ECONOMICAL VIABILITY OF THE PAYMENT FOR ENVIRONMENTAL SERVICES IN THE STATE OF AMAPÁ USING RISK ANALYSES

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Abstract

The present study analyzed the Payment for Environmental Services (PES) mechanism as an economic strategy for land use policies in the state of Amapá – Brazil, situated in the Western Brazilian Amazon. The state of Amapá presents an area of 142,828 km^2, where the largest part is located north of The Equator, and limited to the east by the Atlantic Ocean, to the south, southeast and west by the State of Pará and to the northwest it borders French Guiana and Suriname. The biomes present in the State of Amapá are significantly represented by the diversity of the Amazonian ecosystems where three great scenarios are predominant: the wetlands, the cerrado and the firm lands that make up respectively 18.55%, 6.87% and 71.86% of the total area. Valuing the opportunity costs in these areas, aiming its conservation or the payment for environmental services (PES) is of great scientific challenge for the Amazonian states. It is necessary to develop econometrical models to execute valuing procedures for the opportunity costs, for example, applying the Monte Carlo Simulation (MCS) to consider the uncertainties in long term decisions. For this, the @RISK software was the statistic tool adopted to elaborate

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economic scenarios for opportunity costs. The Monte Carlo method was chosen and applied to three different land use systems in the State of Amapá. The following types or areas of land use were predominantly considered (wetlands and firm land): 1 – the farming and harvesting of açai for the production of fruits in the floodplain area; 2 – the extensive farming of buffalo cattle in the wetlands and 3 – the planting of manioc (*cassava*) for the production of flour on the firm land. The input variables of the method were the costs and revenues of the referred land use systems. The output variables were represented by financial indicators such as: Net Present Value (NPV); Equal Annual Equivalent (EAE); Internal Rate of Return (IRR) and Benefit-cost Ratio (BCR). Ten thousand interactions were executed in the Monte Carlo Simulation considering a time horizon of twelve years at rates of 6%, 8% and 10% per year. These rates represent the following economical scenarios for opportunity cost: optimistic, most probable and pessimistic, respectively. The results indicate that all three analyzed systems are economically viable, where the farming and harvesting of açai for the production of fruit in floodplains presented the best profitability and low risk, while the extensive farming of buffalo cattle in wetlands presented good profitability and also low risk and the planting of manioc for the production of flour on the firm lands presented the lowest profitability and medium risk. After that, through percentile analysis, the minimum estimated price of the ton of carbon to be annually paid to compensate the opportunity cost in each land use system was calculated for the optimistic, most probable and pessimistic scenarios. The price of the ton of carbon was used for the calculation of compensation, and not the price of the ton of CO_2. It was limited to the municipalities of Mazagão, Oiapoque and Cutias because, for these, presented in the year of 2009 the highest production of açai fruit in floodplains, the largest area of manioc plantation on firm land and the largest buffalo herd in wetlands, respectively. Only one land use system was taken as reference for the opportunity cost basis for the abovementioned municipalities, considering the most

important one among the ones that were analyzed, where the predominant biome firm land, floodplains or wetlands was taken into account. The forest areas considered to the calculation of compensation were the woods and/or natural forests not destined to Permanent Perservation Area (PPA) or Legal Reserve (LR) used by agriculture and also by family enterprises in the State of Amapá. These areas can be kept through economic incentives to the landowners where the PES, including the REDD+ modality, assumes an important role, mainly regarding avoided emissions and biodiversity conservation. The value of the compensation can be even bigger, since the Brazilian Forest Code, still active, foresees that the LR can be used under the sustainable forest management regime. Thus, the small family property should be stimulated to conserve and recover its LR area in a way to obtain earnings by sustainably using the forest. Therefore, the present work tried to demonstrate the most precise value to be paid for the native forest areas used by agriculture and by rural family enterprises in the State of Amapá in the possibility of implementing a PES mechanism.

Key-words: Land use. Family agriculture. Economic viability. Payment for Environmental Services (PES). REDD+. Monte Carlo Simulation. Risk Analysis.

1. Introduction

The Payment for Environmental Services (PES) is a kind of financial transference from the beneficiaries to those who, by means of their activities and practices, conserve nature and contribute to an ecologically balanced environment. This way, connecting the working of the ecosystems to the well-being of humans (Fisher *et al.*, 2009).

The concept of environmental services changed from preservation of nature as a sacrifice of the well-being to the perception of the environment as natural capital. The challenge now is to provoke society to recognize the value of this natural capital, where the valorization of environmental services is the method to resolve this question (Liu *et al*., 2010).

The State of Amapá has perspectives to generate carbon credits from the standing forest, since it has a large strip of preserved forest (CI-Brasil, 2007). Therefore, a more effective economic assessment of the land use systems with closer characteristics to its main forest areas is necessary.

2. Material and methods

A scheme was elaborated to better illustrate the main steps of the methodology applied to this work (Fig. 1).

