Carbon-based Payments for Tropical Forest Conservation – A Case Study for Evergreen Forest in Cambodia

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As negotiations to include reduced emissions from deforestation and degradation (REDD) in the post-Kyoto agreements are underway, study on carbon payments for the REDD projects become urgently important. Having experienced rapid degradation and deforestation, Cambodia's highly stocked evergreen forest is the first priority forest to be conserved if carbon payments are available. Using inventory data and timber royalties in Cambodia, we analyze the costs for and revenues from timber harvesting against that from other five land use alternatives, namely forest-to-Teak, forest-to-Acacia, forest-to-Rubber, forest-to-Oil palm, and forest conservation. Annual Equivalents Values (AEVs) for timber harvesting are \$8.23–81.87 ha^{-1}. AEVs for other alternatives are \$0.92–16.16 for forest-to-Teak, \$0.92–16.65 for forest-to-Rubber, and \$46.38–461.35 ha^{-1} yr^{-1} for forest conservation. Forest-to-Acacia and oil palm are not profitable in Cambodia due to low productivity and high production costs. Discount rates strongly affect the revenues from all land use options. We estimate the costs for forest conservation at \$0.27–2.68 MgC^{-1} depending on discount rates. These carbon prices are well within the range of previous studies. A well-developed conservation plan identifying the roles and responsibility of stakeholders at all levels is required to ensure the success of the REDD projects as well as the sustainable development of the local communities.

Keywords: REDD, Forest Conservation, Carbon Payments, Avoided Deforestation, Cambodia

1. Introduction

Tropical deforestation is responsible for the release of about 1.5–2.2 PgC yr^{-1} (1 PgC=10^{15} gC) (IPCC, 2007; Gullison et al., 2007; Houghton, 2003) in the 1990s. Furthermore, as all commercially large timber species are indiscriminately harvested, tree species composition may influence carbon balance in tropical forests up to 600% (Bunker et al., 2005), forest degradation may account for another 25-42% and 132% of carbon emissions from forests in tropical Asia (Flint and Richards, 1994; Iverson et al., 1994) and tropical Africa (Gaston et al., 1998), respectively. Additional to the increased carbon emissions, deforestation and degradation in the tropics have caused the loss of biodiversity and ecosystem services (Foley et al., 2007; Costanza et al., 1997). These huge emissions and biodiversity loss prompted the Intergovernmental Panel on Climate Change (IPCC) to recognize the urgent need for preventing carbon emissions from tropical forests as the largest and most immediate carbon stock impact in the short term (IPCC, 2007).

Defined as *protecting and managing forestland for sustained flow of full ecosystem services*, forest conservation plays an increasingly important role in poverty eradication and carbon emission reductions through reduced carbon emissions from deforestation and forest degradation (REDD) initiative. International negotiations to include REDD in the post-Kyoto agreement have been intensified in recent years. In 2005, the issue of reducing emissions from deforestation was discussed in relation to a request by the governments of Papua New Guinea and Costa Rica that compensation be provided for reducing emissions from deforestation in developing countries at the Conference of the Parties (COP11) of the United Nations Convention on Climate Change (UNFCCC) in Montreal. In the following year at the COP12 in Nairobi, further discussions, especially on policy issues were held, and finally in December 2007 at the COP13 held in Bali, the parties to the UNFCCC through their Bali Action Plan reaffirmed the urgent need for tackling the climate change and tropical deforestation through the inclusion of REDD in the post-Kyoto agreement (UNFCCC, 2008a). At the COP 14 held on 1–12 December 2008 in Poznań, Poland, discussions on the inclusion of REDD were intense, and an agreement on the central role of conservation in the REDD was reached (IISD, 2008). The potential roles of the REDD as a new mitigation for the post Kyoto agreement have been recently studied (but see Sasaki and Putz, 2009), ranging from reduction potentials to relative costs for such reductions (Gullison et al., 2007; Ebeling and Yasue, 2008; Grassi et al., 2008; Kindermann et al., 2008).

