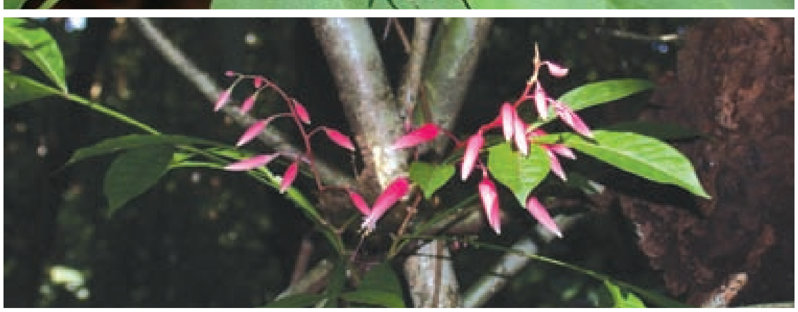
OUT OF THE WOODS

A REALISTIC ROLE FOR TROPICAL FORESTS IN CURBING GLOBAL WARMING



Union of Concerned Scientists

Citizens and Scientists for Environmental Solutions

OUT OF THE WOODS

A REALISTIC ROLE FOR TROPICAL FORESTS IN CURBING GLOBAL WARMING

Doug Boucher

Union of Concerned Scientists

DECEMBER 2008

Doug Boucher is the director of the Tropical Forest and Climate Initiative within the UCS Climate Program.

The Union of Concerned Scientists (UCS) is a nonprofit partnership of scientists and citizens combining rigorous scientific analysis, innovative policy development, and effective citizen advocacy to achieve practical environmental solutions.

The UCS Tropical Forest and Climate Initative analyzes and promotes ways to cut global warming pollution by reducing tropical deforestation.

More information about UCS and the Tropical Forest and Climate Initiative is available on the UCS website at *www.ucsusa.org/REDD.*

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Executive Summary

A great deal of information is now available on an option that not only averts global warming's worst consequences but also generates enormous co-benefits for biodiversity conservation and sustainable development. That option is reducing emissions from deforestation in developing countries (REDD). A review of the literature, combined with additional analyses of the data, shows that REDD could substantially decrease the severity of climate change.

Much information is available on the costs as well, and it shows that REDD is clearly an inexpensive approach compared with emissions reductions in the energy sectors of industrialized countries. The costs per ton of reducing current carbon dioxide emissions from deforestation by half—even with pessimistic assessments and including not only opportunity costs but also REDD's implementation, transaction, administration, and stabilization costs—are less than a third of current (mid-2008) capped carbon market prices. Conservative estimates show that $5 billion in funding annually could reduce deforestation emissions in the year 2020 by over 20 percent; that $20 billion could reduce them by 50 percent; and $50 billion could result in a drop of 66 percent. The latter level of funding is equivalent to developed countries devoting just 0.13 percent of their annual GDP to REDD (the commitment made by Norway at the Bali convention in December 2007). Using the cost curves of the U.S. Lieberman-Warner bill to determine the potential emissions reductions from its market-linked funding, we estimate that the bill's allocation of 2.5 percent of allowance revenues for REDD could reduce emissions in 2020 by an amount equal to 9 percent of the United States' total emissions in 1990.

However, the development of a worldwide REDD system is likely to be held back considerably by political and institutional constraints. The skewed distribution of emissions from tropical deforestation, with just two countries (Indonesia and Brazil) accounting for almost half the emissions and the next 35 percent spread among 14 other countries, means that just a few countries

Rain forest, Crater Lakes National Park, Australia

can dramatically affect the potential of a REDD system by themselves. Data indicating the capacity and interest of these major tropical forest countries to participate in REDD show that only a small number of them are likely to do so immediately after 2012, when the next climate regime goes into effect, and the system is not likely to include three-fourths or more of deforestation emissions until 2020 or later. Thus the low cost of REDD does not mean it can contain the costs of international climate change mitigation over the short run. On the other hand, this reality also reduces the danger of the world carbon market soon being flooded with cheap REDD credits.

Conservative estimates show that $5 billion in funding annually could reduce deforestation emissions in the year 2020 by over 20 percent, and that $20 billion could reduce them by 50 percent.

Estimates of "the cost of REDD" should not be expressed as single numbers (e.g., $X/ton of CO_2) but rather as curves showing prices and total costs as functions of emissions reduction. These supply curves and cost curves reflect the important fact that price and cost increase nonlinearly with the amount of reduction achieved. Some of the variation in estimates of the economic potential of REDD is due to their applying to different percentage reductions in emissions, but there is still a considerable degree of unexplained variation. Twenty-nine regional empirical estimates give the lowest costs (mean of $2.51/t$CO_2$), area-based estimates such as the Stern Review are intermediate, and global economic models predict the highest costs (and are therefore the most conservative with respect to potential).

Further analytic work can reconcile some of these differences. But there are other as-yet-unquantified factors that can render the potential of REDD either greater or smaller. Moreover, evaluation of whether REDD can be done efficiently—so as to realize its economic potential, as estimated by the models—will depend on actual implementation of national-scale programs. Nonetheless, REDD clearly can and should be a major element of the global effort to prevent warming of 2°C over pre-industrial temperatures, thereby reducing the likelihood of dangerous climate change.

CHAPTER ONE

Introduction

WHAT IS REDD AND WHAT LIMITS IT?

With the growing recognition that tropical deforestation contributes about 20 percent of greenhouse gas emissions worldwide and is thus an important cause of global warming, there is great interest in approaches to *reducing emissions from deforestation in developing countries* (Metz et al. 2007, Ramankutty et al. 2007). These approaches are generally abbreviated as REDD, the term adopted by the United Nations Framework Convention on Climate Change (UNFCCC) at Bali in December 2007. While other terms, such as "avoided deforestation" and "compensated reduction," are also used, they are not exact synonyms. In some contexts, they imply particular approaches or proposals for implementing REDD or financing it.

