



Production and cash flow of oil palm intercropping systems an amazonian degraded area

Raimundo Nonato Carvalho ROCHA^{1*}, Maria do Rosário Lobato RODRIGUES²,
Ricardo LOPES², Alex Queiroz CYSNE², Jeferson Luiz Vasconcelos de MACEDO²

¹Empresa Brasileira de Pesquisa Agropecuária, Embrapa Pesca e Aquicultura, Palmas, Tocantins, Brasil.
²Empresa Brasileira de Pesquisa Agropecuária, Embrapa Amazônia Ocidental, Manaus, Amazônia, Brasil.
(ORCID: 0000-0003-3617-5112; 0000-0002-5559-9685; 0000-0003-3943-4159; 0000-0002-5327-2128)
*E-mail: raimundo.rocha@embrapa.br (ORCID: 0000-0003-3093-6144)

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ABSTRACT: The objective of this study was to analyze the technical viability and cash flow of intercrop cultivation in the first three years after oil palm planting in a degraded area of the Amazon. Four intercropping systems were tested: SI - oil palm + banana; SII - oil palm + cassava; SIII - oil palm + pineapple, and SIV - oil palm in monoculture. Intercropping was performed during the first three years of oil palm planting and the cash flow of the systems evaluated during this period. The oil palm bunches production was evaluated from 7th to 10th year after planting. SIII had best financial performance, with deployment and maintenance costs 100% amortized over the three years of the system. The SI and SII systems amortized 86.7% and 64.5% of the costs, respectively. Oil palm bunches production was not affected by intercropping. Yield of intercrops was similar to that expected from the crops in monoculture. The intercropping systems evaluated provide a technically and economically viable alternative to generate income and amortize planting and maintenance costs during oil palm juvenile phase in degraded areas of the Amazon.

Palavras-chave: costs; *Elaeis guineensis*; integrated production.

Produção e fluxo de caixa de dendezeiro com culturas intercalares em área degradada na Amazônia

RESUMO: O objetivo deste estudo foi analisar a viabilidade técnica e o fluxo de caixa do cultivo de culturas intercalares nos três primeiros anos após o plantio do dendezeiro em área degradada da Amazônia. Foram testados quatro sistemas de cultivo: SI - dendezeiro + banana; SII - dendezeiro + mandioca; SIII - dendezeiro + abacaxi e SIV - dendezeiro em monocultivo. O cultivo intercalar foi realizado durante os três primeiros anos de cultivo do dendezeiro e o desempenho financeiro dos sistemas avaliado pelo fluxo de caixa neste período. Para verificar a influência das culturas intercalares na produção do dendezeiro na fase adulta foi avaliada a produção de cachos do dendezeiro do 7º ao 10º ano após o plantio. O SIII apresentou melhor desempenho financeiro, com os custos de implantação e manutenção 100% amortizados nos três anos do sistema. Os sistemas SI e SII amortizaram 86,7% e 64,5% dos custos, respectivamente. A produção do dendezeiro não foi afetada pelos cultivos intercalares. A produtividade dos cultivos intercalares foi similar à esperada no monocultivo das espécies. Os cultivos intercalares testados são uma alternativa técnica e economicamente viável para gerar renda e amortizar os custos de implantação e condução do dendezeiro na fase jovem da cultura em áreas degradadas da Amazônia.

Keywords: custos; *Elaeis guineensis*; produção integrada.

1. INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.) is responsible for most of the vegetable oil produced in the world, around 38.2% in the 2016/17 crop, followed by soybeans, which in the same period accounted for 29.2% of production (UNITED STATES DEPARTMENT OF AGRICULTURE - USDA, 2017).

The worldwide consumption of vegetable oil is increasing and is expected to reach 240 million tons by 2050 (CORLEY, 2009). This growth in consumption will also be accompanied by an expansion of oil palm cultivation, especially in the humid tropics, a climate to which the species is very well adapted.

In Brazil such expansion must occur on areas that have already been deforested, as provided in the Law Project 7.326/2010, and under the *Programa de Produção Sustentável da Palma de Óleo* (Oil Palm Sustainable Production Program). Agroecological Zoning for oil palm cultivation in deforested areas of the Legal Amazon identified more than 30 million hectares of deforested areas suitable for oil palm cultivation (RAMALHO FILHO et al., 2010).

