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Competing Ecosystem Services: an Assessment of Carbon and Timber in the Tropical Forests of Central America

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Competing Ecosystem Services: An Assessment of Carbon and Timber in the Tropical Forests of Central America

Kaysara Khatun[1]

The Millennium Ecosystem Assessment (MEA 2005) has classified a number of ecosystems good and services (EGS) provided by tropical forests, namely cultural, provisioning, regulatory and support services. The primary focus of this paper is to carry out an economic assessment by comparing the financial costs and returns of selected EGS, namely carbon and timber in the tropical forests of Central America. Timber is unusual from the other EGS provided by forests in that it competes with the other services, i.e. biodiversity, recreation and water services. Carbon storage is the non-timber value most often included in forest accounts and can be equated directly with timber available in terms of biomass content.

The study provides a quantitative appraisal of the carbon and timber stocks and flows of tropical (primary) forests and the associated trade-offs by evaluating them simultaneously using data and market values from a number of sources. The provision of reliable and accurate estimates of the economic value of these services is crucial to plan adequate conservation policies that encourage the protection and sustainable management of tropical forests such as those under REDD/REDD+. Results indicate that the economic return for managing natural forests is influenced by timber and carbon prices as well as the discount rate applied. Timber on face value is the better land use option; however, there are many issues that need to be considered when valuing timber, especially regarding the management regimes. Revenues under REDD/ REDD+ option would be higher if co-benefits, which include monies from the sustainable extraction of timber under Sustainable Forestry Management (SFM) are considered.

Keywords: Carbon, Environmental Goods and Services, Forests, REDD/REDD+, Timber

JEL Classification: F18, Q2, Q3, Q4,Q5, O2, P42

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1. Introduction

The forestry sector is unique in that it not only contributes significantly to global carbon dioxide (CO_2) emissions through deforestation, pests and fire, but it can also provide opportunities to lower the levels of CO_2 by reducing the amounts from the atmosphere through a process referred to as the carbon cycle, driven by respiration and photosynthesis (shown in figure 1). CO_2 is stored as carbon in biomass in tree trunks, branches, foliage, roots, providing the long-term storage in vegetation, soils, and geological formations (Khatun 2010). Carbon storage is the estimated total amount of woody biomass held in a tree's stem and branches over its life and terrestrial carbon sequestration is the estimated amount of carbon a tree's stem and branches take up during one year of growth. However, it is important to recognize that carbon sequestered in trees and soils can be released back to the atmosphere, and that there is a finite amount of carbon that can ultimately be sequestered. Forests can act as sources or sinks at varying stages of the growth cycles (as well as during different seasons of the year). On a global scale, forest and agriculture play an important role in the global carbon cycle, as they have high rates of ecosystem productivity, and therefore of carbon sequestration, and thus have the capacity of temporarily storing large amounts of carbon per unit land area (Houghton 2003).

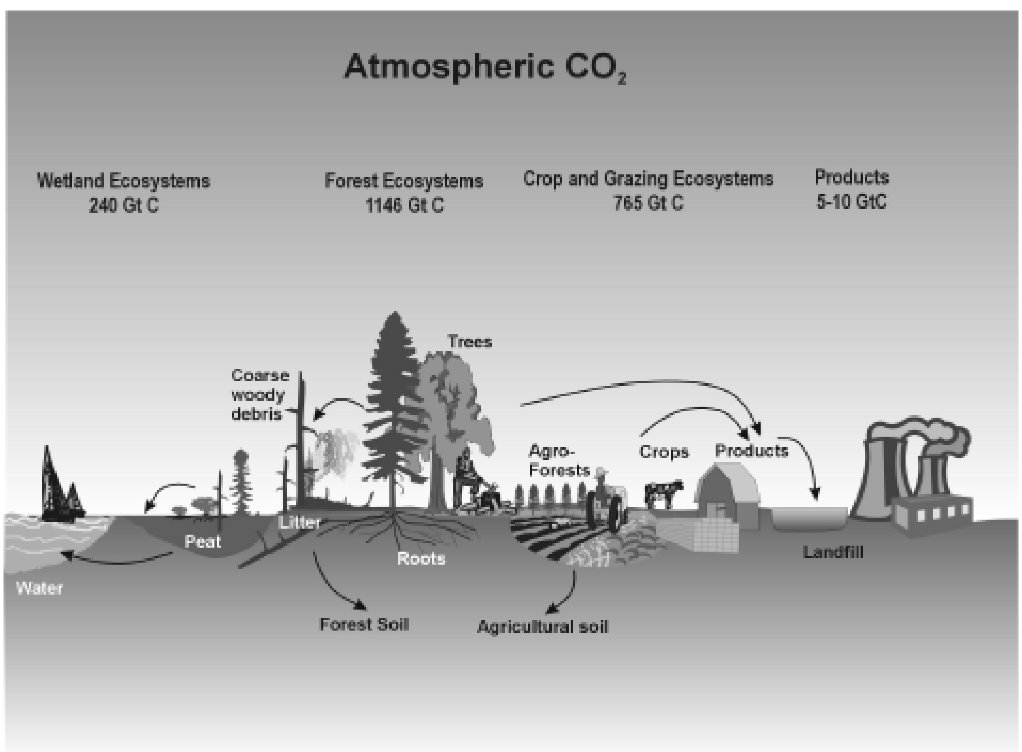

Figure 1: Carbon sequestration activities of forest and agricultural ecosystems. Source: Apps 2003

The carbon reservoir of the forest biosphere is gigantic, around an estimated 1146 gigatonnes (Gt) of carbon (GtC) are stored within the 4.17 billion hectares of tropical, temperate and boreal forest area, figure 2 illustrates the global spatial distribution of terrestrial carbon sequestration, a third of which is stored in forest vegetation and the rest in forest soils (Watson et al 2000). The most recent forest resource assessment (FAO 2010) estimates that the world's forests store 289 GtC in their biomass alone. Carbon sequestration rates vary by tree species, soil type, regional climate, topography and management practices and are substantially higher in the tropics than in other type of forest biome.

