WORKING PAPER

Estimating the costs of reducing forest emissions

A review of methods

Sheila Wertz-Kanounnikoff

CIFOR

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Contacts

Sheila Wertz-Kanounnikoff
Center for International Forestry Research (CIFOR)
P.O. Box 0113 BOCBD
Bogor 16000
Indonesia
Tel: +62 251 8622 622
Fax: +62 251 8622 100
Email: s.wertz-kanounnikoff@cgiar.org

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Disclaimers

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Acronyms and abbreviations

CDM	Clean Development Mechanism
CIFOR	Center for International Forestry Research (Indonesia)
DIMA	The Dynamic Integrated Model of Forestry and Alternative Land Use
GCOMAP	The Generalized Comprehensive Mitigation Assessment Process Model
GHG	Greenhouse gas
GTM	The Global Timber Model
IBGE	Brazilian Institute of Geography and Statistics
IIED	International Institute for Environment and Development (UK)
INPE	Brazilian Institute for Space Research
IPCC	Intergovernmental Panel on Climate Change
NPV	Net present value
PES	Payments for environmental services
RED	Reduced emissions from deforestation
REDD	Reducing emissions from deforestation and forest degradation
WRI	World Resources Institute

Executive summary

This paper reviews main approaches to estimate the costs of REDD, with a focus on the opportunity costs. These can be classified into local-empirical, global-empirical and global simulation models. In local-empirical models, per-area opportunity cost estimates are derived from detailed studies (surveys) and carbon density estimates – both specific to the particular area studied. Global-empirical models use local-empirical estimates, aggregate these to global per-area costs of reducing deforestation, and use uniform values of carbon density (ton/ha) to obtain a single, global estimate of opportunity costs ($/tCO2eq). Global partial equilibrium models simulate the dynamics of the world economy to estimate supply of REDD services (or avoided deforestation), represented in supply curves.

One striking observation is that the cost of REDD differs substantially across model approaches: global simulation models yield far higher REDD prices than empirical models, including the Stern estimate. The 'true' cost estimate is most likely to lie somewhere in between the values provided by the local-empirical models on the one hand (lower end) and global simulation models on the other (higher end).

The following messages arise from this review:

Alternative cost assessment methods suit different needs

Each method has its own advantages and disadvantages: for an indication of total costs of REDD as a climate change mitigation option compared to alternatives, the use of global simulation models seems adequate. Local models are useful complements of global estimates, in particular for capturing sub-national or sub-regional variations in opportunity costs.

Need for systematic transaction cost assessments

Transaction costs are important components of the costs of REDD, but methods for systematic assessment remain limited. Investment in guidelines for systematic transaction cost assessments could be of added value. This could be done in a manner similar to the three-tier methodologies developed by the IPCC Guidelines for land use and forestry projects where alternative methods are proposed depending on existing resources and capacity.

REDD costs depend on the degree of emission abatement (all versus almost all)

The marginal costs of REDD are increasing which means the more emission abatements are sought, the more has to be paid for one additional unit of REDD until no more reductions can be made (i.e., the maximal level of reductions is reached). In turn, emissions from deforestation and forest degradation to nearly zero requires far higher costs than would be needed when only reaching for the 'low hanging fruits', i.e., those emission reductions that can be achieved at lower costs. REDD policies could consider this option to reduce the costs of emission abatements.

REDD costs also depend on payment design

The costs of REDD further differ depending on the ultimate REDD payment design. Uniform payments, where every landowner receives the same amount of payment for REDD, are more costly (up to 4 times as found in one case in the Brazilian Amazon) than differentiated payments where each landowner receives just his/her opportunity costs. Because alternative payment schemes have different cost implications, and provided differentiated landowner payments are considered feasible in REDD schemes[1], it could be useful to dedicate some efforts to cost-benefit analyses of alternative payment schemes.

1 There are pros and cons regarding uniform/differentiated payments in the context of REDD, but more important is the political decision whether or not all countries will receive the same $/tCO_2$ price.

1. Introduction

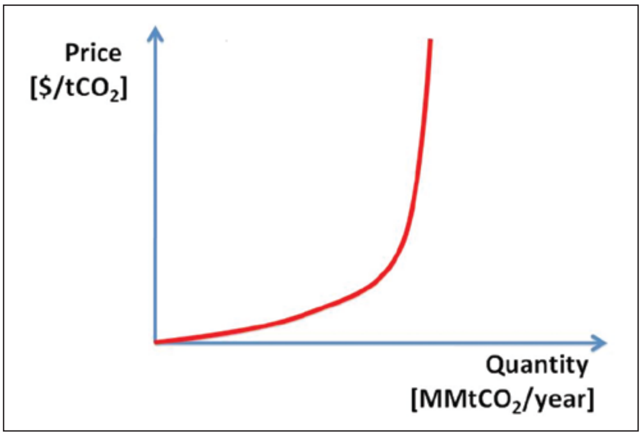
The costs associated with the reduction of greenhouse gas (GHG) emissions from deforestation and forest degradation (REDD) shape both the demand for, and supply of, REDD services. Investors and policymakers in particular are highly interested in REDD cost information – not only for budget reasons, but also to decide where to allocate investments (sector and country), and to assess how much benefit (in terms of reduced emissions) is received in return for investment.

