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# Economic analysis and generation of certificates of reduced emissions in cupuassu trees in Belém, State of Pará

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## ABSTRACT

The objective of the work was to quantify the plant biomass and analyze its potential for generating Reduced Emission Certificates - CERs in the cupuassu tree crop. For the purpose of economic analysis, all costs and revenues involved in the activity and the estimated cash flow for a 25-year plan were raised. Based on the cash flow, the Net Present Value, the Internal Rate of Return, and the sensitivity analysis were calculated, varying the levels of the main economic variables. The carbon stock in the cupuassu plantation at 25 years old was 14,901 t C $ha^{-1}$. The estimated carbon stock for planting cupuassu at 25 years was 54.68 t C $ha^{-1}$, corresponding to 393 CERs/ha. It is concluded that cupuassu is a crop capable of storing carbon in its biomass for an extended period of time.

**Keywords:** Cupuassu tree, Reduced emission certificates, Economic analysis, Carbon storage.

## Análise econômica e geração de certificados de redução de emissões em cupuaçuzeiros em Belém, Estado do Pará

## RESUMO

O trabalho teve como objetivo quantificar a biomassa vegetal e analisar o potencial de geração de Certificados de Emissão Reduzida - RCEs na cultura do cupuaçuzeiro. Para efeito de análise econômica, levantaram-se todos os custos e receitas envolvidos na atividade e o fluxo de caixa estimado para um planejamento de 25 anos. A partir do fluxo de caixa foram calculados o Valor Presente Líquido, a Taxa Interna de Retorno e a análise de sensibilidade, variando os níveis das principais variáveis econômicas. O estoque de carbono na plantação de cupuaçuzeiro aos 25 anos era de 14.901 t C $ha^{-1}$. O estoque de carbono estimado para o plantio de cupuaçuzeiro aos 25 anos foi de 54,68 t C $ha^{-1}$, o que corresponde a 393 RCEs/ha. Conclui-se que o cupuaçuzeiro é uma cultura capaz de armazenar carbono em sua biomassa por um longo período de tempo.

**Palavras-chave**: Cupuaçuzeiro, Certificados de emissão reduzida, Análise econômica, Armazenamento de carbono.

## 1. Introduction

The large number of gases emitted as a result of human activities, mainly the burning of fossil fuels and deforestation, has been causing the accumulation of carbon in the form of $CO_2$ in the atmosphere and, consequently, the rise in global temperature. Seeking to establish measures to reduce the emission of Greenhouse Gases (GHG), the Kyoto Protocol was ratified, which determines deadlines and targets for GHG reductions and provides flexibility mechanisms. Among these mechanisms, the Clean Development Mechanism (CDM) stands out, which allows developed countries to offset their emissions by financing environmental projects based in developing countries.

Within this economic context, the State of Pará finds itself in an extremely valued position, since it has ample environmental space. In this way, companies and highly industrialized countries, forced to curb global warming by reducing gas emissions, will be able to participate in reforestation projects and promote the adoption of clean technologies in the region. Pará has its greatest wealth in the environment. Environmental preservation can be the source of foreign exchange inflows into the State. Pará would receive for its low emission of gases and for the enormous environmental capacity of absorption and atmospheric regeneration.

As most of Pará's $CO_2$ emissions come from deforestation and fires, the State's greatest contribution to reducing emissions would be through mitigation and control of deforestation and fires. Pará has large areas devoid of vegetation, but with a high potential for planting and conserving forests, which could be used for carbon sequestration projects. Even though this area is located around projects that emit carbon, a large part of this emission would be absorbed by the forest, incorporating the now atmospheric carbon into the plant biomass, which defines a carbon sequestration project.

A project translates into the investment of resources for some time, in the expectation of obtaining products in subsequent periods. In this way, it almost always makes sense to analyze one or more sequences of investments, within a determined or pre-established period of time or planning horizon (Rezende and Oliveira, 2001). In this context, the cupuassu tree in consortium with açaí trees presents itself as a project option for the generation of CERs and a candidate for election as a CDM project.