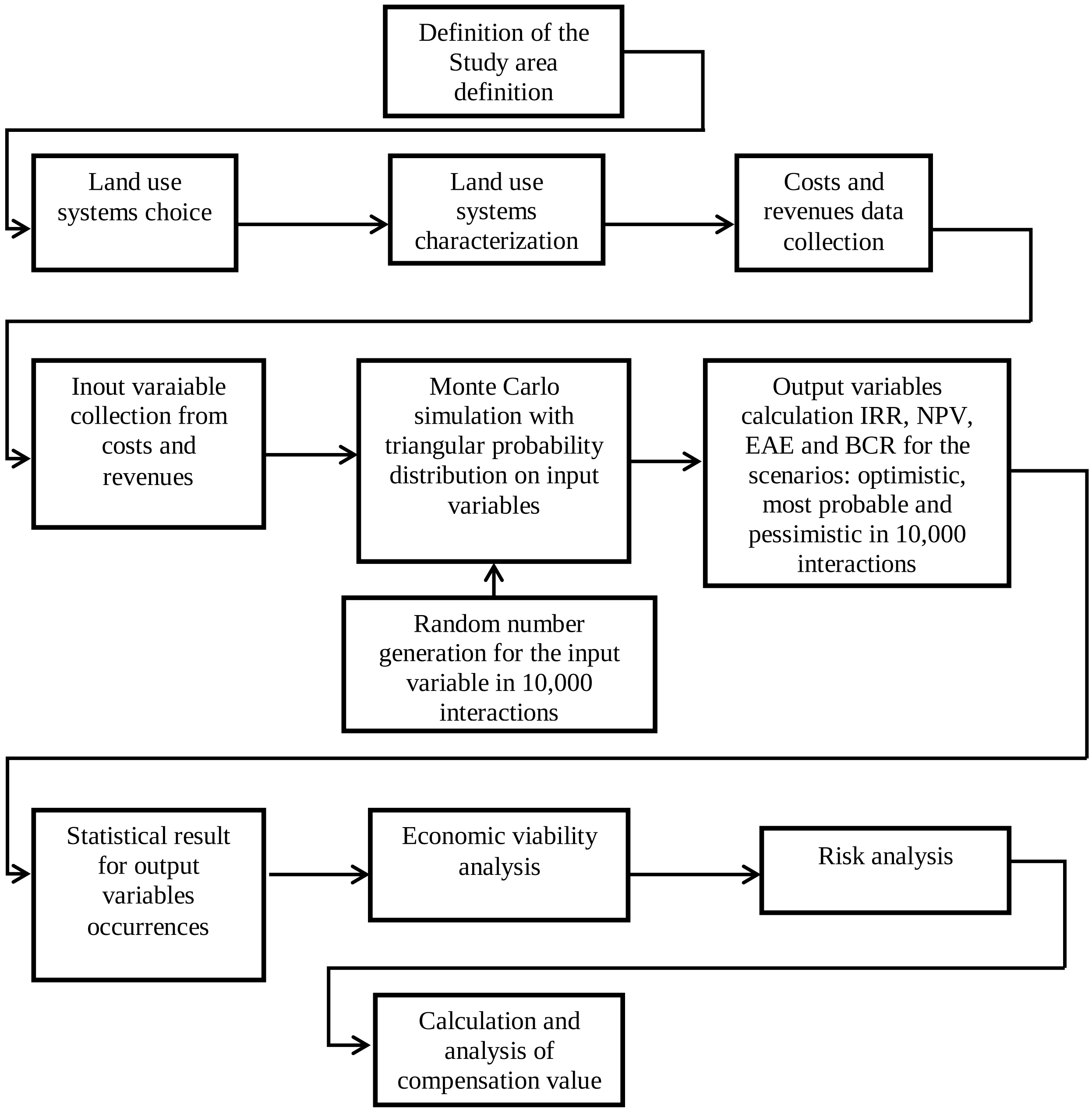

Fig. 1 – Main steps for the elaboration of economic viability analysis, risk and opportunity cost compensation using the Monte Carlo Simulation for three land use systems in the State of Amapá.

2.1. Risk and Uncertainty

Uncertainty is a reflection of the inability to estimate an exact value. It is the lack of knowledge or level of ignorance, on a determined phenomenon that can be minimized by additional measures or more studies on the aforementioned phenomenon (Wu and Tsang, 2004).

Now, as for risk, it can be defined as being a probability of a discrete event that may or may not take place, hence the term chance can be appointed where a negative connotation is not necessarily appropriate. Risk is represented exclusively by an estimation of probability and it can be considered as an estimation of the level of uncertainty (Ross, 2004).

2.2. The Monte Carlo Simulation method (MCS)

According to Hildebrandt and Knoke (2011) the techniques for financial assessment are slowly infiltrating in management related to ecosystems. The decision takers often see themselves facing extremely long time horizons and a lot of uncertainties. This requires careful assessment approaches that, many times, are disregarded.

Most of the approaches used in financial assessments are based on probability distribution comparisons estimated from possible results from investments. The MCS method is commonly used to obtain probability distributions for decision taking considering uncertainty.

The MCS method is a computational algorithm used to assess the uncertainties of a result in a risk assessment. The process involves, initially, the identification and assessment of the main variables that will serve as input to a model. A probabilistic distribution that best describes the degree of uncertainty around the expected value is assigned for each variable. The model combines the input to generate an estimated value for the result. The process is then repeated thousands of times to generate a probability distribution of the possible results. This method has an extra advantage which is that it helps in minimizing the bias of more optimistic or more pessimistic scenarios (Almansa and Martínez-Paz, 2011).

2.3. Study Area

The State of Amapá occupies an area of 142,828 Km², with most of its land located north of The Equator. It is limited to the east by the Atlantic Ocean, to the south, southeast and west by the State of Pará and to the northwest it borders French Guiana and Suriname. The State of Amapá synthesizes in its territory great part of the diversity from the Amazonian ecosystems which, together, represent three great units of landscape (Fig. 2).