The economic concept of the supply curve suggests that there is no single cost-value, but that alternative levels of REDD supply are associated with different costs. For example, while some landowners can reduce emissions inexpensively, others will require a higher price per ton of CO_2 reduced. This logic is reflected in the supply curve, which graphs the quantity supplied against the price paid (see Figure 1). In other words, there is no single "cost per ton" but rather a range of costs depending on the quantity – up to a point where no more reductions are possible (due to limited forestlands).

The costs of REDD fall into two categories:

1. The first represents the 'opportunity costs', i.e., the forgone profits from alternative land uses such as cash or food crops (including revenues from timber sales), which correspond to the minimum price to be paid for REDD services.
2. The second kind represents the 'transaction costs', which encompass all costs associated with establishing and running the scheme (government transaction costs), and the costs individual landowners have to bear in order to participate in the programme (private transaction costs).

Figure 1: Example of REDD supply curve



This paper reviews current methods to estimate the costs of REDD, with a focus on opportunity costs. It is organised as follows: Section 2 describes alternative approaches used to estimate the opportunity costs of REDD; Section 3 reports how transaction costs are estimated or used in REDD cost calculations; and Section 4 comprises concluding remarks.

2. Estimating the opportunity costs of REDD

Three approaches to estimating REDD costs can be identified in the literature (Boucher 2008):

1. Local-empirical models.
2. Global-empirical approaches.
3. Global simulation models.

Sometimes these approaches are simply grouped into local and global models.[2]

2.1 Opportunity cost calculation with local-empirical models

Estimates from local-empirical models are based on detailed studies (surveys) in a particular area. Both the per-area cost estimates ($/ha) and the carbon density estimates (ton/ha) are specific to the particular region studied, and the division of per-area opportunity costs by carbon density gives the opportunity costs on a per-ton basis (Boucher 2008). Since results are specific to a particular region, their extrapolation or generalisation can be problematic (Grieg-Gran 2006).

The literature on opportunity costs of tropical forestland is growing rapidly. Based on a review of 23 studies, Boucher (2008) finds that the resulting values (data points, not entire supply curves) of opportunity costs tend to be quite low with the mean being $2.51/$tCO_2$eq. To him, one possible explanation refers to the likely position of these data points in the early stages of the respective supply curves.

More sophisticated empirical studies giving whole supply curves are now emerging (see Box 1). These studies differ in several aspects including scope (deforestation, forest degradation), level of discount rate, degree of spatial disaggregation (accounting for geographic variation of key determinants, especially carbon densities), inclusion of transaction costs, practicability (replication of methods can be constrained if data or capacity requirements are very demanding) and accuracy. Table 1 summarises key characteristics of three selected local-empirical studies of opportunity cost estimation. Areas of improvement for these important approaches include more explicit integration of transaction costs, spatial heterogeneity in estimates and emissions from forest degradation.

Although approaches that give particular attention to the spatial heterogeneity of land-use change determinants (e.g., Nepstad et al. 2007) or that rely heavily on ground measurements (e.g., Swallow et al. 2007) are likely to yield more accurate estimates, they are more difficult to replicate in other parts of the tropics precisely because of their data and capacity requirements. Approaches that are only based on secondary data (e.g., Börner and Wunder 2008) are therefore likely to be of greater operational use – at least initially.

2.2 Opportunity cost calculation with global-empirical models

Global-empirical models use local-empirical estimates and aggregate them to global per-area costs of reducing deforestation (Boucher 2008). The conversion of the global area-based costs ($/ha) to emission-based costs ($/$tCO_2$eq) tend to be based on uniform values of carbon density (ton/ha), obtaining a single, global estimate of opportunity costs ($/$tCO_2$eq). Although it essentially ignores carbon density variation across space, this permits data on per-area opportunity costs to be used for regions where no per-ton-carbon costs exist (Boucher 2008). This method was, for example, applied in the Stern Review (see Box 2).

To compare this with emission-based estimates on REDD costs obtained from other studies, Boucher (2008) converts Grieg-Gran's 2006 estimates to emission-based estimates using global carbon density values (538 tCO_2eq/ha) from Houghton (2007). The resulting cost estimates correspond to a range of $1.74 - 5.22/$tCO_2$eq, with the midpoint ($3.48/tCO_2eq) being 36% higher than the mean of his aforementioned review of local-empirical estimates. One reason therefore refers to the uncertainty in deforestation and carbon density estimates (Boucher 2008).

2.3 Opportunity cost calculation based on global simulation models

Global partial equilibrium models simulate the dynamics of the world economy to estimate supply of REDD services, represented in supply curves. Generally, they include the forestry sector, the agricultural sector, and other important parts of the economy that affect land use. They also consider the energy sector and other parts of the economy that reflect fossil fuel use and affect carbon prices, but do not simulate them in detail to calculate economic equilibria. In turn, these models are termed dynamic 'partial equilibrium models' (Boucher 2008). Examples of where such models have been applied include the Intergovernmental Panel on Climate Change Report (IPCC 2007) and the Eliasch Review on REDD finance (Eliasch 2008).

2 See for example the recent workshop 'The Costs of Reducing Emissions from Deforestation and Forest Degradation' held at the World Bank in May 2008 (http://go.worldbank.org/WGOVBCRCG0).