The cupuassu tree has normally been planted in a wide spacing, allowing intercropping with other crops. It is quite suitable for this purpose since it is a crop that needs shading from the implantation phase to the production phase. Considering this, the objective of this research was to quantify plant biomass and analyze its potential for generating Emissions Reduction Certificates - CERs in the cupuassu crop.

## 2. Material and Methods

The study was carried out using C stock data obtained in the cupuassu tree experiment intercropped with açaí trees in an area of Embrapa Amazônia Oriental, Belém, State of Pará, located between the coordinates comprising an irregular polygon of 2,706.48 hectares limited by the coordinates 01º24'59 " and 01º27'40" south latitude, and 48º20'55" and 48º26'59" west longitude of Greenwich, encompassing areas of the municipalities of Belém and Ananindeua, 200 meters above sea level. The average monthly temperature in Belém is 28ºC, with a relative humidity of 80%.

The "Biomass Quantification and Generation of Carbon Credits" was carried out in an area of 4,300 $m^2$, where the cupuassu tree culture had been planted in a space of 5 x 5 m with two progenies (186 and 215). For the biomass data collected in the field, a sampling of five trees was used, from each progeny at each of the ages, using the direct (or destructive) tree method (Carmo et al., 2004). The whole cupuassu stem was weighed to obtain the total biomass and a disk-shaped sample of approximately 2.5 cm thickness was taken from the lower, middle, and upper thirds, based on a study by Oliveira Neto et al. (2003).

In the set of branches, fragments of all the branches located in different positions of the tree crown were taken, which were mixed, forming a composite sample. From this sample, a subsample of 500 g was taken, which was properly weighed and labeled. The total dry biomass of the cupuassu tree was determined through the sum of the dry biomass of the tree compartments and in each year of the experiment. Then, this value was extrapolated to 1 ha, considering a density of 400 cupuassu plants spaced 5 x 5 m.

After the samples of the plant components were previously dried and crushed, the carbon estimate was made, where the total carbon contents were determined, at the Ecophysiology Laboratory of Embrapa Amazônia Oriental, using the methodology of (Bezerra Neto and Barreto, 2004). The carbon stock was extrapolated to tons per hectare. Due to the fact that negotiations in the carbon credit market are carried out based on $CO_2$ equivalent, it became necessary to convert carbon into $CO_2$. The conversion of carbon into $CO_2$ equivalent ($CO_2$eq) was carried out according to the methodology adopted by Face (1994).

For the purpose of this study, it was considered that there were no market demand restrictions for the evaluated product and that the entire amount of carbon stored could be converted into carbon credits, in other words, the baseline of the project was that no carbon was stocked in the soil. The validity or not of the carbon credits was not considered in the study, as its objective was to evaluate the potential for carbon

storage by planting the cupuassu tree, for possible negotiations with carbon credits. It is important to point out that there are also other components in the cupuassu plantation where carbon is stored, such as the fruits and the soil, which were not accounted for in this study.

The quantification of CERs and the economic analysis were carried out for a simulation of a cupuassu plantation with a production cycle of 25 years. The estimate of the cupuassu tree's carbon stock from the seventh to the twenty-fifth year was based on the work of Teixeira and Oliveira (1999), who obtained an average increase at 20 years of age of 0.71 t C ha/year with cocoa. These procedures were adopted because the plants belong to the same family and have similar characteristics.

It should be noted that, in the case of forestry projects that are submitted for approval by the CDM Executive Committee, the accounting of CERs must be carried out taking into account the difference between the amount of carbon fixed by the project at the end of the cycle and the amount of GHG (greenhouse gases) emitted by the burning of fossil fuels, use of fertilizers, plant decomposition, etc. during its production chain, plus what was in place before the project was implemented. However, this balance was not carried out in this study; emphasis was placed only on accounting for the CERs corresponding to the carbon fixed in the cupuassu tree compartments, considering that the initial carbon stock in the area was equal to zero.

Cash flow represent estimates of income and expenditure of monetary resources on a given productive project over time. The net result of this flow is calculated by subtracting the revenues from the project expenses, associated with each period (Santos et al., 2002). All costs and revenues incurred in the project were organized annually in a cash flow, according to Rezende and Oliveira (2001).