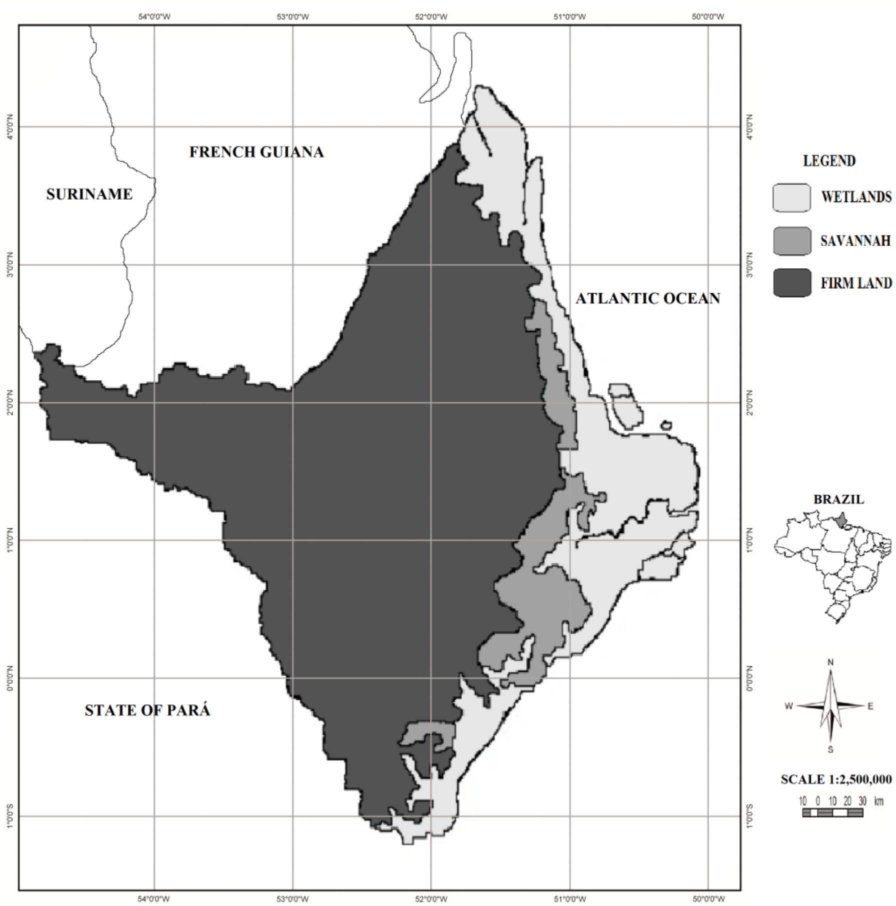

Fig. 2 – Distribution of the three main units of landscape in the State of Amapá

In the coastal plains belt there is the presence of lakes, floodplains and wetlands, all of them of wetland nature and they make up 18.55% of the area of the State, of which 4.85% are floodplain forests and 11.20% are floodplain fields. More to the countryside there are areas of savannah nature and cerrado that represent 6.87% of the area. On the highlands or on firm land the dense large scale vegetation predominates in an area equivalent to 71.86% of the total area of the State of Amapá (IEPA, 2008).

The present study considered only the areas of wetland nature and the firm land used for farming and for rural family enterprises that follow the criteria defined by Law nº 11.326, from July 24th, 2006 that establishes the guidelines for the formulation of the National Policy for Family Agriculture and Rural Family Enterprise, which considers a rural family farmer one who does not hold, in any way, an area larger than 4 fiscal modules[1]; which uses, mainly, family labor and with familiar income mostly originated from the economic activities carried out on their own land.

2.4. The analyzed land use systems

Açai (*Euterpe oleracea Mart*.) is a tropical species that has a purple colored fruit grouped in bunches (Rufino *et.al*, 2010). In the State of Amapá, the acai palm tree constitutes one of the most representative species in the floodplain forests (IEPA, 2008), especially in the city of Mazagão (Carim *et al.,* 2008).

The acai fruit harvesting assumed an importance in the extractive economy, obtained income, occupation and also basic feed for the riverine populations when associated to fish, shrimp or meet (Ferreira, 2006). Besides that, the picking of the fruit can be developed with low

[1] According to the Agrarian development Ministry, one fiscal module for the Legal Amazon is equivalent, in average, to 76 hectares. Available at: < http://www.mda.gov.br>.

impact in the forestall diversity provided they follow simple orientations from handling plans (Queiroz, 2004).

Manioc (*Manihot esculenta Crantz*), also known as cassava, is a woody perennial shrub that is well adapted to low fertility and very acid soils, which are common to the Amazon. It is cultivated along the tropics generally by small farmers without mechanization or inputs (Wilson, 2003).

According to Matos and Bezerra (2003) the planting of manioc in the State of Amapá is carried out through the migratory farming system, based on the itinerant system of "fields" inherited from the indigenous. As a result, large areas of woods with firm land are felled and burned. After successive years of cultivation the area becomes unproductive, due to soil fertility depletion, and it is then abandoned by the farmer. For that reason, manioc production is considered one of the biggest responsible for the environmental degradation in the State of Amapá.

The whole manioc production in the State of Amapá goes to the manufacturing of flour, which presents a yield of 30%, i.e., for each 100 kg of roots, 30 kg of flour is produced. The municipality of Oiapoque is considered the largest producer of flour in the State of Amapá (Domingues, 2004).

According to the IBGE (Brazilian Institute of Geography and Statistics) of 2009 the State of Amapá has the second largest buffalo herd of Brazil, with 201,898 heads, only surpassed by the State of Pará with 442,405 heads. The municipality of Cutias do Araguari has the largest herd in all the State of Amapá.