Until recently, only a handful of modeling studies have been made to estimate the costs for conserving the tropical natural forests in the framework of the REDD. Recent studies have estimated the costs for avoided deforestation in the tropics as varying from \$0.40–\$6.90 (Kindermann et al., 2008; Bellassen and Gitz, 2008; Niles et al., 2002), and as high as \$19.70 MgC^{-1} if the cost for improving forest management is included (Kim Phat et al., 2004). Although such estimates provide useful information on the potential overall ranges of the abatement costs, studies that did not take into account the logging practices and revenue collecting system based on timber royalty charged on harvested wood by tree species in a country in concern may not be applicable for actual implementation. Detailed estimates of forest revenues from timber harvesting as permitted in logging practice code, revenue collecting system or regulations are necessary for smooth implementation of the REDD projects. Furthermore, due to the concern over international leakages, developed counties prefer to have full international participation in the implementation of the REDD projects when the REDD is adopted (UNFCCC, 2008b). This provides further strong incentive for country-level studies of the REDD's costs.

Like many other countries in Southeast Asia, Cambodia has experienced rapid forest degradation and deforestation since the last few decades. Losing about 0.1 million ha yr^{-1} (0.7%), deforestation coupled with degradation are responsible for the release of about 13.7 TgC yr^{-1} (1 TgC = 10^{12} gC) from natural forests in Cambodia between 1973 and 2003 (Sasaki, 2006). Since forest resources play developmentally, culturally, and environmentally important roles in Cambodia, there is urgency to reduce deforestation and degradation through conservation, and only carbon payment schemes under the international agreements could realize this conservation. Accounting for 33.8% of the total forest area, evergreen forest has been repeatedly logged. Over the last 5 years between 2000 and 2005, about 29% of primary forests (mainly evergreen forest) were lost to severely degraded forests or other types of land uses (FAO, 2005). Some of this degraded evergreen forest has re-grown or has been gradually replaced by mixed forest (Ty, 2005) whose timber or carbon stock is much lower than that in undisturbed evergreen forest. Therefore, special attention should be paid on the conservation of evergreen forest as a first conservation priority.

In order to provide a range of the costs for conserving tropical natural forests, it is essential that tree species composition, tree grades, timber royalty rates, and the laws of the concerned country be incorporated in the studies. The aim of our study is to estimate the profitability (in terms of carbon prices) of six alternative land uses with special emphasis on timber harvesting and forest conservation for full ecosystem services. A natural evergreen forest in Cambodia was chosen as a case study. We structure our study as follows: forest inventory data conducted in evergreen forest are revisited and analyzed and the resulting stem density, basal area and volume are classified into five tree grades so that costs and revenues from timber harvesting can be estimated. Then, Net Present Values (NPVs) and Annual Equivalent Values (AEVs) from timber harvesting are estimated and compared with those from other land use alternatives; then the carbon price for not harvesting the forest is estimated. Finally, carbon prices for each land use alternatives are estimated.

2. Materials and Methods

2.1. Forest inventory

Data from 23 clusters (one cluster contains 9 plots of 20m x 60m size) conducted in evergreen forest in Cambodia were analyzed (Kim Phat et al., 2000) and the results are presented in Table 1.

Table 1. Aboveground and belowground carbon stock by DBH classes and tree grades (in MgC ha^{-1})

DBH Class / Tree Grade	5–9.9	10–29.9	30–up	Total	Percentage (%)
GLT (luxury grade)	0.7	1.0	0.9	2.6	1.5
G1T (first grate)	0.5	1.9	12.8	15.3	8.9
G2T (second grade)	1.3	10.3	67.9	79.6	46.2
G3T (third grade)	1.5	10.0	15.8	27.3	15.8
OGT (out of grade)	4.2	15.6	27.6	47.4	27.5
Carbon Stock	8.2	38.9	125.1	172.2	100.0

2.2. Net Present Values (NPV)

NPV and Annual Equivalent Value (AEV) are compared for the following land use alternatives: timber harvesting, converting evergreen forest to Teak plantation (forest-to-Teak hereafter), forest-to-Acacia, forest-to-Rubber, forest-to-Oil palm, and forest conservation.