These values were updated using financial formulas, for a given moment in the time horizon. The discount rate applied was 10% per annum. This rate was chosen because it is widely used in the analysis of forestry projects and also because it is recommended by the Center for Integrated Studies on the Environment and Climate Change of the Ministry of the Environment, in the document that deals with the eligibility criteria and sustainability indicators for the evaluation of CDM candidate projects (BRASIL, 2002). The costs used to carry out the economic analysis were those related to labor and inputs used to carry out the following activities: implantation of planting (preparation of the area, acquisition of seedlings and planting), maintenance (cultural treatments), and harvest.

In order to analyze the economic viability of the cupuassu tree culture, two situations were studied: a) cupuassu without generation of CERs: the economic analysis was carried out considering only the costs of the forestry project and the revenues obtained from the sale of the cupuassu fruit; b) cupuassu tree with the generation of CERs: in this scenario, in addition to the costs of the forestry project and the revenues obtained from the sale of the fruit, the cost of the carbon credits project and the revenue from the sale of the CERs were also included.

The cost related to the carbon project to obtain the CERs refers to the following steps: project definition and preparation, feasibility study, negotiation, baseline determination, monitoring plan, certification, and validation. In the present study, the cost of obtaining CERs was estimated considering a fixed cost per project of US$ 260,000 (R$ 423,800.00, considering US$ 1.00 equal to R$ 1.63), a value suggested by the World Bank (2004) and a project size that results in the absorption of 50,000 t $CO_2$eq./year, which, according to Haites (2004), is the minimum economically viable project size for generating CERs.

Based on this minimum project size and the cupuassu plantation's CER generation capacity, which was 2.19 CERs ha year, due to the accumulation of 54.68 t $CO_2$eq./ha at the end of the 25 years of the project, estimated It is known that an area of 22,831 ha (50,000 t CO2eq./year divided by 2.19 t CO2eq./ha year) will be needed to absorb 50,000 t CO2eq./year, which is equivalent to 50,000 CERs/year. Thus, the cost of preparing the project to obtain the CERs, per hectare, was estimated by diluting the fixed cost of the project by the planting area, corresponding to the value of R$ 18.56/ha (R$423,800.00 divided by 22,831). It was considered that this cost occurred in the year of implementation of the forestry project.

Income from the cupuassu plantation were those related to the sale of the fruit and the CERs. The cupuassu revenues were obtained by multiplying the annual production by the respective market prices. The price considered for selling the cupuassu fruit was R$ 1.00, the price received by the producer (Sagri, 2011). Revenues from the sale of CERs were obtained by multiplying the ton of $CO_2$ by the price of US$ 16.3531, as suggested by Haites (2004) and Lecocq (2004). It was considered that the revenue obtained with the CERs occurred in year 1 of the project so that the transactions necessary for issuance and commercialization (project elaboration, identification of investors, preparation of documentation, determination of the baseline, etc.) were carried out in the year of implementation of the forestry project.

The economic analysis was carried out using the criteria, according to Rezende and Oliveira (2000) and

Silva et al. (2002). The economic viability of a project analyzed by the NPV method is indicated by the difference between revenues and costs, updated, at a given discount rate. A project will be economically viable if its NPV is positive at a given rate of interest.

$$VPL = \sum_{j=0}^{n} Rj(1+i)^{-j} - \sum_{j=0}^{n} Cj(1+i)^{-j}$$

Where: NPV= net present value; Rj = revenue in the year; Cj = cost in the year and i = discount rate.

The Internal Rate of Return is the discount rate that equals the current value of (future) revenues to the current value of (future) costs of the project, that is, it is the rate at which the NPV is equal to zero, thus reflecting the rates discount rates of the project for which the investor equals benefits and costs. If the IRR is greater than the discount rate required by the investment, it is concluded that the project is viable.

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

Where: Rj = revenue in a year; Cj = cost in a year; i = discount rate; j = occurrence period of the cost or revenue and n = duration of the project, in years.

