are planted in a dispersed way, such as lemon, papaya, annatto, ingá, cocoa, among others, and these were not analyzed in this study, as they are crops for self-consumption.

Fig. 1. Sketch of the model of the Agroforestry System of the Sustainable Development Settlement - Paraíso, located in Alenquer, Pará, Brazil



Source: prepared by the authors (2022).

From the cultivation of cassava in the six AFS, cassava flour, gum, and tapioca flour were obtained (Table 1). However, gum and tapioca flour were produced by AFS 2, 4, and 6 only in 2018, and production was interrupted in the following year, due to the high costs of labor, logistics, and low profitability. Therefore, these products were not considered in the economic analysis, as they do not present significant revenues and costs/expenses.

Table 1 - Species and products traded from the agroforestry systems of six agroextractivists from the Sustainable Development Project Paraiso, Alenquer, Pará, Brazil (2018 to 2022).

Common Name	Scientific Name	Product
Cassava	<i>Manihot esculenta</i>	Cassava flour Tapioca flour Tapioca gum
Cumaru	<i>Dipteryx odorata</i>	Almond

Source: prepared by the authors (2022).

Cash flow composition

The cash flows were calculated for a period of analysis of 5 years, comprising the years 2018 to 2022, although the AFS were implemented in 2016. The intentional choice for the start of the analyses to take place in 2018 is because this was the first year of cumaru collection, as well as production of cassava flour, in the AFS. This choice was based on the study by Rodrigues et al. (2008) who carried out the analyses from the first year of agricultural cultivation in the area, regardless of the beginning of the implementation of the AFS.

Revenues, costs, and expenses were determined through notes from agroextractivists and invoices for sales made through the National School Feeding Program (Programa Nacional de Alimentação Escolar – PNAE) to the Municipal Education Department of Alenquer and in establishments such as open-air markets and supermarkets, located at the head office of the municipality.

The composition of costs/expenses for both supply chain activities and the products were characterized by the main activities indicated by the agroextractivists. These were divided into two main costs: “inputs and services”; and “preparation and general” (Arco-Verde and Amaro, 2018).

The main costs for “inputs and services” were the purchase of herbicides, fertilizers, and fuel for generating electricity in the production of cassava flour. Among the “preparation and general”

costs, the main expenses were related to labor for preparing the area, which is done by felling, by slashing and burning biomass, by manually planting seedlings according to the spacing described above, and by manual weeding performed every three months, sometimes more frequently in the first three years of the AFS.

Also, the “preparation and general” costs, obeying the accounting principle of prudence, included a percentage of 20% of the total cost that was estimated as “indirect expenses” for expenses related to marketing, logistics, and miscellaneous. Martins, Gelbcke, Santos, and Iudícibus (2013) mentioned that this principle aims to establish a certain precaution in estimates so that assets and revenues are not overestimated, and liabilities and expenses are not underestimated.

The estimated price for labor corresponds to R\$ 60.00 man/day, as this is the price practiced in the region. In addition to hiring external labor, the opportunity cost was also calculated according to Varian (1993), which corresponds to the cost we give up when one performs the work themselves.

Revenue basically came from the sale of cumaru and cassava flour. As previously mentioned, the revenues obtained from the sale of tapioca gum and flour were not considered, given they had low value and were not produced by all AFS's. The production levels did not occur in the years after 2018, due to the high cost of labor, logistics, and low profitability.

Economic indicators

For the economic viability analysis, the payback period, Net Present Value (NPV), Equivalent Annual Value (EAV), Internal Rate of Return (IRR) were calculated, and the five-year profit/loss was also calculated. Each of these indicators corresponds to a specific purpose and, therefore, within the scope of economic analyses of projects, whatever they may be, specialists recommend that decisions be based on these and other combinations of analyses (Marquezan, 2006).

The payback period is an indicator that reveals the average investment recovery time, taking the generated cash flows as a reference, while the net present value (NPV) deals with the amounts that

can be “gained or lost”, according to a percentage called minimum interest rate (MIR). The internal rate of return (IRR) consists of a projection in percentage terms of the intended profitability, and the Equivalent Annual Value (EAV) shows the discounted profit that the project provides each year.