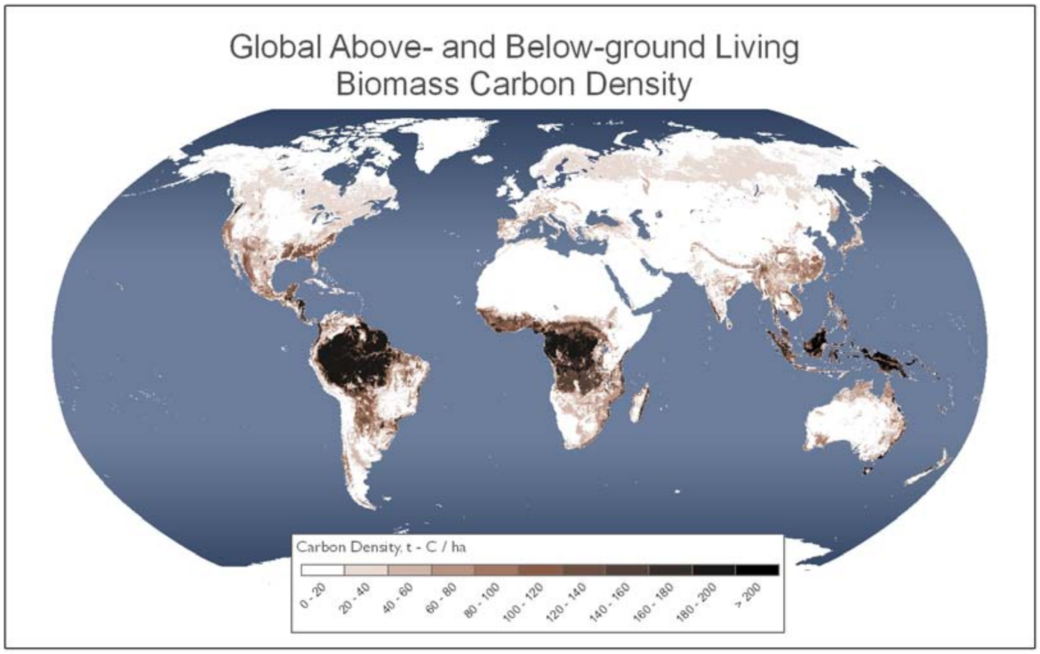

Figure 2 New IPCC Tier-1 Global Biomass Carbon Map for the Year 2000. Source Ruesch et al (2008)

Although burning fossil fuels remains the largest contributor to human-induced emissions, according to United Nation (UN) data (FAO 2005), the destruction of the world's forests (mainly in the tropics) releases about two billion tonnes of carbon per year thus tropical deforestation accounts for around 25% of anthropogenic emissions of CO_2 and 18% of total greenhouse gases. The latest figures by the FAO (2010) show that there are signs that these numbers are decreasing in several countries but nonetheless continue at an alarmingly high rate in others. Globally, around 13 million hectares of forest were converted to other uses or lost through natural causes each year in the last decade compared to 16 million hectares per year in the 1990s. For the world as a whole, carbon stocks in forest biomass decreased by an estimated 0.5 Gt annually during the period 2005–2010, mainly because of a reduction in the global forest area (FAO 2010). The loss of forest ecosystem services driven by deforestation is expected to be serious if the rate is maintained at the current high levels. Deforestation and therefore natural resource depletion have become major threats to the environment and economies of many developing countries as well as globally due to the large amounts of CO_2 that are being emitted due to forest clearing. This has been judged to be a huge cost to society; regionally in terms of local resources, impacts on the biodiversity and severe environmental problems of soil erosion, soil fertility loss, watershed deterioration, and the destruction of coastal fisheries habitats, all with adverse effects on the livelihoods the rural population (De Groot & Ruben, 1997).

The Millennium Ecosystem Assessment (MEA 2005) has classified a number of EGS´s provided by tropical forests, namely cultural, provisoning, regulatory and support services, carbon falls under regulatory and timber under provisioning. In the past, the rationale for forest conservation was simply to sustain the forests' productive role for the timber industry; we now acknowledge forests provide a number of services, timber production is just one. This is in line with climate change issues that are currently being debated regarding the role of forestry in the stabilization of Green House Gas (GHG) emissions, officially recognized at COP13 in Bali in December 2007 as vital issues.

Deforestation is mainly due to timber extraction and land use change: forest to agriculture and forest to cattle pastures. Current global timber harvests are approximately 1.6 billion m3 of industrial roundwood per year (FAO 2005). An assessment of timber market studies suggests that these figures could rise to 1.9 – 3.1 billion m3 by 2050, depending on timber demand growth and relative price changes (Solberg et al. 1996). A number of studies (Irland 2001, Sohngen and Sedjo 2000 and Sohngen et al. 1999, 2001, Lindner et al. 2002, Sohngen et al 2009a, 2009b) based on timber projections under climate change have shown that both timber stocks and the harvest intensities are predicted to increase. The results suggest that the assumed climate change scenarios would generally be beneficial for the timber-products sector over a 120-year projection. The assumption being that increased forest growth leads to increased log supply and hence to reductions in log prices that, in turn, means that consumers generally benefit. The aforementioned studies have carried out their analysis with the producers and consumers of timber in mind and have not taken into account other benefits provided by forests. The conclusions contrast with estimates by Ravindranath et al (2006) who predict that there would be large negative consequences from climate change, particularly in developing countries, where ecosystems will shift and the natural forests areas are expected to decline due to the impacts of climate change.