Buffalos were introduced in Amapá in the 1950s, through the Marajó Island and it constitutes the most expressive segment of livestock in the State. It is characterized for being preferentially a cattle herd, raised extensively in natural pastures, in the wetlands, essentially with family labor. In the summer, when the waters recede, there can be up to 3 heads/hectare (Domingues, 2004).

The extensive farming of buffalos causes a violent environmental impact and it compromises biodiversity (Monteiro, 2009). Therefore, Brito (2008) states that throughout the course of the Araguari river, a river that passes by the city of Cutias do Araguari and flows into the Atlantic Ocean, the extensive farming of buffalos significantly impacts the soil and destroys the river banks. Moreover, Bárbara (2010) affirms that the water quality of the Araguari River already presents clear signs of degradation due to buffalo farming in the region.

Thus, the municipalities of Mazagão, Oiapoque and Cutias do Araguari (Fig. 3) are the biggest representatives of the açai farming and harvesting systems for the production of fruits in the floodplains, manioc planting for the production of flour on firm land and the extensive farming of buffalo in wetlands, respectively.

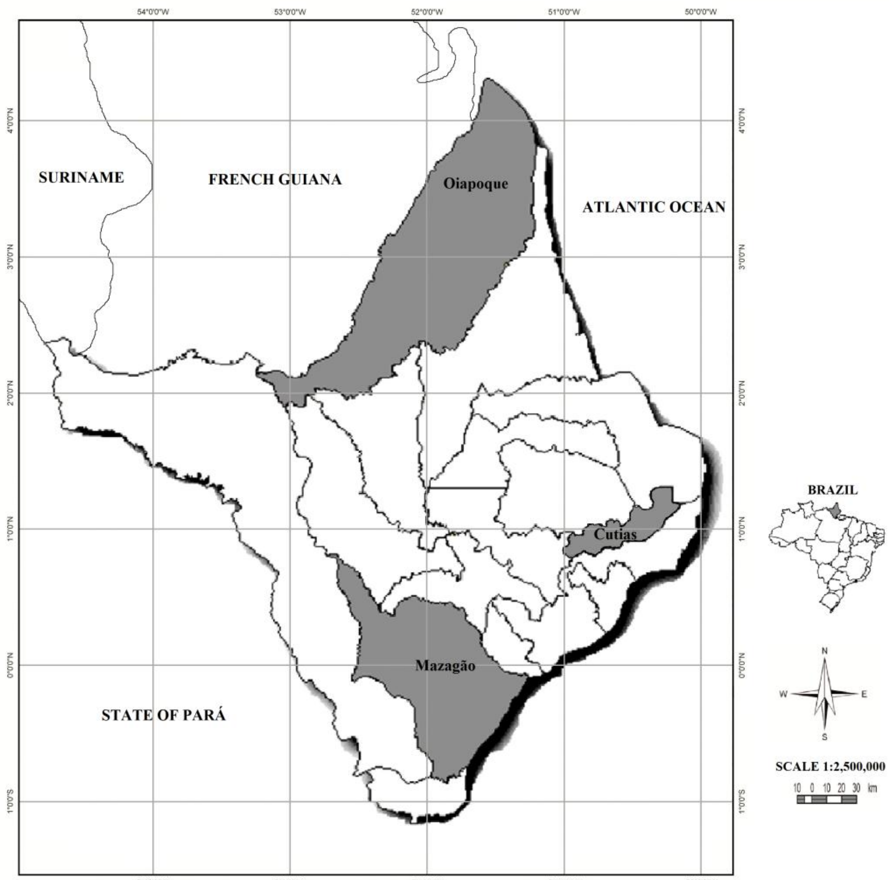

Fig. 3 – Localization of the cities of Mazagão, Oiapoque and Cutias do Araguari in the State of Amapá.

2.5. Estimated carbon storage

2.5.1. Estimated carbon storage for firm land areas

The carbon storage for the firm land areas was estimated at 179.94 tons of carbon per hectare (tC/ha) (personal communication)[2] and it was based on the result from the data analysis of Amapá’s Carbon Project. This project had as main objectives the quantification of carbon storage and the study and assessment of the potentialities of the natural resources from Amapá’s State Forest (IEF, 2008).

[2] Interview with the Director of the Forest State Institue of Amapá (IEF-AP) in may 2010

The destructive or direct method was used in Amapá's Carbon Project. This method consists of felling and weighing a significant number of trees in a fixed quota of a determined area. Thus, it was possible to quantify the biomass that is present in 1 hectare of the study area (Andrade and Higuchi, 2009).

2.5.2. Estimated carbon storage for the wetlands

Due to the absence of studies on the carbon storage for wetlands, that is, floodplains and wetlands, in the State of Amapá, the value of 134.30 tC/ha was considered as an amount reasonable estimated. This particular value was obtained in a work carried out by Santos *et al*. (2004) for the estimation of dry biomass above the soil and agroforest systems carbon storage (AFS) in the floodplains of the Juba River, community of the Juba Island, Cametá, State of Pará. State of Pará belongs to the Brazilian Amazon, being a neighbor of the State of Amapá.

Such consideration took into account the fact that the floodplain forests in the estuarine region of the State of Amapá are dominated by palm trees, where açai is the most common tree, this species is considered very important to the municipality of Mazagão, where the floristic composition of its floodplain forests compared to other floodplain forests of the Amazon present a similarity of occurrence of 55% of the species (Carim *et al.*, 2008).

The work carried out by Santos *et al.* (2004) used the indirect method. In the indirect or non-destructive method the estimatives are produced from forest inventory data that have as finality the exploration planning and forest handling (Higuchi *et al.*, 1998).