REDD may be achieved in many ways, including the classic approaches to protecting forests established in the industrialized world over centuries: parks, wilderness areas, and other kinds of protected areas. There are also a wide range of programs, such as integrated conservation projects, sustainable development initiatives, extractive reserves, and ecotourism, that are particularly suited to developing countries. Some of the most effective approaches are indirect, dealing with important "drivers of deforestation." These approaches include, for example, modifying plans for road building and asphalting so as to channel them into already-cleared regions rather than open up new

Clearings in Palo de Mayo forest, southeastern Nicaragua

areas of forest to logging and agricultural development (Rudel et al. 2005, Chomitz et al. 2006).

Similarly, recognition of the rights of indigenous and forest peoples can be one of the most effective ways to protect their lands from deforestation (Nepstad et al. 2006). Even programs that improve conditions in urban areas, such as education, health care, and sanitation, can reduce emissions from deforestation by encouraging migration to cities (i.e., making migration to forest regions less desirable).

Regardless of method, REDD involves costs. Beyond those of implementing the particular approach adopted, an "opportunity cost" is incurred in retaining existing forestland. That is, retention means sacrificing the opportunities that would be gained by converting the forest to other uses, such as crops or pasture. Because it is reasonable to assume that this opportunity cost sets a minimum amount that would have to be paid to keep the land in forest, regardless of the way it is done or the source of the funding for doing it, opportunity cost is the basic starting point for economic analyses of REDD. To convert costs expressed in units of money/area (e.g., dollars per hectare) to the form relevant to reducing emissions, one divides the opportunity cost per hectare by the carbon density of the forest (e.g., tons per hectare) to get a figure in units of dollars per ton.

Opportunity cost is not the whole story, however. Indeed, *economics* is not the whole story. Adding other costs, such as for implementation and administration, to the opportunity costs gives an overall economic cost estimate, which is combined with the funding available to estimate the tons of emissions reduced. But in reality this amount of reduction will never be reached. Political and institutional constraints will slow the development of the international REDD system, thereby limiting emissions reductions to a lower amount.

These constraints are of many kinds, but most fundamentally they can be classified into two categories: capacity and interest.

Capacity includes the ability of forest nations to measure and monitor their emissions and related factors, such as emissions "leakage" (deforestation goes down in one area but goes up in another) and "non-additionality" (deforestation drops, but no more than it would have dropped anyway without the REDD program). Capacity

Rain forest tree, Atherton Tableland, Australia

also includes the ability to decide how to reduce deforestation and to implement those decisions effectively; thus it deals with questions such as governance, planning, and the rule of law. Finally, capacity includes the ability to present evidence for the reductions in emissions to those who will pay for them, to collect the money due, and to use that money to implement further reductions in the future.

Interest is a different question. If a country can reduce its emissions—that is, it has the capacity to do so—but does not wish to participate in the available funding programs, then not all the emissions reductions that are possible will actually be realized. Even if the incentives provided by an international REDD program are sufficient to outweigh the costs, some countries may simply opt out.

Thus figuring out the greenhouse gas emissions that can be decreased by programs to reduce deforestation is necessarily a two-step process. The first is to analyze the economics, with estimates of opportunity costs of tropical forestland as a starting point. The results of this quantitative process can be used to construct supply curves and cost curves—estimates of the prices ($/ton) and costs ($) for given amounts of reductions of emissions (tons). However, because the second step—inclusion of the political and institutional constraints on the development of the system—is somewhat qualitative, once it is added to the mix one can no longer make precise numerical estimates. Yet it is possible to compare countries as "greater than" or "less than" in terms of some of the important measures (e.g., Papua New Guinea is more interested in participating in REDD than is Myanmar but currently has a lower capacity to implement it than does Brazil). Such "ordinal" comparisons make it possible to estimate how long it will take before most of the economically feasible reductions in emissions are actually achieved.

WHAT THIS REPORT COVERS AND ASSUMES, AND WHAT IT DOESN'T

The goal of this report is twofold: to estimate the decreases in greenhouse gas emissions achievable through systems that fund reductions in tropical countries' deforestation, and to estimate how long it may take to realize this potential. In other words, how much can emissions be cut, at what cost, and over what time period? While pursuing these ends, this report does not propose or analyze any specific way to implement such emissions decreases. Moreover, the results presented here are not specific to any particular way of funding REDD, though they do recognize the different funding sources and ways of evaluating them.

Funding sources for REDD can be judged by several criteria (Coalition for Rainforest Nations 2005). They should provide financing on the scale that is needed, in a reliable fashion (e.g., not dependent on annual government appropriations), and in amounts that increase as the carbon market grows or carbon prices rise. We want funding sources to be usable not only to pay for reductions in emissions that have been made, measured, and verified but also to support the capacity building, stabilization, monitoring, and other activities that are necessary for REDD but do not directly translate into quantifiable and verifiable reductions. Lastly, we want funding sources both to lower the world's overall cost of ameliorating climate change and to make further reductions beyond those of the cap-and-trade systems established by industrialized countries.

Funding sources should be usable not only to pay for reductions in emissions that have been made, measured, and verified but also to support the capacity building, stabilization, monitoring, and other activities that are necessary for REDD but do not directly translate into quantifiable and verifiable reductions.