If the government decides to manage a forest for timber production, the NPV of one hectare of forest over a 25-yr cutting cycle (T) for timber harvesting is

$$\mathrm{NPV} = \sum_{t=0}^{T} \frac{(\mathrm{TR}_t - \mathrm{TC}_t - \mathrm{TC}_{\mathrm{REDD}})}{(1+r)^T} \qquad (1)$$

where NPV is net present value (\$ ha^{-1}), TR_t is total revenues (\$ ha^{-1}), TC_t is total costs (\$ ha^{-1}), TC_{REDD} is the total costs for monitoring, reporting and verifying as required under the REDD agreement. Due to the lack of information on $\mathrm{TC}_{\mathrm{REDD}}$, a fee equivalent to that of forest certification of \$1.40 per cubic meter of harvested wood (Kim Phat et al. 2004) is assumed for timber harvesting; TC_{REDD}=45.31*1.40=63.43 or about 1% of the TC_t. For other land use alternatives, TC_{REDD} is assumed to be 1% of the TC_t. r is the discount rate, and T is the management or cutting cycle (years). For financial comparisons, 3 discount rates are taken. They are a currently high rate (but under unstable economic growth) of 18.5% in Cambodia, a rate of 8% in a more stable economic development in least-developed country (Hunt, 2002), and a of 4% used by van Beukering et al. (2003) to study ecosystem services in a national park in Sumatra, Indonesia.

Total revenues (TR_t):

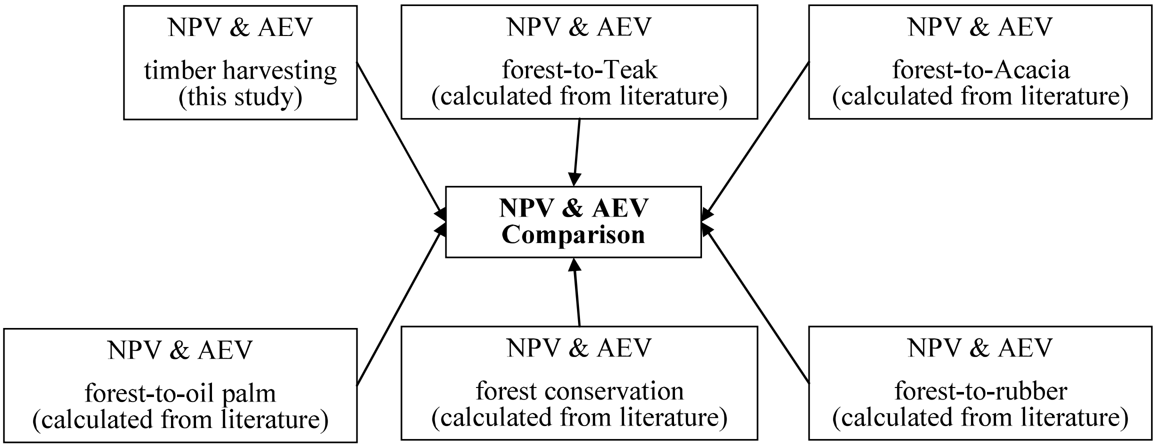
$$TR_t = R_{GOV} + R_{COM} \qquad (2)$$

where R_{GOV} is revenues from timber harvesting for government as resource owner. R_{COM} is logging company's total revenue (\$ ha^{-1}) taken from Kim Phat et al. (2001). R_{GOV} is derived by:

$$R_{GOV} = \left(\sum_{i=1}^{5} R_i \times HW_i + Tax \right) \qquad (3)$$

R_i is timber royalty (in \$ m^{-3}) of harvested wood (HW_i in m^3 ha^{-1}) of tree grade i, *Tax* is various taxes, fees and services relative to timber harvesting and wood exporting (see Table 1 for details). *Tax* includes fees for reforestation, export tax on final products 10% of reference price of freight on board (FOB), service charge for export (1% of reference price of FOB), custom charge (0.085% of reference price of FOB), concession fees, fees for social and infrastructure obligations (Kim Phat et al., 2001). Reforestation tax in 1997 was reported by Kim Phat (1999) at about \$8.7, \$2.6, \$0.9, \$0.5, and \$0.5 per m^3 of harvested wood in log stockpiles, respectively for GLT, G1T, G2T, G3T, and OGT. In order to calculate the taxes on exported wood products, i.e., sawnwood or veneer, we need an estimate of proportion of harvested wood (HW) is processed at the sawmills. Based on several studies (FAO, 2001; Holmes et al., 2002; Sist and Sridan, 1998), about 20–40% of the HW is wasted due to skidding, trimming and transporting, and therefore only about 60–80% is available at the sawmills for further processing. For this study, 30% of the HW is taken as wood waste. The remainder 70% is further processed for end-use products i.e. sawnwood or veneer in our study. G1T and G2T are usually processed for veneer products at a conversion rate of 54% (Kim Phat, 1999), while the rest are used for sawnwood at a conversion rate of 49% (Kim Phat, 1999). Information on forest concession fees is not available in Cambodia at the time of this study. Forest concession fees have been reported at about \$0.30 and \$2.40–3.90 ha^{-1} yr^{-1} in Gabon (GFW, 2000a) and Cameroon (GFW, 2000b), respectively. Low fee was reported in Nicaragua at \$0.7 km^{-2} or about \$0.007 ha^{-1} yr^{-1} (Gray and Hagerby, 1997). For our study, \$1.0 ha^{-1} yr^{-1} is taken as concession fee in Cambodia.