2.5.3. Considered areas for the calculation of carbon storage for the cities of Oiapoque, Mazagão and Cutias do Araguari.

The areas that were considered for the calculation of carbon storage for the cities of Oiapoque, Mazagão and Cutias do Araguari are estimated areas of woods and/or forest that are not destined to Permanent Preservation (PPA)[3] or Legal Reserve (LR)[4] used by family agriculture as shown in Table 1.

Table 1 – Estimated areas by city used for family farming

City	Production area (ha)	Woods and/or forest area destined to LR or PPA (ha)	Woods and/or forest area not destined to LR or PPA (ha)	Total area (ha)
Cutias do Araguari	1,627.72	277.18	264.00	2,168.90
Mazagão	9,014.73	1,165.29	9,428.51	19,608.53
Oiapoque	860.30	267.50	447.00	1,574.80

Values obtained from the 1112 table of the Agricultural Census (IBGE, 2006)

2.6. Cash flow formation

The flow of costs and revenues was analyzed for each land use system that was considered; the time horizon was of 12 years and the mean land price in the State of Amapá was obtained from the Brazilian Agriculture Yearbook (AGRIANUAL, 2007).

The data obtained for the cash flow formation of the acai farming and harvesting system for the production of fruits in the floodplains were based on the work carried out by Ferreira (2006) and the data obtained for the cash flow formation for the manioc planting system for the production of flour on firm land were based on the work carried out by Mattos and Bezerra (2003).

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[3] Law 4.771 of September 1965 defines Permanent Preservation Area as na area covered or not by native vegetation, with an environmental role of preserving hydro resources, landscape, geological stability, biodiversity, gene flow of fauna and flora, protect the soil and ensure the well being of human populations.

[4] Law 4.771 of September 1965 defines Legal Reserve as the area located inside a property or rural possession except for the permanent preservation area, necessary to the sustainable use of natural resources, to the conservation and rehabilitation of ecological processes, to the conservation of biodiversity and to the shelter and protection of the native fauna and flora.

The cash flow formation for the extensive farming of buffalo cattle in wetlands was adapted from data based on extensive farming of bovines with 500 Animal Units (AU) [5] obtained from the Brazilian Livestock Yearbook (ANUALPEC, 2007). Such adaptation was necessary, since no acceptable and clear data was found regarding the costs and revenues related to the extensive farming of buffalo cattle in the State of Amapá. Therefore, the cash flow considered that the referred extensive farming takes place, mostly, in natural pastures and with family labor thus disregarding costs with employees' payroll, pasturage, tractors and vehicles and inputs such as mineralized salt and ration.

To update the values on the same timeline, the General Prices Index – Internal Availability (IGP-DI)[6] from the Getúlio Vargas Foundation was used. Hence, all the values considered on this study are updated until March 2012.

2.7. Economic Assessment

The following financial indicators were used to perform the economic evaluation: Net Present Value (NPV); Equal Annual Equivalent (EAE); Benefit-cost Ratio (BCR) and Internal Rate of Return (IRR). These indicators were used in several studies on environmental economic assessment (Robertson *et al.*, 2004; Balmford, *et al.*, 2002; Alvarado *et al*., 2008; Homma, 2010; Bentes-Gama *et al.*, 2005; Tamubula and Sinden, 2000; Silva *et al.*, 2007; Bellassen and Gitz, 2008).

[5] One AU is equivalent to 450 kg of live weight

[6] General Prices Index – Internal Availability is determined monthly by the Getúlio Vargas Foundation. It is a price variation indicator adopted in the national economy and it registers price inflation from raw material, to goods and final services.

2.7.1. Net Present Value (NPV)

Net Present Value (NPV) is an economic concept of profit from a flow of benefits and costs throughout time (Tamubula and Sinden, 2000). A positive NPV (NPV>0) indicates that the expected rate of return of the project is higher than the discount rate, meeting the required rate of return and, therefore, economically viable (Robertson *et al.*,2004). NPV can be represented by the following equation:

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

Where: R_j = revenues in the period j; C_j = costs in the period j; i = discount rate;

j = occurrence period of R_j and C_j; n = duration in years or in number of time periods.

2.7.2. Equal Annual Equivalent (EAE)

NPV, in terms of profit, can be converted into an equal annual equivalent (EAE) (Bryan *et al.*, 2010). EAE can be represented by:

$$EAE = NPV\left(\frac{i((1+i)^n)}{(1+i)^n - 1}\right) \qquad (2)$$

Where; *NPV* = Net present value; *n* = periods in years; *i* = discount rate.

2.7.3. Benefit-cost Ratio (BCR)

This indicator is calculated by the division of present value of benefits by the present value of costs. If the present value of costs exceed the present value of benefits, the BCR will be lower than the unit, (BCR <1), indicating that the project is not viable (Robertson *et al.*, 2004). And so, the project will be considered economically viable if it presents the ratio value higher than the unit (BCR >1), where the higher this value is, more feasible the project will be (Sanguino *et al.*, 2007). The BCR can be represented by the following equation:

$$BCR = \frac{\sum_{j=0}^{n} Rj\left(\frac{1}{(1+i)^j}\right)}{\sum_{j=0}^{n} Cj\left(\frac{1}{(1+i)^j}\right)} \quad (3)$$

Where *Rj* = revenue at the end of the year *j*; *Cj* = cost at the end of the year *j*; *i* = discount rate; *n* = duration in years.

2.7.4. Internal Return Rate (IRR)

IRR can be considered the interest rate annulling the NPV of a cash flow. It represents the marginal efficiency of capital and corresponds, ultimately, to the rate of expected profitability from investment projects. Therefore, the higher the IRR, more desirable the investment will be (Dossa *et al.*, 2000).