Table 1: Characteristics of local/regional-empirical models to estimate REDD costs

	Börner and Wunder (2008)	Swallow et al. (2007)	Nepstad et al. (2007)
Study area	2 states of the Brazilian Amazon: Mato Grosso and Amazonas.	3 sites in Indonesia, 1 in Peru and 1 in Cameroon (results n/a for Cameroon).	Brazilian Amazon region.
Scope	Deforestation only.	Deforestation only.	Deforestation and forest degradation.
Assumptions/ constraints	Only private landholdings considered	n/a	Zero deforestation after 10 years; baseline 20,000 km2 per year.
Analysis level	Municipal level.	Pixel-level (resolution n/a); results aggregated to province/regional level.	Pixel-level (4 km2); results aggregated to regional level.
Spatial heterogeneity	Low (within-municipal variation not captured, linear transportation costs).	Medium (no spatial variation of prices).	High, across all variables (except transaction costs).
Data sources	Medium resolution remote sensing data; secondary data (from existing surveys).	Medium-resolution remote sensing data; own survey data (extensive field work).	Remote sensing data; secondary data.
Discount rate	10%	10% (private), 3% (social).	5%
Carbon density value	Uniform value (Houghton et al. 2001).	Time-averaged, land use specific (own survey).	Spatially-explicit (Saatchi et al. 2007).
Opportunity costs [$/tCO2]*	Choke price†: 12.34 for Mato Grosso; 3.24 in Amazonas.	5 for majority of deforestation in Indonesia (64-92%) and Peru (90%).	1.49 for reducing 100% deforestation, 0.76 for reducing 94%.
Transaction costs	Not included, but discussed.	Not included.	Partly included.
Accuracy	Probably lower (use of aggregate data).	Probably higher (robust methodology).	Probably high (bottom-up modelling).
Strength of analysis	State-level supply curves. Simple, straight-forward framework for indicative, rapid assessment. Prospective approach (ex-ante).	Province-level supply curves. Analysis consistent with IPCC†† guidelines for Annex I inventories. Potential to use this retrospective analysis for baseline and prediction. Full accounting approach.	Highly spatially-explicit model of land use change. Account of degradation (explicit logging model). Certain consideration of transaction costs. Prospective.
Weakness of analysis	Limited to private landholders only. Limited account of intra-municipal variation. No account of reduced emissions from degradation.	No forest degradation. No transaction costs. Extensive data needs. Retrospective (ex-post). Use of time-averaged carbon stocks rather than actual carbon stocks. Insufficient account of spatial price variations.	Strong assumption of zero deforestation after 10 years. High data/capacity needs for land use models.
Replicability of analysis	Probably easy (due to use of secondary data sources).	Probably more difficult (due to high data needs).	Probably more difficult (due to complex model).

* While most international data sources provide emissions data in terms of CO2 or CO2E, many U.S. sources provide emissions data in units of carbon (C) or carbon equivalents (CE). Emissions reported in CO2 or CO2E units are 3.67 times emissions reported in C or CE units (www.pewclimate.org/global-warming-basics/facts_and_figures/gwp.cfm).

† The choke price is the price that allows compensation of all avoided deforestation.

†† Intergovernmental Panel on Climate Change.

Box 1: Examples of local/regional-empirical approaches to estimating the costs of REDD*

Example 1: Opportunity costs of RED in the Brazilian Amazon. Source: Börner and Wunder (2008)

The authors estimated municipal-level opportunity cost (REDD supply) curves for private landholdings in two Brazilian states in the Amazon region: Amazonas and Mato Grosso. Combining remote sensing data on deforestation from the Brazilian Institute for Space Research (INPE) with municipal-level survey data from the Brazilian Institute of Geography and Statistics (IBGE), the authors extrapolated municipal-level deforestation rates from 2000-2006 to 2007-2016. For each municipality, the share of private landholdings, forestland on private landholdings, land-use mixes and expansion of land-use categories were calculated. Gross per-hectare returns were calculated and combined with estimates of timber revenues and transport costs – the first implying an increase, the latter a decrease of net returns of up to 20 per cent, depending on the distance to the state capital. A 10 per cent discount rate was used in the calculation of net present value. To obtain opportunity costs per ton CO_2, carbon biomass values were used from Houghton et al. (2001) lowest estimates (to remain conservative). Transaction costs are discussed, but not explicitly integrated into the analysis framework.

Example 2: Opportunity costs of RED in Indonesia, Peru and Cameroon. Source: Swallow et al. (2007); Swallow (2008)

The authors conducted a retrospective, spatially explicit analysis of the tradeoffs between carbon and economic returns in five sites across the tropics – three in Indonesia, and one each in Peru and Cameroon. The opportunity cost analysis comprises five main steps for each site: i) clarification and description of major land uses, ii) calculation of time-averaged carbon stocks (t-ave C) for the major land uses, iii) calculation of the private and social profitability of the land uses in terms of discounted net present value (NPV) using a 20-25 year time horizon with a 10 per cent private and a 3 per cent social discount rate, iv) land-use characterisation and land-use change analysis (since 1990) using medium resolution remote sensing data and extensive ground-truthing, and v) identification of sequestering and emitting land-use changes based on a pixel-by-pixel analysis of change in NPV and t-ave C, measured in terms of units CO_2 equivalent (CO_2eq).