According to Cambodia's SubDecree 050 on timber harvesting, 30–50% of stand volume of the mature trees (except luxury grade) shall be harvested depending on the proportion of mature trees in the forests concerned. The field forest inventory officer will decide the rate of harvesting. For this study, 30% of mature stands are assumed to be harvested on a 25–yr cutting cycle. Mature trees are determined in accordance with DBH minimum limit for harvesting: all trees whose DBHs are greater than the DBH minimum limits are considered to be mature trees, of which 30% are then available for harvest. Based on the tree list in the Forestry SubDecree 050, all trees in luxury grade have a DBH minimum limit at 45 cm (if harvest is allowed). Averages of DBH limit for 25 and 23 trees in grade 1 and grade 2 in Table 2 are 43.6 and 45.4 cm, respectively. For this study, 45 cm is assumed for both grades. Average DBH of 31 trees of grade 3 in table 2 is 37.6 cm. For this study, DBH minimum limit for grade 3 and out of grade trees is both assumed at 40 cm.



Note: highest AEV is attractive, and therefore it is a baseline for REDD carbon payments

Fig. 1 – NPVs and AEVs comparisons for various land use alternatives

TC_t is total costs:

$$TC_t = TC_{GOV} + TC_{COM} \qquad (4)$$

where TC_{GOV} is total costs incurred by the government, TC_{COM} is total costs incurred by logging companies. TC_{GOV} is be derived by

$$TC_{GOV} = \left[\frac{(W_{STAFF} + A_{STAFF} + O_{STAFF}) \times T_{STAFF}}{H_{AREA}} \right] \qquad (5)$$

W_{STAFF} is mean annual wage (\$ staff^{-1}), A_{STAFF} is mean annual allowance (\$ staff^{-1}), O_{STAFF} is mean annual overhead (\$ staff^{-1}), T_{STAFF} is total forestry staff in Cambodia, H_{AREA} is annual harvesting area (ha)

Due to the lack of reliable information about the wages of the government officers referred to as staff in this study, the annual GDP per capita is assumed to be the same as the mean annual wage for each of all 1,622 forestry staff (T_{STAFF}) in 1998 (Kim Phat, 1999). Cambodia's GDP per capita in 1998 was \$745.1 person^{-1} (W_{STAFF}=745.1). Fieldwork (forest management activities) is usually carried out in dry season between November and April. For this study, each forester is assumed to spend 4 months (4 x 30 = 120 days) per year for fieldwork activities. Based on personal communications with Cambodian foresters, daily allowances of \$10 for food and another \$10 for accommodation are being paid to government foresters by government or project developers. Therefore, total allowances for fieldwork for each forester are 120 days x \$20/day = \$2400 (A_{STAFF}=2400). With this assumption, a total monthly salary for a government forest is \$262.09. Based on author's own experience (more than 20 years), this salary is reasonable for government officers to live without relying on other sources of incomes. O_{STAFF} is assumed at 50% of W_{STAFF} and A_{STAFF} [(O_{STAFF} =W_{STAFF} +W_{STAFF})*0.5]. According to Kim et al. (2006), total area of forest concession in

Cambodia was 5,274,143.6 ha in 1997, of which 50% is operable. Therefore, the H_{AREA} is 105,482.9 ha yr^{-1} (=5,274,143.6*0.5/25) over a 25-yr cutting cycle currently practiced in Cambodia. TC_{COM} is taken from Kim Phat *et al.* (2001). Although Cambodian Code for Forest Harvesting requires that logging companies pay for social and infrastructure development to forest-dependent communities, the rate for such payments is not available, and therefore, it is neglected in our study. When REDD agreement is reached, this kind of payments should be clearly defined before the REDD projects can be implemented.