By these criteria, each of the three kinds of different funding sources has different advantages, summarized in Table 1 (p. 6). Carbon market offset credits are considered able to mobilize large amounts of funding in reliable amounts, to lower the overall cost of making the emissions reductions needed globally, and to pay only for verified reductions. Market-linked sources (e.g., auction revenues, allowance allocations, or dual market systems) can provide moderately large amounts of reliable funding and make added cuts in emissions beyond those made by the caps in cap-and-trade systems. Given that they are not used as offsets, they do not cause increased net emissions globally if leakage or non-additionality is associated with REDD, and they have the flexibility to be used

TABLE 1: **Approaches to Financing REDD**

	Carbon Market Offset (e.g., REDD credits purchased by developed-country emitters)	**Market-Linked** (e.g., auction revenues, allowance allocations, dual markets)	**Voluntary** (e.g., official development assistance, voluntary offset purchases)
Potential funding	**Large (many $10s of billions/year)**	Medium ($10s of billions/year)	Small ($100s of millions/year)
Market size effect on funding	**Positive**	**Positive**	None
Carbon price effect on funding	**Positive**	**Positive**	None
Funding amount fairly reliable?	**Yes**	**Yes**	No
Annex 1 compliance costs	**Lowered**	Same	Same
Effect on net global emissions	Offset	**Additional reduction**	**Additional reduction**
Pays for verified reductions?	**Yes**	Not necessarily	Not necessarily
Pays for stabilization?	No	**Yes**	**Yes**
Pays for capacity building?	No	**Yes**	**Yes**
Mobilizes voluntary efforts	No	No	**Yes**
Funding availability	After reductions are made	When cap-and-trade starts	**Immediately**

See text for detailed discussion. Bold type indicates desirable characteristics.

for capacity building, stabilization, and other needs that do not directly result in emissions reductions. Voluntary efforts such as official development assistance share the advantages of flexibility and providing added cuts beyond the caps, and they can help mobilize the willingness of countries and citizens to contribute freely to reducing tropical deforestation.

Because of this diversity of advantages, it is desirable to include all three kinds of sources in a future REDD system, as in the "basket of approaches" proposed by the Coalition for Rainforest Nations (Gullison et al. 2007). Therefore this report makes no assumptions about the combination of specific sources or financing mechanisms that may be adopted. We simply ask: given $X billion for REDD, however it may be made available, what could be accomplished?

CHAPTER TWO

Methods

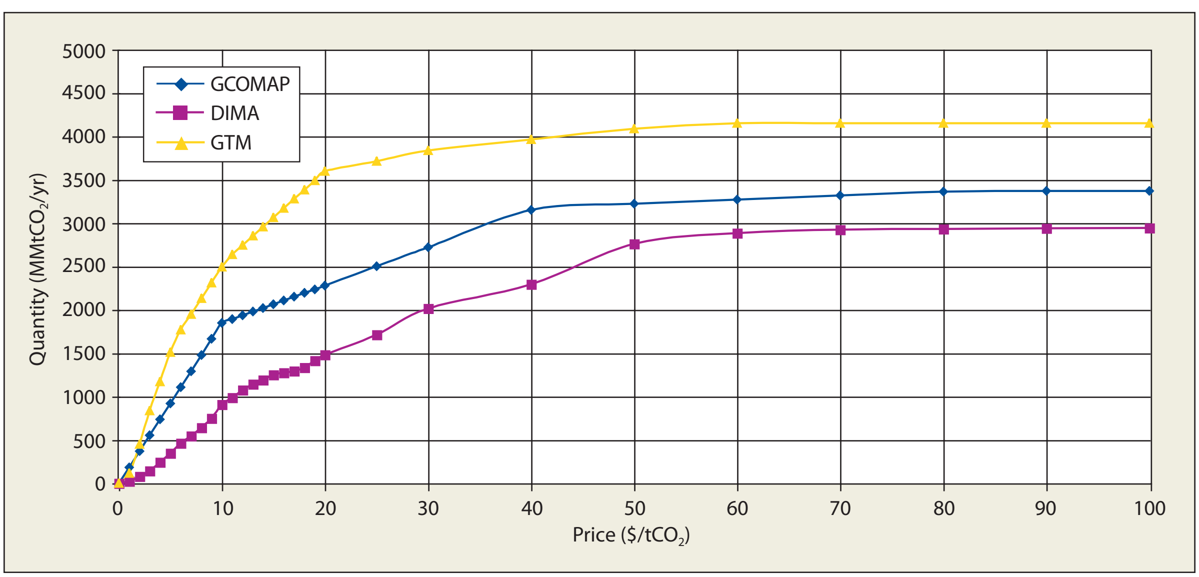
UNDERLYING CONCEPTS: SUPPLY CURVES AND COST CURVES

Because the supply curve is fundamental to this report's economic analysis, it is worthwhile to explain this concept's meaning and how the author uses it to estimate the costs and potential of REDD in a conservative manner. The supply curve is based on the understanding that different "producers" of a good or service—including the service of reducing emissions from deforestation—have different levels of cost for production; and that any given producer incurs costs that vary according to the amount produced. Some producers can reduce emissions inexpensively, while for others the reductions will cost more per ton of CO_2 reduced. Given that just a few will be able to cover their costs if the price they are paid is low, only a small amount of reduction will be supplied at low prices. At higher prices, on the other hand, the number of suppliers who can cover their costs, and can therefore supply reductions, will be higher, and so will the total amount supplied. Eventually, when the price paid gets high enough, all potential suppliers will be able to cover their costs, so no further amounts will be supplied even if the price increases.

This logic implies that the supply curve, which graphs the quantity supplied against the price paid, will start at a low level of reduction, rise, and then eventually level off. Figure 1 shows this property for a typical set of supply curves. (Note that economists normally reverse the axes, graphing price on the y-axis and quantity on the x-axis; here the author considers price to be an independent variable and thus puts it on the x-axis.) The shape of the supply curve is concave downward: it starts at the origin, rises quickly at first, then rises more slowly, and finally levels off.

The concept is simple, but it has some important implications. First, cost is not a single constant value—it has a different value for each quantity of reduction. Initially the cost is low, but it increases as one makes greater reductions. This means that to estimate the amount of reduction in emissions, one *cannot* simply divide the amount of funding available by "the price" or "the cost per ton" to get the quantity of reduction ($\$ \div \$/tCO_2 = tCO_2$). The reason is that there is no

FIGURE 1: Supply Curves for 2020 from the Global Models



Supply curves for 2020 based on the three global, partial equilibrium models. Note that quantity of emissions reductions (in million metric tons of carbon dioxide equivalent, or $MMtCO_2eq$) is plotted on the y-axis and price ($\$/tCO_2eq$) is plotted on the x-axis.

single "cost per ton" but rather a range of costs that vary with quantity. Alternatively stated, cost per ton is not a single point; it is a line.