Sensitivity analysis was performed for the NPV criterion, considering the scenario in which the sale of CERs was included. For this purpose, the interest rate, the labor cost item, the prices of the cupuassu fruit, and of the CERs were submitted to a variation of their values of -20% and +20%, identifying leveling points between the different uses. Due to the variation in costs and prices in that range, they may vary due to the maintaining of the project viability, in terms of the NPV criterion.

## 3. Results and Discussion

The carbon stock and the amount of accumulated $CO_2$ from the first to the seventh year are shown in Table 1. It can be seen that the results from the first to the seventh year of the research point to a C stock of 2.12 t $ha^{-1}$ and for the amount of $CO_2$ of 7.77 t $CO_2$ $ha^{-1}$. In order to arrive at the final results up to the twenty-fifth year of production, the results found by Teixeira and Oliveira (1999) were adopted.

The total carbon stocks in the different parts of the cupuassu plant (stem, leaves, primary branches and secondary branches) and their respective percentages are shown in Table 1. The total carbon obtained in the seven years of the experimented was added to those found by Teixeira and Oliveira (1999), from the eighth to the twenty-fifth year as a comparison between cultures, thus obtaining the total carbon stored in the cupuassu tree the age of 25, Table 2.

**Table 1.** Estimate of the carbon and $CO_2$ (eq) of the cupuassu tree at 25 years of age

| Planting length | Carbon (tC/ha) | Stock of $CO_2$ (eq) ($tCO_2$/ha) |
|---|---|---|
| Cupuassu tree (1-7 years) | 2.121 | 7.78 |
| Cupuassu tree (8-25 years) | 12.78 | 46.90 |
| Total | 14.901 | 54.68 |

**Table 2.** Estimative and percentage values of carbon stock in cupuassu tree compartments at 7 years of age.

| Tree compartment | Carbon (kgC/ha) | Percentage value (%) |
|---|---|---|
| Stem | 350.57 | 16.53 |
| Primary branches | 453.31 | 21.38 |
| Secundary branches | 692.27 | 32.64 |
| Leaves | 624.62 | 29.45 |
| Total weight | 2,120.77 | 100.00 |

Thus, the CERs generated by the planting of cupuassu correspond to 54.68 t $CO_2$ $ha^{-1}$, referring to the carbon stored in the tree biomass of the cupuassu tree. Although there are other components where carbon is stored in the cupuassu tree culture (fruits, litter and soil), the CERs were accounted only with the carbon fixed in the biomass of the stem, leaves and branches. Based on this minimum project size and the CERs generation capacity of the cupuassu plantation, which was 2.19 CERs h/year, due to the accumulation of 54.68 $tCO_2$(eq). $ha^{-1}$ at the end of the 25 years of the project, it was estimated that an area of 22,831 ha (50,000 tCO2eq./year divided by 2.19 tCO2eq./ha.year) will be required for the absorption of 50,000 tCO2eq./year, which is equivalent to 50,000 CERs/year.

Thus, the cost of preparing the project to obtain the CERs, per hectare, was estimated by diluting the fixed cost of the project by the planting area, corresponding to the value of R$ 18.56/ha (R$ 423,800.00 divided by 22,831 ha). It was considered that this cost occurred in the year of implementation of the forestry project. In the economic analysis, activities and costs per hectare were considered, referring to a cupuassu planting project defined as low technology, with reduced use of machines, equipment and inputs in its implementation. The activities, production, costs and revenue of cupuassu tree planting without the CERs can show in Table 3.

It can be seen in Table 3 that cupuassu production remained constant from the fourth year to the 25$^{th}$. An average of 20 fruits per plant was considered, in 400 plants on 01 ha with a spacing of 5 x 5 m. The economically viable production starts from the 4th year. Current cash flow from cupuassu plantation without including CERs is shown in (Table 4).