The two major strategies for preventing increased build-up of atmospheric CO_2 concentration through **land use, land use change and forestry (LULUCF)** activities are to preserve existing carbon stocks through better management of the terrestrial biosphere, reduced deforestation and to increase existing carbon stocks through planting forests to sequester carbon. Many LULUCF activities can be carried out immediately, appear to present a relatively cost-effective emission reduction component of international climate policy, and may generate environmental co-benefits including increased biodiversity and other EGS. LULUCF systems can both contribute to the accumulation of greenhouse gases in our atmosphere, as well as be used to help prevent climate change. Analysis indicates that if society follows an "optimal" carbon abatement policy using afforestation, reforestation and deforestation (ARD), as defined in Nordhaus (2009), forestry could accomplish roughly 30% of total abatement over the century. Around 42% of this would arise from avoided deforestation, with the rest roughly equally split between afforestation and forest management options.

In the Copenhagen Accord at the Fifteenth Conference of the Parties (COP15) to the United Nations Convention on Climate Change (UNFCCC) in December 2009 a global climate change mitigation agreement through reducing emissions from deforestation and forest degradation (REDD), promoting sustainable forest management, and enhancing carbon sinks referred to as REDD+ (+ signifying enhancement) was reached. For tropical countries most of the carbon potential over the 2020-2050 time period results are from REDD and REDD+ (Sohndgen et al 2009a).

The objective of REDD is primarily emission reductions, but it has the potential to deliver a range of "co-benefits", allowing for a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological, economic and social functions of the forest in a sustainable manner. This will enable community based forestry to be implemented immediately and aid towards development and poverty alleviation in forested regions. Forestry projects are still the only means through which much of the world's poor communities can hope to access financial benefits from internationals tools such as REDD.
The recognition of REDD+ suggests that sustainable forest management in the tropics will be promoted to include sustainable timber production and other ecosystem services. REDD+ is defined as **conservation, sustainable management** and **enhancement** of carbon stocks (Parker et al 2009). These enhancement activities are not linked to emissions reductions, rather, it is a call for investment for tropical forests, which store carbon, increase sequestration by restoring lost carbon pools & creating new carbon pools in forest areas and thus creating rain, moderating weather conditions and protecting biodiversity (Varghese 2009).

Achieving emission reduction while helping developing countries achieve sustainable development is among the central goals for the Kyoto protocol (2008–2012), and the climate change agreement post Kyoto is likely to retain this element. Policy responses fall under the following, governance, legislative, adaptive and capacity and reflect that existing legislations may be effective against several causes and can present a vast array of possible policy responses to forest practices. Such multiplicity reflects the complex context in which forest practices occur and the extreme diversity of the sectors that must be considered to implement mechanisms such as REDD/REDD+.

1.1 Location

Central America consisting of Belize, Costa Rica, El Salvador Guatemala, Honduras, Nicaragua and Panama, collectively contains 22, 411 hectares of forest, approximately 43.9 % of the total land area that are entirely of the tropical variety. Overall, Central America lost 19% of its forest between 1990 and 2005; in 1999. The rate of loss was estimated at about 2% annually in recent decades, among the highest of any region in the world (FAO 1999). However, consistent with global trends, the deforestation rates are slowing. Several governments, including Costa Rica, have passed policies to enhance the protection of forests. Many countries have developed eco-tourism as a means to generate revenue to protect forests. Sohngen et al (2009a) have found that REDD provides the best option for Central and South American compared to afforestation providing almost 3 times as much income as through A/R (1209 and 356 million tons of CO_2 respectively) for the period 2020-2050 based on a carbon price of $30.

Deforestation in Central America is mainly due to timber extraction and land use change. Increasing income and population will continue to result in greater demands being placed on forest resources for the production of industrial roundwood and fuelwood. The population of Latin America is expected to grow by 70% between 1990 and 2030 (Winograd, 1995). However, at the same time, these same pressures will also increase the demands placed on forests for the other services they provide for the conversion of forests to other land uses. In Central America from 1955 to 1975, the surface area used for livestock production increased from 3.9 million to 9.4 million hectares. In Costa Rica from 1950 to 1984 the proportion of land dedicated to agriculture increased from 16.3% to 44.4%, while the area remaining in forests fell from 47% to 26%. Such statistics has generated growing interest worldwide from policy makers to non-governmental and private decision-makers (FAO, 2007) in compensating landowners and nations for the environmental services they may protect or provide through conservation of the natural forests.

Following the introduction in section 1, the structure of the paper is as follows; section 2 highlights the aims and objectives as well as displays the basic structure of the methodology, and the model employed in order to value timber and carbon. Section 3 provides a discussion and justification for the choices of the input variables. Section 4 studies the implications of the results empirically. Finally, section 5 presents the conclusions reached and the policy implications and recommendations.

2. Methodology

2.1 Aims and objectives

The main aim is to compare forest productivity, commercial value of timber and carbon sequestration of natural (primary) forest systems for the Central American region. Timber is unusual from the other EGS provided by forests in that it competes with the other services, i.e. biodiversity, recreation and water services. Carbon storage is the non-timber value most often included in forest accounts.

The study analyses the impact of deforestation in Central America by assessing carbon stocks and flows over a 15 year time period 1990-2005, based on data obtained from a number of institutes including the Food and Agricultural Organisation (FAO), the World Resource Institute (WRI), the International Tropical Timber Organization (ITTO) and, where applicable/available, from national sources.