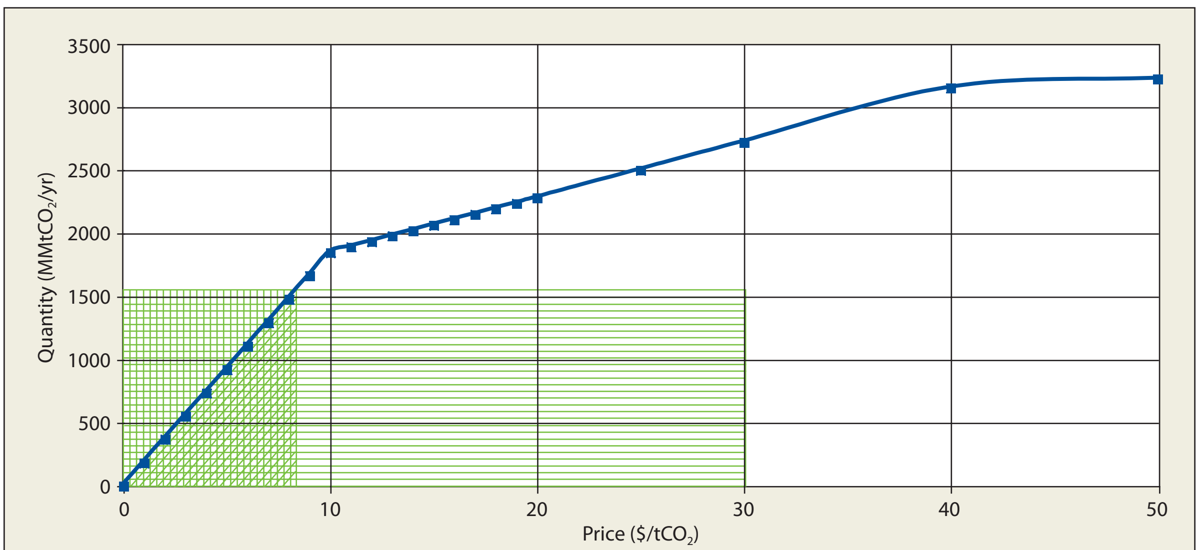
Further, this function should be a curved line, starting out with a steep slope but bending so that it eventually reaches a plateau at what is called the "choke price"—the price that would have to be paid to get the total quantity of emissions reductions available. In terms of REDD, it is the price that would eliminate 100 percent of deforestation. Thus, as one would expect, the choke price will be very high, but this does not mean that lesser reductions—say, reducing deforestation emissions by 10 percent or even 50 percent—cannot be made much more cheaply.

How then do we estimate the cost of reductions—or conversely, the amount of reduction possible for a given amount of money—from the supply curve? There are three possible ways, illustrated with a typical supply curve (the global one for the GCOMAP model in 2020) in Figure 2. The quantity of reductions for which the cost is estimated in this graph is the 46 percent reduction that corresponds to the estimate of the Stern Review (2006).

The first possibility assumes that each supplier—in this context, each country that is making reductions in its deforestation emissions—is paid just enough to cover its costs. Thus each country gets a different price, with the low-cost countries receiving less than the high-cost ones. For this to happen, there must be a single "buyer" or a cartel of buyers, and they must use their market power to pay the minimum amounts necessary. In economic terms, they act as a monopsony. They can identify the lowest-cost countries by holding a reverse auction—in which supplier countries each bid to make reductions at a price they would accept—and the cartel then simply makes its purchases starting from the lowest prices offered and working upward. Graphically, the total cost of this approach is represented by the area under the supply curve. In Figure 2, it is the roughly triangular-shaped area with the diagonal lines.

The second possibility is that all countries making emissions reductions are paid the same amount per ton of reduction, regardless of their cost, as in a typical market. In this case, the calculation is much simpler. One simply multiplies the price (P) that the

FIGURE 2: Three Ways to Calculate Costs from Supply Curves



This supply curve corresponds to the GCOMAP model for 2020, and the costs are represented by the lined areas. a) The triangular area with diagonal lines represents the cost if a single buyer or a cartel uses its market power to pay each country only its own opportunity cost. This estimate, for the curve shown, is $8 billion/year. b) The smaller rectangle with vertical lines is the P·Q approach, under which all countries are paid equally at the price of the highest-cost country. This estimate is $16 billion/year. c) The larger rectangle with horizontal lines is the world carbon market approach, in which all countries are paid equally at the price prevailing in the world carbon market. This rectangle shows the cost if the price in a world carbon market including REDD were $30/tCO$_2$; in mid-2008 the E.U. ETS price, not including REDD, was approximately $40/tCO$_2$, translating into a cost of $57.4 billion/year.

highest-cost supplier needs to cover its costs by the quantity (Q) that would be provided by that supplier and all lower-cost suppliers. The resulting number is the total cost (C). Graphically, this is the area of the smaller rectangle with vertical lines in Figure 2. It includes the area below the curve but also the area above it, and so this cost is greater than that using the buyers' market-power approach.

The third possibility is that although the price will be the same for all suppliers, it will be set not by their costs but by the price of energy-sector reductions in the world carbon market. Because REDD costs are considerably lower than average energy-sector reduction costs (see Chapter Three), the price set by the carbon market would be higher than for REDD alone (and therefore further to the right along the x-axis). Thus the cost of the third approach—represented by the area of the large rectangle with horizontal lines in Figure 2—will be higher than the costs of the other two approaches. If the total amount of REDD reduction is small relative to the total amount of energy-sector reduction, this cost will closely approximate the world carbon market price without REDD (e.g., the mid-2008 value of about U.S. \$40/tCO_2 in the European Union's ETS market). As REDD reductions increase relative to energy-sector reductions, the carbon-market-including-REDD price will move lower and the overall cost of REDD will be reduced.

