Economic analysis of the cumaru almond production in agroforestry systems in Alenquer, Pará state

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Abstract: Deforestation is one of the biggest problems in the Amazon, affecting a large area in Pará state, Brazil. Most of the natural forests of Alenquer city (PA) have been replaced by pastures, which has compromised cumaru species sustainability. The economic viability of cumaru (*Dipteryx* sp) almond with cassava in two agroforestry systems (AFS) in Alenquer city was evaluated. The economic evaluation criteria were: net present value, equivalent periodic benefit, benefit-cost ratio, expected land value and average production costs and family labor revenue considering two planning outlooks (10 and 20 years), using a minimum attractiveness rate (MAR) of 7% per year. We analyzed price variation effects of labor, almond (Kg) and cassava flour (Kg) and minimum attractiveness rate on net present value (NPV). Agroforestry systems were found to be economically viable. Processing costs were the highest than other system activities. Cassava commercialization contributed to current net revenue and reduced initial costs. Agroforestry systems A, with smaller spacing, presented equivalent periodic benefit of R$4557.91 ha^{-1}. The NPV was more sensitive to variations in the price of flour and almond. This form of production is an alternative for profitable soil use in Pará state.

Keywords: *Dipteryx* sp, economic indexes, profit, non-timber forest products.

Classificação J.E.L.: G11; R14; Q23

Análise econômica da produção de amendoa de cumaru em sistemas agroflorestais em Alenquer, estado do Pará

Resumo: Um dos maiores problemas da Amazônia é o desmatamento, que atinge maior área no estado do Pará. No município de Alenquer (PA) boa parte das florestas naturais foram substituidas por pastagens, comprometendo a sustentabilidade de várias espécies florestais como o cumaru. Diante desta realidade, avaliou-se a viabilidade econômica de dois sistemas agroflorestais (SAFs) visando à produção de amêndoa de cumaru em consórcio com a mandioca em Alenquer-PA. Os critérios de avaliação econômica foram: valor presente líquido, benefício periódico equivalente, razão benefício/custo, valor esperado da terra, custo médio de produção e remuneração da mão de obra familiar para dois horizontes de planejamento (10 e 20 anos), considerando uma taxa mínima de atratividade (TMA) de 7% ao ano. Verificou-se o efeito da variação do preço da mão-de-obra, do preço do quilo da amêndoa, preço do quilo da farinha de mandioca e da TMA no valor presente líquido (VPL). Os sistemas agroflorestais foram economicamente viáveis e remuneraram a mão de obra familiar. Os custos com o beneficiamento foram mais elevados comparado a outras atividades dos sistemas. A venda da mandioca contribuiu com as receitas líquidas, amortizando os custos iniciais. O sistema agroflorestal A, com menor espaçamento,

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mostrou-se mais atrativo com benefício periódico equivalente de R$4.557,91 ha^{-1}. O VPL foi mais sensível às variações do preço da farinha e da amêndoa. Essa forma de produção mostrou-se uma alternativa de uso do solo rentável ao produtor no estado do Pará.

Palavras-chave: *Dipteryx* sp, indicadores econômicos, lucro, produtos florestais não-madeireiros.

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1. INTRODUCTION

The Amazon region has a diverse natural heritage, but since colonial times, predatory native forest exploitation has led to deforestation and degradation. The annual deforestation rate in Pará state was estimated as highest in 2016, with about 37.9% of the total area of the Legal Amazon felled (INPE, 2017).

The use of non-timber forest products (NTFP) originating from native forest management, plantations or agroforestry systems (AFS) (KOPPEL, 1995; SHACKLETON; DELANG; ANGELSEN., 2011), represents an economically viable alternative for unsustainable timber exploitation. In addition, it reduces the negative environmental impacts more than timber harvesting, contributing to natural resource sustainability (ARNOLD and PÉREZ, 2001) and generating income for agro-extractive producers (HALL and BAWA, 1993; COSTA *et al.*, 2016). Non-timber forest products include all products from the forest except for timber such as leaves, fruits, flowers, seeds, nuts, roots, branches, range, fibers, essential oils, fixed oil, latex, resins, vine, bamboo and animal products (MACHADO, 2008).

Some Amazon farming communities invest in AF systems as an economical alternative (SÁ *et al.*, 2000). Agroforestry systems are a form of land use, which deliberatly integrates trees, crops and/or animals in the same area (NAIR, 1993), simultaneously or sequentially introduced (YOUNG, 1991). Interim plantation of trees with cassava and other agricultural crops such as beans and corn are examples of such systems (ABDO; VALERI; MARTINS, 2008). According to Henkel and Amaral (2008), planting tree species in "roça" (farming land) is a common practice in small farming families, but there is little research to confirm its economic viability. The farmers in Alenquer (Pará state) are intercropping cumaru with cassava. This experiment is one way to minimize the effects of deforestation in the region, because there have been reports that in Alenquer, large areas of natural forest containing cumaru were converted into pastures (IDESP, 2011).