Commercial production of oil palm bunches begins at the end of the third/beginning of the fourth year after planting. In this unproductive period of approximately three years, a large investment of resources occurs with no immediate fiscal recompense. This is one of the main obstacles to the

expansion of the crop, especially for family farmers (LIMA et al., 2002).

An option for income generation in the juvenile phase (unproductive) of oil palm, is to grow annual or semi-perennial plants between rows of palms, which also allows for more efficient exploitation of environmental resources such as soil, space, sunlight and CO₂ (NCHANJI et al., 2016; AYNEHBAND et al., 2010; REZIG et al., 2010; ABERA; FEYISA, 2009).

In Malaysia, Ismail et al. (2009) cultivated banana, pineapple, peanut and soybean between rows in the oil palm unproductive phase and showed this to be technically and financially viable in all studied options. In Brazil, Alves et al. (2015) studying oil palm intercropping systems in Roraima, reported different economic performances, depending on the crop arrangements and cultivation locations.

The current study analyzed the technical viability and cash flow of intercropping systems in the first three years after oil palm planting in a degraded area in Central Amazonia.

2. MATERIALS AND METHODS

The study was conducted at the Suframa Agricultural District Experimental Station/Embrapa Western Amazon, located at km-54 on the BR-174 (2° 31' S, 60° 01' W), altitude 102 meters. The local climate is hot and humid, with average

temperatures from 25-28°C and annual rainfall between 2,000 and 2,800 mm. The annual relative humidity is high (between 85 and 90%), and luminosity ranges from 1,500 to 3,000 hours/year of solar radiation.

According to the results of the analysis performed before the experiment was installed local soil is a Yellow Latosol with very clayey texture, low available nutrient content and high aluminum saturation (Table 1). The pH was measured in water (ratio 1:2.5), the nutrients P, Na, K, Fe, Zn, Mn, Cu were extracted by the Mehlich-1 method, Ca and Mg were extracted by the KCl 1 mol L⁻¹ method and H+Al⁺ by Calcium Acetate extractor 0.5 mol L⁻¹ (pH 7.0). Particle size analyzes were based on the pipette method and the textural classification and performed following Santos et al. (2013).

The experimental area was covered by native forest until 1977, when forest removal occurred and *Brachiaria humidicola* pasture was established for cattle raising. In 1986, the animals were removed and the area abandoned to natural regeneration. Prior to the preparation of the area for the experiment in 2003, the area was covered with capoeira-type vegetation, with low green biomass production, consisting mainly of herbaceous species (*Borreria verticillata* and *Rolandra fruticosa*), shrubs and trees from the genera *Vismia*, *Solanum*, *Anona* and *Laetia*. Preparation of the experimental area was occurred between January to February 2004, with the clearing and of the cover vegetation, and the removal and harrowing of the area.

Tabela 1. Características químicas e físicas do solo da área, antes da implantação do experimento, obtidas por amostragem da camada de 0 a 20 centímetros de profundidade.

Table 1. Chemical and physical characteristics of the soil of the area, prior to experiment initiation, obtained by sampling the layer from 0 to 20 centimeters in depth.

Chemical analysis									
pH H ₂ O	C	M.O.	N	P	K	Ca	Mg	Al	H+Al
	----- g / kg-----		(%)		-----cmol _c / dm ³ -----				
4.2	13.7	23.7	1.32	1.00	13.80	0.21	0.07	0.83	5.59
Physical analysis									
Course sand	Fine sand	Total sand	Silt	Clay	Texture classification				
-----g / kg-----									
104.8	29.1	134.0	180.0	686.0	Very clayey				

Soil acidity was corrected with application of 1.5 t ha⁻¹ of dolomitic limestone. The Oil palm seedlings were planted in June 2004, with a spacing of 9 m x 9 m in an equilateral triangle (143 plants ha⁻¹). Between oil palm rows (7.8 m) was alternated an inter-row where spontaneous vegetation that had covered the soil before the preparation of the area for planting was piled, and other used for intercrops cultivate. The intercrops were cultivated keeping 1.5 m away from oil palm rows, occupying area of 4.8 m wide in inter-rows.