This report used the second of these three approaches—the P·Q approach, with P not dependent on energy-sector prices—to estimate costs. This option has several advantages over the other two. It approximates the cost that would result from a REDD market with many buyers and sellers, and it has neither the inequity problem that comes from the first approach nor the unnecessarily high cost of making REDD reductions that comes from the third. Further, cost can be calculated from REDD supply curves fairly simply, while the third approach requires also simulating the future energy-sector supply curves—which will depend on the amounts of reductions agreed to by industrialized countries in future climate agreements.

Using the P·Q approach is straightforward. The supply curve graphs Q against P; multiplying these two together gives Cost (C), against which one can graph Q to produce a cost curve. These curves, which show how much reduction in emissions from deforestation can be achieved for a given cost, thus provide the basis for estimating the potential of REDD.

Shown in this way, the cost curve will typically be concave downward or, alternatively stated, exhibits diminishing returns as the scale of emissions reduction increases. Spending twice as much money will not get you twice as much emissions reduction but rather somewhat less, and eventually the amount achievable will reach a plateau, virtually unchanging no matter how much money is available to pay the costs. Or, expressed in a common metaphor of politics and economics, the "low-hanging fruit" are easiest to get and cost you the least. Once they are picked, your remaining money does not go as far.

Spending twice as much money will not get you twice as much emissions reduction but rather somewhat less, and eventually the amount achievable will reach a plateau.

STEP 1: ECONOMIC ANALYSIS

With this background, we can now get into the economic analysis of the potential of REDD, which is fundamentally based on the opportunity costs of forested land in the tropics. However, even this basic factor can be analyzed in several ways. The economics literature on REDD shows that three basic methods have been used to examine opportunity costs, and this report compares all three. They are:

1. ***Regional, on-the-ground, empirical estimates, based on detailed studies 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. Division of per-area opportunity cost by carbon density gives the opportunity cost on a per-ton basis: (\$/ha) ÷ (ton/ha) = \$/ton. Most of these studies estimate single points, not whole supply curves, and often do not indicate how the quantity of emissions reduction they would achieve is related to the total quantity of deforestation emissions in the area studied. (Recently, however, more sophisticated empirical studies have been published that give whole supply curves, either for province-size regions [Swallow et al. 2007] or for whole countries and the entire globe [Strassburg et al. 2008]). The literature on opportunity costs of tropical forestland has now become relatively substantial, with more than two dozen estimates available from different regions. The

author reviewed this literature (the sources are given in Appendix 1) and analyzed it statistically, both to summarize the overall trends and to look for patterns of differences (e.g., between continents or the kinds of land use—such as annual crops, pasture, plantations, or timber—that served as a basis for the estimates).

2. The second approach uses the above-mentioned per-area estimates but combines them to give a ***global per-area cost of reducing deforestation*** (Grieg-Gran 2006/2008). This method, used in the Stern Review (Stern 2006) and in the "Field Approach" of Strassburg et al. (2008), has the advantage of making it possible to use opportunity cost estimates that lack corresponding carbon density estimates. However, to convert the global per-area cost to a per-ton cost, one needs to make an assumption about the mean carbon density for the regions studied. As above, this is calculated using (\$/ha) ÷ (ton/ha) = \$/ton, but here there is only a single value of carbon density (ton/ha) and thus a single global estimate of opportunity costs (\$/ton). This approach essentially ignores carbon density variation from region to region but makes it possible to use data from many more regions. The author used the conservative value (i.e., low-end estimate of density) of 390 tCO_2/ha—based on the recent estimates of 3.94 billion tCO_2 of emissions from 10.1 million hectares deforested—as a conversion factor for mean carbon density (Strassburg et al. 2008).

3. ***Global, partial equilibrium models*** of the forest sector simulate the dynamics of the world economy. They estimate supply curves for REDD emissions reductions (tons) in relation to prices (\$/ton). Therefore such models recognize the fact that the cost of reducing emissions depends on the depth of the reductions. Instead of point estimates of costs, they give us curves, which are concave—not straight lines—acknowledging the fact that the "low-hanging fruit" are cheaper to pick. Thus there is no single value for "the cost of REDD;" rather, the cost starts out low and increases with the amount of reduction. Also, the curves vary over time, generally with more reduction being achievable at lower costs in the early years than

Tree ferns, Hawaii Volcanoes National Park

later on, because as time goes on some forests will have been cut down and thus their emissions reduction potential will have been lost.

Given that the use of global, partial equilibrium models involves a more involved methodology than do the other two approaches, it is worth taking a bit of space to explain it. These models, which simulate the relevant parts of the entire world economy, generally include the forestry sector, agriculture sector, and other important determinants of land use. They also take into account the energy sector and economic activities that reflect fossil fuel use and affect carbon prices, but they do not simulate them in detail in order to calculate economic equilibria. Thus, these are *partial* equilibrium models.

To date, three global, partial equilibrium models have been used for this purpose: GTM (Sohngen et al. 1999, Sohngen and Mendelsohn 2006, Sohngen and Sedjo 2006), DIMA (Kindermann et al. 2006, Marland and Obersteiner 2007, Marland and Obersteiner 2008) and GCOMAP (Makundi and Sathaye 2004, Sathaye et al. 2006, Anger and Sathaye 2008). These three models differ in many of their details, including the sectors included, how their dynamics are simulated, how they divide up the globe spatially, and the interest rates used internally for calculating equilibria. They are also based on different data sets for such factors as the distribution of carbon densities in the world's forests and the total amount of deforestation. However, they share a common approach in that they are all based on the opportunity costs of different land uses. In that sense, the underlying data for the models is the same as for the Stern Review estimate and for the regional empirical estimates.