Example 3: Costs of REDD in the Brazilian Amazon. Source: Nepstad et al. (2007)

The authors developed a conceptual framework to estimate the costs to tropical nations of implementing REDD programmes and applied this framework to the Brazilian Amazon. A bottom-up approach was used to estimate opportunity costs. Spatially explicit rent models for high-carbon (timber) and low-carbon (agriculture, ranching) uses of the Brazilian Amazon forest were derived from biophysical, climatic and infrastructure constraints to agriculture and livestock expansion in tropical forest regions. For each analysed pixel (4 km^2), rents for each competing land use (soy, cattle, timber) were calculated for 30 years, assuming a 5 per cent discount rate and a pre-determined schedule of highway paving. The maximum opportunity costs of forgone profits from non-forest land uses were used as upper limit benchmark for the level of REDD payments to landowners. The cost calculation assumes close to zero deforestation after the first 10 years of the programme. To obtain the costs per ton carbon (tC), pixel-level opportunity costs are divided by the carbon stock for each forested pixel using the forest carbon map developed by Saatchi et al. (2007). One important additional component of this study (compared to others) is that in addition to opportunity costs of REDD, the costs of implementing an REDD scheme (i.e., establishing and running three relevant funds) are considered.

* Note that in example 1 and 2, only 'avoided deforestation' was considered, not 'avoided forest degradation' as in example 3.

In simulations on the cost of REDD, such models take into account the fact that the cost of reducing emissions depends on how deep those reductions are (i.e., the costs start out low and increase with the amount of reductions made). In addition, the supply curves vary over time. In the earlier years, more reduction will be achievable at lower costs than in later years because opportunity costs will rise in response to greater land productivity upon increasing agricultural intensification induced, *inter alia*, by REDD policies.

There are currently three main global partial equilibrium models that have been used for this purpose, known as GTM, DIMA and GCOMAP (see Box 3). The three models differ in various details including the sectors included, how their dynamics are simulated, how they divide up the globe spatially, the interest rates used internally for calculating equilibria, and data sets used (Boucher 2008).

Recently, the developers of the three models have collaborated to compare their models by generating a series of runs – using similar initial conditions – on the potential contribution of avoided deforestation activities to reducing GHG emissions (Kindermann et al. 2008). To this end, a baseline of future deforestation was specified under a zero price for REDD. As each model's baseline embeds model-specific assumptions

Box 2: Example of a global, area-based approach to estimating the costs of REDD

Estimating the global costs of avoided deforestation for the Stern Review. Source: Grieg-Gran (2006)

A combination of local-level estimates of returns and more generic/average estimates was used to calculate opportunity costs of avoided deforestation for the purpose of the Stern Review. The analysis assumes 100% additionality, zero leakage, and is limited to the 8 main tropical forest nations (Brazil, Bolivia, Cameroon, Democratic Republic of Congo, Ghana, Indonesia, Malaysia and Papua New Guinea), which make up 46 per cent of global deforestation. Main inputs to the analysis are: (i) the return per hectare under different land uses and different conditions, and (ii) the size of the area to which the different cost estimates should be applied. Annual returns per ha are converted to net present values (NPV) per hectare, with a 10 per cent discount rate and a time horizon of 30 years.

Three sets of cost estimates were calculated: i) the first scenario assumes that no returns to one-off timber harvesting have to be compensated as part of land conversion, ii) the second assumes that timber is harvested over 100 per cent of the deforestation area, and iii) an intermediate scenario takes into account the practical limitations on timber harvesting in some of the countries concerned.

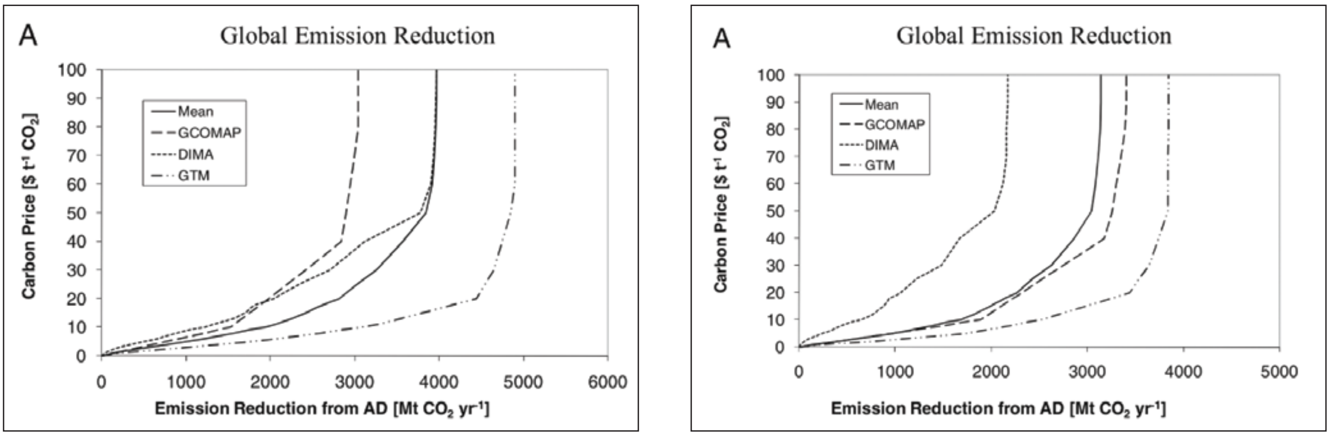
One important element in the analysis is information on how much of the area converted will be used for each land-use form (i.e., whether pasture, soybeans, food crops etc.). Because land-use patterns depend on a number of local factors (soil, climate, access to markets etc.), it is difficult to make robust predictions. Where available, predictions from the literature were used. In most of the cases, however, this information was derived from subjective assessments of %-breakdown from qualitative statements found in the literature.