The experiment was established in a randomized block using a factorial scheme, with four intercropping systems, with and without liming, and three replications. Each oil palm plot contained 48 plants (eight rows of six plants), being four inter-rows of the plot used for intercropping. The intercropping treatments consisted of: System I – Two rows of the banana cultivar Thap Maeo were planted in each of the four oil palm inter-rows, with 2.5m spacing between plants and 3.0m between rows. Each plot consisted of 168 plants, occupying 37% of the total plot area (a density of 494 banana plants ha⁻¹). Subsequent management followed the recommendations for northern region banana cultivation of GASPAROTTO; PEREIRA (2010). Harvesting occurred at 11, 16 and 23 months after planting. Immediately after

harvesting, the bunch fresh weight was obtained, then the hand of the each bunch was removed and weighed, thus giving the weight of hands. System II - Three successive cultivation cycles of five rows of cassava, cultivar Aipim Manteiga, planted in each of the four rows of oil palm with a 1.0 m x 1.0 m spacing. Each plot consisted of 1080 plants (a density of 3,200 cassava plants ha⁻¹), occupying 32% of plot total area. Crop management followed cassava cultivation recommendations for the State of Amazonas (DIAS et al., 2003). Harvesting occurred eight months after planting. Yield was assayed using fresh weight of harvested roots. System III - Four double rows of a traditional pineapple variety used by farmers in the region in 1.0 m spacing between double rows with 0.4 m between row and 0.4 m between plants in a row. Each pineapple plot consisted of 1,928 plants (a density of 12,850 pineapple plants ha⁻¹) occupying 36% of the total plot area. Crop management followed the recommendations for pineapple cultivation in the State of Amazonas (SILVA et al., 2004). Fruit harvesting began 15 months after planting and ended 18 months after planting. Number and weight of fresh fruit were evaluated. Fruits were classified into three categories: prime (weight > 1.5 kg), second (weight 1.5-1.0 kg) and third (weight <1.0 kg). System IV - Oil palm

monoculture in conventional system, using cultivar BRS C2501, with between rows weed control by mechanical mowing. Crop management followed recommendations for oil palm cultivation in the Amazon (VIÉGAS; MULLER, 2000). Cluster production was recorded in the adult phase, from the 7th to the 10th year after planting. Harvesting occurred every 15 days across the 48 study months. Bunch production was expressed in kg ha⁻¹ year⁻¹ of fresh fruit bunches (FFB), total number of bunches (NB), in units ha⁻¹ year⁻¹ and mean bunch weight (BW), obtained by FFB/NB ratio, in kilos.

For cash flow analysis of the four cultivation systems, production cost and the revenue from the sale of production were considered. Cash flow, the object of analysis, is represented by the net nominal revenue that results from the subtraction of the inputs (revenues) from the outputs (costs) (SANTANA, 2005).

Cost calculations included manual operations (crop planting, management and harvesting), mechanized operations (area clearing), inputs (organic and chemical fertilizer, limestone, seeds, seedlings and pesticides), equipments and tools. Human labor costs were calculated considering a daily remuneration of R\$ 20.00 for the first and second year, and R\$ 30.00 for the third year of the experiment. For inputs, equipment and tools, average prices in the Manaus market from 2004 to 2006 were considered.

To calculate revenues, prices paid to producers in the Manaus market at harvest time were used: R\$ 0.50/kg of bananas in the 1st, 2nd and 3rd cycle; pineapples R\$ 1.20/unit for prime-quality, R\$ 0.80/unit for 2nd and R\$ 0.30/unit for 3rd-class fruits and R\$ 0.24/kg fresh cassava

root for 1st crop, R\$ 0.30 for the 2nd crop and R\$ 0.40 for the 3rd crop.

3. RESULTS

Oil palm bunch production in adult phase, evaluated from the 7th to the 10th year after planting, did not differ statistically between the four cropping systems for any of the three evaluated variables (Table 2), FFB, NB and BW, indicating that the cultivation of the intercropped species did not influence oil palm productive performance.