**Tabel 3.** Costs, revenue and production of cupuassu planting without CERs.

| Year | Activities | Cost (R$/ha) | Production (fruits/ha) | Revenue (R$/ha) |
|---|---|---|---|---|
| 0 | Cupuassu tree implantation | 5,500.00 | - | - |
| 1 | Production maintenence | 3,130.00 | - | - |
| 2 | Production maintenence | 3,130.00 | - | - |
| 3 | Production maintenence | 3,130.00 | - | - |
| 4 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 5 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 6 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 7 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 8 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 9 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 10 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 11 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 12 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 13 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 14 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 15 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 16 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 17 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 18 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 19 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 20 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 21 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 22 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 23 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |
| 24 | Production maintenence | 3,130.00 | 8,000.00 | 8,000.00 |

Analyzing the current cash flow from the cupuassu plantation without including the CERs (Table 4), it was found that it was negative until the fourth year, when fruit production began, becoming positive from the 4th year onwards. The negative balance in the first years is justified by the fact that the cupuassu tree plantation does not present revenues until the fourth year and by the increase in costs with the implantation of the culture.

The accumulated cash flow from the cupuassu tree showed that for the scenario without the CERs, the project's profit started to occur only from the fourth year, when the revenues were higher than the costs, remaining so until the end of the project cycle. Even though cupuassu tree planting involves costs in the first few years and revenues only from the fourth year onwards, its cash flow has shown that the activity is profitable. In addition, it should be taken into account that the cupuassu tree has a long cycle, which makes it possible to obtain revenue for a long period of time and practically during all months of the year.

The behavior observed in this cash flow does not differ from those generally found in most forestry projects. High initial costs and long-term revenue are characteristics that often make projects of this nature unattractive. One way to add revenue and minimize the negative cash flow from planting cupuassu would be to implement agricultural crops between the planting rows. However, this possibility was not considered in the present study, since the main objective was to analyze the economic viability disregarding and considering the generation of CERs, which, for the first commitment period of the Kyoto Protocol (2008 to 2012), are valid only for forest species.

The cash flow of the scenario considering the sale of carbon credits differed from the previous one due to the inclusion of the project cost for generating CERs (R$ 168.16/ha) in the year of forest implementation and the increase in revenue (R$ 1,388.03/ha) in the year 1, from CERs (Table 5). It was observed that the revenue from the CERs in year 1, even though it did not allow covering the costs of implanting the cupuassu tree, enabled a greater gain, even without anticipating the return on investment in the 8th year, when compared to the previous scenario. The accumulated cash flow in the following years proved that the inclusion of carbon credits in cupuassu plantation is an option to make the activity more profitable.

One factor that interferes with the prices of CERs is the type of project that will issue the certificates. CERs from afforestation and reforestation projects have been quoted at lower prices. It is alleged that this type of project does not offer security in terms of perpetuity, being subject to the occurrence of accidents (fire, pests) or elimination to be replaced by another type of crop, jeopardizing compliance with commitments regarding the reduction of emissions.

**Table 4.** Cost, revenue and cash flow (current, updated and accumulated) for cupuassu planting without the inclusion of CERs.

| Year | Total cost | Revenue | Cash flow R$/ha | | |
|---|---|---|---|---|---|
| | R$/ha | R$/ha | Current | updated | Accumulated |
| 0 | 5,555.00 | - | -5,555.00 | -5,573.57 | -5,555.00 |
| 1 | 2,845.45 | - | -3,130.00 | -2,845.45 | -8,400.45 |
| 2 | 2,586.78 | - | -3,130.00 | -2,586.78 | -10,987.23 |
| 3 | 2,351.62 | - | -3,130.00 | -2,351.62 | -13,338.85 |
| 4 | 2,137.83 | 5,464.11 | 4,870.00 | 3,326.28 | -10,012.57 |
| 5 | 1,943.48 | 4,967.37 | 4,870.00 | 3,023.89 | -6,988.68 |
| 6 | 1,766.80 | 4,515.79 | 4,870.00 | 2,748.99 | -4,239.70 |
| 7 | 1,606.18 | 4,105.26 | 4,870.00 | 2,499.08 | -1,740.62 |
| 8 | 1,460.17 | 3,732.06 | 4,870.00 | 2,271.89 | 531.27 |
| 9 | 1,327.43 | 3,392.78 | 4,870.00 | 2,065.36 | 2,596.63 |
| 10 | 1,206.75 | 3,084.35 | 4,870.00 | 1,877.60 | 4,474.23 |
| 11 | 1,097.05 | 2,803.95 | 4,870.00 | 1,706.91 | 6,181.13 |
| 12 | 997.31 | 2,549.05 | 4,870.00 | 1,551.73 | 7,732.86 |
| 13 | 906.65 | 2,317.32 | 4,870.00 | 1,410.67 | 9,143.53 |
| 14 | 824.23 | 2,106.65 | 4,870.00 | 1,282.42 | 10,425.95 |
| 15 | 749.30 | 1,915.14 | 4,870.00 | 1,165.84 | 11,591.79 |
| 16 | 681.18 | 1,741.03 | 4,870.00 | 1,059.85 | 12,651.65 |
| 17 | 619.25 | 1,282.76 | 4,870.00 | 963.50 | 13,615.15 |
| 18 | 562.96 | 1,438.87 | 4,870.00 | 875.91 | 14,491.06 |
| 19 | 511.78 | 1,308.06 | 4,870.00 | 796.28 | 15,287.34 |
| 20 | 465.25 | 1,189.15 | 4,870.00 | 723.89 | 16,011.24 |
| 21 | 422.96 | 1,081.04 | 4,870.00 | 658.09 | 16,669.33 |
| 22 | 384.51 | 982.77 | 4,870.00 | 598.26 | 17,267.59 |
| 23 | 349.55 | 893.43 | 4,870.00 | 543.87 | 17,811.46 |
| 24 | 317.78 | 812.20 | 4,870.00 | 494.43 | 18,305.89 |

