Co_2 MITIGATION SERVICE OF COSTA RICAN SECONDARY FORESTS AS ECONOMIC ALTERNATIVE FOR JOINT IMPLEMENTATION INITIATIVES

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SUMMARY

This paper summarizes work in progress by the Silviculture and Natural Forests Management Project (PROSIBONA) CATIE-COSUDE[1] on quantification and valuation of carbon sink service in humid tropical forests. The study deals specifically with secondary forests and the possibility for this ecosystem to be an option for Costa Rican joint implementation initiatives.

The results demonstrated the economic potential of secondary forests for its carbon sink service, basically for carbon storage. According to our calculations, if all of Costa Rican secondary forests were included in joint implementation accounting at the current negotiated price of US$10 tC stored, they could generate an estimated US$77.3 million during a period of 20 years that the current "carbon parking" schemes are promoted.

If international negotiations determines that Joint Implementation Initiatives should use current best knowledge on marginal costs of global warming, preliminary valuation results suggest, that carbon storage by Costa Rican secondary forests could generate US$127.4 millions product of one time discounted economic benefits and carbon sequestration reach a value of US$308 per hectare per year. According with this study, promoting the preservation of secondary forest ecosystem Costa Rica could mitigate current and avoid future CO_2 emissions.

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[1] Swiss Cooperation for Development.

[2] One of the ecological functions or services that has been recognized at the international level is carbon sequestration capacity, for both natural forests and plantations. Through photosynthesis, plants capture CO_2 from the atmosphere, fixing carbon (C) in their biomass and releasing oxygen (O_2) back into the atmosphere. It is estimated that forest ecosystems contain 20 to 100 times more carbon per unit area than agricultural ecosystems (Andrasko 1990; Schoeder et al. 1993).

INTRODUCTION

Traditionally, forests have been perceived as a source of timber, wood and other extractive products such as medicinal and ornamental plants. The importance of the ecological services provided by the forests had been neglected. However, this perspective has recently undergone a considerable change, due to international as well as local initiatives to visualize them as ecosystems rendering a multitude of productive and service functions[2].

The use of forests to mitigate the atmospheric concentration of toxic gases was introduced on the political agenda by the Intergovernmental Panel on Climate Change (IPCC). The United Nations Convention on Climate Change was a result of the Río Conference process, and was signed by 162 countries and ratified by more than 20 already. Nearly all these countries have agreed to reduce their carbon dioxide (CO_2) emissions to 1990 levels by the year 2000 (Andersen 1996).

In order to comply with their commitments in the Convention, a meeting of the parties in Berlin in 1995 agreed to establish a pilot phase program of "joint implementation". Joint implementation refers to cooperative initiatives between two or more governments with the aim of reducing future CO_2 emissions or sequestering CO_2 currently in the atmosphere.

Parties to the convention have the option to achieve mitigation credits via joint action along two routes; by reducing their domestic emissions through the introduction of improved technologies or by financing forest regeneration and preventing future land use changes through conservation measures[3]. Therefore, joint implementation might be an important instrument for increasing forest area and sequestering the CO_2 currently in the atmosphere, or for slowing the process of deforestation and land use change thus avoiding future emissions.

This study aims to determine the magnitude of the global service of carbon dioxide sequestration and storage that is being rendered by Costa Rica's humid tropical secondary forests. It explores how the rapid increase in secondary forest areas of recent years could be considered in the international joint implementation negotiations between the Costa Rican Government and foreign countries wanting to reduce overall CO_2 emissions outside their own borders. A specific objective is to determine the potential economic value of these forests' carbon sink service within the context of Costa Rica's Joint Implementation agreements.

[3] According to the IPCC (1990) deforestation has been the cause of releasing up to 1.6 billion tons of carbon (1 tC= 3.67 tCO_2) into the atmosphere. The Panel estimates that one would need to plant 450 million hectares of forest (i.e., an area about the size of Australia) in order to sequester the estimated 2.9 billion tons of carbon accumulated in the atmosphere as a result of all past emissions.

BENEFITS FROM JOINT IMPLEMENTATION INITIATIVES

Joint implementation (JI) efforts render different benefits at the national and global levels (OCIC, 1995). At the global level these include:

- Mitigation of global warming through sequestration of atmospheric CO_2 and the reduction of potential future CO_2 emissions.
- Support environmentally sound, sustainable development initiatives in developing countries through the transfer of funds from industrialized countries.