Liming at the time of tillage also had no significant effect on the variables of oil palm cluster production during the evaluation period. The average annual yield of oil palm clusters was approximately 21 t ha⁻¹ in all four forms (Table 3).

Intercropped banana plantation yields were 7,980 kg ha⁻¹, equivalent to 21,568 kg ha⁻¹ under monoculture. For cassava roots, mean intercrop yields across three cultivation cycles was 6,370 kg ha⁻¹, equivalent to 19,906 kg ha⁻¹ under monoculture. For pineapple 11,732 fruits were harvested per intercropped ha, equivalent to 32,589 fruits ha⁻¹ under monoculture.

The cost per hectare, considering planting and maintenance during the first three years of system cultivation, ranged from R\$ 12,729.45 to R\$ 9,418.74 between intercropped systems, and R\$ 7,016.28 for oil palm monoculture (Table 4). Considering human labor used for area preparation, seedling planting, post-implantation management and harvesting, this component represented the majority of the costs in the evaluated systems, ranging from 37% for oil palm monoculture to 48% in oil palm + banana system.

Tabela 2. Resumo da análise de variância do peso total de cachos de frutos frescos (PTC), número total de cachos (NTC) e peso médio de cachos (PMC) de dendezeiro, avaliado do 7º ao 10º ano após o plantio, em quatro sistemas de cultivo (monocultura e consórcios nos três primeiros anos após o plantio com banana, macaxeira e abacaxi), com e sem calagem.

Table 2. Summary of variance analysis of total weight fresh fruits bunch (FFB), total number of bunches (NB) and mean bunch weight (BW) for oil palm, assayed across 7-10 years after planting, in four cropping systems (monoculture and intercropping in the first three years after planting with banana, cassava and pineapple), with and without liming.

FV	DF	FFB (PTC)		NB (NTC)		BW (PMC)	
		QM	F	QM	F	QM	F
System (Sys)	3	896946	0.04 ^{ns}	20477	0.265 ^{ns}	1.12	0.84 ^{ns}
Liming (Lim)	1	1215765	0.05 ^{ns}	18721	0.242 ^{ns}	0.18	0.14 ^{ns}
Sys*Lim	3	1221087	0.53 ^{ns}	61956	0.801 ^{ns}	0.86	0.65 ^{ns}
Residual	16	2305940		77331		1.32	
CV (%)		22.9		13.7		11.2	

^{ns} – not significant at 5% = probability (F test) SV – Source of Variation; DF – Degrees of freedom; MQ – Medium quartile.

Tabela 3. Produtividade de cachos de frutos frescos (PTC) do dendezeiro e das culturas intercalares, frutos de abacaxi, cachos de banana e raízes de mandioca, cultivadas nas entrelinhas nos três primeiros anos após o plantio do dendezeiro.

Table 3. Fresh fruit bunch (FFB) yield of oil palm and intercropping crops, pineapple fruits, banana hands and cassava roots, grown between the oil palm rows in the first three years after planting

Cultivation system	FFB ¹ for oil palm (kg bunches ha ⁻¹ yr ⁻¹)	Yield of intercrops per cultivation cycle ²		
		Intercropped	Monoculture ⁴	Unit
Oil palm monoculture	20,891.4	-	-	-
Oil palm + Pineapple	20,467.8	11,732	32,589	Fruits ha ⁻¹
Oil palm + Banana	21,353.6	7,980	21,568	Kg bunches ha ⁻¹
Oil palm + Cassava	21,177.2	6,370	19,906	Kg roots ha ⁻¹
Mean	20,972.5	-	-	-

¹ Mean value of harvests from seventh to tenth year after planting for one hectare with 143 plants ha⁻¹; ² Banana: total of three harvests, made 11, 16 and 23 months after planting. Cassava: mean value of three cultivation cycles harvested at eight months after planting. Pineapple: total fruits harvested from the 15th to the 18th month after planting; ³ Yield of intercropping cultivated between oil palm rows, considering one hectare of banana system occupying 37%, cassava 32% and pineapple 36% of total area; ⁴ Yield under monoculture estimated from the mean plot values, retaining the same planting density used in the intercropping.