The IRR must be higher than a given interest rate *i*, taken an comparison and that reflects the capital opportunity cost. Since this criterion is of long term, it is important to use the Long Term Interest Rate (in Portuguese TJLP)[7] (Sanguino, 2007). In Brazil, the Long Term Interest Rate averaged 8.80% per year[8] in the last 12 years.

The IRR must make the following equality true:

$$\sum_{j=0}^{n} Rj\left(\frac{1}{(1+IRR)^j}\right) = \sum_{j=0}^{n} Cj\left(\frac{1}{(1+IRR)^j}\right) \quad (4)$$

Where: IRR = Internal return rate; the other variables have already been defined.

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[7] The Long Term Interest Rate (TJLP) was instituted by Provisory Measure nº 684, of 31/10/94. It is the rate used by the goverment for the correction of their bonds and also as a basic indexer for loan contracts given by the National Development Bank (BNDES).

[8] Available at: <http://www.bndes.gov.br/SiteBNDES/bndes/bndes_pt/Institucional/Apoio_Financeiro/Custos_Financeiros/Taxa_de_Juros_de_Longo_Prazo_TJLP/>.

2.8. Simulation

The simulations were performed in a model by the @RISK software, version 5.5/2010, on a Microsoft Excel 2010 spreadsheet of the Palaside Corporation in which the costs and revenues of each land use system analyzed were the input variables of the method. Ten thousand interactions were applied for all simulations.

The financial indicators NPV, EAE, IRR and BCR were considered as output variables and were obtained from the net profit of each analyzed system for a 12 year time horizon. The discount rates of 6%, 8% and 10% per year were applied to the aforementioned indicators representing an optimistic, most probable and pessimistic scenario, respectively.

Several authors used models with the @RISK (Tamubula and Sinden, 2000; Bentes-Gama *et al.*, 2005; Silva *et al.,* 2007; Bellassen and Gitz, 2008).

3. Results and discussion

The simulation results returned to the financial indicators a set of parameters, formed by the minimum and maximum value, average, mode, standard deviation, variation coefficient and the percentiles. The percentiles identify the probability of reaching a specific result or associated value with any level of probability.

The use of the variation coefficient was necessary because that this coefficient measures the risk and return variations of a sample more accurately (Gimenes and Famá, 2003). This coefficient is commonly found in agricultural field trials and it is classified as low, when lower than 10%; medium, when between 10% and 20%; high, when between 20% and 30% and very high, when higher than 30% (Lana *et al*., 2005).

The results from the simulations for all three land use systems that were analyzed by this work indicate that IRR assumed values much higher than the rates of 6%, 8% and 10% per year. Results also indicated that NPV and EAE took positive values, that is, (NPV>0) and (EAE>0) and that the BCR presented values higher than the unit (BCR>1) for all verified percentiles for all the analyzed scenarios. Thus, all the abovementioned land use systems are economically viable.

On the subject of risk, the açai farming and harvesting system for the production of fruit in floodplains and the extensive farming of buffalo cattle in wetlands presented, for all scenarios, low dispersion with values below 10%, which indicates that the aforesaid systems are of low risk. Nonetheless, for the manioc planting system for the production of flour on firm land the variation coefficient presented mean dispersion for all scenarios with values between 10% and 20%, which indicates that it is a medium risk system.

3.1. Opportunity cost and compensation

According to Wunder (2008) the opportunity cost is the lost value for not choosing an economic activity that is considered profitable, in favor of forest conservation and that currently does not have economic models or simulation that allow the analysis of opportunity costs in a regional extent, including production systems relevant to family agriculture.

Nepstad *et al.* (2008) calculated conservation opportunity costs in the Amazonian region using simulated economic returns, coming from activities such as soy cultivation, logging and cattle raising. They also calculated the price in money that should be paid to compensate the opportunity cost for forest maintenance dividing the opportunity cost by forest carbon storage of a determined study portion.

3.2. Estimated compensation value

To estimate the compensation value it was necessary to calculate the minimum estimated price of the ton of carbon in $/tC to be annually paid to compensate the opportunity cost for each land use system in the optimistic, most probable and pessimistic scenarios.

The minimum estimated price was obtained by the reason between EAE, which considers net annual profit by hectare of each land use system and the estimated carbon storage by hectare for firm land and wetlands (Table 2).

Table 2 – Minimum estimated price of the ton of carbon for opportunity cost compensation ($/tC)

	Açai farming and harvesting for the production of fruit			**Manioc planting for the production of flour**			**Extensive farming of buffalo cattle**		
	Discount rate			Discount rate			Discount rate		
	6%	8%	10%	6%	8%	10%	6%	8%	10%
Percentiles									
10%	5.01	4.57	4.15	2.67	2.54	2.41	1.17	1.11	1.05
20%	5.22	4.77	4.34	2.96	2.82	2.68	1.23	1.17	1.10
30%	5.37	4.92	4.48	3.17	3.03	2.89	1.27	1.21	1.14
40%	5.51	5.05	4.61	3.34	3.20	3.06	1.30	1.24	1.17
50%	5.64	5.17	4.72	3.51	3.37	3.22	1.34	1.27	1.21
60%	5.76	5.29	4.83	3.68	3.54	3.39	1.37	1.31	1.24
70%	5.90	5.42	4.96	3.87	3.72	3.57	1.41	1.34	1.28
80%	6.06	5.58	5.10	4.07	3.92	3.77	1.45	1.39	1.32
90%	6.27	5.77	5.29	4.35	4.20	4.05	1.51	1.44	1.37
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

From the estimated woods and/or native forest area not destined to LR or PPA, from the estimated carbon storage for the firm land or wetlands and from the minimum estimated price for the ton of carbon it was possible to calculate the annual estimated compensation value (ECV_A) for all three land use systems (Figs. 4, 5 and 6).