Cassava (*Manihot esculenta* Crantz) is an important product in Pará state (SANTOS *et al.*, 1997). It is the main raw material harvested in Alenquer which manufactures flour. Meanwhile, cumaru (*Dipteryx* spp.) is a specie that can fruit after four years (PINTO; MORELLATO; BARBOSA, 2008). This motivates farmers to invest in cumaru plantations, because they will provide quicker financial returns.

The cumaru almond has medicinal properties, and possesses a substance called coumarin, which is used to produce perfume and cosmetics (CARVALHO, 2009). The greatest production of cumaru in Brazil is in Pará state, especially in Alenquer city (IBGE, 2015).

Introducing cumaru into an AF system allows sustainable native forest fruit harvesting and prevents cumaru species extinction, given that the cumaru may not leave or remain for a long period in the system, due to its marketable product being the fruit and not the wood. There are no studies that show how to expand cumaru production in an economical and sustainable way. The IDESP (2011) reported a shortfall in cumaru production in the region.

It is essential to evaluate cumaru economic viability in AF systems, in order to encourage its use and contribute to cumaru forest activity in Pará state, Brazil. Therfore, the object of this study was to evaluate the economic performance of two agroforestry systems using cumaru in Alenquer, Pará state, Brazil, seeking to minimize deforestation and ensure return on capital invested in family farming.

2. MATERIALS AND METHODS

2.1. Study site

Alenquer city is located in northwest of Pará state, which is considered the lower Amazon mesoregion, microregion of Santarem, limited by Óbidos, Curuá, Monte Alegre, Santarém and Almeirim cities. It occupies an area of 23.645,452 km², and possesses a population density of 2.23 inhabitants per km² (IBGE, 2015). The economy of Alenquer is based on agriculture, animal husbandry and plant extraction.

2.2. Data Analysis

We carried out semi-structured interviews (DESLANDES; GOMES; MINAYO, 2012) with two farmers who had agroforestry systems with cumaru almond production, in 2013, to construct a database. We prepared an interview guide based on the supplies, implantation, harvest, processing, maintenance costs, production of cassava and cumaru and revenues of two AF systems. We estimated all AF system values based on information from farmers and local markets.

2.3. AF System Description

We considered two agroforestry systems (AFS A and AFS B), both containinmg cumaru (*Dipteryx* spp.) and cassava (*M. esculenta* Crantz). The AF A system was deployed in 2005 whereas AF B system was in 2002. Mortality reduced the total number of cumaru that made up the systems (Table 1).

We collected three samples of each cumaru species for identification. The procedure of collecting the botanical material was carried out according to Martins-da-Silva (2002) and the genus and species of the samples were identified. The AFS A is composed of *Dipteryx punctata* Blacke, *Dipteryx odorata* and *Dipteryx* sp. The AFS B is composed of *Dipteryx alata* and *Dipteryx* sp.

TABLE 1 - Agroforestry system (AFS) characterization observed in the field, in Alenquer, Pará State, Brazil

AFS [1]	Spacing (m)		Total property area (ha)[3]	AFS useful area (ha)	Age (years)	Tree cumaru	Cassava[4]
	Cassava[2]	Cumaru					
A	1 x 1	6 x 6	12	0,3	7	72	2695
B	1 x 1	12 x 12	6,5	0,4	10	24	3877

Source: Prepared by authors in 2013.
[1] AFS: agroforestry system; [2] This spacing and cassava plants presented numbers composed only the AFS A in the first year of planting and the AFS B in the first two years; [3] ha: hectare; [4] Considered rounded values.

Production units have different sizes and, in order to facilitate analysis, all calculations were made using one hectare (ha) as the main unit for both AFS.

Site preparation was carried out manually. Plants were planted during the rainy season (december-may), with cumaru plants distributed in rows and cassava cuttings in row and inter-row.

In both AFS, hand weeding occurred more frequently between the first and fourth year, at intervals of four months. From the fourth to the eighth year, in AFS A twice annual hand weeding took place, and after crown closing, just once a year. In AFS B, from the fourth year until the end of the planning outlook up to two annual hand weeding took place, due to a greater weed density. To facilitate harvesting in both AFS, one weeding took place before maturation cassava and fruits of cumaru.