The review yields total annual opportunity costs for 8 countries as: US$ 3 billion (scenario 1), US$ 6.5 billion (scenario 2) and about US$ 5 billion (scenario 3).* Transaction costs were estimated (based on a literature review) to be around US$4-15/ha/year. Important factors that affect the costs include i) the discount rate used to calculate NPV, ii) the time horizon, iii) the estimates of commodity prices, and iv) the assumption about the proportion of deforested area that will be in high- or low-value agricultural alternative use. Moreover, compensation costs are likely to be higher if the assumptions of 100 per cent additionality and zero leakage were weakened.

* Note that the update of these estimates produced for the Eliasch Review yields higher estimates of annual opportunity costs: US$ 4.4 billion (scenario 1), US$ 8 billion (scenario 2) and US$ 6.6 billion (scenario 3). The increase is explained by the significant increase of returns to oil palm since 2005 (Grieg-Gran 2008).

about future changes of biological and economic conditions (including population, technology, and trade), the three models yield different deforestation and carbon-emission projections. To determine the marginal costs of carbon storage resulting from avoided deforestation, additional simulations were conducted with the three models and assuming constant carbon prices ranging from US\$0/tCO_2 to US\$100/tCO_2. Marginal costs tend to rise over time because the lowest-cost opportunities are adopted first and rates of deforestation decline, while later the opportunity costs of land rise due to increasing agricultural productivity (see Figure 2). The resulting marginal cost curves differ across models for a number of aforementioned

Figure 2: Supply curves from global models (Source: Kindermann et al. 2008)



Supply curves in 2010
REDD costs: \$20/tCO_2 can abate on average almost 3000 mtCO_2/yr.

Supply curves in 2030
REDD becomes more expensive: \$20/tCO_2 can abate on average about 2200 mtCO_2/yr.

Box 3: Global models to estimate the costs of REDD (Source: Kindermann et al. 2008)

The Dynamic Integrated Model of Forestry and Alternative Land Use (DIMA)

This model assesses land-use options in agriculture and forestry in 0.5 degree grid cells across the globe. It predicts deforestation in forests where land values are greater in agriculture than in forestry and, vice versa, afforestation of agricultural and grazing lands where forestry values exceed agricultural use. To this end, the model calculates the NPV of forestry and NPV of agriculture and compares the two. Main determinants for the NPV of forestry are: income from carbon sequestration, wood increment, rotation period length, discount rates, planning costs, and wood prices. Main drivers for the NPV of agriculture on current forestland are: population density, agricultural suitability, and risk adjusted discount rates. The two values are compared and deforestation is subsequently predicted to occur when the agricultural value exceeds the forest value by a certain margin.

The Generalized Comprehensive Mitigation Assessment Process Model (GCOMAP)

This is a dynamic partial equilibrium model that analyses afforestation in short- and long-run species, and reductions in deforestation in 10 world regions. Specifically, the model simulates the response of the forestry sector to changes in future carbon prices. It uses data on country-specific activity, demand, and costs of mitigation options and land-use change by region. The model allows explicit analysis of the carbon benefits of reducing deforestation in tropical countries. However, it does not consider the impact of increasing CO2 concentration (CO2 fertilisation) on changes in the carbon cycle, and its effect on biomass growth. The model's objective is to estimate the land area that land users would plant above the reference case or prevent from being deforested, in response to carbon prices.

The Global Timber Model (GTM)

This is a dynamic optimisation model that optimises the land area, age class distribution, and management of forestlands in at least 146 timber types globally. Specifically, it maximises the NPV of consumers' plus producers' surplus in the timber markets. Because forestland competes with agricultural land, it models the interaction between the two markets via land supply functions that account for the costs of renting forestland. These land supply functions are specified for each timber supply region in the model. They are either constant or shift over time, depending on the assumptions about future development of agriculture in the region.

reasons, including the input data sets and modelling methodologies and assumptions. As depicted in Figure 2, the GTM model tends to predict the greatest emissions reductions for a given cost, whereas the position of the GCOMAP and DIMA estimates vary over time (Kindermann et al. 2008).

Weaknesses of these models include: often simplifying assumptions about potential rents from agriculture and livestock on tropical forestlands (Nepstad et al. 2007), the use of empirical estimates from the literature that in part may come from far away (Sohngen 2008), and the exclusion of transaction costs and other institutional barriers that raise the costs in practice (Kindermann et al. 2008). On the other hand, they all share a common approach as they are all based on the opportunity costs of different land uses (Boucher 2008), and are able to capture within-sector and cross-sector interactions that can have important implications for REDD costs (Sohngen 2008; Kindermann et al. 2008).

3. Estimating the transaction costs of REDD

Transaction costs exist as the result of limited knowledge and information and refer thus to the costs incurred in making an economic exchange. Transaction cost research yields various empirical approaches, each with separate focus and methodology – which further differ whether government agency cost or only individual costs are considered (Antinori and Sathaye 2007).[3] According to Milne (1999) important categories of transaction costs include: information and procurement, scheme design and negotiation, implementation, monitoring, enforcement and protection, and verification and certification.