Pandey (2001) also emphasizes that the time of retention of carbon in the tree is an important consideration for projects that are candidates for the generation of CERs. Based on the fixed cost of the CERs project (R$ 423,800.00) and the sale value of US$ 16. 35/t CO2 (R$ 26.65, considering US$ 1.00 equal to R$ 1.63 ), it was concluded that for the revenue from the CERs to cover this cost, a minimum area of 290 ha planted with cupuassu tree would be necessary, which would imply the generation of 15,900 CERs at the end of the 25 years.

During the 25-year period, the updated total cost of implanting the cupuassu culture per hectare, without and with carbon credits, was R$ 33,677.25 and R$ 33,695.82, respectively. It was found that the cost related to maintenance was the highest, corresponding to 76.67% of the total cost. Of the cost related to maintenance, 83.89% was attributed to labor and 16.11% to inputs. The second component with the highest value was the cost of implanting the cupuassu tree (16.49%). Of this total, 72.46% corresponded to labor, 9.00% to the acquisition of seedlings, and 18.54% to inputs. Lastly, with the lowest contribution percentage, is the cost of cultural treatments with crowning and mowing (6.84%).

Considering the total cost, it was found that 92.89% were related to labor, being distributed as follows: 64.31% in the maintenance stage, 35.69% in the implementation. So, it can be stated that labor is the main component of the total cost of planting cupuassu palms. This fact is attributed to the intensive use of manual practices in all stages of cultivation of this crop during almost the entire year and, also, to the high social charges levied on the payroll of employees.

The absorption of labor and, consequently, the contribution to the generation of jobs and income in rural areas are characteristics that make the cupuassu tree planting able to meet one of the objectives of the CDM: to contribute to the sustainable development. The costs of implanting cupuassu trees may vary according to the region where the project is being carried out, especially the costs related to fertilization and the application of pesticides. This variation can be attributed to the edaphoclimatic characteristics of each location, the type of genetic material used and, consequently, the susceptibility to the attack of pests and diseases on the crops.

**Table 5.** Cost, revenue and cash flow (current, updated, accumulated) for cupuassu planting with the inclusion of CERs.