For the country investing in carbon certificates:[4]

- Cost-effectiveness through access to cheaper mitigation alternatives per ton of carbon sequestered/not emitted.
- Compliance with commitments to greenhouse gas emissions reduction when available domestic mitigation measures are not sufficient.

For the host country:

- A source of funds for investment in productive activities that prevent undesirable land-use changes and biodiversity conservation, fundamental pillars of local sustainable development policies.
- The transfer of cleaner technologies for reducing national CO_2 emissions at a lower cost.
- Employment generation in urban areas and for forest owners in rural areas.

The Costa Rican Office for Joint Implementation (OCIC) was created in 1995 in order to direct and facilitate the international negotiations on JI initiatives. At the local level, Costa Rica established the National Investment Found for Forest Financing (FONAFIFO) to handle the payment for environmental services to farmers and forest owners (PSA)[5]. (Figure 1).

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[4]Carbon certificates vouch the contribution of polluting countries to solve the global warming problem through international initiatives that reduce CO_2 emissions at a specified amount.

[5] Environmental Services Payment

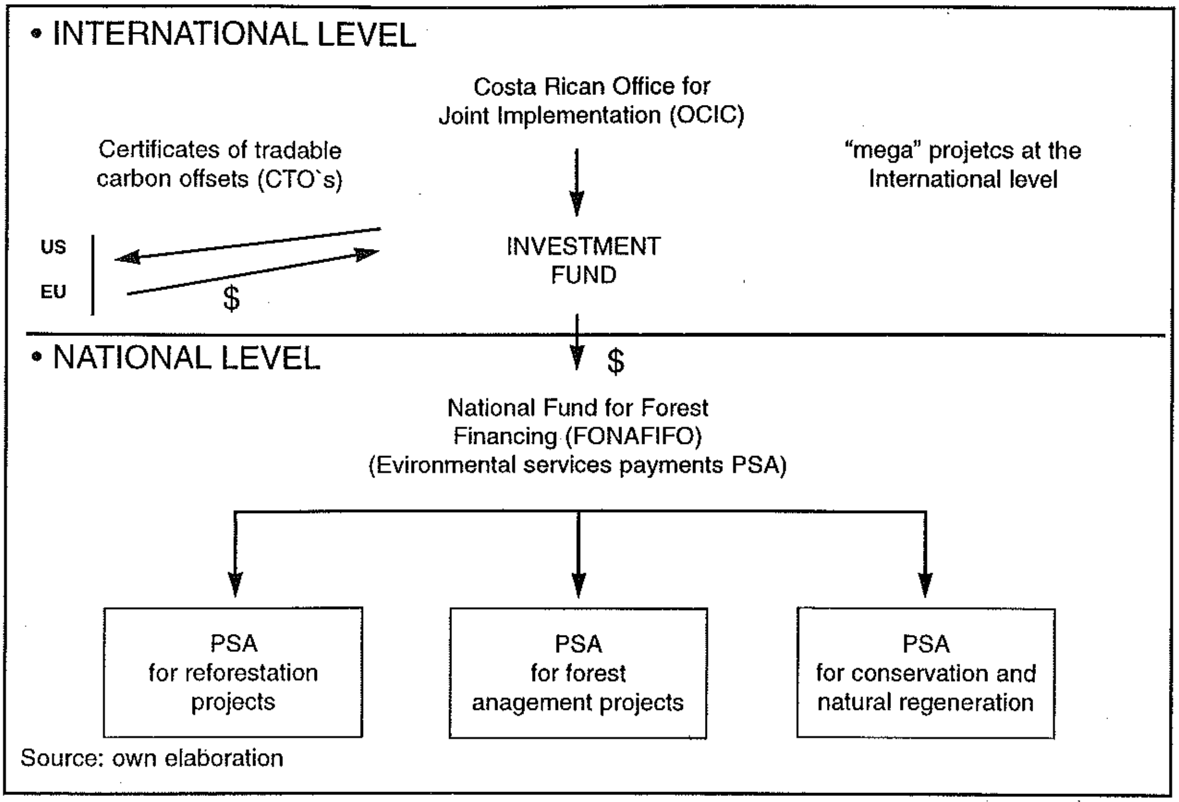

Figure 1. Costa Rican structure for Joint Implementation initiatives

The OCIC is promoting Costa Rican projects that undertake a commitment to preserve natural forests, to promote/aid their regeneration, or to plant artificial forests (plantations) in return for a per hectare compensation by industrialized countries who receive equivalent carbon credits. For example, an agreement with Norway worth U.S.$2 million was signed for the parking[6] of 200 thousand tons of carbon through watershed conservation and hydropower development in the Virilla basin in the Central Valley. Joint implementation projects promoted by the OCIC also include alternative energy generation and transportation solutions.