The discount rate influenced the compensation value for all the systems, the higher the discount rate, lower the annual estimated compensation value.

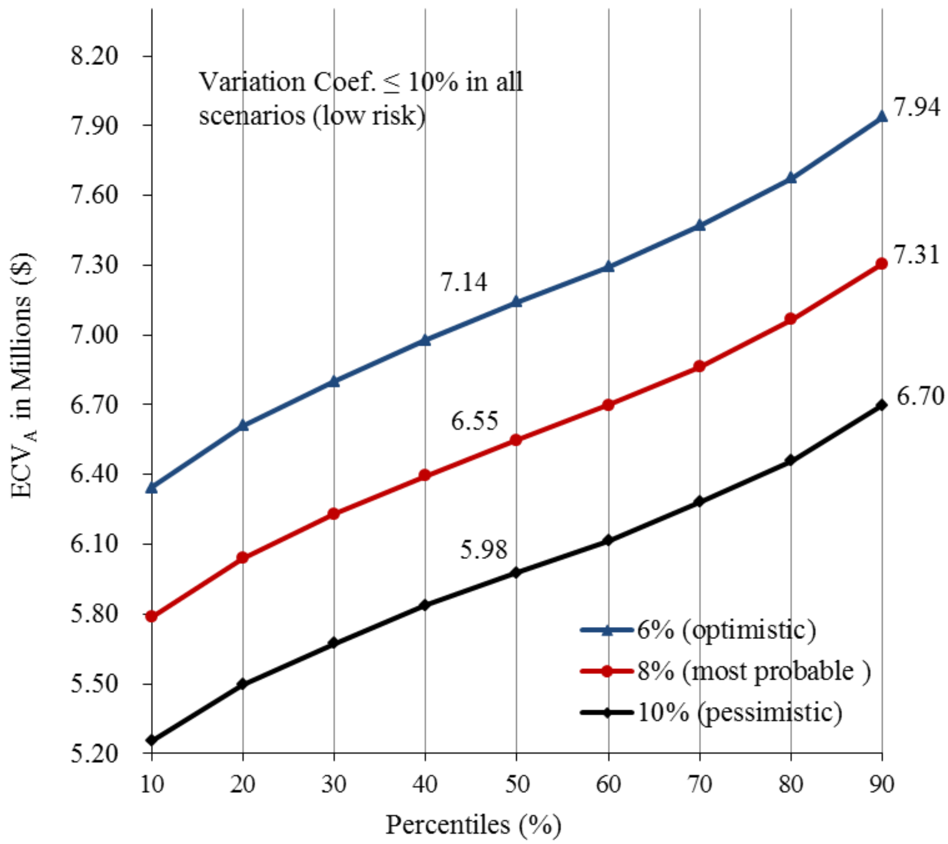

Fig. 4 – Annual estimated compensation for the acai farming and harvesting system for the production of fruit in floodplains in the municipality of Mazagão.

The açai farming and harvesting system for the production of fruit in floodplains presented, for all the analyzed scenarios, the most significant estimated compensation values. This took place due to the minimum estimated price of the ton of carbon, for all the percentiles, being higher when compared to other analyzed systems, as it can be seen on columns 2, 3 and 4 of Table 2. And, mainly, because of the larger estimated woods and/or native forest area not destined to LR or PPA used by family farming in the municipality of Mazagão, which is approximately 9,428.51 hectares.

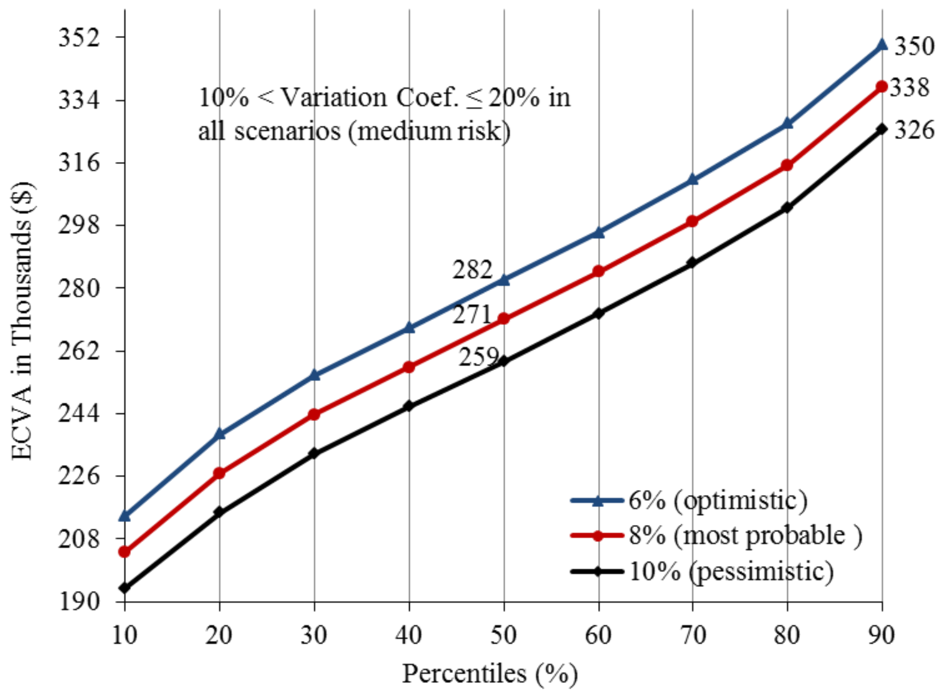

Fig. 5 – Annual estimated compensation for the manioc planting system for the production of flour on firm land in the municipality of Oiapoque.