Pest control was assessed once a month in both AFS. Initial pruning consisted of removing the tree's terminal bud, which took place when forest species reached about one meter high. This generally occurs in the second year. After that, pruning occurred once every six months until the third year with the primary aim to provide more branches and better crown formation.

Cassava remained in the agroforestry system during the first four years of the enterprise. Cassava roots were harvested and converted into flour, according to the needs of commercialization. Cassava was removed from the agroforestry system from the fourth year and only cumaru almonds were collected. Thus, the main focus of the forest enterprise is the cumaru almond, which has continued to be produced over time.

The period of cumaru fruit harvesting depended on precipitation in the region. Cumaru almond value adding consists of breaking the fruit, selecting the seeds and drying them. According to producers, one worker is able to process 4 to 6 kg of seed per day.

2.4. Structure of costs and revenues

Cumaru seedling price also included the value paid by producers for shipping. There was an increase of 10% in the amount of seedlings for replanting. Cassava foliage (stem cutting) was obtained on the farmer's property or in the neighborhood. The value of the insecticide was local market value. To calculate annual value of land, R$400.00 ha^{-1} was considered to be the land cost, and that value represents an area without forest coverage (IKEGAMI, 2013) (Table 2 and 3).

TABLE 2 - Cost per hectare, agroforestry system A in Alenquer, Pará State, Brazil.

Specification	Year of occurrence	Unit[1] (u)	Cost (R$/unit)	Total quantity		Total cost (R$ ha⁻¹) [2]	
				10 years	20 years	10 years	20 years
Supplies							
Seedlings of cumaru	1	u	3.5	306.00	306.00	1071.00	1071.00
Insecticide	1 - 20	ml	0.20	2085.00	4170.00	417.00	834.00
Subtotal						1488.00	1905.00
Implantation							
Cleaning the area	1	dh	30.00	46.40	46.40	1390.70	1390.70
Alignment, flagging, manual pit of cumaru	1	dh	30.00	2.80	2.80	83.40	83.40
Planting cumaru	1	dh	30.00	2.80	2.80	83.40	83.40
Preparation of cuttings	1 - 3	dh	30.00	1.80	1.80	53.06	53.06
Manual pit and planting the cuttings	1 - 3	dh	30.00	9.40	9.40	282.97	282.97
Subtotal						1893.52	1893.52
Harvest							
Harvest cassava	2 - 4	dh	30.00	28.30	28.30	848.92	848.92
Harvest cumaru	4 - 20	dh	30.00	218.90	1196.30	6567.75	35888.06
Subtotal						7416.67	36736.98
Processing							
Husking of cassava	2 - 4	dh	20.00	222.90	222.90	4458.22	4458.22
Washing, trituratying, pressing and sifting cassava	2 - 4	dh	30.00	74.30	74.30	2229.11	2229.11
Cassava flour roasting	2 - 4	dh	50.00	148.60	148.60	7430.37	7430.37
Subtotal cassava						14117.71	14117.71
Breaking of the fruit, selection and drying cumaru almond	4 - 20	dh	30.00	322.70	1597.90	9682.14	47937.72
Subtotal cumaru						9682.14	47937.72
Subtotal of processing						23799.85	62055.43
Maintenance							
Pruning	2 - 3	dh	30.00	5.20	5.20	156.38	156.38
Manual weeding	1 - 20	dh	30.00	160.10	200.20	4803.84	6004.80
Pest control	1 - 20	dh	30.00	104.30	208.50	3127.50	6255.00
Subtotal						8087.72	12416.18
Annual Land Cost	1 - 20	dh	28.00			280.00	560.00

Source: Prepared by authors in 2013.
[1]dh: day man; [2]Total cost current.

Labor price, for most activities, was R$30,00 per day which included food expenses. Except for cassava shelling (R$20,00 per day) and flour roasting (R$50,00).

Following Pimentel *et al.* (2009) and Francez and Rosa (2011), social charges were not analyzed as there is no employment relationship for the aformentioned activities. There are no rural property taxes for small farmers who use family labor and possess a farming area smaller than 50 ha in Eastern Amazonian (BRASIL, 1996) and administration and depreciation costs were not analyzed, because all activities were undertaken manually, using low tech tools.