2.3. Annual Equivalent Value (AEV)

AEV is adopted for our study because NPV is not appropriate for comparisons of economic feasibility of projects with different lifetimes (Gutiérrez et al., 2006). AEV is derived by

$$\mathrm{AEV} = \frac{\mathrm{NPV}\cdot \mathrm{r}\cdot(1+\mathrm{r})^{\mathrm{T}}}{(1+\mathrm{r})^{\mathrm{T}+1}-1} \qquad (6)$$

Costs for and revenues from other land use alternatives were obtained from the literatures (see Table 2), except NPVs and AEVs whose values were obtained using equations (1) and (6). Detailed explanations are given in the results section.

2.4. Carbon Price for Conserving Forests

In order to conserve tropical natural forest, carbon gained in the forest should be priced at or above the profit break-even point. Carbon price (*CP*) per hectare of forest is estimated by

$$\mathrm{CP} = \frac{\mathrm{AEV}}{\sum\sum(\mathrm{CS}_{ij}-\mathrm{CS}_{\mathrm{MAI}}-\mathrm{CS}_{\mathrm{CON}})} \qquad (7)$$

where AEV is annual equivalent value for each land use alternative, where CS_{ij} is carbon stock of tree grade *i* in DBH class *j* (MgC ha^{-1}) (see Eq. 2 in SM for calculation), CS_{MAI} is the mean annual increment (MgC ha^{-1} yr^{-1}), CS_{CON} is the mean annual wood consumption by local communities (MgC ha^{-1} yr^{-1}). For simplicity, it is assumed that $\mathrm{CS}_{\mathrm{MAI}} = \mathrm{CS}_{\mathrm{CON}}$, and thus $\mathrm{CS}_{\mathrm{MAI}} - \mathrm{CS}_{\mathrm{CON}} = 0$.

3. Results and Discussions

3.1. Costs for and Revenues from Timber Harvesting

Stand volume of mature trees is estimated at 61.8% of the total stand volume or about 151.00 m^3 ha^{-1}. Because only 30% of the mature trees are allowed to be harvested, total harvest wood is 45.31 m^3 ha^{-1} for all tree grades per 25-yr cutting cycle. Trees of GLT (only 0.24 m^3 ha^{-1}) are also assumed to be harvested due to unavoidable road construction. Of the 45.31 m^3, 0.24, 4.35, 26.24, 4.92, and 9.56 m^3 are for GLT, G1T, G2T, G3T, and OGT, respectively. In terms of timber royalty, \$38.06, \$260.98, \$1049.63, \$157.46, and \$191.23 ha^{-1} are from the five-grade trees above, respectively, with a total of \$1697.40 ha^{-1} per 25-yr cycle. Revenues per harvesting cycle from various taxes such as taxes on reforestation, concession fees, and export services of processed wood (sawnwood and veneer wood) are estimated at \$44.22, \$25.00, and \$747.06 ha^{-1}, respectively (Table 2). All together, revenues from harvesting one hectare of tropical natural forest are estimated at \$2513.68 ha^{-1} per cutting cycle. In order to monitor and control timber harvesting and collection of taxes, the government employs 0.015 staff ha^{-1} equivalent to about \$72.54 ha^{-1}. Costs for monitoring, reporting and verifying as required by the REDD agreement are \$63.43 ha^{-1}. For company, based on Kim Phat et al. (2001), total revenues and costs are estimated at 10491.48 and 11741.76 ha^{-1}, respectively. Depending on timber market prices, a logging company in Cambodia would make \$27.60 (with confidence interval of \$16.80–38.60) per every cubic meter of wood harvested, processed and exported. Totally, revenues and costs for timber harvesting are estimated at \$14255.44 and \$10627.46 ha^{-1}, respectively.

Table 2. Timber revenues from timber harvesting (unit: ha^{-1})

Description Tree Grade	GLT	G1T	G2T	G3T	OGT	Total
1. Harvested Wood						
30% cut (m^3)	0.24	4.35	26.24	4.92	9.56	45.31
Royalty (\$/ha)	*38.06*	*260.98*	*1049.63*	*157.46*	*191.27*	*1697.40*
2. Reforestation fee						
\$ m^3 of HW	8.70	2.60	0.90	0.50	0.50	
Total fees	*2.06*	*11.31*	*23.62*	*2.46*	*4.78*	*44.22*
3. Concession fees (\$1 ha^{-1} yr^{-1})						*25.00*
4. Taxes and Services on processed wood						
WP=0.7 × HW (m^3)	0.17	3.04	18.37	3.44	6.69	
edWP=0.65 * WP (veneer in m^3)		1.64	9.92			
edWP=0.49 × WP (sawn wood in m^3)	0.08			1.69	3.28	
Taxes (10%+1%+0.085% of FOB price)						
FOB price of veneer (\$ m^{-3})		430.00	430.00			
FOB price of sawn wood (\$ m^{-3})	350.00			350.00	350.00	
Total taxes (\$)	*3.15*	*78.37*	*472.80*	*65.48*	*127.26*	*747.06*
Total Revenues (1+2+3+4)	43.26	350.66	1546.04	225.40	323.31	2513.68