Even though the estimated carbon storage is higher in firm land area, the annual estimated compensation values for the manioc planting system for the production of flour were not so significant for all the analyzed scenarios. This occurred because the estimated price for the ton of carbon assumed a lower value, as it is shown in columns 5, 6 and 7 of Table 2. Moreover, the woods and/or native forest area not destined to LR or PPA used by family farming in the municipality of Oiapoque is of only 447 hectares.

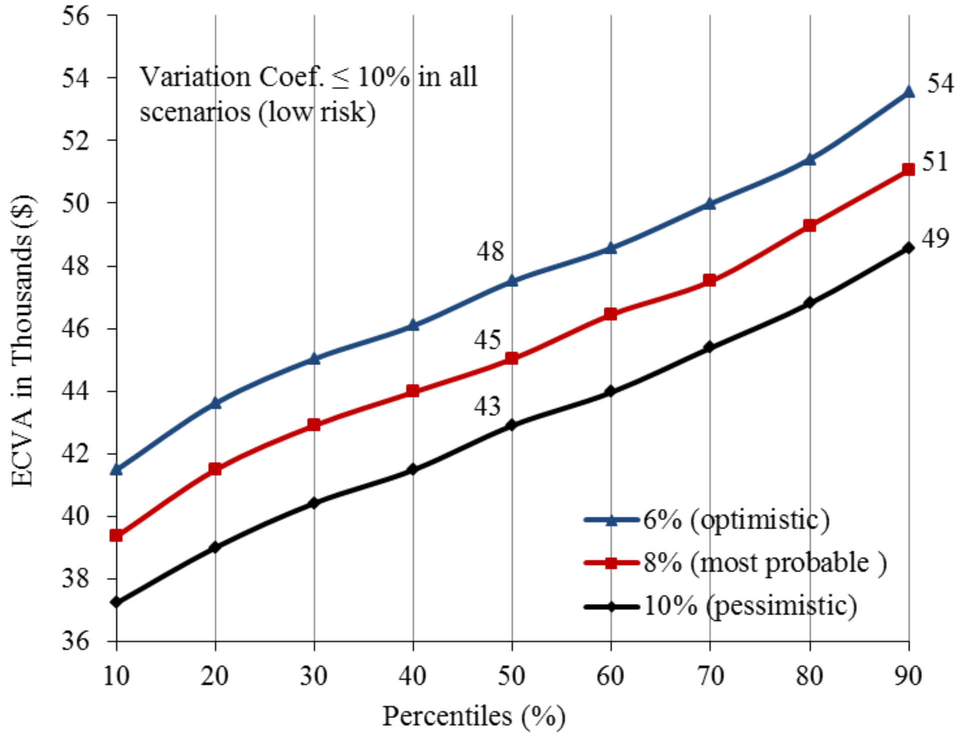

Fig. 6 – Annual estimated compensation for the extensive farming of buffalo cattle in wetlands in the municipality of Cutias do Araguari.

The extensive farming of buffalo cattle in wetlands in the municipality of Cutias do Araguari presented the lowest estimated values of annual compensation, when compared to the other two land use systems analyzed by this work. The factors that contributed to this result were: the estimated area, approximately 264 hectares, of woods and/or native forest not destined to LR or PPA used by family farming in the municipality of Cutias do Araguari, representing a much lower value when compared to the municipalities of Mazagão and Oiapoque. And also by presenting, among all the analyzed land use systems, the lowest estimated value for the price of ton of carbon for opportunity cost compensation as it can be verified in columns 8, 9 and 10 of Table 2.

4. Conclusions

This work analyzed the economic viability and the opportunity cost compensation through risk analysis by the @RISK software modeling using the Monte Carlo Simulation for three land use systems in the State of Amapá.

All the analyzed land use systems were considered economically viable, where the açai farming and harvesting for the production of fruit in floodplains and the extensive farming of buffalo in wetlands present low risk, whereas the planting of manioc for the production of flour on firm land presented medium risk.

The results not only demonstrated what could happen, but also the probability of occurrence for each result, that is, the effect of uncertainty in the referred systems for the evaluated financial indicators. And through statistics and probabilities appreciation, a more detailed assessment of the possible economic variation of the market considering a 12 year horizon was possible.

The opportunity cost estimative considered only one land use system for each predominant biome, firm land, floodplains or wetlands. Naturally, other agricultural and/or agroforestry activities are developed; the ideal for the compensation calculation would be the combination of opportunity costs of all these other activities.

The areas of native Forest used by family farming that are not destined to LR or PPA were considered for the compensation calculation. These areas can be kept standing through economic incentives to the landowners where the PES, including the REDD+ modality, plays an important role, especially regarding avoided emissions and biodiversity conservation.

An important point to be considered is that the Brazilian Forest Code predicts that the LR can be under the sustainable forest management regime. Thus, the small family property should be stimulated to conserve and recover its LR so that they increase their income through sustainable forest use.

It is important to highlight that the price of the ton of carbon, and not the price of the ton of CO_2 was considered for the compensation estimative. The conversion to CO_2 is necessary for the negociations in carbon credit markets or for the Low Emissions Certificates (LEC). Therefore, the compensation can reach much higher values.

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