Recently, the developers of the three models have collaborated to compare their models, generating a series of runs based on similar initial conditions (Kindermann et al. 2008). Although these runs do not use exactly the same data sets and assumptions—as mentioned, factors such as carbon densities and interest rates vary from model to model—they do help to compare the predictions of the models using similar inputs.

If all three methods for examining opportunity costs—local empirical studies, the Stern Review approach, and the global models—gave more or less the same estimates of what is achievable through REDD, it would not matter greatly which one we chose to use. However, as will be seen below, this is not the case. The global models give much higher estimates of the costs of reduction—and, therefore, lower estimates of how much reduction is achievable for a given cost—than do either the regional empirical estimates or the area-based estimates of the Stern Review.

Faced with this range of estimates, this report tends toward the conservative when applying the economic analysis. "Conservative" here means choosing methods that give low estimates of what can be accomplished, based on what may be high estimates for opportunity costs. The value of the conservative approach is that it not only helps avoid promising too much, but also helps compensate for the fact that opportunity costs, although fundamental, are not the only costs of reducing emissions from deforestation and forest degradation. There are also a number of other costs involved (collectively called implementation costs), relating to establishing baselines, planning programs, building the capacity to execute them, measuring and monitoring the results, and carrying out the transactions necessary to receive compensation. The author estimates these costs, but the estimates are based on very limited data.

All these implementation costs will vary according to how REDD is implemented; they will be different for direct carbon market payments, voluntary efforts unconnected to the carbon market, and market-linked systems such as those based on auction- or allowance-allocation. In particular, systems in which REDD reductions are traded for increased fossil fuel emissions in the carbon market—and in which the reductions offset the emissions—have significant requirements. These systems need more accurate baselines, better monitoring and measuring, tighter quality control (e.g., evidence of additionality or lack of leakage), and stronger guarantees in the transaction process than do systems in which REDD reductions are added to those made in fossil fuel sectors. The reason is that if there is a failure of a system in which REDD reductions are offset by fossil fuel increases, an increase of one ton in fossil fuel emissions will be generated by what is in fact a decrease of *less* than one ton in emissions from deforestation. The net result will thus be that overall emissions actually *increase* because of the REDD system. If, on the other hand, there is a failure of a REDD system that does not involve offsetting (a voluntary or market-linked system), the net result will simply be that the net decrease will be less than expected. Thus the consequences of failure are much more detrimental to the overall emissions-reduction effort in direct-offset carbon market systems, and accordingly the guarantees against failure must be stronger. This will necessarily increase their costs.

Unfortunately, we have relatively few quantitative data on which to base *any* estimate of the additional non-opportunity costs, let alone one that varies according to the way in which REDD is funded and implemented. The only generalization that seems possible is that these additional costs probably show economies of scale: the costs will be relatively high for small projects and small reductions, but they will diminish (relative to the quantity of emissions reduction) as one moves toward regional and national-scale reductions (Antonori and Sathaye 2007). Thus their cost per ton of reduction drops as the quantity of reductions increases, whereas the opportunity cost per ton of reduction rises. This has the simple consequence that the ratio between opportunity and additional costs is not constant; one should not simply add on a fixed multiplier or percentage for additional costs. This report uses the limited data available to estimate these additional costs but does not assume that they have economies of scale, even though that is probable. This makes the overall cost estimate higher, tending again to make the estimate of REDD's potential a conservative one.

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STEP 2: POLITICAL AND INSTITUTIONAL CONSTRAINTS ON THE DEVELOPMENT OF THE SYSTEM

Carrying out the analysis based on the three economic methods explained above, choosing the most conservative of the three, and adjusting for additional costs will give an estimate of the potential greenhouse gas emissions reduction that can be achieved through REDD. This estimate, however, remains purely theoretical, and it tends to exaggerate what can be achieved in the real world, where substantial political and institutional constraints on the development of a REDD system will exist. In particular, the estimate assumes global application (either by using global models or by extrapolating a set of regional cost estimates to the rest of the world) and a REDD system's availability for use as soon as it is set up (e.g., when it is established globally by a new protocol signed in Copenhagen in December 2009 or by domestic legislation passed by one or another major developed country or region).

The normal expectation in economics is that more actors in a market will tend to lower costs, and thus that a REDD system with many actors will be most efficient. However, even when a global system is set up, not all countries will immediately join, and some may not join for a very long time. So it follows that a limited REDD market with only some countries participating will have higher costs than are implied by the global economic analyses, and that the market will therefore accomplish less.

As mentioned in Chapter One, the political and institutional constraints on participation in a REDD

TABLE 2: The Skewed Distribution of Deforestation

Share of Deforestation Emissions (%)	Number of Countries with This Share	Proportion of All Deforestation Emissions	Cumulative Proportion of Deforestation Emissions
10% or more	2	47.8%	47.8%
1% to 9.9%	14	35.8%	83.6%
0.1% to 0.9%	40	15.1%	98.7%
Less than 0.1%	42	1.3%	100.0%
All	98	100.0%	

Distribution of deforestation emissions in 2000, from Hare and Macey (2007). Original data are from the World Resources Institute's CAIT 4.0 database; the table has been rearranged and relabeled slightly.

system involve two kinds of limits: capacity and interest. Some countries will not be able to participate in the system at its inception, while others will be able to but will not want to. These limitations can apply both to the tropical countries that reduce emissions from deforestation and to the industrialized countries that provide the funding. Thus the second step of this report's analysis is to determine which countries will be able to participate, which of them will be willing to do so, and when?