Tabela 4. Custo total do monocultivo do dendezeiro e dos sistemas de cultivos intercalares do dendezeiro com abacaxi, banana e mandioca durante os três primeiros anos após o plantio do dendezeiro, e percentual de participação dos principais componentes no custo total de produção.

Table 4. Total cost of oil palm monoculture and oil palm intercropping systems with pineapple, banana and cassava during the first three years after planting oil palm, and percentage of participation of major components in total production cost.

Production components	Cultivation System				
	Oil palm	Oil palm + Pineapple	Oil palm + Banana	Oil palm + Cassava	
Total Cost (R\$)	7,016.28	11,295.00	12,729.45	9,418.74	
	Participation of each component (%) in total cost				
Area preparation	Mc ¹	17	11	10	13
	Mn ²	5	5	6	5
Fert ⁵	Ch ³	25	33	29	25
	Or ⁴	-	-	3	-
Pesticides	-	3	-	-	-
Equipments and tools	4	3	3	4	4
Post-implantation	37	29	29	36	36
Seedling	12	12	12	10	10
Harvest	-	4	8	7	7

¹ Mc – mecânico; ² Mn – manual; ³ Ch – Chemical; ⁴ Or – Organic; ⁵ Fert. – Fertilizers. Productivity extrapolating average plot values to one hectare of monoculture with the same planting density as used during intercropping.

The second component with the largest cost share was fertilizer, ranging from 25 to 33% among the systems tested. And considering all the evaluated systems it was observed that the costs generated in the first year of cultivation ranged from 51 to 66% of the total costs per hectare.

In the oil palm monoculture system, total cost per hectare, including preparation/planting and maintenance in the unproductive phase, that is, until the third year after initiation, was R\$ 7,016.28 (Figure 1A). In the oil palm + pineapple intercropping system, the total cost per hectare, considering system implementation and maintenance across three years was R\$ 11,295.47 (Figure 1B). The pineapple crop cycle varied from 16 to 18 months, so it provided no revenue in the first year. In the second year the gross revenue of the system was R\$ 11,636.00 per hectare, producing 6,766 first; 4,115 second and 750 third-class fruits, traded at R\$ 1.20, R\$ 0.80 and R\$ 0.30 per unit, respectively. Total revenue from pineapple crop, including amortizing 100% of system during implementation and maintenance costs, gave a net revenue of R\$ 340.53 at the end of the three years.

For the oil palm + banana system, in the first year after planting there were only costs. The sale of banana in hands produced in the second and third year gave total gross revenues of R\$ 11,031.00 ha⁻¹, corresponding to 86.7% of system implementation and maintenance costs (Figure 1C).

For the oil palm + cassava crop, due to the cassava crop cycle being just eight months, there was revenue generation in the first year of cultivation, with R\$ 1,473.36 generated from 6,146.00 kg ha⁻¹ of fresh roots. For all the three years, gross revenue of R\$ 6,079.26 ha⁻¹ was obtained (Figure 1D), this value covers 64.5% of the implantation and maintenance costs of the system.

Under the conditions of this study, in Manaus municipality, it was possible to amortize the system implementation costs with pineapple cultivation, reaching the equilibrium point in the 3rd year after planting. Thus, from the first year of oil palm harvest (the fourth year after planting), incurred costs would relate only to maintenance, with the producer already obtaining net income.

4. DISCUSSION

The annual average value of FFB observed in this study was similar to that estimated by Silva (2006) from commercial

plantation FFB production in the state of Pará for cultivars Deli x La Mé (that includes the BRS C2501 cultivar used here). However, Ramalho Filho et al. (2010) highlight that this cultivar has a productive potential of 25 to 30 t of FFB ha⁻¹ year⁻¹, values that were not attained during the evaluation period. This lack of high production levels can be attributed to planting site pedoclimatic conditions, especially the soil, with had low fertility and a very clayey texture. In addition, according to equations for estimating yields of FFB given by Silva (2006), increases in productivity are still expected ten years after planting. Therefore, considering the planting age and the pedoclimatic conditions of the experimental area, an acceptable level of oil palm productivity was reached, one similar to those found in commercial plantations in the Amazon (Silva, 2006).