| Year | Total cost R$/ha | Revenue R$/ha | Cash flow R$/ha | | |
|---|---|---|---|---|---|
| | | | Current | Updated | Accumulated |
| 0 | | 0.00 | -5,573.57 | -5,573.57 | -5,573.57 |
| 1 | | 1,388.03 | -1,741.97 | -1,583.61 | -7,157.18 |
| 2 | | 0.00 | -3,130.00 | -2,586.78 | -9,743.96 |
| 3 | | 0.00 | -3,130.00 | -2,351.62 | -12,095.57 |
| 4 | | 8,000.00 | 4,870.00 | 3,326.28 | -8,769.30 |
| 5 | | 8,000.00 | 4,870.00 | 3,023.89 | -5,745.41 |
| 6 | | 8,000.00 | 4,870.00 | 2,748.99 | -2,996.42 |
| 7 | | 8,000.00 | 4,870.00 | 2,499.08 | -497.34 |
| 8 | | 8,000.00 | 4,870.00 | 2,271.89 | 1,774.55 |
| 9 | | 8,000.00 | 4,870.00 | 2,065.36 | 3,839.90 |
| 10 | | 8,000.00 | 4,870.00 | 1,877.60 | 5,717.50 |
| 11 | | 8,000.00 | 4,870.00 | 1,706.91 | 7,424.41 |
| 12 | | 8,000.00 | 4,870.00 | 1,551.73 | 8,976.14 |
| 13 | | 8,000.00 | 4,870.00 | 1,410.67 | 10,386.80 |
| 14 | | 8,000.00 | 4,870.00 | 1,282.42 | 11,669.23 |
| 15 | | 8,000.00 | 4,870.00 | 1,165.84 | 12,835.07 |
| 16 | | 8,000.00 | 4,870.00 | 1,059.85 | 13,894.92 |
| 17 | | 8,000.00 | 4,870.00 | 963.50 | 14,858.42 |
| 18 | | 8,000.00 | 4,870.00 | 875.91 | 15,734.34 |
| 19 | | 8,000.00 | 4,870.00 | 796.28 | 16,530.62 |
| 20 | | 8,000.00 | 4,870.00 | 723.89 | 17,254.51 |
| 21 | | 8,000.00 | 4,870.00 | 658.09 | 17,912.60 |
| 22 | | 8,000.00 | 4,870.00 | 598.26 | 18,510.86 |
| 23 | | 8,000.00 | 4,870.00 | 543.87 | 19,054.73 |
| 24 | | 8,000.00 | 4,870.00 | 494.43 | 19,549.16 |

For the scenario in which carbon credits were considered, it was found that the cost of CERs was equivalent to 0.16% of the total project cost per hectare. As the cost of CERs is generally fixed per project, it can be inferred that this cost per hectare can be diluted according to the size of the project area or the amount of CERs generated. Furthermore, as the sale of carbon credits is a new activity in the market, it is expected that, as new projects are approved and the methodologies for quantifying emissions and reductions become more simplified, these costs will be reduced, thus providing greater viability to CDM projects.

The value found for NPVs showed that the cupuassu planting provided a profit of R$ 18,287.32/ha and R$ 19,549.16/ha without and with carbon credits, respectively. Comparing the two scenarios, there was a 6,9% increase in NPV when carbon credits were considered. Thus, it can be inferred the inclusion of revenues from carbon credits is an alternative capable of increasing the viability of cupuassu planting and acting as an attraction for investment in projects of this nature. As previously mentioned, it is expected that after the consolidation of the carbon credit market, foreseen by the Kyoto protocol, the price of CERs will increase and the cost of the project to generate these will decrease, consequently, being able to enable even more carbon credits projects.

Using the IRR criterion, it was verified that for the scenario without the inclusion of the CERs, the IRR was 22.08%, which can be considered an above reasonable profitability. However, high interest rates in Brazil and the propensity for risks that forestry projects present (attack by diseases, pests, fire, etc.) are factors that reduce their attractiveness, even if such projects appear to be viable. The increase in the IRR to 23.78% when considering the CERs indicated that the carbon credits provided an excellent return on capital and could be considered an attractive investment in forestry projects. The results of the sensitivity analysis showed that the NPV was sensitive to percentage changes in the prices of CERs and sharp changes in the price of cupuassu, labor cost and interest rate. Among these variables, the ones that most affected the viability of cupuassu planting was the price of cupuassu (Figure 1).