Because a REDD system could include dozens of tropical forest nations and dozens of industrialized countries, a country-by-country consideration would be lengthy and difficult. Luckily, this is not necessary, since there are only a small number of tropical countries with large enough emissions for their participation or nonparticipation to make a difference to the overall market (Hare and Macey 2007, Table 2). Similarly, only a small number of developed countries are wealthy enough to be able to contribute large amounts of funding to REDD systems if they participate; further, many of them are joined together in the European Union (E.U.) and can be considered a single unit. Thus the political-institutional analysis of capacity and interest need only be done for the largest potential participants. Brazil, Indonesia, Malaysia, the Democratic Republic of the Congo, Papua New Guinea, and a few other countries and regions would be the main players on the supply side; and the European Union, the United States, Japan, and Australia would have the greatest impacts on the demand side.

As indicators of capacity, this report used the 2006 values of two of the broad groups of indicators compiled by the World Bank and made available on its website. These were the *governance* indicators, which include estimates of variables such as political stability, regulatory quality, and the control of corruption (*http://info.worldbank.org/governance/wgi/index.asp*); and the *social* indicators, which include educational, health, and demographic variables (*http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20535285~menuPK:1192694~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html*). Thus the data used in this report were similar to what was analyzed by Stern (2006) and Estrada Porrúra et al. (2007). The author took each country's percentile rank on the measures for which there were complete data, averaged them, and then converted the results into ordinal ranks as a basis for grouping the countries.

TABLE 3: The Coalition for Rainforest Nations (CfRN)

Bangladesh	Indonesia
Bolivia	Kenya
Cameroon	Lesotho
Central African Republic	Malaysia
Chile	Nicaragua
Colombia	Nigeria
Congo Republic	Panama
Costa Rica	Papua New Guinea
Democratic Republic of the Congo	Paraguay
Dominican Republic	Peru
Ecuador	Samoa
El Salvador	Solomon Islands
Fiji	Thailand
Gabon	Uganda
Ghana	Uruguay
Guatemala	Vanuatu
Honduras	

TABLE 4: The Forestry Eleven (F11)

Brazil
Cameroon
Colombia
Congo Republic
Costa Rica
Democratic Republic of the Congo
Gabon
Indonesia
Malaysia
Papua New Guinea
Peru

As indicators of interest, this report used each country's participation in activities related to international negotiations: membership in the international groups pushing for REDD (the CfRN [Table 3] and the Forestry Eleven [Table 4]), and nations making submissions to the UNFCCC meetings on REDD in 2006–2008 (Table 5, p. 14). Here again, the author used the variables ordinally as a basis for grouping the countries.

Done this way, the political-institutional analysis is not fully quantitative and thus will not tell us exactly which countries will be participating in future REDD systems at particular dates. At best, it can approximate

TABLE 5: Nations Making Submissions on REDD

Bonn, June 2008	Bali, December 2007	Cairns, March 2007	Bonn, May 2006
Colombia Costa Rica Gabon Indonesia Paraguay Sri Lanka Vanuatu	Belize Bolivia Brazil Central African Republic Chile Colombia Congo Costa Rica Democratic Republic of the Congo Dominican Republic Equatorial Guinea Gabon Ghana Guatemala Honduras Kenya Lesotho Liberia Madagascar Panama Papua New Guinea Paraguay Sierra Leone Solomon Islands Thailand Tuvalu Uganda Vanuatu Viet Nam	Argentina Bolivia Brazil Chile Colombia Costa Rica Dominican Republic Gabon	Bolivia Brazil Costa Rica Gabon El Salvador Indonesia Malaysia Nicaragua Panama Papua New Guinea Peru

the order in which countries are likely to join over a period of many years. Some of the measures used are numerical while others, particularly those relating to interest, are only qualitative, but among individuals who have been following the international negotiations on climate change there would probably be substantial agreement on the countries' relative order (Ott et al. 2008).

Thus while the political-institutional analysis of Step 2 can provide useful information on the development of a global REDD system, it cannot be integrated with the economic analysis of Step 1 in a simple quantitative fashion. Its value is to indicate to what extent any limited capacity or interest in participating in REDD systems will reduce those systems' emissions-reduction achievements below the potential indicated by the cost-based estimates. As capacity and interest in participating increase over time and the systems come closer to the truly global basis on which the cost- and supply-curve analysis was based, the reductions should come closer and closer to what those analyses tell us is possible.

CHAPTER THREE

Results

COST ESTIMATES

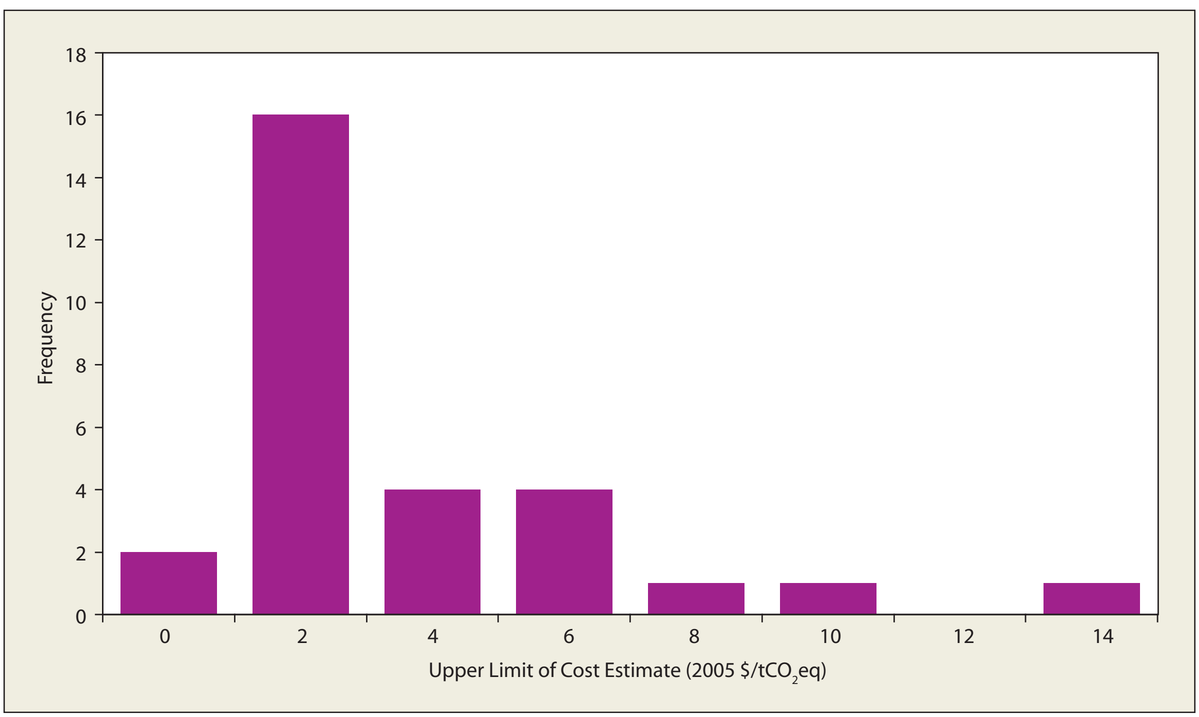
R*egional empirical estimates.* The author was able to locate 29 opportunity cost estimates measured in carbon emissions terms and convert them into common units (2005 U.S.$/t$CO_2$eq); their frequency distribution is shown in Figure 3. Clearly, most of the values are quite low. The mean is $2.51/t$CO_2$eq (standard deviation = $3.00), and 18 of the 29 estimates are under $2. The 29 estimates range from less than zero to a maximum of $13.34, and all but one are below $10. Thus the conventional wisdom that converting tropical forest to other uses is not very profitable appears to be correct. For comparison, emissions prices in mid-2008 in the European Union's Emissions Trading Scheme—by far the largest capped market at the time—were running about $35–$40/tCO_2eq. (It should be remembered in making comparisons that these E.U. ETS prices are at the margin, not estimates of average costs.)