The Costa Rican government is currently promoting various other initiatives to the international community, that involve monetary compensation for the global carbon sink services provided by its forests. In this regard, there is considerable interest in a more accurate estimation of the magnitude of the services being provided through plantation forestry and natural forest regeneration/conservation. As well, it is necessary to determine the level of compensation that should be transferred to forest growers/owners, since the value of the current "forest conservation certificates" (U.S.$200 per hectare of primary or secondary forest, regardless of its initial stage) was established on an ad-hoc basis.

[6] The price of U.S.$10 per ton of carbon, lower that the average marginal damage costs figures mentioned above could be attributed to the fact that this specific agreement was for carbon parking. Net sequestration was not required.

Costa Rican secondary forests as a joint implementation alternative

Secondary forest cover in Costa Rica has increased during the last 15 years mainly due to the abandoning of large areas previously used for cattle ranching. In 1984, 2,3 million hectares of pasture land were being used for beef production, by 1995 this had been reduced to around 2 million hectares. During the same period, it is estimated that areas under secondary forest increased from 229 to 425 thousand hectares (Kaimowitz, 1995; CORFOGA, 1995). In contrast, according to the Ministry of Environment, there were 705 thousand hectares of secondary forest in Costa Rica during the early 1990's (MINAE, 1993); while Toumasjukka (1996) estimates that there are now more that 1.1 million hectares. In any event, it would appear that a large share of the abandoned pasture land has been left to regenerate into secondary forest.

The Costa Rican government has recognized the importance of natural forests because of the environmental services that they provide. In law No. 7575 it has established legal measures to compensate owners for the services provided by forests in reducing greenhouse gases[7]. Ecosystem studies conclude that the dry biomass contained in tropical forests varies between 150 and 382 tons per hectare. Assuming a carbon to dry biomass ratio of 45% (Houghton, Skole and Lefkowitz, 1991; Brown, *et al*, 1993), their maximum carbon storage capacity would be between 67.5 and 171 tons per hectare. On the other hand, Fearnside et al. (1996) measured biomass levels of 52.8 tons/ha in 5 year old stands of Brazilian secondary forest, that reached 196.6 tons/ha after 20 years, which implies an increase in carbon storage capacity of 88.5 tons in 20 years.

In contrast, carbon storage in pasture land has been estimated at approximately 10 tons/ha; at 140 tons/ha in mature primary forests; an at 55 tons/ha in partially intervened forests (Andersen, 1996). By comparison calculations for primary forests in Costa Rica have yielded biomass levels of between 167 and 283 tons/ha, and of between 152 and 237 tons/ha for secondary forests (Carranza, *et al*, 1996). This is equivalent to 75.15-127.3 and 68.4-106.6 tons of carbon per hectare, respectively. On the basis of these initial figures it is easy to appreciate the carbon storage potential of secondary forests. However, compared to primary tropical forests, these ecosystems have been minimally studied, and this lack of information and interest contributes to their being very vulnerable to land use change.

Methodology

Eight years of data from the monitoring of silvicultural management practices in the demonstration areas of the PROSIBONA Project are used for the biomass analysis. The data

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[7] Law 7575, Art. 3, paragraph k states "Environmental Services are those provided by forests and plantations which directly protect and improve the environment, and include the following: mitigation of greenhouse gases (fixing, reduction, sequestration, storage, and absorption), protection of urban, rural and hydropower sources of water, protection of biodiversity through its conservation and sustainable use for scientific, pharmaceutical, research and genetic improvement purposes, protection of ecosystems, life-forms and natural scenic beauty for tourism and scientific purposes (Alcance No.21 a la Gaceta No.72 del 16 abril de 1996).

comes from of 4 different demonstration areas and 9 experimental plots in secondary humid tropical forests with stands between 2 and 44 years old, which allowed for an analysis of biomass accumulation across stands of different ages.