Therefore, the payback period is seen as an evaluation tool to measure simple projects, in order to verify the time needed for the company - in this case the agroextractivist family - to recover the initial investment. In this case, the cumulative revenues are equal to the initial investment, thus reaching the break-even point (Assaf Neto, 2016). From the point of view of economic viability for analysis purposes, the project must be accepted if the payback period is less than the maximum period projected by the investor to obtain the return, and if it is longer, the project must be rejected.

The Net Present Value (NPV) aims to measure the present value. That is to say, the cash flows generated by the project over time give it a value for the current date. Therefore, the NPV can be defined by the current value of revenues obtained by cash-generating activities minus the current value of costs (Bonfatti Júnior et al., 2020; Garcia et al., 2017; Rezende and Oliveira, 2013; Silva et al., 2005; ; Souza et al., 2019).

The calculation of the Net Present Value (NPV) is performed using the following Equation 1:

$$NPV = \text{Initial investment} - \frac{CF 1}{(1+i)^1} + \frac{CF 2}{(1+i)^2} + \frac{CF 3}{(1+i)^3} (\dots)$$

Where: CF = Cash Flow; i = interest rate; and n = cash flow period number.

The interest rate (i), using 8.1% for this study, corresponds to the discount percentage of cash flows over the analyzed periods. It is based on several factors, such as the purpose of the investment, the type of business, cost of capital, and opportunity cost, among others. For Assaf Neto (2016), a positive NPV of the investment project indicates that it must be accepted, and when it is negative, it must be rejected.

The IRR corresponds to the discount rate, which is calculated by the sum of revenues over

the period equal to that of disbursements. That is to say, it normalizes between the present value of revenues and that of costs/expenses (Nishi et al., 2005).

To calculate the IRR, a rate of 8.1% per year of interest was assigned. This referenced the effective rate of the National Program for Strengthening Family Agriculture – Pronaf (Programa Nacional de Fortalecimento da Agricultura Familiar), and included crop insurance, according to the studies carried out by Palma et al. (2020), Ewert (2020), and Arco-Verde and Amaro (2018).

In terms of analysis, the project is financially viable if the IRR is greater than the minimum interest rate. The IRR can be calculated by Equation 2:

$$IRR = \sum_{i=1}^n \frac{CF\ 1}{(1+i)^n} - \text{Initial investment} = 0$$

Where: CF = cash flows for the period; i = period of each investment; n = final period of investment.

Finally, the Equivalent Annual Value (EAV) corresponds to an economic indicator that complements the Net Present Value (NPV). This provides a constant annual flow of revenues/costs over the project periods (Silva and Farias, 2015). The EAV can be calculated using the formula:

$$EAV = \frac{NPV \cdot [(1+i)^t - 1]}{1 - (1+i)^{-tn}}$$

Where: EAV = Equivalent Annual Value; n = project periods; t = number of compounding periods.

If the EAV is positive, it is assumed that the project is economically viable, since the revenues are greater than the costs of the analyzed period. Thus, the option that presents the highest EAV from a given discount rate should be chosen (Rezende and Oliveira, 2013).

Results and discussion

In the SDP Paraíso, approximately 200 families of settled farmers reside in three communities: São Paulo, Igarapé Preto, and Benfica. These families live off the agroextractivism of almond (*Dipteryx odorata*), Amazon nut (*Bertholletia excelsa*), and the generation of other products, such as cassava for the production of flour, tapioca starch and flour, vegetables, beans, cocoa (*Theobroma cacao*), ingá (*Inga sp.*), and açai (*Euterpe oleracea*), and these have been introduced as an experiment in the “productive home gardens” since 2021.

Cassava flour, starch, and tapioca flour already reach institutional markets through the National School Feeding Program (Programa Nacional de Alimentação Escolar - PNAE), as well as being sold at street markets and supermarkets in the municipality.