Information on the transaction costs of REDD schemes remains limited. Most of the discussions tend to build upon insights and anecdotal evidence from other experiences, such as payments for environmental services (PES) schemes or forestry Clean Development Mechanism (CDM) projects (see Table 2). Transaction costs are reported either in the form of total costs or as percent-share of the entire budget. In the national-level PES schemes in Mexico and Costa Rica, administrative costs are ceiled by law at 4 per cent (Mexico) and 7 per cent (Costa Rica) of the respective budget, but also

3 See Antinori and Sathaye (2007) or Milne (1999) for a review of transaction cost concepts and applications in carbon project assessments.

Table 2: Non-exhaustive list of studies on transaction costs associated with REDD schemes

Study	Coverage	Cost category	Data source	Costs [$/tCO2eq]
Grieg-Gran (2006).	8 tropical countries.	Administrative.	Expert consultation, PES schemes.	0.01 - 0.03[3]
Nepstad et al. (2007).	Regional (Amazon).	Implementation.	Expert consultation, existing schemes.	0.58
Kindermann et al. (2008).	Global.	Transaction costs.	CDM projects.	0.3 - 4.05 (weighted average 0.26).
Antinori and Sathaye (2007).	11 forestry projects.	Transaction costs.	Climate projects.	0.66 - 16.4 (weighted average: 0.36).
Cacho et al. (2005).	6 projects (tropical countries).	Transaction costs.	AIJ* projects.	0.14-1.07

* This corresponds to Grieg-Gran's (2006) estimate of $4-15/ha converted to tCO2 using Houghton's (2007) carbon density values. Note that Grieg-Gran's (2008) update refers to a lower upper bound of administrative costs, i.e., between $4-9/ha, which yields 0.01-0.02 $/ tCO2.

† Activities Implemented Jointly

Table 3: Transaction cost information from PES schemes (adapted from Wunder et al. 2008)

PES scheme	Transaction costs (US$)	
	Start-up	*Recurrent*
Local, user-financed schemes:		
Los Negros, Bolivia	46,000 (17/ha)	300/yr (1/ha)
Pimampiro, Ecuador	37,800 (76/ha)	3600/yr (7/ha/yr)
PROFAFOR, Ecuador	4.1 million (184/ha)	76,600/yr (3/ha/yr)
Vittel, France	Not divided up.	Total costs (incl. payments) 1993-2000: 24.5 million (600/ha/yr).
Large-scale, government-financed schemes:		
Payments for Environmental Services (PSA), Costa Rica	N/A	7% of payments (limited by law); some costs transferred to buyers.
Payments for Hydrological Services (PSA-H), Mexico	N/A	4% of payments (limited by law).
Conservation Reserve Program (CRP), USA	High investment in geo-referenced system.	15.5 million (2005); <1% of CRP transfers (+research costs).
Environmentally Sensitive Area (ESA) Scheme, UK	Not separated out.	1992/3 – 1996/7: 18% administrative costs (startup + running).
Wimmera, Australia	High, due to pilot nature of scheme (65,000 – 100,000).	High, due to pilot nature (33 – 465,000/yr).

slightly under-estimated since some of the transaction costs were covered outside the legally designated agencies (Muñoz-Piña et al. 2008; Pagiola 2008). In Costa Rica for example, private transaction costs (i.e., those borne by landowners entering into a PES contract) are reported to be in the range of 12-18 per cent of the environmental service payments (Wünscher et al. 2008). Table 3 provides further information on transaction costs associated with PES schemes (generally referring to the costs of setting up and running a scheme, not private transaction costs).

No consistent methodology for collecting data on transaction costs could be found. Transaction costs are often intangible and therefore difficult to measure directly. As mentioned before, the examples found in the literature differ in the categories of transaction costs that are analysed, and the way transaction costs are incorporated into an overall cost analysis. This makes it difficult to compare values across projects or regions. Quantitative analyses of transaction costs associated with carbon projects are emerging (e.g., Antinori and Sathaye 2007).

Insights from PES and CDM schemes suggest that transaction costs tend to be particularly high in early stages of a scheme (startup costs), and when the size of the scheme is small. Cacho et al. (2005), for example, show that for four carbon projects in Indonesia the startup costs can be quite large whereas running costs tend to be more manageable. Similar evidence can be found in the local PES schemes in Ecuador (see Table 3). Evidence for the economies of scale pattern of transaction costs includes Antinori and Sathaye's (2007) assessment of 28 GHG projects, and the comparative study of 15 PES schemes by Wunder et al. (2008).

One general observation is that existing information on transaction costs is limited. Good estimates are rarely available; their generally intangible nature makes them hard to estimate. In addition, transaction costs can vary substantially across governance contexts. Realising projects or PES-like arrangements in weak governance contexts is likely to imply higher transaction costs than in settings where institutions and rights are well-defined and well-functioning. At a practical level, this suggests a need for careful selection of projects. Nevertheless, transaction costs are in most cases not prohibitive.

4. Concluding remarks

This review of methods reveals that various approaches to estimate REDD opportunity costs exist. The suitability of these approaches depends on the objective of the analysis. One striking observation is that the cost of REDD differs substantially across model approaches: global simulation models yield far higher REDD prices than empirical models, including the Stern estimate. One explanation is that global simulation models not only consider the opportunity costs, but also the costs arising from interrelations with other sectors and from the fact that for practical reasons land users are likely to be paid a uniform price, not differentiated according to their opportunity costs (Eliasch 2008). However, as global models can be criticised for their use of aggregated data and other simplifications, the 'true' cost estimate lies more likely somewhere in between the values provided by the local-empirical models on the one hand (lower end) and global simulation models on the other (higher end).