3.2. Comparisons of Annual Equivalent Values (AEVs) from other Land Use Alternatives

AEVs for six land use alternatives are compared (see Fig. 1). Cassava, which is farmed elsewhere in Southeast Asia is not profitable in Cambodia due to high production cost and low productivity (Huang et al., 2002).

AEVs for timber harvesting: AEVs for government as resource owner are estimated at \$55.09 and \$30.53, and \$5.54 for 4%, 8.0% and 18.5% discount rates, respectively per 25-yr cutting (Table 3). For a logging company, harvesting one hectare of evergreen forest could provide company with a AEVs of \$26.78, \$14.84, and \$2.69 for 4%, 8.0%, and 18.5% discount rates, respectively per 25-yr cutting cycle. All together, total AEVs from timber harvesting is \$81.87, \$45.38, and \$8.23 for three discount rates above (Table 3).

AEVs for forest-to-Teak: Converting natural forests to Teak plantation incurred a total cost of \$41.25 ha^{-1} yr^{-1}, while a total return is about \$1000 ha^{-1} yr^{-1} (Agrifood Consulting International, 2005), equaling to AEVs of about \$16.16, \$7.77, and \$0.92 ha^{-1} yr^{-1} for 4%, 8.0%, and 18.5% discount rates, respectively per a 30-yr cutting rotation (Table 3).

AEVs for forest-to-Acacia: If plantation of *Acacia* or *Eucalyptus* species is established over a 10-yr cutting rotation, the annual cost and revenue are \$688.88 and \$61.60 ha^{-1} yr^{-1}, respectively (Agrifood Consulting International, 2005), representing a loss of AEVs of about \$46.51, \$37.68, and 21.22 ha^{-1} yr^{-1} for the same discount rates above. Converting natural forest to *Acacia* or *Eucalyptus* plantations (mainly *E. grandis* and *A. auriculiformis*) is not profitable because the mean annual increments for these species in Cambodia are very low at about 2.8 m^3 ha^{-1} yr^{-1} (Agrifood Consulting International, 2005) compared to 34 and 45 m^3 ha^{-1} yr^{-1} (average) for *Acacia mangium* and the *Eucalyptus hybrid* clone 0321 in Brazil (Rossi et al., 2003), 68 m^3 ha^{-1} yr^{-1} for *Eucalyptus grandis* in Brazil (Dedecek et al., 2001), 21 m^3 ha^{-1} yr^{-1} for *Eucalyptus robusta* in Malaysia and India (NAS, 1983), 28 m^3 ha^{-1} yr^{-1} in Thailand (Mayers, 2000), and 7-15 m^3 ha^{-1} yr^{-1} in Vietnam (GTZ, 2007). The lack of access to local market is another factor that leads to the increase in production cost.

AEVs for forest-to-rubber: Rubber plantations are the second source of government revenues, earning \$83 million or about 4% of the total national exports in 2004. Area of rubber plantation is projected to increase rapidly from 66,000 ha in 2004 to 94,000 ha in 2010, to 124,000 ha in 2020, and to 150,000 ha in 2030 (Cambodian Embassy, 2007). Although information on total costs and revenues from rubber plantation in Cambodia is partially available, on average for the initial years between year zero and year six, cost per ha ranges from \$1520.00 (MAFF, 2006) to \$2460.00 (Marubeni, 2004) or about 253.30 to 410.00 ha^{-1} yr^{-1}. The annual maximum maintenance costs after the year 6th is estimated \$200.00 ha^{-1} yr^{-1} (Agrifood Consulting International, 2005). The price of rubber production is, on average \$1500.00 ha^{-1} annually from the year 6th until the year 30th. Over a 30-yr period, average cost for rubber plantation and the sale of rubber production are \$211.93 (MAFF, 2006) and \$250.50 (Marubeni, 2004), and \$1200.00 ha^{-1} yr^{-1}, respectively. Therefore, the AEVs for rubber plantation are \$16.00–16.65, \$7.70–8.01, and \$0.92–0.95 ha^{-1} yr^{-1} for the three discount rates above (Table 3).