However, the main market for the sale of tonka beans (*Dipteryx odorata*) in the SDP – Paraíso is the British company Lush Fresch Handmade Cosmetics, which uses the extracted oil to produce analgesics, sedatives, and cosmetics. The first tonka bean commercialization contract signed with this company took place in the 2017 harvest, and it resulted in the production of 1 ton of almonds, sold for a total price of R\$ 53,000.00 (Souza, Sousa and Azerêdo, 2020). According to Azerêdo et al. (2022) that used data provided by the Municipal Department of Education (2021) of Alenquer through the PNAE, SDP Paraíso sold R\$ 57,594.61 of cumaru in 2021.

According to the president of APARAÍ, 1 ton of almond was sold in 2020, and in 2021, production was approximately 9 tons, at the price of R\$ 80.00 reais per kilo. For the year 2022, the sales estimate is around 3 tons, where there was a significant drop due to the rise in prices that reached R\$ 120.00 reais per kilo, as well as the increased competition with other agroextractivists who are developing the activity in the Lower Amazon region.

As for the revenues generated in the AFS, the production of cassava flour stands out, which corresponded to about 94% of the revenues of all six AFS evaluated. This can be explained by the irregularity of the cumaru harvest, which depends on the planting period, climatic conditions, soil,

and oscillation in the selling price, as well as the fact that cassava flour is the basis of food in many locations in the state of Pará.

For Steve and Robert Harrison (2016), AFS generating revenue right at the beginning of the project, as is the case with the cultivation of cassava for the production of flour, reduces the dependence on generating revenue from essentially forestry projects. Thus, the producer needs greater investments until able to harvest the trees or collect almonds, for example.

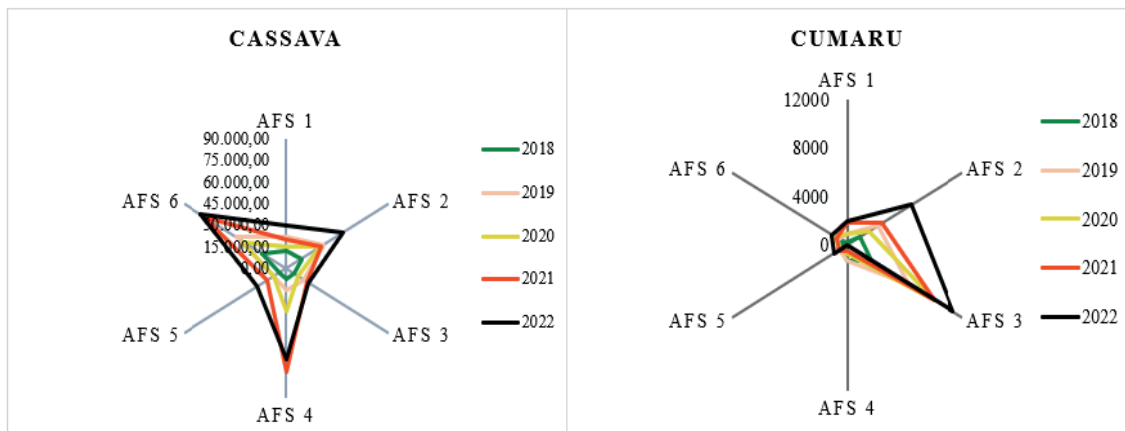
Another aspect that should be highlighted in all AFS is that there is no concern for soil exhaustion in relation to cassava production. The agroextractivists are guided only by the Institute of Forestry and Agricultural Management and Certification (Instituto de Manejo e Certificação Florestal e Agrícola – Imaflora), and they do not have specialized technical assistance from any public agency.

Since 2009, the Institute of Forestry and Agricultural Management and Certification (Instituto de Manejo e Certificação Florestal e Agrícola – Imaflora) has contributed to important initiatives in the SDP – Paraíso, such as the construction of nurseries, the implementation of AFS, and agricultural production without the use of fires. In 2015, 11,000 cumaru seedlings were produced, intended for reforestation and the increase of this productive activity in the settlement territory. In 2022, more than 18,000 seedlings were planted, of which 1,200 cocoa, 600 ingá, and 600 açaí seedlings are being cultivated in the experimental phase.