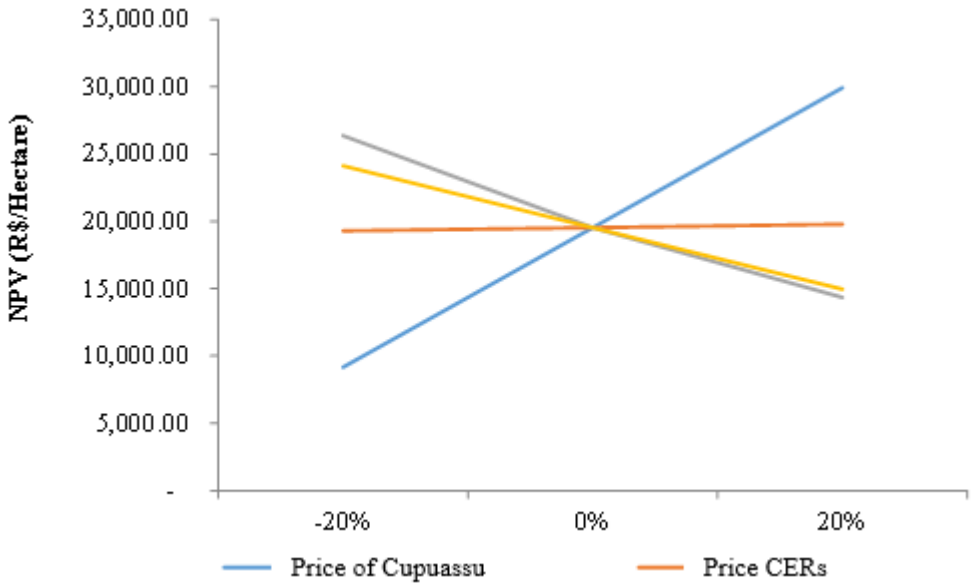


**Figure 1.** Values for cupuassu tree planting, considering the interest rate of the variation percentage, cupuassu price, labor cost and CERs price.

It was also observed that the 20% decrease in the interest rate caused an increase from R$ 19,549.16 to R$ 26,369.92 in the NPV, which corresponded to a 35% increase in the project's viability. The greater variation observed for the NPV criterion due to variations in the interest rate proves that the interest rate is one of the main factors that affect the economic viability of planting the cupuassu crop. This is due to the nature of the cash flow of this type of project, in which costs are incurred from start to finish and revenues only occur after the initial costs, usually after the 6th year.

It was also observed that both the increase and the decrease of 20% in the price of CERs, the viability of planting cupuassu varied by only 1.2 and 1.3%, respectively, remaining stable, therefore. This can be explained because the revenue from the CERs represents a smaller amount when compared to the total cost of the investment; as a result, when interest is incurred, CER revenue is less affected than project costs. Another factor is the period of incidence of interest on revenues and costs. As CERs are traded in year 1, they are less influenced by the discount rate.

The greater influence of the cupuassu price variable on the NPV criterion, in relation to the other variables, is justified by the amount of revenues arising from the product. Through the analyzes carried out, it was verified that, maintaining the production costs and the discount rate of 10% p.a., the project will be economically viable even without the revenues from the CERs.

## 4. Conclusions

The maintenance cost is the main component of the total cost of planting cupuassu, representing 76.46% of it. The transaction cost of the CERs project, per hectare, corresponds to 0.16% of the total cost. The planting of cupuassu is an economically viable activity for scenarios with and without CERs. The CERs increase the viability of planting cupuassu trees by 3.4% in terms of the NPV criterion, which makes the project more attractive.

The interest rate is the item that most affects the economic viability of planting cupuassu trees. For the scenario that considers the sale of CERs maintaining the price of the cupuassu, it may suffer a reduction of up to 46.8%, even though the project remains viable. The planting of cupuassu is a project option with the potential of approval by the United Nations Framework Convention on Climate Change, under the Clean Development Mechanism modality, proposed in the Kyoto Protocol.

## Authors' Contribution

During the experiment, the participation of each member was important for the elaboration of the article. In formatting the data and preparing the statistical analyses, the contribution was made by the members Jessivaldo Galvão and Mauro Pacheco. With regard to writing, it fell to Ismael Viegas, Jessivaldo Galvão, Marco Antônio Santos and Mauro Pacheco. Member Hugo Manoel and Antônia Bronze prepared the bibliographic research and formatted the article according to the magazine.

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