TABLE 3 - Cost per hectare, the agroforestry system B in Alenquer, Pará State, Brazil

Specification	Year of occurrence	Unit[1] (u)	Cost R$/unit	Total quantity 10 years	Total quantity 20 years	Total cost (R$ ha^{-1}) [2] 10 years	Total cost (R$ ha^{-1}) [2] 20 years
Supplies							
Seedlings of cumaru	1	u	2.00	77.00	77.00	154.00	154.00
Insecticide	1 - 20	ml	0.20	750.00	1500.00	150.00	300.00
Subtotal						304.00	454.00
Implantation							
Cleaning the area	1	dh	30.00	10.00	10.00	300.00	300.00
Alignment, flagging, manual pit of cumaru	1	dh	30.00	0.70	0.70	21.00	21.00
Planting cumaru	1	dh	30.00	0.70	0.70	21.00	21.00
Preparation of cuttings	1 - 3	dh	30.00	2.10	2.10	63.41	63,41
Manual pit and planting the cuttings	1 - 3	dh	30.00	11.30	11.30	338.17	338.17
Subtotal						743.58	743.58
Harvest							
Harvest cassava	2 - 4	dh	30.00	33.80	33.80	1041.51	1041.51
Harvest cumaru	4 - 20	dh	30.00	26.30	146.90	787.50	4406.25
Subtotal						1802.01	5420.76
Processing							
Husking of cassava	2 - 4	dh	20.00	246.70	246.70	4934.04	4934.04
Washing, trituratying, pressing and sifting cassava	2 - 4	dh	30.00	82.20	82.20	2467.02	2467.02
Cassava flour roasting	2 - 4	dh	50.00	164.50	164.50	8223.39	8223.39
Subtotal cassava						15624.45	15624.45
Breaking the fruit, selection and drying cumaru almond	4 - 20	dh	30.00	47.00	257.00	1411.20	7711.20
Subtotal cumaru						1411.20	7711.20
Subtotal of processing						17035.65	23335.65
Maintenance							
Pruning	2 - 3	dh	30.00	1.30	1.30	39.38	39.38
Manual weeding	1 - 20	dh	30.00	169.30	250.00	5080.32	7499.52
Pest control	1 - 20	dh	30.00	37.50	75.00	1125.00	2250.00
Subtotal						6244.70	9788.90
Land Annual Cost	1 - 20	dh	28.00			280.00	560.00

Fonte: Prepared by authors in 2013.
[1]dh: day man; [2]Total cost current.

AFS income originated from cumaru dry almond and cassava flour sales. The former occurred in the fourth year, while the later took place between the second and fourth years.

All product prices presented in this study are based on Alenquer (PA) average prices. Cassva flour price was based on the 2012 market value. For both products, freight price was inlcuded, resulting in a final cost for almonds of 22.00 R$/kg and cassava flour of 1.50 R$/kg.

We estimated almond production based on 2012 productivity, during the period prior to data collection. In fact, according to local farmers, almond productivity tends to increase over time, and will not damage the AF system.

2.5. Cash Flow

All costs and profits were annually ordered in cash flow format. Farmers appointed cumaru implantation costs in the first year and cassava during three years. The other costs were distributed according to a planning outlook of the table 2 and 3. Profits were earned at the end of each crop. A 10 and 20 years planning outlook was drawn up, and 7% per year hurdle rate (BCB, 2013), annual income of the savings account was established. This interest rate represents the alternative use of capital (MATSUSHITA et al., 2010) invested in the agroforestry system, used in the forestry sector (LIMA JÚNIOR, 1997; MAESTRI et al., 2004; MATSUSHITA et al., 2010; COELHO and COELHO, 2012; FERNANDES, 2013; SILVA and FARIAS, 2015).

2.6. Economic evaluation criteria

To economically evaluate AFS, we considered cash variation over time, and verified if the incomes repaid or not all investments, using the following criteria as indicators: net present value, equivalent periodic benefit, cost-benefit ratio, land expectation value, average cost of production and family labor revenue.

Net Present Value (NPV): AFS economic viability was determined by the positive difference between incomes and expenditures updated for a specified discount rate (REZENDE and OLIVEIRA, 2001; SILVA; JACOVINE; VALVERDE, 2008). Better projects present greater NPV. NPV was calculated using equation:

$$NPV = \sum_{j=0}^{n} R_j (1+i)^{-j} - \sum_{j=0}^{n} C_j (1+i)^{-j} \quad (1)$$

where: Rj = incoming in period j, in R\$ ha^{-1}; Cj = the costs in period j, in R\$ ha^{-1}; i = discount rate; j = time period, in years; n = period of the project, in years.

Equivalent periodic benefit (EPB): This method determinates the constant and periodic portion that pays a value equal to NPV along its planning horizon (REZENDE and OLIVEIRA, 2001; SILVA; JACOVINE; VALVERDE, 2008). EPB was calculated using equation:

$$\text{EPB} = VPL \frac{(1+i)^t - 1}{1 - (1+i)^{-nt}} \quad (2)$$

where t = number of capitalization periods; the other variables defined previously.