The paper looks to answer the following question when accounting for forest depletion;

1. ***How do we reconcile the provision of timber with the other EGS´s when valuing tropical forests?***

To achieve this goal the main objectives are to:

Quantify the Present Value (PV) and the Net Present Value (NPV) of carbon and timber stocks and flows for a 15 year time period 1990-2005 for Central America by:

a) **Calculating the flow of timber production and carbon sequestration pools associated with the biomass of the forest floor for the specified time period**
b) **Examination of the economic controlling factors by exploring a number of carbon prices and discount rates for two timber species; teak (*teak grandis*) and eucalyptus.**

The Net Present Value (NPV) method is employed to carry out the financial analysis for two services provided by tropical primary forests, namely timber and carbon sequestration. The NPV is defined as the difference between the present value (PV) of future revenues and the PV of the expected future costs, with the costs and returns discounted at the appropriate interest rate (Jacobson 2000). The aim is to compare the value of a hectare of forest should it be conserved and hence preserve carbon stock, or alternatively, the forest is deforested for its teak (teak grandis) or eucalyptus timber. Teak and eucalyptus are chosen for analysis in this study for illustrative purposes to reflect higher and lower end of the market prices attainable for timber. Teak remains one of the most valuable of all hardwoods and is known for its beauty, strength, durability and weather-resistant qualities. The international market pays premium prices for teak due to the limited availability of natural teak and the considerable decline in available native supply, which is anticipated to even increase in the future (Centeno1997). Eucalyptus is the most popular plantation species in many tropical countries. However, there are no established prices in teak or eucalyptus, varying with region and year. The trees for timber are valued as standing stock.

Formula for the Net Present Value Source: (Jacobson, 2003)

NPV = present value (PV) of revenues - PV of costs.

$$PV = \sum_t \frac{\$_t}{(1+i)^t}$$

$$NPV = \sum_{t=1}^{T} \frac{TR_t - TC_t}{(1+i)^t}$$

Where T = management cycle (years).

TC_t = Total Costs (\$ Ha^{-1})

TR_t =Total Revenue (\$ Ha^{-1})

i= the discount rate (%)

t = the year of the cash flow (US$)

$\sum$ = sum

The analysis is carried out from two databases, for carbon and timber created using variables that reflect both stocks and flows in order to assess the PV and subsequently the NPV. The annual forest change rates are based on the FAO data (table 1) with the assumption that the change in forest area was a proportional increase/decrease in timber production, thus deforestation in this case is due to timber production.

Table 1: Forest area increase/decrease for the period 1990-2000, source FAO 2008

Country/area	Forest						
	Area			Annual change rate			
	1990	2000	2005	1990-2000		2000-2005	
	1000 ha	1000 ha	1000 ha	1000 ha/yr	%	1000 ha/yr	%
Belize	1,653	1,653	1,653	0	0	0	0
Costa Rica	2,564	2,376	2,391	-19	-0.8	3	0.1
El Salvador	375	324	298	-5	-1.5	-5	-1.7
Guatemala	4,748	4,208	3,938	-54	-1.2	-54	-1.3
Honduras	7,385	5,430	4,648	-196	-3.0	-156	-3.1
Nicaragua	6,538	5,539	5,189	-100	-1.6	-70	-1.3
Panama	4,376	4,307	4,294	-7	-0.2	-3	-0.1
Total Central America	**27,639**	**23,837**	**22,411**	**-380**	**-1.5**	**-285**	**-1.2**

Based on a hypothetical hectare of forest land and its subsequent changes, this study attempts to gauge deforestation and the losses and gains in monetary terms. Reforesting costs are not taken into account; it is assumed that the trees are taken from the primary forest directly.

The study is structured as follows: forest inventory data are analyzed, and the resulting stem density, and volume data are classified into the two tree species so that revenues from timber harvesting and carbon for each tree type can be estimated. It is paramount that consideration and justification be given to the input variables; these are discussed in the following paragraphs.

3. Description and justification of model inputs

3.1 Discount rates

The notion of discounting originates from the study of finance and more specifically the concept of the time value of money. Discount rates are the rate, per year, at which future values are diminished to make them comparable to values in the present (Deardorff 2010). The discount rate aims to make the costs and benefits of future activities comparable with current ones. The rates of return vary across regions but are held constant over time. In developing countries the discount rate could be as high as 10%–12% compared to 4% in developed countries. The international banks use these rates, for example, in appraising investment projects in developing countries (IPCC 2001: Working Group III: Mitigation, Chapter 7). Sathaye et al (2005) apply 12%-19% for short rotation forestry for Africa and Latin America. These rates are derived from sources specific to these regions, and are higher than societal discount rates and the rates for long-rotation forestry 6% to 11% for Africa and Latin America. Dutschke and Schlamadinger (2003) analyze the attractiveness of temporary credits from emission reductions for discount rates between 3 and 9%. Based on the premise that the value of temporary credits depends on two parameters, the price and the discount rate, the former is speculation therefore, they focus on estimating the crediting period necessary to obtain parity between a stream of temporary credits and permanent credits from emission reductions on the basis of a number of discount rates. They highlight the importance of high discount rates and the lag between the credits obtained from forestry compared to those obtained from other sectors. Hunt (2002) proposes 8% as a sustainable discount rate in least developed countries, whereas an FAO study by Camino et al (2002) for teak in Central America use a range from 4%-16 %. Based on these studies, this paper analyzes the impact of using a range of discount rates 4%, 8%, 12%, and 16 % respectively.

3.2 Carbon valuation

Forestry credits, also known as tCERs have less value than permanent CERs but they remain attractive as they can contribute to the host country's sustainable development objectives by providing biodiversity benefits, employment opportunities and reducing imports of timber and fossil fuel and if projects go to plan, will result in real climate benefits (Schlamadinger 2004). The amount of carbon sequestration per year depends on the growth process, age, species and distribution of the trees, fire, insects and harvest.