AEVs for forest-to-oil palm: Agrifood Consulting International (2005) conducted analysis of oil palm plantation in Cambodia. According to their analysis, the total annual costs for oil palm plantations in Cambodia over a 25-yr planting cycle are \$852.49 ha^{-1}, while the total revenues are only \$747.60 ha^{-1}, resulting in a loss of AEVs of about \$2.37, \$1.31, and 0.24 ha^{-1} yr^{-1}. Thus, converting natural forests to oil palm plantation is currently not profitable in Cambodia. This is because oil palm productivity in Cambodia is low at 10.6 ton ha^{-1} yr^{-1} over a 25-yr cycle (Agrifood Consulting International, 2005), compared to 23.0–26.0 ton ha^{-1} yr^{-1} in Sumatra, Indonesia (Redshaw and Sigg, 1993, Butler et al. 2009).

AEV for forest-to-conservation: Although no detailed study of forest ecosystem services has been conducted in Cambodia, profits from collecting non-timber forest products (NTFPs) in Phnom Kok community forests range from \$55 to \$320 $person^{-1}$ yr^{-1} (Kim et al., 2008). Similar amounts were also estimated at \$280-345 per household per year (Heov et al., 2006). Based on Costanza et al. (1997), the values of tropical forests for such functions as disturbance regulation, water regulation, water supply, soil erosion control, soil formation, nutrient cycle, waste treatment, food production, genetic resources, recreation, and cultural services account for 73.2% of all ecosystem services. This 73.2% is assumed for our study, and the total revenues from forest conservation are estimated at \$24690.43 ha^{-1}. Total conservation costs account for 17.1% of the total revenues (Mogaka, 2009) or \$4247.42 ha^{-1} (17.1% of revenue plus REDD fees). With these assumptions, the AEVs for forest conservation for full ecosystem services are \$461.35, \$255.68, and \$46.38 ha^{-1} for 4%, 8%, and 18.5% discount rates, respectively (Table 2).

CDM credit through afforestation and reforestation: the immediate clearance of natural forests for any type of forest plantations is not eligible for carbon credits, and therefore, carbon sinks in planted forests and associated carbon trading are not considered in this study.

Table 3. Costs, revenues, and AEV from different land use options

Management Options	$TC+T_{CREDD}$ (\$ ha^{-1})	TR (\$ ha^{-1})	Cycle (yrs)	AEV 4%	AEV 8.0% (\$ ha^{-1} yr^{-1})	AEV 18.5%	Carbon Price*[2] 4%	Carbon Price*[2] 8.0% (\$ MgC^{-1})	Carbon Price*[2] 18.5%
Timber harvesting	10627.46	14255.44	25	81.87	45.38	8.23	0.48	0.26	0.05
Government	72.54	2513.68	25	55.09	30.53	5.54	0.32	0.18	0.03
Company*[1]	10554.91	11741.76	25	26.78	14.84	2.69	0.16	0.09	0.02
Teak Plantation	41.25	1000.00	30	16.16	7.77	0.92	0.09	0.05	0.01
Eucalyptus or Acacia plantations	688.88	61.60	10	-46.51	-37.68	-21.22	-0.27	-0.22	-0.12
Rubber plantation	211.93	1200.00	30	16.65	8.01	0.95	0.10	0.05	0.01
Rubber plantation	250.50	1200.00	30	16.00	7.70	0.92	0.09	0.04	0.01
Oil palm plantation	852.49	747.60	25	-2.37	-1.31	-0.24	-0.01	-0.01	0.00
Conservation	4247.42	24690.43	25	461.35	255.68	46.38	2.68	1.48	0.27

*[1]: for harvesting density of 45.3 m^3 ha^{-1}
*[2]: AEV divides by 172.2 MgC ha^{-1} (see Table 1)
*[3]: 17.1% of the TR (based on Mogaka, 2009)
*[4]: 73.2% higher than TR from timber harvesting (based on Costanza et al., 1997)