Cost-benefit ratio (BCR): This method determines the relationship between the present value of benefits and the present value of the costs for a given interest rate (REZENDE and OLIVEIRA, 2001). The AF system is considered economically viable if the ratio B/C> 1. The most appropriate AFS is one that has a higher ratio B/C (SILVA; JACOVINE; VALVERDE, 2008). BCR was calculated using equation:

$$BCR = \frac{\sum_{j=0}^{n} R_j (1+i)^{-j}}{\sum_{j=0}^{n} C_j (1+i)^{-j}} \quad (3)$$

where the other variables were previously defined.

Land expectation value (LEV): It is based on perpetual liquid incomes, excluding land cost. It represents the maximum price that a farmer can pay for the land, considering an infinite series. AFS is considered economically viable if it presents an LEV higher than the market land price (SILVA and FONTES, 2005).

$$LEV = \frac{VoRL(1+i)^T}{(1+i)^T - 1} \tag{4}$$

where T = cycle duration; V_0RL = current value of net revenue that is repeated each cycle; the other variables previously defined.

Average cost of production (ACP): To determinate almond ACP, we did not consider cassava flour production costs, and to calculate flour ACP we did not consider cumaru costs. ACP divides the present value of total costs by the equivalent production. The equivalent production is the quantity produced discounted or updated according to the interest rate. It indicates the point at which production shows a minimum cost. If it is smaller than Market price, AFS will be classified as viable (SILVA; JACOVINE; VALVERDE, 2008).

$$CMPr = \frac{\sum_{j=0}^{n} CT_j (1+i)^{-j}}{\sum_{j=0}^{n} PT_j (1+i)^{-j}} \tag{5}$$

Where CT_j = updated total cost in each period, in R$ ha^{-1}; PT_j = Equivalent total production in each period in Kg ha^{-1}.

Average cost of production and family labor revenue (ACPFL): this directly compares the remuneration that the farmer can get by selling their labor (their opportunity cost) and what they can earn on their property. It represents the maximum value that the AFS can give to the farming family (SÁ *et al.*, 2000; SÁ *et al.*, 2002; SANTOS *et al.*, 2002; SÁ; OLIVEIRA; NASCIMENTO, 2004). If ACPFL value was greater than the value paid by market labor, it means that the farming family can adopt the AFS. The calculation of ACPFL considered the division between the family labor revenue and the number of day worked on activities related to the AFS.

Annual cost of land (ACL): was estimated considering the interest rate on the land value (SILVA and FONTES, 2005).

2.7. Sensitivity analysis

The sensitivity analysis investigates possible variations in farm profits caused by risks and uncertainties, which can arise during production and comercialization (DOSSA *et al.*, 2000). Variations of ±20 were simulated on main supply variables (labor price, almond price, cassava price and minimum attractiveness rate), and then its effects on NPV were analyzed.

3. RESULTS

3.1. System Costs and Income

Total system costs undercapitalized for a 10 years planning outlook were R$31580.73 (AFS A) and R$20970.80 (AFS B), while for 20 years they were R$56433.36 (AFS A) and R$25772.17 (AFS B). The costs with processing in all AFS and planning outlook were the greatest, and represented more than 50% of total costs (Figure 1).