Table 2: Reported carbon prices paid for forestry credits in the voluntary and regulatory sector. Source adapted from Campbell et al 2008 and Kollmuss *et al.* (2008)

Credit issuer	Credit type	Price (us $)tCO2e
CCX (Chicago Climate Change Exchange)	Forestry	$1.5-$3
CDM (world bank)	Forestry	$3
Climate community and Biodiversity standards (NGO´s and the private sector	LULUCF	$3.5-$14
Conservation international	Avoided deforestation Forest restoration	$5 $8-$12
Climate Care	Community based energy and some forestry	$12
FONAFIFO	Forestry	$3
Plan Vivo	LULUCF	$3.5-$14
Face Foundation	Forestry	$15-$19
Future Forests	Forestry	$12
Prima Klima	Forestry	$2
Scolel de te	Avoided deforestation for Mexico	$10-$12
World Bank´s Biocarbon fund	Forestry	$3
New forests	Avoided deforestation	$3-$11
China CDM	Forestry	$4
Eco-carbone et al: Jatropha Curcas Plantation Project in Mali	Forestry	$7* ($3.5for communities)
Literature (various)	Forestry	$5-$100- not used

*converted from Euros

The price of carbon offsets will have an effect on the long term success of any conservation/mitigation activity. Vickers and Mackenzie (2007) deduce that the poverty reduction potential of forestry projects depends on the economic value of the carbon sequestered and even at prices of under $4 per tCER; there is clear potential to deliver results in terms of poverty reduction. By looking at an existing large plantation in China (a registered CDM project) and another in Vietnam, they conclude that the revenues represent a substantial contribution to poor households from these projects. However, there are a number of studies

(Khatun et al 2010, Ravindranath et al 2007, Sathaye et al 2005), which suggest that current prices for temporary credits are undervalued and do not reflect the total benefits of all aspects of biodiversity and/or sustainable development and thus do not make forestry a worthwhile venture for land already in high demand from other modes of agriculture. A review of forest carbon market prices in the voluntary and regulated carbon market suggests that the mode value of forest carbon is likely to be $3 and that $5-10 is the most likely range for forest carbon. In some cases where certification is involved, prices will be higher. In this study the carbon paths that will be analyzed fall within the following ranges: $3 as the most frequent value representing the price that can be obtained in the regulatory sector. The median value $7.50 is also used, and for the top end of the assessment $20 is employed. The latter value is more aligned with those in the permanent sector and is used here to reflect other co-benefits that conservation and forestry provide. The price per tonne of carbon is evaluated by multiplying the tonnes of carbon stocked per hectare by the value of the carbon offset.

3.3 Timber

A tree can be seen to be consisting of four parts, roots, stump, stem and crown. The merchantable volume of an average tree is about 55-65% of the cubic volume of the complete tree, excluding foliage and the crown of the tree excluding foliage is 15-20 % of the complete volume for softwoods and 20-25% for hardwoods (Hutsch et al 2003).