1. Description of Experimental Areas

Data from four different experimental sites was used for the biomass accumulation analysis: the "Florencia" experimental area, the "Tirimbina" forest, the Ian Hutchinson experimental farm and the "Espaveles" experimental farm.

The Ian D. Hutchinson demonstrative site is in a 44 year-old secondary forest. The original primary forest was selective exploited and, thereafter, cut down and used for cattle ranching. However, this activity did not render acceptable economic results and the site was later abandoned (RENARM, 1994). This forest covers a total area of 180 ha's distributed in two blocks, "La Sandía" and "Laguna" with an extension of 90 ha's each. It is a humid tropical forest (bh-T), according to the life zone classification of Holdridge (1982). PROSIBONA started experimental studies in this site in 1987. In 1988, plots were established and a first measurement was taken when the forest was 34 years old; follow up measurements were obtained in 1989, 1990, 1991, 1993, 1994 and 1995.

The "Tirimbina" demonstrative site is located in Sarapiqui, in the Atlantic zone of Costa Rica. It is in a life zone classified as very humid premontane forest transition to basal (bmh-P) and very humid tropical forest (bmh-T), according to Holdridge (1982). This secondary forest has an extension of 29.16 ha's and contains 5 permanent plots that are 2, 5, 15 and 25 years of age. Its origins are traced to the abandonment of rice crops after only one year of farming. The minimum diameter for the first measurement was 5 cm at breast height for the 2 to 15 year old forests; and 10 cm for the 25 year old forest. The PROSIBONA project started the studies in this area in 1986. The first measurement was taken in 1987, and follow ups were made from 1988 through 1992 and in 1995.

The "Espaveles" has an extension of 20 ha's, which combine primary and secondary forests. The secondary forest represents 33% of the total area (6.6 ha.). It is located in Turrialba, Costa Rica, and classified as a humid premontane forest (bh-P) according to Holdridge (1982). The original vegetation was cut down in 1937 and the area was dedicated to rubber (Hevea brasiliensis) plantations in 1944. Additionally, other crops such as plantain and pineapple were grown, and experimental studies with rice production conducted. The area was abandoned in 1954. (Salcedo, 1986). The PROSIBONA studies started in 1986, and a first measurement was taken in 1988 when the secondary forest was 35 years old; follow up measurements were made annually during the 1989-1992 period and then in 1997.

"Florencia" is in Florencia de San Carlos, in the Northeast of Costa Rica. It contains 32 ha's of secondary forest located in a very humid tropical forest (Bmh-T) life zone according to Holdrige (1982). The soils have a low productivity (Guillén, 1997). The PROSIBONA Project started measurements in 1993 when the forest was 27 years old. Follow up measurements were made in 1994, 1995 and finally in 1998.

2. Biomass Storage Estimation

Biomass accumulation was estimated using an equation for humid tropical forests by Brown et al (1989), which rendered a coefficient of multiple determination (R^2) of 90%[8]:

(1) $Y = 13.675 - 6.1181\,(D) + 0.8391(D^2) + e$

where Y is total biomass storage in kg of dry weight, D is the diameter at breast height (DAP) for any given tree and e is an error term. Biomass accumulation per-unit-area is estimated by adding up the results for all trees. Simple averages of the four experimental sites were used to infer levels of biomass accumulation through time as well as maximum biomass storage.

Besides, we used the equations estimated specifically for secondary forests by Saldarriaga, et al (1988). We tasted the following equations:

$$Y = -0.29 + 0.39(D^2) + 0.087(H); \quad (r^2 = 0.93)$$
$$LnY = -1.981 + 1.047\ln(D) + 0.572\ln(H) + 0.931\ln(d); \quad (r^2 = 0.92)$$
$$LnY = -1.086 + 0.876\ln(D) + 0.604\ln(H) + 0.871\ln(d); \quad (r^2 = 0.93).$$

Where Y is biomass storage in kg of dry weight, D is the diameter at breast height (dbh); H is the height and d is wood density. We assume a wood density according with the dominant tree population in the different farms.

3. Valuation of carbon sink service

In valuing the carbon sink services it is important to make the distinction between three different accounting philosophies, partially reflected in current joint implementation programs: Carbon storage, carbon parking and carbon sequestration. Carbon storage is related to the forest capacity to maintain a certain quantity of biomass per ha, which means carbon that is not being released

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[8] This equation was obtained with data from humid tropical primary forests, however, it is not unreasonable to assume that wood density would be similar in primary and secondary forests of the same type.

into the atmosphere. In this case, pricing refers to a one-time payment for forest conservation in which land-use change is permanently voided (i.e. through the establishing of a national park). The value of this permanent carbon storage service lies in avoiding potential future CO_2 emissions forever.