In the same year, initiatives to restore soil nutrients are increasing the areas of AFS, done by inserting new crops. For example, cocoa has been highlighted as one of the main products in the bioeconomy in Pará, and inga is a nutrient fixer and develops well in low fertility soils (ANDRADE et al., 2015).

Given the economic potential of this type of production in the state of Pará, the support of technical assistance and rural extension (TARE) is essential, together with the development of new technologies capable of contributing to the maximization of sustainable production and development of the local and regional economy (RÊGO et al., 2017).

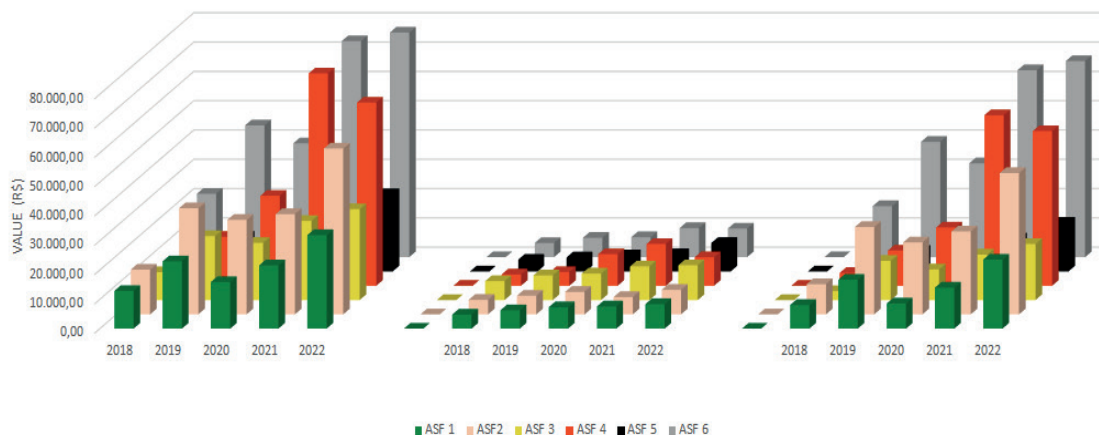
Fig. 2. Annual revenues of the AFS components of the Sustainable Development Settlement - Paraíso, located in Alenquer, Pará, Brazil (2018 to 2022).



Source: created by the authors, (2022).

As mentioned, the sale of almonds in 2022 showed a significant reduction as a result of competitiveness with other agroextractivists and the rise in prices. This reduced demand from the British company Lush Fresch Handmade Cosmetics, which buys all production from SDP – Paraíso and uses the Association of the Sustainable Development Settlement Project SDP - Paraíso (Aparaí) as a depository.

Fig. 3. Revenues, Costs, and Annual Profit/Loss of the SAFs of the Sustainable Development Settlement - Paraíso, located in Alenquer, Pará, Brazil (2018 to 2022).



Source: created by the authors, (2022).

According to Figure 3, AFS 1, 2, 3, and 5 maintained consistent revenues without significant changes during the period from 2018 to 2021, but the operation is enhanced in 2022 through greater cassava flour production, which emerged as an alternative during the decline in cumaru sales. Furthermore, AFS 4 and 6 basically doubled their revenues from 2018 to 2022 by expanding the production of cassava flour.

The increase in costs shown in Figure 3 follows the trend of increased cassava flour production. Above all, the producers note intensive use of labor to peel the roots, soak them in water, grate, press, sift, and roast the flour, as well as preparing the land and buying fuel for power generation.

From an economic-financial point of view, all AFS demonstrate viability (Table 2). Based on the payback period, the initial investment was recovered in less than 8 months for all productive arrangements, indicating an almost immediate return, while SAF 6 recovered the initial investment in just over two months.

Crop diversification in AFS offers the opportunity to take advantage of different markets and product demands. A greater variety of products corresponds to greater possibility for farmers to adapt

to the preferences and needs of consumers. This can lead to increased income opportunities as farmers can diversify their sources of income and take advantage of seasonal and regional fluctuations.

