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Evaluation of Different Forestry Options to Improve Carbon Content in Rural Communities in Marajo Island, Brazil

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Abstract

Brazilian Amazonia rain forest has suffered changes with high deforestation rates taking place during the past few years. Furthermore, common practices such as slash-and-burn, shifting cultivation and abandonment, can release quantities of greenhouse gases that are significant both in terms of their present impact and in terms of the implied potential for long-term contribution to global warming. Land use change and forestry activities associated to smallholders' traditional practices can affect the local uptake or emissions of carbon by increasing or decreasing the carbon stocks and associated fluxes. Therefore, emissions could be reduced if small agriculturalists adopted better practices or change their land use. In the case of Marajo Island, an area composed of a series of islands geographically constrained but still with a large forest area, environmental services through carbon sequestration appears to be a reasonable alternative for the major part of small farmers which can not integrate the traditional markets and need alternatives for income generation. The Cost Benefit analysis was the main tool applied to evaluate the forestry-carbon options selected for the area using as criteria, the net present value. Further, a sensitivity analysis is employed to simulate different conditions, in terms of interest rates, output, carbon and products prices. The paper discusses selected forestry options to be implemented in the region in order to improve the carbon content and assesses the associated carbon benefits that could emerge in the presence of a carbon trade.

Keywords: Carbon , Cost Benefit analysis, forestry activities, greenhouse gas emissions, land change

1. Introduction

The land based opportunities to sequester carbon dioxide from the atmosphere have long received attention. Such concern is largely based on the argument that carbon sequestration by vegetation/forests is an ecological service since it provides a desirable outcome due to its potential to take out carbon of the atmosphere. Land based mitigation options include, in general, forestry, agriculture and grassland. These sectors are responsible for emissions of CO_2 associated with land use changes, but they can also function as a carbon sink through photosynthesis processes. This study concentrates on carbon sequestration by forestry activities assuming that it is the most appropriate approach to provide environmental and economic benefits to local population making use of the large areas of rainforest and deforested land. Therefore the objectives of this study are: to identify the carbon forestry options that could be implemented in the region with sustainable objectives to the local population; to assess the economic profitability of carbon options and; to estimate and simulate the performance of different options in order to provide policy recommendations.

2. Study area and household survey

The field survey was carried out in six different areas (communities), namely Santo Amaro, Bom Jesus, Piriá, Estrada, Guajará and Nova Jericó located in Southeastern forest region of Marajo Island, Brazil. The communities are composed of small landowners which use diversified farming systems and are located approximately 1 to 50 km inland of the border of the rivers. The survey was oriented to capture the main aspects of the farm households and included sections regarding to: (1) general aspects of households and farm characteristics, (2) information on access to infra-structure and public services, (3) land resources and use, (4) agricultural production and extractive activities, (5) households' opinion on land resources, (6) forest use and expectations. A total of 100 respondents provided answers for this group of questions including all relevant households' socio-economic data.

3. Methodological approaches

The most of the studies found in the literature which carries out analysis on the land use change and forestry options are developed using the Cost Benefit Analysis (CBA). CBA is a framework for evaluating the social costs and benefits of an investment project. This involves identifying, measuring and comparing the private costs and negative externalities of a scheme with its private benefits and positive externalities, using money as a measure of value. The present study follows the Present Value model used by ANTLE *et al.* (2000) adjusted to account only the carbon present in tree biomass. The net present value (NPV) of implementing a land use system *i* for T periods is given by:

$$NPV(i) = \sum_{t=1}^{T} D_t \left[NR(p_t, w_t, z_t) + g_t(i) - CM_t(i) \right] - CE(i)$$

Where,

D_t = (1/(1+r))t and r is the annual interest rate

$NR(p_t, w_t, z_t)$ = net returns for system *i* in period t, given product price pt, input prices wt and capital services zt (R$/ha/yr)

$g_t(i)$ = payments for carbon sequestration service in the system *i* (R$/ha)

$CM_t(i)$ = annual maintenance costs (R$/ha/yr)

$CE(i)$ = establishment costs (R$/ha).

In addition, the financial analysis included three payments schemes often cited in the literature: i) "Business as usual scenario", where no carbon payments are available and the farmer earns NPV(*i*); ii) Ex-ante full carbon payment contract (MOURA-COSTA and WILSON, 2000), in this modality the farmer receives carbon payment in full when the project starts and, iii) Tonne-year carbon payment contract, where the farmer receives payment according to amount of carbon sequestered per year.

4. Results

The field study results showed that despite the fact that many households own relative large farm areas (on average, 33 ha), they dedicate small areas to agriculture activity. Another important aspect derived from the field survey is regarding to the distribution of cultivated land among the households: households with less than 1 ha farmed are found to be 44% of total, followed by households cultivating between 1 and 2 hectares with 38% of total. Only 6% informed to farm between 2 and 3 hectares. The percentage of households that have no farmed land is found to be 12%. Small farmers located in southeastern Marajo Island are usually subject to several constraints to develop agricultural activities and some of these constraints are typical for Amazon flood plain areas and include low soil fertility, weed pressure and availability of land and labor (SCATENA *et al*., 1996). The agricultural production in the survey areas is based on traditional annual crops mainly manioc shifting cultivation in previous forested land with low economic profitability and productivity. In addition, this type of land use has low carbon content during the cultivation and after abandonment. Some perennials such as cupuacu, pupunha and acai-palm were often found in the household garden.