For intercrop cultivation, considering the edaphoclimatic conditions under which the experiment was conducted and the potential of the cultivars or species used, good overall yields were obtained. According to Gasparotto et al. (1999) the productive capacity of the Thap Maeo banana cultivar in Amazon Region low fertility soils may reach 25,000 kg hands ha⁻¹. The cassava cultivar Aipim manteiga, harvested between 8 and 10 months after planting has production potential of around 15,000 to 17,000 kg of roots ha⁻¹ (Dias et al., 2003). For pineapple, as it is a regional variety grown by local producers, there are no yield estimates reported in the literature. However, according to the recommendations for pineapple cultivation in the Amazon (SILVA et al., 2004) it is possible get up to 42,000 fruits ha⁻¹. Averages yields achieved by intercrops and oil palm demonstrates the technical feasibility of these intercropping oil palm systems during the first three years after oil palm planting.

Most of the cultivation practices in the systems were performed manually, including part of the area preparation, planting, thinning, fertilization, control of spontaneous vegetation in the palm crown and inter-rows, as well as the harvesting. This is typical of the operational system of a small family farmer. In the study by Alves et al. (2015), which evaluated seven oil palm intercropping systems, including annual and semi-perennial plants, in different associations with cowpea, corn, peanut, cassava, banana and pineapple crops, the authors also identified for almost all systems the labor as main cost component. As in family agriculture

manual labour is performed predominantly by the family, intercropping systems of oil palm cropping with annual or semi-perennial crops can provide an excellent alternative for income generation and amortization of oil palm implementation costs during three first years after planting, unproductive phase of oil palm cultivation.

A study in Pará by Muller; Furlan Júnior (2001) obtained similar results for the participation of labor in oil palm cultivation production costs. The authors noted that the costs of such agricultural operations as tillage, nursery, planting, mowing, pruning and fertilization, all of which are predominantly carried out manually by the family farmer, represent the largest percentage of total production costs. These ranged from 27% to 67% in practically all phases of the oil palm production cycle. The authors found fertilizers to be the second most important production cost. The total first year cultivation costs for the current study match those of Lopes et al. (2015), who observed values greater than 50% in first year oil palm intercropping systems in Roraima, Brazil. Nchanji et al. (2016), in a study conducted in Cameroon, noted that acquisition of seeds and seedlings represented

34% of the costs in the implementation and maintenance phase of different food crops intercropped with oil palm. However, these authors did not include in the analysis the costs related to labor, which according to San Cortés (2003) is predominantly family-based in small production units in Cameroon.

For oil palm monoculture system the total cost per hectare was similar to the costs reported by Lopes et al. (2015) in Roraima, R\$ 8,086.56, and somewhat higher than the total cost per hectare in the state of Pará, R\$ 4,746.00 (AGRIANUAL, 2011).

For an oil palm monoculture in Pará, Muller and Furlan Júnior (2001) reported that the equilibrium point of the agricultural component was reaching at the 9th year after oil palm planting. Anticipating the break-even point of agricultural component of oil palm plantation due to income from intercrops can substantially contribute to increasing viability of oil palm cultivation by family-based farming. The choice of the species to be cultivated in intercropping with oil palm will depend on the analysis of the demand and value paid for products in the local market.