Table 2 - Payback period, Net Present Value – NPV, Internal Rate of Return – IRR and Equivalent Annual Value (EAV) of the AFS of the Sustainable Development Settlement - Paraíso, located in Alenquer, Pará, Brazil

AFS	Payback period	Net Present Value – NPV (R\$)	Equivalent Annual Value – EAV (R\$)	Internal Rate of Return – IRR (%)
AFS 1	4 months	76,778.74	19,229.73	312.72
AFS 2	3.5 months	129,063.58	32,324.81	392.24
AFS 3	7 months	77,201.14	19,335.52	208.35
AFS 4	5 months	137,724.88	34,494.09	303.93
AFS 5	7 months	50,941.05	12,758.51	201.73
AFS 6	2 months	189,897.28	47,561.00	526.25

Source: created by the authors, (2022).

The net present value (NPV) showed very significant values in AFS's 2, 4, and 6, which obtained the highest profits among the AFS evaluated (Table 2), due to the sale of cassava flour and the commercialization of tonka bean.

The internal rate of return (IRR) for all AFS is at least 26 times greater than the minimum interest rate, noting that AFS 6 presented an IRR almost 65 times greater than the discount rate. Corroborating the result of these analyses, Nunoo and Owusu (2017) stated AFS with these characteristics tend to be more profitable in the intermediate phases, as is the case with the increase in tonka bean extractivism.

Following the same trend of the Net Present Value, SAF 6 presented the best performance in the Equivalent Annual Value, where there was an annual discounted profit of R\$ 47,561.00. AFS 1 and 3 and AFS 2 and 4 present similar EAVs (Table 2), and AFS 5 presented a lower value of R\$ 12,758.51.

In addition to the productive activity in the areas of each SAFs, the agroextractivists have their income subsidized by the productive home gardens, where they grow vegetables, annatto, beans,

and lemons and raise pigs and chickens for their own consumption. The agroextractivists from SAFs 1, 3, 4, and 5 still collect Amazon nuts in scattered areas, and the agroextractivists from SAF 6 act as intermediaries in the purchase of tonka beans and Amazon nuts from agroextractivists in the SDP – Paraíso and other surrounding communities.

Despite the predominance of men in agroextractive activity, the work regime at SDP Paraíso is family oriented. This highlights the role of women, who assume responsibility for carrying out domestic tasks, also work in these activities.

Final considerations

Agroforestry systems constitute a viable alternative for family agroextractive production. In optimizing these areas, the local economy is boosted and, more importantly, environmental socioeconomic sustainability is promoted in rural territories, including in agrarian reform settlements. These systems combine the practice of agriculture with the preservation and sustainable use of the forest and, in this way, allow for greater diversification of productive activities, reduce production costs, and increases productivity.

In this study, the AFS show economic viability, high profitability, and a quick return on investment, where everyone managed to recover their investments in 2 to 8 months. No future projections were made because the market for the commercialization of tonka beans and cassava flour is unstable, given the aspects of production and new market entrants in the Lower Amazon.

Some agroextractivists from the AFS have a profile more focused on agricultural activity, while others focus on extractivism. For the purposes of this study, only these results from the AFS were considered; however, some agroextractivists also act as middlemen in the purchase of tonka beans and Amazonian nuts, as an alternative to augment family income. If the combination of the extractive activity of cumaru almonds with cassava flour were enhanced, profits could be greater.

In addition, the formulation of public policies to encourage the development of agroforestry

systems, combined with the awareness of society about the importance of environmental preservation of ecosystems, can create a favorable environment for the establishment of these agroforestry systems, furthering a virtuous cycle capable of generating economic and social benefits for the region.

However, there is still a lack of studies evaluating the economic and financial performance of these production systems. This fact can be understood, given the difficulty in obtaining reliable financial information over the evaluated periods. This is especially true in the first years of systems implementation, which makes a study with a time frame of more than five years unfeasible.

As a recommendation, it is suggested to carry out comparative studies with other supply chains and activities, such as breeding of livestock, fries, pigs, and chickens and cultivation of corn, beans, and vegetables, among others, and one should use a combination of these and other indicators.

Acknowledgements

Michael. pela tradução...

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