According to Table 3, timber harvesting is financially more attractive than teak or rubber plantations. However, based on experience elsewhere in the tropics (Huth and Ditzer 2001), a 25-yr cutting cycle is very short in order to sustain a commercial timber yield that requires 45.3/25=1.8 m^3 ha^{-1} yr^{-1} of mean annual increment (MAI). MAI in Cambodia is generally accepted at only 0.33 m^3 ha^{-1} yr^{-1}. Therefore, it will take 137 (=45.3/0.33) years in order to reach the current level of harvesting. This clearly shows that the current level of harvesting can not be sustainable, and will lead to forest degradation. As consequences, the future availability of full ecosystem services (including timber) is compromised. Furthermore, the current conventional logging method causes huge damages to residual stands, up to 1% every year of the whole stocking volume (Sist et al., 2003). Another attractive option of land use is the conservation if incentives under a new climate change agreement are made possible. Forest conservation option will ensure the sustainability of forest resource and well-functioning ecosystems, which in term continuous flows of ecosystem services will benefit forest dependent communities as well as government, logging companies, and other stakeholders that switch from unsustainable harvesting practices to, or participate in forest conservation.

3.3. Carbon Prices for various Land Use Alternatives

The Bali Action Plan (UNFCCC, 2008a) encourages parties to the UNFCCC convention to start implementing the REDD projects on a voluntary basis, while the negotiation for including REDD in the next climate agreement is in progress. Sustained interests in the REDD were seen through the intensive discussions for its inclusion in the new climate agreement at the COP14 held in December 2008 in Poznan, Poland. If agreement on REDD is reached, compensation for tropical forest conservation is likely to be made in terms of carbon price per ton of carbon (MgC) avoided from deforestation or stored in the forests. Because AEVs for other land use alternatives are smaller than timber harvesting and forest conservation, only the carbon prices from these two alternatives are compared. Carbon prices are estimated at \$ 0.05–0.48 MgC^{-1} (about \$0.18–1.78 $MgCO_2^{-1}$) if compensation is made for not harvesting timber depending on discount rates, or about \$0.27–2.68 MgC^{-1} (about \$0.99–9.84 $MgCO_2^{-1}$) for forest conservation (Table 5). Cambodian government priced the carbon from its REDD project at \$3.00 per ton CO_2 (Khun, 2008). Affecting mainly by discount rates, our estimates of carbon prices are in the range of previous studies i.e. \$0.18–0.71 MgC^{-1} (Osborne and Kiker, 2005), \$0.30–2.40 MgC^{-1}, and for 10% and \$2.30–10.40 MgC^{-1} for 50% reduction of deforestation in Southeast Asia (Kindermann *et al.*, 2008) and \$2.8 MgC^{-1} in Cameroon (Bellassen and Gitz 2008).

3.4. Policy Implications

Under the voluntary carbon markets whose value increased to \$705 million in 2008 from just \$335 million in 2007, a REDD project has been signed between the Royal Government of Cambodia and a U.S.–based Terra Global Capital to conserve 60,000 ha of forests in Northwestern Cambodia (Khun, 2008). It can be argued that Cambodia has the political wills and basic infrastructures for implementing the conservation or REDD projects. Domestic leakages are urgent problems that need to be addressed. It is of urgent priority that Cambodian government prepare detailed management plans of forest resources across the country. The detailed plans should include forests designated for the REDD projects, forest stand structures (for degradation monitoring), regular resource assessment, the roles and responsibilities of all stakeholders at all levels, and the benefit sharing scheme among all stakeholders. Capacity building should also be made available to all levels of stakeholders so that smooth and effective implementation of the REDD project can take place. Socio-economic and environmental impact assessments of the resource use and management should also be provided. Other plans for managing none-REDD forests are also prerequisite in order that domestic leakages can be avoided to the minimum.

4. Conclusion

Our results suggest that the carbon costs for conserving natural forests for full ecosystem services in Cambodia is higher than that for other land use alternatives. Conservation ensures the sustainability of forest resources, ecosystem functioning, and most importantly sustainable development of the poor communities who depend almost entirely on ecosystem services, which could not be obtained, otherwise. The conservation costs for full ecosystem services of \$0.27–2.68 MgC^{-1} is well below carbon prices traded in European carbon market. A well-developed forest conservation plan identifying the roles and responsibility of stakeholders at all levels is required to ensure the success of the REDD projects. This plan should not compromise the traditional uses of natural forests by indigenous populations either as wood materials for housing for their newly married families, or for cultural and social practices. Capacity building in forest resource management and conservation, and expanded education about the consequences of different management options should be provided regularly to all stakeholders.

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