Carbon parking is less restrictive than carbon storage, since pricing refers to the principle currently adopted in the agreements with land owners in Costa Rica. This sanctions land-use changes during a limited period of time (20 years), in return for an economic compensation of U.S.$200 per hectare per year during the first five years of the agreement. In mature forests, little net carbon sequestration takes place, but deforestation and potential land-use change is forestalled avoiding potential carbon emissions into the atmosphere while the agreement is in force.

Carbon sequestration refers to the removal of CO_2 currently in the atmosphere, i.e. the mitigation of past emissions. Payments are made for net sequestration (which is function of biomass growth rates), i.e. the increase in the global carbon stock on an annual basis as long as the forest is a net absorber of CO_2. Assuming that the marginal damage of past and future greenhouse gas emissions is about the same, marginal economic or damage cost avoidance values can be used for pricing in this case. Valuing the amount of CO_2 sequestered at social damage costs is the more conceptually correct approach.

However, the government of Costa Rica uses a value of U.S.$10 per ton for all three types of carbon sink services provided by forests; independently of whether it is storage, parking or sequestration. This is the market price agreed in the Costa Rican joint implementation initiatives negotiated with the Norwegian government, but it does not necessarily reflect the marginal economic value of reducing atmospheric CO_2, or of avoiding that it increases.

Table 1. Estimates of Marginal Social Costs of CO_2 Emissions (1990 U.S.$)

Author(s)	Type of Study	Period	
		1991 – 2000	2001 - 2010
Nordhaus	MC	7.3 (0.3 – 65.9)	
Ayres and Walter	MC	30 – 35	
Nordhaus, DICE - certainty/best guess - uncert./exp.value	CBA	5.3 12.0	6.8 18.0
Cline	CBA	5.8 – 124	7.6 - 154
Peck and Teisberg	CBA	10 – 12	12 - 14
Fankhauser	MC	20.3 (6.2 - 45.2)	22.8 (7.4 - 52.9)
Maddison	CBA/MC	5.9 - 6.1	8.1 - 8.4

MC = marginal social cost; CBA = shadow value in a cost-benefit analysis
Source: Fankhauser and Tol, 1995.

Table 1 illustrates the wide range of marginal social damage costs estimated by various authors. For emissions occurring during the period 1991-2010, for example, the marginal social cost estimated by Nordhaus (1991) is of between U.S.$0.3 and U.S.$65.9 per ton. The average of all available estimates is of approximately U.S.$20 per ton. Since net CO_2 sequestration occurs during the growth stage of a secondary forest (0-25 years), it is appropriate to use the former average for valuation.

V. Quantification and valuation of carbon sink services of total Costa Rica`s humid tropical secondary forest

1. Biomass Accumulation

Figures 2 and 3 provide an overview of biomass sinking capacity per hectare in secondary forest at the four different demonstration areas of the CATIE/PROSIBONA project.