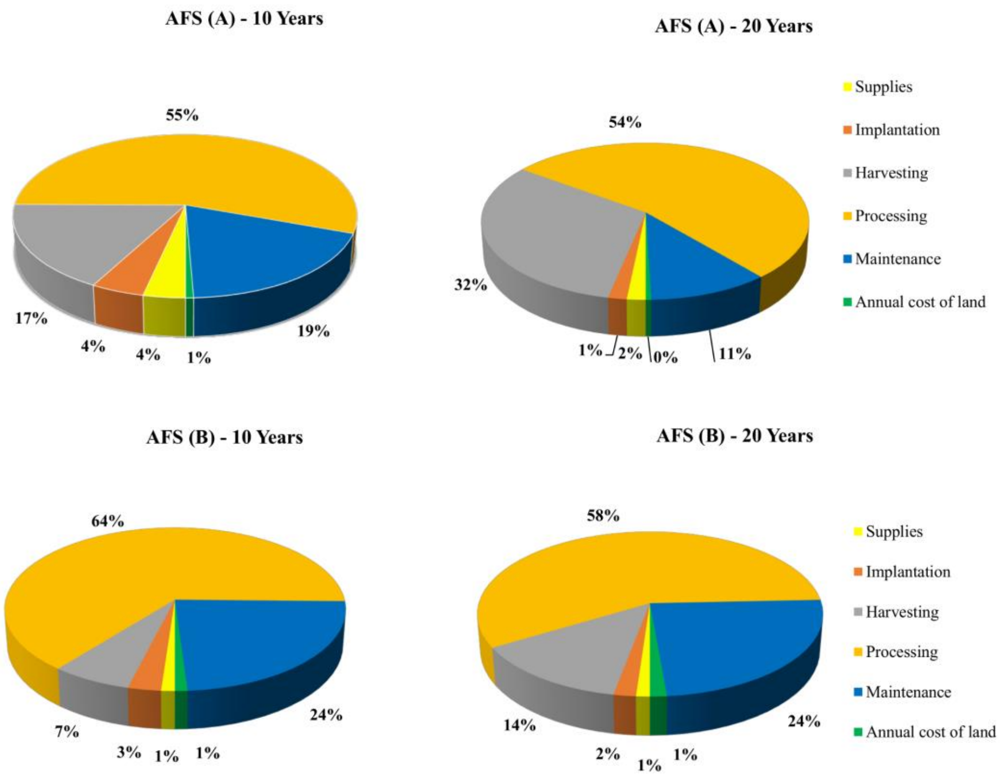

FIGURE 1 - Participation of the components in total cost formation in agroforestry systems in Alenquer, Pará State, Brazil
Source: Prepared by authors in 2013.

The cost of maintenance was the second highest cost of AFS A and B over a 10 year outlook, followed by harvesting, implantation, supplies and annual cost of land. However, cost of harvesting was the second highest for AFS A, over a 20 years outlook, followed by maintenance, supplies, implantation and annual land costs (Figure 1).

For activities that constituted the processing costs, in the AFS A breaking the cumaru fruit constituted 40.7% and 77.2%, over the 10 and 20 years planning outlooks respectively. In the AFS B, cassava processing (husking, washing, trituratying, pressing, sifting and roasting flour) influenced 91.8 % and 67.0% of the total costs over 10 and 20 years, respectively.

Cassava flour production in the AFS A decreased over time and was less than AFS B by 47.0%, providing an actualized revenue of R$23442.48. In the AFS B, it remained constant in the first and second years of production, only decreasing in the third year, constituting an income of R$33929.37.

Almond production occurred after the fourth year following an increasing trend, adding to AFS A a quantity 8.3 times higher when compared to AFS B, presenting an actualized revenue of R$22583.16 over 10 years and R$81277.46 over 20 years. The AFS B system presented an income of R$2707.81, over 10 years, and R$9745.50, over 20 years.

3.2. Cash flow

Cash flow was negative in AFS A only in the first year. It made a non-actualized net income of R$5345.90 in the tenth year and R$13700.83 in the twentieth year. AFS B demonstrated lower values when compared to AFS A during same period, R$207.91 and R$1053.91 respectively.

In both agroforestry systems, cassava production, that has a medium cycle, started in the second year and it was possible to pay for implantation costs, resulting in positive liquid profits. However, after its exclusion from AFS B, profits were negative between the fifth and seventh years.

3.3. Economic analysis

The majority of AFS economic indicators, except average cost of production on AFS B, showed values that demonstrate systems economic viability. However, AFS B showed better economic indicators on the 10 years planning horizon. Conversely, AFS A offered bigger profits along the time.

NPV and EPB showed the same trend. For the 10 years planning outlook, AFS A was approximately 8% below the AFS B. However, over the 20 years outlook, the economic indicators for AFS A were 2.7 times greater than the those presented by the ASF B. The increasing production of cumaru fruits is an explanation for that behavior, showing that AFS A is more attractive than AFS B (Table 4).

Benefit-cost ratio analysis showed values for both AFS greater than 1, indicating economic viability. It means that for each R$1.00 invested, the financial return for AFS A was R$0.46 and R$0.86; while for AFS B it was R$0.75 and R$0.79 (Table 4).

Average cost for almond production in AFS A was 3 times and 2.3 times less than in AFS B, over a 10 and 20 years planning outlook, respectively. However, the ACP for flour in the AFS A was 33% greater than for the AFS B, over 10 and 20 years (Table 4).

TABLE 4 - Economic indicators of agroforestry systems (AFS) for 10 and 20 planning outlook, in Alenquer, Pará State, Brazil

Economic indicators	Unit	10 years		20 years	
		AFS - A	AFS - B	AFS - A	AFS - B
NPV	R$ ha^{-1}	14444.91	15666.39	48286.58	17902.70
EPB	R$ ha^{-1} year^{-1}	2056.63	2230.54	4557.91	1689.89
BCR	-	1.46	1.75	1.86	1.79
LEV	R$ ha^{-1}	28980.11	31461.67	64712.70	23738.06
ACP almond	R$ kg^{-1}	18.20	55.49	11.79	26.26
ACP cassava flour	R$ kg^{-1}	1.19	0.80	1.19	0.80
ACPFL	R$ day^{-1}	4.77	53.98	44.95	50.97

Source: Prepared by authors in 2013.