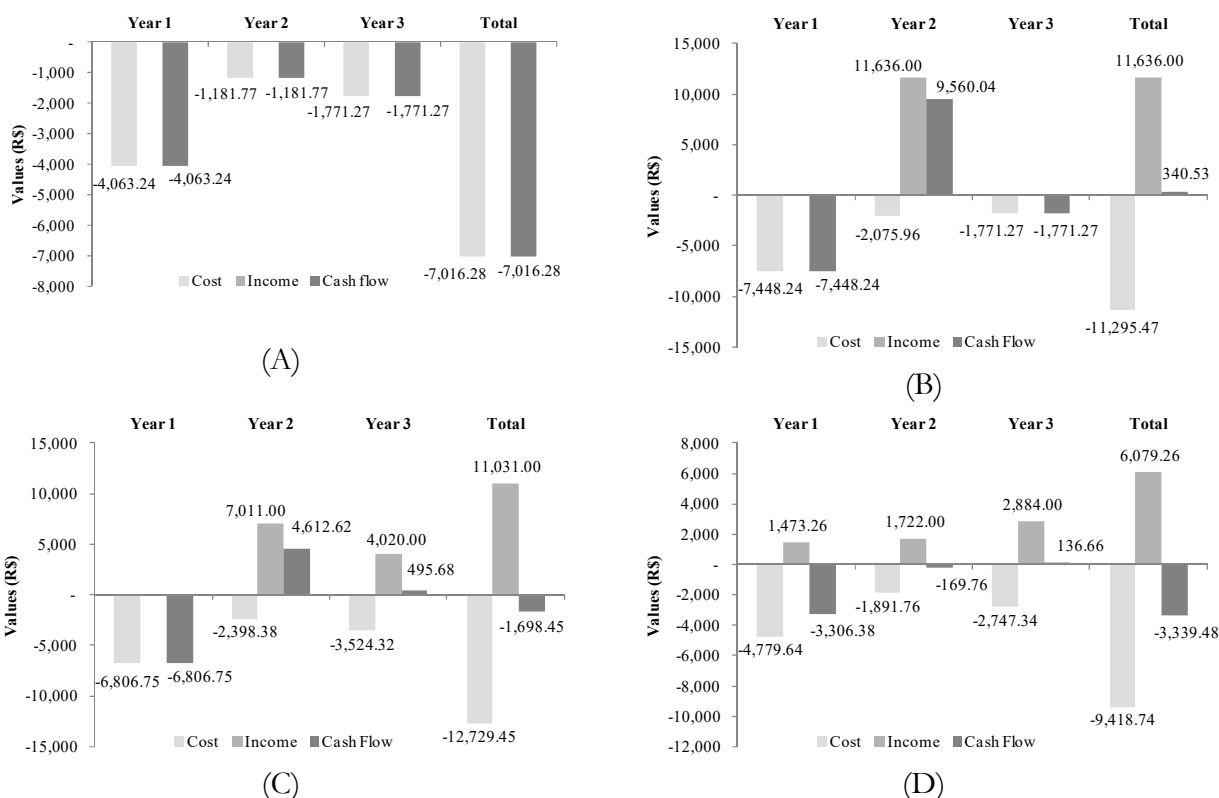


Figura 1. Custo, receita e fluxo de caixa do dendezeiro em monocultivo (A) e com o cultivo intercalar de abacaxi (B), banana (C) e mandioca (D) durante três anos pós-plantio do dendezeiro.

Figure 1. Cost, income and cash flow for oil palm monoculture (A) and intercropping with pineapple (B), banana (C) and cassava (D) for three years after planting oil palm.

The use of cash flow to compare oil palm intercropping systems allows the producer to choose those systems giving the highest net nominal revenue (PADOVEZE, 2011). However, if poorly planned, this can lead to erroneous decisions jeopardizing the producer's investments (HANSEN; MOWEN, 2013).

The possibility of generating income in the unproductive phase of oil palm cultivation, as is possible via intercropping systems, provides a means of circumventing one of the main constraints of family-based oil palm cultivation, the

generation revenue to pay for the implementation and maintenance costs of the crop in the unproductive phase and also to support the producers until the sale of oil palm bunches production begins. Nchanji et al. (2016) also point out that the use of intercropping in the young phase of oil palm plantations helps not only to amortize the costs of planting the crop, but also to maximize the use of the area with income generation, reducing the need for small producers to deforest land in order to plant food crops during the unproductive oil palm period. Thus, the proposed

systems has the potential to provide agricultural, social, economic and environmental benefits.

5. CONCLUSÕES

Cultivation of pineapple, banana and cassava intercropped between the oil palm rows, in the initial three years, does not affect the oil palm productivity when the appropriate cultivation recommendations are adopted.

The yield of the crops: pineapple, banana and cassava, grown between rows of oil palm in the three years after planting is similar to that obtained from monocultures of these crops.

The cultivation of pineapple, banana and cassava between oil palm rows, during the three years after planting, is a technically and economically viable alternative for income generation and amortization of oil palm implementation and maintenance costs during its non-productive initial phase.

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