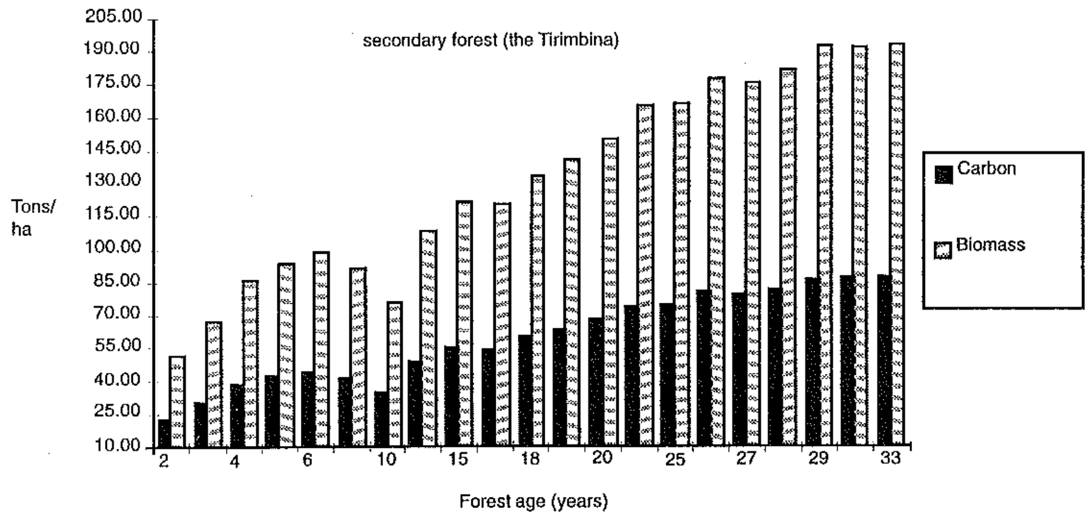

Figure. Biomass and carbon accumulation in a Costa Rica young secondary forest

Close examination of figures 2 and 3 reveals irregularities in biomass accumulation levels through time, while one would expect to observe a relatively smooth parabolic growth and stabilization of biomass content for any given stand over its lifetime. This is due to the relatively small size of the measurement plots (1 ha). In general, it would appear that biomass accumulation can reach anywhere between 100 and 200 tons per hectare in stands of 25 to 40 years of age. It is also apparent that some sites could plateau at different maximum biomass accumulation levels that others, although at about the same time (30-35 years).

Adapting the Saldarriaga´s equations to our data we estimated a biomass accumulation of 82.25 t biomass per ha. for the range of trees with dbh less that 5 cm.; 120.7 t biomass per ha. for the range among 5 and 20 dhp cm; and 115.7 for the range dhp superior to 20 cm. Which means and average of biomass accumulation of 106.21 t biomass per ha for first measurement[9] in Tirimbina´s secondary forests.

[9] It was only for the first measurement because we did not had height measurements for the rest years.

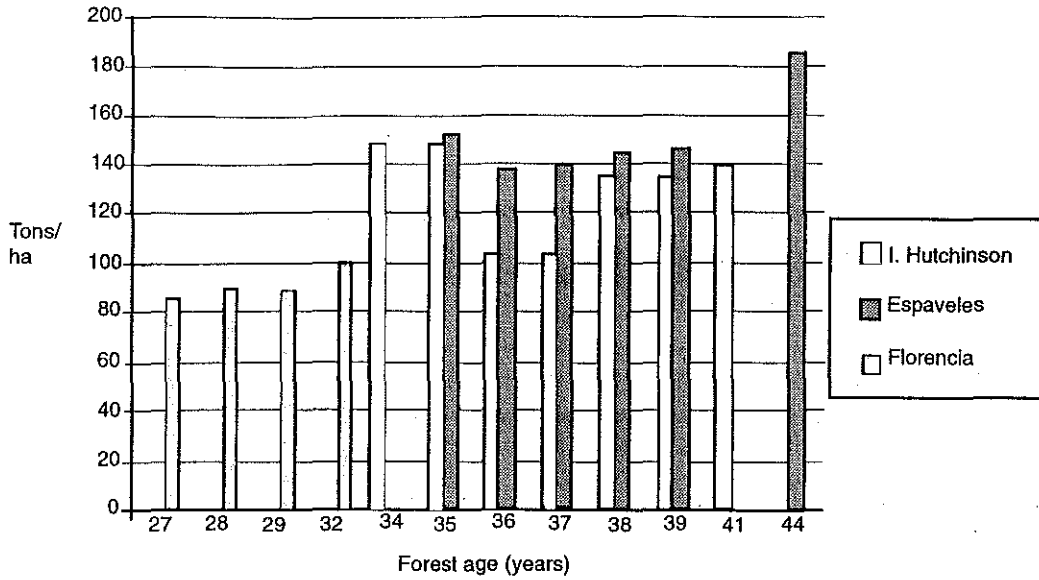

Figure 3. Biomass accumulation in 3 Costa Rica humid secondary forest between 27 and 44 years of age Source: own calculations.