The LEV was greater than the medium land price in the region, which classifies both AF systems to be economically viable. The average for labor is greater than the cost for opportunity in the region (R$30.00). It means that the daily wage paid to the farmers in other activities is less than what they earn on their farms.

3.4. Sensitivity analysis

Of the six variables analyzed, only average cost for almond production in AFS B made the AFS unviable, but a variation of 20% changed the NPV. In the 10 years outlook, the cost that had the biggest impact on AFS A was the price of cassava flour, that changed the NPV by ± 32.5%, reducing it to R$9756.41 or increasing it to R$19133.40. Over the 20 year outlook the price of almond provoked a change of ± 27.0% in the NPV, reducing it to R$35237.50 or increasing it to R$61335.66. In the AFS B the price of flour caused further changes, provoking, over the 10 years outlook, a variation of ± 43.3% in NPV, reaching R$8880.51 e R$22452.26. Over the 20 years outlook, it varied by ± 37.9%, which in absolute values were R$11116.83 and R$24688.58.

On the other hand, the variable with least impact on AFS A was the value of R$20.00paid for the labor, which caused a change of ± 5.4% ans ± 1.5%, over 10 and 20 years respectivelly. The AFS B was little influenced by the price of almonds, which led to pertubations of ± 3.5%. Over the 20 years outlook, the labor price of R$20.00 influenced the criteria by ± 4.6%.

4. DISCUSSION

The higher cost for processing in agroforestry systems was due to its greater labor intensiveness in comparison to other activities. Labor is an important supplier into NTFP production, making it a determinant of the cost of production (CALDERON, 2013). The labor used in the extractor has low yield, increasing its cost (HOMMA, 2012).

High system maintenance costs over the 10 years outlook were due to the large amount of weeding, especially in the first four years, owing to the presence of cassava. Graça, Rodigheri and Conto (2000) observed that forestry plantations and agroforestry systems are activities with a high maintenance cost. The cost of harvesting in AFS A over 20 years was due to higher production of cumaru fruits in this system, because it has a greater number of trees. Harvesting costs vary proportionally to the volume produced (POKORNY; PALHETA; STEINBRENNER, 2011).

Breaking the cumaru fruit increased the total costs of processing in the AFS A by 46.6% (over 10 years) and 82.7% (over 20 years) of total processing labor, for this activity alone. In the AFS B the value paid for labor to toast the flour was very high.

The reduction of flour production in AFS A occurred because cassava spacing decreased over time, reducing its quantity. The cassava spacing in AFS B was reduced in the third year of production, because it had a larger spacing than AFS A. Spatial arrangements with greater land use and wider spacing between the lines of the forest component in agroforestry systems allow intercropping with agricultural crops over longer periods (OLIVEIRA et al., 2009).

The higher production of cumaru almonds in AFS A was due to the greater number of trees in the system, with less spacing between the trees. When the forest has a greater number of trees in operation, the total volume of the non-timber product can be increased, as was the case with copaiba oil-resin in Acre (BALZON; SILVA; SANTOS, 2004). However, a very high number of trees per hectare can affect the production of some fruits, such as bacuri (HOMMA et al., 2007). The low density of many non-timber products decreases land productivity (HOMMA; CARVALHO; MENEZES, 2001). More densely spaced trees compete over time for light, due to excessive shading, water and nutrients, reducing productivity, as was already observed in the combination of cocoa and rubber tree (MÜLLER and GAMA-RODRIGUES, 2012). This fact may imply the cultivation of cumaru in systems with less spacing, because this species depends on luminosity for its development in the forest (ALENCAR and ARAUJO, 1980; KANASHIRO and SIST, 2011) and it has a leafy canopy with extensive branching (CARVALHO, 2009), consequently affecting production. The canopy size is directly proportional to production (OLIVEIRA, 2009)

The negative cash flow during the first year in the AFS is due to costs related with supply, implantation and maintenance activities, such as the number of cumaru seedlings, cleaning of the area, alignment, flagging and manual pit of cumaru, cumaru planting, preparation of cuttings, manual pit and planting the cuttings, weeding and pest control. However, the presence of a negative cash flow at the beginning of AFS activities is common. Sanguino *et al.* (2007a; 2007b) also observed a negative cash flow in first year of an AFS in Pará state, with mahogany (*Swietenia macrophylla*), African mahogany (*Khaya* sp.), Australian cedar (*Toona ciliata*), cupuaçu (*Theobroma grandiflorum*) and caupi beans. Among three different AFS analyzed by Bentes-Gama *et al.* (2005) in Rondonia only AFS T_1 (castanha-do-brasil [*Bertholletia excelsa*], banana [*Musa* sp.], pimenta-do-reino [*Piper nigrum*] and cupuaçu [*Theobroma grandiflorum*]) presented positive cash flow in the first year.