4.1 Alternative REDD cost assessment methods suit different needs

Despite the large difference in price results between local and global models, each method has its own advantages and disadvantages. For an indication of total costs of REDD as a climate change mitigation option compared to alternatives (i.e., for a worst-case cost scenario), the use of global simulation models seems adequate, although these models are often based on simplified assumptions and tend to exclude transaction costs elements. There remains room for improvement such as: including the consideration of avoided forest degradation, the use of more consistent parameters across models, and the use of more disaggregated data (especially as regards values of carbon density and deforestation rates). Furthermore, the important interrelation between deforestation abatement (REDD) and biofuel production remains little explored (R. Lubowski, pers. comm.).

Local models are useful complements of global estimates, in particular for capturing sub-national or sub-regional variations in opportunity costs. In particular, models that consider spatially varying determinants of land-use change (e.g. Nepstad et al. 2007; Swallow et al. 2007) seem useful in this context. However, the data and capacity needs required to develop and use such models may be prohibitive for replication in resource-constrained environments. Simpler approaches, such as the one by Börner and Wunder (2008), could be of greater operational use. Local models could be improved with the more systematic inclusion of private (landowners') transaction costs.

4.2 Need for systematic transaction cost assessments

Because opportunity costs vary across time and space, information on costs will continue to remain an important element in REDD design. This refers not only to opportunity costs, but also transaction costs – a component that has so far generally been neglected in cost models. Investment in creating standard procedures for opportunity cost and transaction cost estimations that yield quality estimates could therefore be of added value. When combined with guidelines for transaction cost assessments (both private and government costs), this could be done in a manner similar to the three-tier methodologies developed by the IPCC Guidelines for land use and forestry projects (Penman et al. 2003) where alternative methods are proposed depending on existing resources and capacity.

4.3 REDD costs depend on the degree of emission abatement (all vs. almost all)

The review of methods also underlines the increasing marginal costs of REDD. In other words, the further advanced along the REDD supply curve, the more has to be paid for one additional unit of REDD until no more reductions can be made (i.e., the maximal level of reductions is reached). This implies that reducing emissions from deforestation and forest degradation to nearly zero requires far higher costs than would be needed when only reaching for the 'low hanging fruits', i.e., those emission reductions that can be achieved at lower costs. It has been argued that REDD costs will be significantly lower if almost all emissions are abated, but not all of them. Boucher (2008) for example cites Nepstad et al. (2007) and their findings for Amazonia, where 1.49 US\$/tCO_2 would have to be paid to abate 100% of emissions versus 0.76 US\$/tCO_2 to abate 94 per cent of emissions. Similar examples can be found from other regions, suggesting that REDD cost assessments should consider this option.

4.4 REDD costs also depend on payment design

This raises important questions on the design of the payment mechanism, as the costs of REDD further differ depending on the ultimate payment design. An analysis of alternative payment mechanisms for REDD is beyond the scope of this paper, but it is important to note that their design can have substantial implications on the costs of REDD. Börner and Wunder (2008), for example, show that compared to differentiated payments (every landowner receives just his/her opportunity costs), uniform payments (every landowner receives the same amount of payment for REDD) increase the total costs of REDD by about 4 (from US$ 680 to US$ 2,745 million) and by nearly 2.5 (from US$ 143 to US$ 363 million) respectively in the Brazilian States of Mato Grosso and Amazonas for reducing total deforestation. Uniform payments predominate in current national PES schemes as they are easier to implement, but simple payment differentiations are also emerging in some national PES schemes (e.g., in Mexico), while differentiation predominates in private sector PES schemes worldwide (Wunder et al. 2008). Because alternative payment schemes have different cost implications, and provided differentiated landowner payments are considered feasible in REDD schemes[4], it could be useful for the purpose of REDD to dedicate some efforts to cost-benefit analyses of alternative REDD payment schemes

4 There are pros and cons regarding uniform/differentiated payments in the context of REDD, but more important is the political decision whether or not all countries will receive the same $/tCO_2$ price.

References

Antinori, C. and J. Sathaye (2007) *Assessing transaction costs of project-based greenhouse gas emissions trading*. Lawrence Berkeley National Laboratory. Berkeley, C.A., USA.

Börner, J. and S. Wunder (2008) 'Paying for avoided deforestation in the Brazilian Amazon: From cost assessment to scheme design'. *International Forestry Review* (forthcoming).

Boucher, D. (2008) *What REDD can do: The Economics and Development of Reducing Emissions from Deforestation and Forest Degradation*. Draft for external review (June). Tropical Forest and Climate Initiative – Union of Concerned Scientists. Washington D.C., USA.

Cacho, O.J., G.R. Marshall and M. Milne (2005) 'Transaction and abatement costs of carbon sink projects in developing countries' in *Environment and Development Economics* 10:597-614.

Chomitz, K.M., P. Buys, G. De Luca, T.S. Thomas and S. Wertz-Kanounnikoff (2006) *At Loggerheads? Agricultural Expansion, Poverty Reduction, and Environment in the Tropical Forests.* Policy Research Report. World Bank. Washington D.C., USA.

Ebeling, J. and M. Yasue (2008) 'Generating carbon finance through avoided deforestation and its potential to create climate, conservation and human development benefits' in *Phil. Trans. R. Soc.* 363: 1917-1924.