2. Valuation of Carbon Sink Services

The biomass data discussed above suggests that true significant CO_2 mitigation (i.e. sequestration) occurs in tropical secondary forest stands up to about 20 years of age. If sequestration were the prime motive of JI agreements, payment should be made to regenerating forest areas while they experience net biomass growth. The payment is this case should be the full mitigation or marginal social cost of U.S.$20 per ton discussed earlier. In addition, payments could be made for avoiding land-use changes in mature secondary forests (i.e. carbon parking at U.S.$10 per ton per 20-year period), which would not be eligible under a "true" CO_2 sequestration agreement. In order to be able to extrapolate per hectare values to all of Costa Rica's humid secondary forests, several strong assumptions have to be made:

•The best secondary forest cover estimates are reasonably correct: A total of 425 thousand ha's, of which 302 thousand (71%) are humid (Solórzano et al, 1991); of the later, 160 thousand (53%) are less than 15 years old and the rest (142 thousand) are over 15 years old.• Forest age distribution is homogeneous within the two former categories. • Most secondary forests are less that 50 years old.

Then, forest areas are divided into two categories according to age: 1-20 years (during which most of the carbon sequestration occurs), and over 20 years old (after which very little sequestration occurs and, thus, only the lower carbon parking price is paid). Average carbon sequestration and parking levels for each category are estimated from the experimental data, as follows:

- On average for all sites, biomass accumulation levels reach 157 tons/ha after 20 years of forest growth, or 70.65 tons of carbon/ha. However, since it is assumed that at year zero (1998) forest areas are more or less evenly distributed within that category (1-20 years of age), the actual average sequestration rate that can be expected to occur during the next 20 years would be 0.5x70.65= 35.325 tons/ha.

- For experimental forest sites from 21 to 50 years of age, the average biomass storage is of 141 tons/ha, or 63.45 tons of carbon per hectare.

Table 2. Economic value of carbon sink services from Costa Rica's tropical humid secondary forests for the period 1998-2028.

Age Range	1-20	21-50
Forest Area ha.	180,290	121,710
Average Carbon Storage	35.32	0
Average Carbon Parking	0	63.45
Value of Carbon Storage	127,356,856	0
Value of Carbon Parking	0	77,224,995
Total Value of Carbon Sink Services	--	**204,581,851**

Source: own calculations.

Table 2 shows the estimated economic value of the carbon sink services of Costa Rica's humid tropical secondary forests; carbon storage using the previously discussed price of U.S.$20 per ton, and carbon parking paid at U.S.$10 per ton stored in the case of older forests. Under those circumstances, the 302 thousand hectares that are believed to exist to date have an estimated economic value of nearly 204,5 million dollars. This is a very conservative estimate for two reasons:

- It is based on a fixed, terminal period of 20 years of services. A second 20-year period of carbon parking services by those same 302 thousand hectares is estimated to be worth an additional U.S.$191.6 million.

- It does not consider the possibility that the recent trend of increased secondary forest areas will continue: Every additional 10,000 ha's of regenerating secondary forests have an estimated initial 20-year carbon storage value of U.S.$14.1 million, and a future potential carbon parking value of U.S.$6.35 million per 20-year period.

- It ignores the value of the large amounts of carbon sequestered from 1984 to 1997 as a result of the previously discussed extraordinary expansion of secondary forest areas in Costa Rica during that period.

Related with carbon sequestration philosophy this ecosystem could provide an average sequestration level of 2 ton/ha/year.). In the case of carbon sequestration the average is 2 ton per hectare per year, and the possible value is US$308 ha/year. (assuming the highest social value from of US$154 from table 1).

FINAL COMMENTS

Valuing carbon sink services assumes that owners of sinks (mainly developing countries) have an implicit right to emit all their stored carbon and should be compensated for not doing so. This is based on the fact that the large incremental amounts of CO_2 already in the atmosphere are the main historical responsibility of industrialized countries.

On the other hand, valuation carbon sequestration only assumes that "sink countries" have no such right and may only be compensated for reducing CO_2 already in the atmosphere, most of which has been emitted by industrialized countries.

In addition to the uncertainty about compensation rights, the supply of carbon sink services from a country like Costa Rica may be much larger than current international demand through JI agreements. It is unlikely that a significant proportion of the value estimated above will be "captured" by Costa Rica in the near future, given the lack of agreement about relative national responsibilities in alleviating global warning and the limited extent of JI markets.

In any instance, its is important that a distinction between carbon storage and carbon parking or permanent storage services begins to be made in countries like Costa Rica, which are attempting to capture international compensation for such services. It is obvious that carbon sequestration carries a larger economic value per unit, and differential payments have to be made in order to improve economic efficiency.

Secondary forests should receive greater attention than at present due to their superior sequestration rates and the fact that, in their early stages of growth, these ecosystems are highly vulnerable to land-use changes, which means avoiding potential future CO_2 emissions.

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