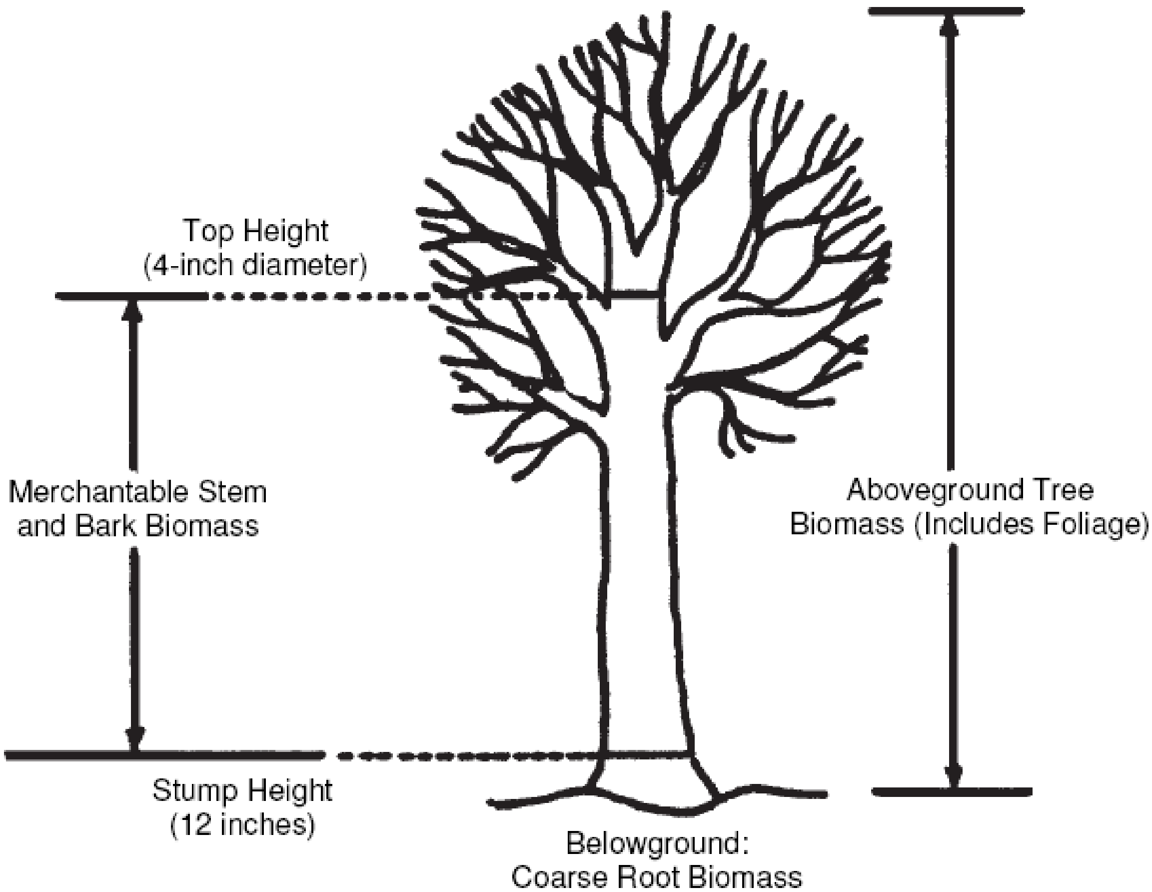

Figure 3: The biomass distribution of an average tree. Source: Jenkins, JC, et al (2004)

Most landowners sell their timber on the stump (standing timber), known as the stumpage value to a timber dealer or manufacturer. Forest owners, lacking the capacity to harvest their own timber, must sell it to stumpage buyers at current stumpage prices, which are lower than the value of the logs (log price) at the mill, reflecting the costs of felling, topping, limbing, skidding, bucking, loading, and hauling. The approach based on the stumpage price multiplies physical stocks with the average stumpage price of the timber removed.

A study developed in Costa Rica by Howard (1995) concludes that the prices paid for standing timber over the past 5 and 10 years had appreciated at very high rates relative to the overall rate of inflation in Costa Rica, and stumpage prices can be expected to continue rising in real terms.

However, other authors (Varmola and Carle 2002) have expressed that a primary issue of concern *is* the pricing, particularly where stumpage rates in natural forests or from government supplies are kept artificially low. This occurred through a number of mechanisms which include intentional under pricing of natural forest wood, long-run concessions or quotas without appropriate price adjustment for inflation, restricting exports and thereby creating an oversupply in local markets, illegal harvesting and trade in timber and inappropriate government market behavior and 'crowding out' of the private sector.

In this study, the values of stumpage prices of teak and Eucalyptus used to calculate the NPV are taken from literature (Spittlehouse 2005) and from commercial websites (www.panamaforestry.com accessed June 2010) averaged at US$200/ m^3 (teak) and $20/ m^3 (eucalyptus). In intertropical zones, forest productivity ranges from a few m^3 to a few dozen m^3 per ha and per year. The sale price can vary from a few $ to a few hundred $ per m^3 and the prices differ from region to region and year to year. The PV values are calculated by taking the mean from the ITTO annual reports (2008), $376/ m^3 for teak and $185/ m^3 for Eucalyptus respectively.

3.4 The PV of timber (teak and eucalyptus) is assessed by taking the following steps:

1. Taking into account that the dry biomass can be converted to carbon content by taking half of the biomass weight (**Carbon content= Biomass(Y) X, X=0.5** ***IPCC default value (Brown and Lugo 1982)***), the biomass values in turn are calculated from the carbon database. For merchantable wood, only above ground biomass is considered, where the root biomass is typically estimated to be 20% of the aboveground forest carbon stocks (Gibbs 2007). The merchantable volume is then taken to be the mean value of 60% of an average tree or above ground biomass.

2. The next step is to compute the stem volume X; Stem volume is a function of a tree's height, basal area, shape, and depending on definition, bark thickness. It is therefore one of the most difficult parameters to measure, because an error in the measurement or assumptions for any one of the above factors will propagate to the volume estimate (IPCC 2006).

   $$Y = A * BEF * x$$

   Where *Y* is the biomass of each forest type, *A* is the forest area in hectares, and *x* is the mean stem volume (in m^3/ha). Where the BEF for Teak is 1.6 (Haripriya 2000) and 1.5 for Eucalyptus (Balteiro and Rodriguez 2006) respectively.

The biomass *Y* is assessed following step (1). Growing stock volume calculated using biomass expansion factors from Brown and Schroeder (1999). Biomass expansion factor (BEF) is defined as the ratio of all stand biomass to living stock volume. The biomass expansion factor takes into account and expands the dry weight of growing biomass stock to account for stump, branches, twigs, foliage etc.

4 Results and discussion

This section presents the findings and discusses some of the policy implications of the results. I compute only the PV for carbon as the costs for conservation are negligible compared to timber extraction.

Table 3. Total carbon above and below ground in 2005 for three carbon price paths

	Carbon stock (Mt Ha^{-1})	Price Ha^{-1}		
		$3	$7.50	$20
Belize	155.00	464.00	1,161.00	3,096.00
Costa Rica	159.00	478.00	1,196.00	3,189.00
El Salvador	127.00	381.00	953.00	2,540.00
Guatemala	147.00	441.00	1,102.00	2,940.00
Honduras	163.00	490.00	1,225.00	3,266.00
Nicaragua	174.00	521.00	1,304.00	3,476.00
Panama	164.00	492.00	1,230.00	3,281.00

PV carbon

Table 4a. The PV of carbon priced at $3 under varying discount rates

	Discount rates			
$3	4	8	12	16
Belize	571.99	514.73	495.64	486.10
Costa Rica	589.13	530.15	510.49	500.67
El Salvador	469.34	422.35	406.69	398.86
Guatemala	543.16	488.79	470.66	461.60
Honduras	603.49	543.07	522.94	512.87
Nicaragua	642.24	577.94	556.52	545.80
Panama	606.10	545.42	525.20	515.09