Eliasch, J. (2008) *The Eliasch Review - Climate Change: Financing Global Forests.* UK Office of Climate Change. Available online at: http://www.occ.gov.uk/activities/eliasch.htm.

Grieg-Gran, M. (2006) *The cost of avoiding deforestation: report prepared for the Stern Review of the Economics of Climate Change*. IIED, London, UK.

Grieg-Gran, M. (2008) *The cost of avoiding deforestation: Update of the report prepared for the Stern Review of the Economics of Climate Change*. Paper commissioned by the Office of Climate Change as background work to its report *Climate Change: Financing Global Forests* (The Eliasch Review). IIED, London, UK.

Houghton, R.A. (2007) 'The role of forests in the global carbon cycle'. Presentation given at the Kathryn Fuller Science for Nature Symposium: Reducing Emissions from Deforestation. World Wildlife Fund. Washington D.C., USA, October 18-19, 2007. Available online at: http://www.worldwildlife.org/science/fellowships/fuller/WWFBinaryitem6992.pdf.

Houghton, R.A., K.T. Lawrence, J.L. Hackler and S. Brown (2001) 'The spatial distribution of forest biomass in the Brazilian Amazon: a comparison of estimates' in *Global Change Biology* 7: 731-746.

IPCC (2007) *Mitigation of Climate Change*, Working Group III Fourth Assessment Report, Intergovernmental Panel on Climate Change.

Kindermann, G., M. Obersteiner, B. Sohngen, J. Sathaye, K. Andrakso, E. Rametsteiner, B. Schlamadinger, S. Wunder and R. Beach (2008) 'Global cost estimates for reducing carbon emissions through avoided deforestation' in *Proceedings of the National Academy of Science of the Unites States of America.* Available online at: http://www.pnas.org/content/105/30/10302.full

Milne, M. (1999) *Transaction costs of forest carbon projects*. Centre for International Forestry Research (CIFOR) Bogor, Indonesia.

Muñoz-Piña, C., A. Guevara, J.M.Torres and J. Braña (2008) 'Paying for the hydrological services of Mexico's forests: Analysis, negotiations and results' in *Ecological Economics* 65: 725-736.

Nepstad, D., B. Soares-Filho, F. Merry, P. Moutinho, H. Oliveira-Rodriguez, M. Bowman, S. Schwartzman, O. Almeida and S. Rivero (2007) *The costs and benefits of reducing carbon emissions from deforestation and forest degradation in the Brazilian Amazon*. WHRC-IPAM-UFMG.

Pagiola, S. (2008) 'Payments for environmental services in Costa Rica' in *Ecological Economics* 65: 712-724.

Penman, J., M. Gytarsky, T. Hiraishi, T. Krug, D. Kruger, R. Pipatti, L. Buendia, K. Miwa, T. Ngara, K. Tanabe and F. Wagner (2003). *Good Practice Guidance for Land Use, Land Use Change and Forestry*. Intergovernmental Panel on Climate Change (IPCC), Kanagawa, Japan.

Rogner, H-H., D. Zhou, R. Bradley. P. Crabbé, O. Edenhofer, B. Hare (Australia), L. Kuijpers and M. Yamaguchi (2007) 'Introduction' in Metz, B., O.R. Davidson, P.R. Bosch, R. Dave and L.A. Meyer (eds) *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Saatchi, S., R.A. Houghton, R.C. Avala, J. Soares, and Y. Yu (2007) 'Distribution of aboveground biomass in the Amazon Basin' in *Global Change Biology* 13:816-837.

Stern, N. (2006) *The Stern Review: The Economics of Climate Change*. Cambridge University Press. Cambridge, UK.

Sohngen, C. (2008) 'Tools for Estimating the Costs of Carbon Sequestration through Avoided

Deforestation: Global Land Use Modeling'. Presentation at the *Workshop on The Costs of REDD*. The World Bank. Washington D.C., USA, May 27th.

Swallow, B. (2008) 'Opportunity Costs of Carbon Emissions from Land Use Change in the Tropical Forest Margins'. Presentation at the *Workshop on The Costs of REDD*. The World Bank. Washington D.C., USA, May 27th.

Swallow, B., M. van Noordwijk, S. Dewi, D. Murdiyarso, D. White, J. Gockowski, G. Hyman, S. Budidarsono, V. Robiglio, V. Meadu, A. Ekadinata, F. Agus, K. Hairiah, P. Mbile, D.J. Sonwa and S. Weise (2007) *Opportunities for Avoided Deforestation with Sustainable Benefits. An interim report of the ASB partnership for the Tropical Forest Margins*. ASB Partnership for the Tropical Forest Margins, Nairobi, Kenya.

World Bank (2008) 'The Costs of Reducing Emissions from Deforestation and Forest Degradation'. Workshop held at the World Bank in Washington D.C. on 27 May 2008. Available at: http://go.worldbank.org/WGOVBCRCG0).

Wunder, S., S. Engel and S. Pagiola (2008) 'Taking stock: A comparative analysis of payments for environmental service programs in developed and developing countries' in *Ecological Economics* 65: 834-852.

Wünscher, T., S. Engel and S. Wunder (2008) 'Spatial targeting of payments for environmental services: A tool for boosting conservation benefits' in *Ecological Economics* 65: 822-833.

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