The sale of cassava flour contributed positive liquid profits in the systems analyzed. Cordeiro *et al.* (2009), showed that the crop of annual or medium cycle with forest species allowed the repayment of the initial outlay to establish AFS. However, even with the presence of short cycle cultures in AFS B, it was not possible to offset initial outlays, and cash flows remained negative. After cassava harvesting in AFS B, profits were negative for three years, which suggests a need for spacing revaluation and management improvement. Other short cycle species could be introduced during the initial period to offset costs (OLIVEIRA et al, 2010; DIAS-FILHO, 2011), considering species genetic material availability, total relevant market and consideration of their ecological group and interactions with the environment.

The higher production and greater market potential of cassava flour in the region allowed AFS B to be more economically attractive over 10 years. However, the high production of cumaru in AFS A, due to its smaller size and larger number of trees, made this system more viable economically over the 20 years outlook. Augustin and Cruz (2015) claims that profitability is more significant in higher fruit yields. According to Oliveira and Carneiro (2011) a higher production results in the greater capital in circulation.

The profit of the analyzed systems was superior to most of the systems with a minimum of 3 species studied by Francez and Rosa (2011) with 10 years planning outlook, in a municipality of Pará state. Sanguino et al. (2007a) and Paula (2011) observed less profit in a 25 years planning outlook than in a 20 years AFS A.

The low production costs of cumaru almonds in AFS A were due to a high almond yield which offset production costs. The low cost of flour production in AFS B was due to high cassava production. If the farmers only cultivate cassava, their profits could be greater than those observed in AFS B, however what motivated farmers to plant cumaru was the diversification of production, reduction of risks, and environmental and cultural gains given that, previously in Alenquer there was many cumaru trees in the natural forests, but deforestation had reduced their numbers (IDESP, 2011).

The LEV found in this study was greater than that determined by Santos, Rodriguez and Wandelli (2002) for four models of AFS in western Amazon. The remuneration of AFS stimulates family members to develop AFS on their properties, because they are paid for the activity. Sá *et al.* (2000), Sá *et al.* (2002) and Santos *et al.* (2002) also confirmed that forest activities also remunerate the labor of the farmers.

Despite all AFS being economically viable and bringing in additional profit for the farmer, there was a lack of technical support, to help them with effective management, to stimulate an increase in production and, consequently, a more sucessful plantation. This limitation was also observed in other locations in Pará state by Francez and Rosa (2011), Pompeu *et al.* (2009) and Vieira *et al.* (2007).

Through the sensitivity analysis, the farmer can better manage the changes with a greater influence on profits, such as almond and flour prices and they can ignore those which do not reduce profits. The AFS will remain economically viable, if the value of the variables remains constant.

Beyond the economic returns that the AFS gave to farmers and their family, the environmental and social benefits that increase quality of life of the family and community were not measured. Taking this into account, it is necessary to realize future research aiming to determine the scale of these benefits. A comparative analysis with cassava and cumaru monocultures could be carried out, supporting the farmers' decisions about production system.

Another proposal is to realize research aiming to identify other management options for these AFS, analyzing better formation, identifying which components are necessary for fertilizing, monitoring production and determining the efficiency of pruning, given that in fruit production this treatment needs to be carefully carried out according to previously studied criteria. Pruning at predetermined times (RAMOS et al., 2011) can assist in fruit production (GONÇALVES et al., 2014).

The economic outcomes seen in this study are prior to market price, which depends on external factors such as supply, demand (OBIZHAEVA and WANG, 2013) and economic crises, as well as other factors. Given this, if there are changes to supply but demand remains constant, the price of almond and flour can change, positively or negatively affecting the economic performance of these systems, according to the degree of sensitivity of cumaru and cassava to price. Because of this, the farmer needs to be aware of this tendency in the market.

5. CONCLUSIONS

The total costs of agroforestry systems A were greater than those of agroforestry systems B, but the agroforestry systems A, with smaller spacing, was more attractive. The economic criteria indicate that AFS are viable, for both planning outlooks. The production of cumaru almond in agroforestry systems can be an investment option to diversify production and increase the income of the region's farmers. However, taking into account all labor benefits, the economic return on AFS will be less.

The farmers must be alert to variation in price of almonds and flour to maintain their profits. If they posess another source income and adequate area for the implantation of this type of AFS in Pará state, this form of production is a profitable choice, because the money invested is capitalized over the medium term.

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