Table 4b. The PV of carbon priced at $7.50 under varying discount rates

	Discount rates			
$7.50	4	8	12	16
Belize	1,429.98	1,286.82	1,239.11	1,215.25
Costa Rica	1,472.82	1,325.37	1,276.23	1,251.66
El Salvador	1,173.34	1,055.87	1,016.72	997.15
Guatemala	1,357.91	1,221.97	1,176.66	1,154.01
Honduras	1,508.72	1,357.68	1,307.34	1,282.17
Nicaragua	1,605.60	1,444.86	1,391.29	1,364.50
Panama	1,515.24	1,363.55	1,312.99	1,287.71

Table 4c. The PV of carbon priced at $20 under varying discount rates

	Discount rates			
$20	4	8	12	16
Belize	3,813.27	3,431.51	3,304.28	3,240.67
Costa Rica	3,927.53	3,534.33	3,403.29	3,337.77
El Salvador	3,128.90	2,815.66	2,711.26	2,659.07
Guatemala	3,621.10	3,258.58	3,137.76	3,077.35
Honduras	4,023.26	3,620.48	3,486.25	3,419.13
Nicaragua	4,281.60	3,852.96	3,710.10	3,638.68
Panama	4,040.64	3,636.12	3,501.31	3,433.90

Teak

Table 5. Wood volume for Teak in 2005

	Volume (m^3/ha)	Price Ha^{-1}	
		$200	$376
Belize	92.88	18,575.81	34,922.52
Costa Rica	95.66	19,132.40	35,968.92
El Salvador	76.21	15,242.00	28,654.97
Guatemala	88.20	17,639.66	33,162.57
Honduras	97.99	19,598.76	36,845.67
Nicaragua	104.29	20,857.22	39,211.58
Panama	98.42	19,683.43	37,004.85

NPV: teak

Table 6a. The NPV of teak under varying discount rates

$200 (stumpage)	Discount rates			
	4	8	12	16
Belize	23,219.76	20,897.78	20,123.79	19,736.80
Costa Rica	25,718.85	23,169.90	22,319.13	21,893.53
El Salvador	23,967.11	21,610.17	20,822.59	20,428.44
Guatemala	26,422.09	23,815.07	22,944.35	22,508.67
Honduras	38,076.17	34,392.87	33,159.15	32,541.18
Nicaragua	32,950.78	29,713.96	28,632.20	28,090.78
Panama	25,214.00	22,698.26	21,859.40	21,439.92

Table 6b. The PV of teak under varying discount rates

$376 (log price)	Discount rates			
	4	8	12	16
Belize	42,608.26	38,347.43	36,927.16	36,217.02
Costa Rica	47,194.08	42,516.77	40,955.60	40,174.64
El Salvador	43,979.65	39,654.67	38,209.46	37,486.19
Guatemala	48,484.53	43,700.66	42,102.89	41,303.41
Honduras	69,869.78	63,110.91	60,847.05	59,713.06
Nicaragua	60,464.68	54,525.12	52,540.08	51,546.58
Panama	46,267.69	41,651.31	40,112.00	39,342.26

Eucalyptus

Table 7. Eucalyptus wood volume in 2005

	Volume (m^3/ha)	Price Ha^{-1}	
		$20	$185
Belize	99.07	1,981.42	18,328.13
Costa Rica	102.04	2,040.79	18,877.31
El Salvador	81.29	1,625.81	15,038.78
Guatemala	94.08	1,881.56	17,404.47
Honduras	104.53	2,090.53	19,337.44
Nicaragua	111.24	2,224.77	20,579.13
Panama	104.98	2,099.57	19,420.99

Table 8a. The NPV of Eucalyptus under varying discount rates

$20 (stumpage)	Discount rates			
	4	8	12	16
Belize	2,476.77	2,229.10	2,146.54	2,105.26
Costa Rica	2,743.34	2,471.46	2,380.71	2,335.31
El Salvador	2,556.49	2,305.09	2,221.08	2,179.03
Guatemala	2,818.36	2,540.28	2,447.40	2,400.93
Honduras	4,061.46	3,668.57	3,536.98	3,471.06
Nicaragua	3,514.75	3,169.49	3,054.10	2,996.35
Panama	2,689.49	2,421.15	2,331.67	2,286.93

Table 8b. The PV of Eucalyptus under varying discount rates

$185 (log price)	Discount rates			
	4	8	12	16
Belize	22,910.16	20,619.15	19,855.47	19,473.64
Costa Rica	25,375.93	22,860.97	22,021.54	21,601.62
El Salvador	23,647.55	21,322.04	20,544.96	20,156.06
Guatemala	26,069.79	23,497.54	22,638.43	22,208.56
Honduras	37,568.49	33,934.3	32,717.03	32,107.29
Nicaragua	32,511.43	29,317.78	28,250.43	27,716.24
Panama	24,877.82	22,395.62	21,567.94	21,154.06

Main findings

- Total value of carbon stock in Central America ranges from $381- $521 at carbon price of $3; $953 -$1,304 at a price path of $7.5 and $2540- $3,476 for $20 in the year 2005 per hectare from the sale of carbon from avoided deforestation. For timber the price range in 2005 is as follows: teak is $15,242-$20,857 for stumpage price $200 $/m^3$ and $28, 655- $39,212 for log price 376/m^3$. Eucalyptus has a range of $1626-$2,225 for stumpage price 20/m^3$ and $15,039-$20,579 for log price 185/m^3$. The countries with the greater forested areas obtain the higher ranges due to more areas available for timber harvesting or alternatively for potential conservation.

- The main incentive for conserving tropical forests is strongly influenced by the carbon price path. If carbon is priced at $3 the mode value, which can be obtained by forestry projects at the moment of writing, the NPV when compared to timber use falls short. However, at $20 carbon credits are comparable with eucalyptus (stumpage prices) but too low for teak.