Therefore, given the availability of deforested land used to shifting cultivation and in accordance with the purposes of carbon content enhancement, this study concluded that there is a potential to introduce agroforestry systems in the survey area. One of the main arguments in favor of this option is that it can sequester significant amounts of carbon while allowing the land to be used for agricultural or livestock production. Overall, agroforestry is a form of sustainable land use that involves growing or managing tree crops in ways that increase and diversify farm and forest production (MOLUA, 2005). Multiple authors concur that the benefits created by agroforestry practices are both economic and environmental. In general, agroforestry may provide a viable combination of carbon storage through enhanced growth of trees with supply of food production needs.

The following criteria were used to selected the wood tree and fruit species in the proposed agroforestry systems: local cash crops, ability to recuperate degraded areas, native species which could contribute to increase the local biodiversity, wood trees with commercial value in the regional market, potential species for tree planting in the local area and wood trees species with fast growth. Therefore, based on these criteria and the field survey, the following tree species were selected: Andiroba (*Carapa Guianensis),* Banana (*Musa paradisiaca),* Brazil Nut (*Bertholletia excelsa),* Cedro (*Cedrela odorata),* Cupuacu (*Theobroma grandiflorum),* Mahogany (*Swietenia macrophylla),* Paricá (*Schilozobium amazonicum)* and Pupunha (*Bactris gassipaes).* The structure of the three agroforestry systems proposed in this study (Table 1) is based on several studies carried out in the Brazilian Amazon region. The density (number of plants per hectare) proposed for the systems is lower than other studies reported in the literature mainly due to the local characteristics such as infrastructure, resources, labor and capital. Furthermore, higher density for some species can strongly influence the growth of others.

Table 1: Structure proposed for the three agroforestry systems (T1, T2 and T3)

AFS	Species	Tree Spacing (m)	Density of trees (trees/ha)
T1	Andiroba	6 x 6	278
	Banana	6 x 6	278
	Cupuacu	6 x 6	277
	Pupunha	6 x 6	278
		Total trees per ha	**1112**
T2	Cedro	6 x 6	278
	Banana	6 x 6	278
	Cupuacu	6 x 6	277
		Total trees per ha	**834**
T3	Parica	6 x 8	208
	Mahogany	12 x 12	32
	Brazil Nut	12 x 12	32
		Total trees per ha	**272**

Costs and financial returns were assessed based on local costs and prices and technical parameters found in the literature. A special procedure was developed to evaluate the benefits derived from carbon sequestration. Firstly, the predicted volume for each tree specie was based on the growth and volume increment equations developed respectively by YAMADA and GHOLZ (2002). Secondly, the annual changes in above ground biomass for each proposed agroforestry systems (T1, T2 and T3) were assessed using the estimated tree annual volume during a 25-year period of time multiplied by the basic wood density. The annual changes in above ground biomass were used to calculate the annual carbon increment (in t/ha) using the factor of 0.5 to convert biomass in carbon content. The annual amount of carbon expected to be sequester in each agroforestry system multiplied by three given carbon prices provide the expected annual benefits projections (undiscounted) of carbon sequestration services for agroforestry systems T1, T2 and T3. Carbon sequestration costs refer to the implementation and maintaining of the agroforestry systems and include all expenses incurred to maintain the plantations. Specific costs related to carbon sequestration services such as monitoring and transaction costs were not included in this analysis. The sensitivity analysis was carried out using three discount rates: 8%, 10% and 12%, and three carbon prices, namely $5.00, $15.00 and $25.00 per ton. A summary of the results is presented in the table 2.

5. Conclusion

The results of empirical analysis allow to infer some conclusions. First, the economic returns of including carbon sequestration services as output of the proposed agroforestry systems which include cash crops (T1 and T2), offer low attractiveness at the tonne year payment scenario, especially for low carbon price. This may be adduced to their regular cash crop annual income included in these systems. Projects including only woody tree species (T3) stock more carbon, however the NPV is lower in comparison to the others. In this case it makes substantial difference when carbon payments are introduced.

Table 2: Sensitivity analysis for NPV (R$ .ha^{-1}) of the simulated AFS T1, T2 and T3 with different discount rates, payment schemes and carbon prices (results in % increased over the base value)

AFS	*Payment scheme*	*Carbon price*	*8%*	*10%*	*12%*
T1	NPV (with no carbon)		43,380.73	33,249.28	25,801.52
	Tonne-year	$5/ton	1%	1%	1%
		$15/ton	3%	3%	4%
		$25/ton	5%	6%	6%
	Ex-ante full Crediting	$5/ton	2%	3%	4%
		$15/ton	7%	9%	11%
		$25/ton	11%	15%	19%
T2	NPV (with no carbon)		47,793.58	34,647.79	25,434.93
	Tonne-year	$5/ton	1%	1%	1%
		$15/ton	2%	2%	3%
		$25/ton	4%	4%	4%
	Ex-ante full Crediting	$5/ton	2%	3%	3%
		$15/ton	6%	8%	10%
		$25/ton	9%	13%	17%
T3	NPV (with no carbon)		16,985.19	11,870.50	8,346.44
	Tonne-year	$5/ton	3%	3%	4%
		$15/ton	9%	10%	12%
		$25/ton	15%	17%	20%
	Ex-ante full Crediting	$5/ton	7%	9%	13%
		$15/ton	20%	28%	39%
		$25/ton	33%	46%	65%

Ex-ante full crediting payment seems to be more attractive however it has more risks. Finally, as recommendation for future improvements of this modality of forestry carbon option, other payments schemes should be designed in order to achieve the economic farmers` expectations and maintain the carbon management over the project life. This could include governmental finance support to the first years of the projects and subsidies for forestry carbon projects in rural communities.

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