- The discount rates strongly influence the NPV and PV for carbon and timber, suggesting that setting lower discount rates would be applicable if the future is valued more compared to higher discount rates which would give precedence to the present, accounting for intergenerational equity. Higher rates are typically set for developing countries as discussed in earlier sections of the paper.

- The timber on face value is the better land use option but it is difficult to determine the true costs from stumpage to log.

The results indicate that the economic return for managing natural forests is influenced by costs of timber and carbon prices and the discount rate applied. Returning to the original question, on whether ***we can reconcile the provision of timber with the other EGS´s when valuing tropical forests,*** there are many issues that need to be considered when valuing timber, especially regarding the management regimes, for example if forests are conserved the value for timber drops to zero. Revenues under REDD/REDD+ option would be higher if co-benefits, which include monies from the sustainable extraction of timber under Sustainable Forestry Management (SFM) are considered. SFM allows extraction of timber for economic gain leading to a periodic yield of wood whilst maintaining the production potential of the forest (Nieuwenhuyse et al 2000). Nieuwenhuyse et al (2000) have set sustainable wood production at 1.33 m^3/ha/year for good sites and 1.0 m^3/ha/year for poor sites.

The results of the analysis clearly illustrates that as a land use option, teak timber is more profitable on a hectare basis than the lower priced eucalyptus. In spite of its simplicity, an interesting characteristic of this study is that it relies on elements that can be easily approximated; the results are highly supportive and consistent of the other empirical studies such as those by Niskanen (1998) which compared teak with eucalyptus production in Thailand, and a study by Camino et al (2002) which looked at teak in Central America. However, it needs to be noted that the NPV -which *is the discounted sum of values of eco-system goods and services that would flow from a forest over a period of time, net of costs incurred*-does not capture the value of the forest wealth or possible change in it, only the flow of goods and services. Whilst net returns from timber are more profitable than those for carbon, the analysis does not reflect the multiple revenue sources available from the natural forests, both direct from carbon (and non- timber products, which are beyond the scope of this study) and indirect (environmental and social), including these revenues makes the carbon option as a more attractive investment.

Although interest in purchasing carbon credits from REDD and REDD+ activities has increased (Neeff et al., 2009), it should be kept in mind that even though the analysis for this study suggests that natural forest management is economically less attractive than timber activities, it reflects how forests are managed and wood is sold today. Typically, little or no management is carried out, and wood is sold to middlemen on stem. If farmers would be willing to carry out a certain degree of management directed to forest enrichment with desired species and furthermore process wood on the farm itself (thereby increasing value added), profits are likely to increase considerably and natural forest management may become more competitive with other land use **(**Nieuwenhuys et al 2000). The only option to preserve forest that competes with timber or in the case of many Central American countries, land suited for agriculture would be to raise incentives to match those from other land use options - otherwise farmers may be willing to leave land under forest only on marginal land or for reasons other than economic ones. This can in some ways pave the way for other EGS to be valued when looking at the forest as a whole. Several Central American countries have had incentive schemes in place, which have led to increase planting (Camino et al 2002), that have potential for carbon storage (Winjum et al 1992, 1993, Winjum and Schroeder 1996), but lack the biodiversity benefits offered by primary forest.

5 Conclusions

Maintaining the world´s forests offers opportunities to protect vegetation on land under the REDD project norms. There exists a huge potential for REDD and REDD+ projects in Central America, however to realize this potential, there is a need to create an environment that promotes low-risk carbon emissions reduction opportunities and underscore the sustainability elements, while optimising transaction costs. Countries that offer the best procedural, regulatory, administrative and financial opportunities together with political stability, are the most likely to become attractive to investors. Countries with less capable human resources, as well as being unfairly disadvantaged in attracting potential investments, are also likely to incur higher transaction costs. The response of governments, forestry officials, private institutes, and rural communities are likely to be influenced by the price path of carbon prices over time and the value of forests is highly contingent on which user perspective is applied. This paper can assist landowners on how to use economics tools and information to make investment decisions using current market values to aid in their decisions on how to use their land and resources. Conservation projects can provide an alternative source of income and with standing vegetation, the benefits to the environment and local livelihoods can continue well into the future, past the crediting periods of carbon. The REDD and REDD+ concepts are works in progress and there is a consistent shifting of key concerns and positions among countries but for many nations sustainable development remains the ultimate aspiration. Moving towards this goal, whilst still achieving greenhouse gas reductions presents tremendous challenges. REDD and REDD+ and its aim towards sustainability should incorporate decisions and planning that allow for better holistic decision- making in the forestry sector where the concept is viewed by nations as more than just a money-making tool.

There is a need to highlight co-benefits reflecting the other uses forests fulfil, which must be seen wholly that reflect multiple ecological and socio-economic functions. Revenues under the REDD+ option would have been higher if co-benefits such as from watershed protection, soil erosion control, recreation, and other non-carbon ecosystem services are included in the estimates for this study. The question of whether or not protection of existing forests through REDD poses any sort of ‘negative’ biodiversity also needs to be explored. The ability of the carbon market itself to provide real and equitable benefits for sustainable development is questionable as can be seen by the range of prices attainable under current forestry projects. The voluntary sector on the whole has been more engaged in a holistic approach as is reflected by the higher carbon prices. The diverse national circumstances of the forested countries need to be accommodated, while developing a policy framework for providing financial incentives under the concept of REDD/REDD+. The protection and sustainable management of forests need to be considered as positive practices to avoid deforestation. Learning from existing good practices in the forestry sector and translating these into effective implementation can ease the path for REDD and REDD + allowing for a set of principles that can be used to orient progress towards enabling an *evolving* policy environment.

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