Second, although there are differences among continents, these are not statistically significant (analysis of variance; $F_{2,26} = 0.12$, $P = 0.89$). The mean prices for Africa, the Americas, and Asia are respectively $2.22, $2.37, and $2.90.

Third, as expected, the opportunity cost of forest when the alternative is an intensive "modern" form of agriculture is higher than when the comparison is with a less-intensive "traditional" form. The mean for intensive agriculture is $2.83; for nonintensive agriculture it is $0.58—a nearly fivefold, statistically significant difference (paired t-test among forms of agriculture in the same regions; n = seven pairs, $P = 0.012$).

Finally, the cost can increase very significantly if one intends to eliminate absolutely *all* deforestation in a region (the so-called "choke" price). This is because

FIGURE 3: Frequency Distribution of Regional Empirical Cost Estimates



Frequency distribution of the regional empirical estimates of REDD costs in the literature, based on opportunity costs (n = 29, mean = $2.51/t$CO_2$eq, standard deviation = $3.00/t$CO_2$eq).

the region's most high-value uses (e.g., commercial logging in Southeast Asia, soybean farming in the Brazilian Amazon) can have high opportunity costs. Although limited to small areas, these areas are typically at the top of the cost curve, where it is almost horizontal. Thus small increases in area produce large increases in cost. Tomich et al. (2005), for example, found that opportunity cost in Sumatra ranged from -\$0.26 to \$5.22 in regions where the highest-value alternative was crop production, but it was \$13.34 where commercial logging had the highest value. Nepstad et al. (2007) estimated that it would cost \$0.76/tCO_2eq to eliminate 94 percent of emissions from deforestation and forest degradation in the Brazilian Amazon, but \$1.49/tCO_2eq to eliminate 100 percent. Thus paying the opportunity costs to compensate for "the last tons" will increase the average cost quite significantly.

Note that the sizes of the "regions" involved in this analysis vary widely. Some are municipalities, with areas in the tens of square kilometers, while the largest (Nepstad et al. 2007) covers the whole of the Brazilian Amazon.

Area-based estimates. The study carried out by Grieg-Gran for the Stern and Eliasch Reviews (2006, updated 2008) is an area-based analysis. Data from eight countries representing the large majority of tropical forestland (Brazil, Bolivia, Cameroon, Democratic Republic of the Congo, Ghana, Indonesia, Malaysia, and Papua New Guinea) gave an estimate that one could reduce deforestation by 46 percent for an opportunity cost of \$5 billion to \$15 billion/year. The 2008 update increased the \$5 billion to \$6.5 billion, but here we use only the 2006 figures (corresponding to the Stern Review as published) because costs changed again with the late-2008 world economic crisis.

Applying the carbon density conversion factor of 390 tCO_2eq/ha to the cost estimates of Grieg-Gran gives a range of \$2.76 to \$8.28/tCO_2eq (midpoint = \$5.52) for per-ton costs. The midpoint is over twice the mean of the regional empirical estimates (Table 6), but still low. Note that there are two important reasons why this area-based estimate would be expected to differ from the regional empirical estimates. One is the uncertainty in deforestation and carbon density values, which figure into both kinds of estimates. The other is the fact that Grieg-Gran's estimate is for avoiding 46 percent of tropical deforestation, not merely deforestation in a small region. Thus it may be estimating the cost for a point considerably further along the supply curve than most of the empirical estimates.

Estimates from global economic models. Using data output from comparable model runs used in the Kindermann et al. (2008) study, the author graphed the global supply curves for 2010 and 2020 for each model (e.g., Figure 1) and used them to calculate global cost curves for those years using the P·Q method (Figure 4). All three cost curves for both years show considerable curvature. For the first few tens of billions of dollars spent, the projected emissions reductions are very substantial, but the curves for all three models and both years begin flattening out as the costs exceed \$100 billion in 2005 dollars. As expected, the plateaus of the 2020 curves are lower than those for 2010, and for 2030 (not shown) they are lower still. This is because in 2020 some of the forests that existed in 2010 will have now been cleared, so it will not be possible to avoid those emissions any longer. Similarly for 2030 vs. 2020. (The 2010 results are most comparable in time to those of the empirical

TABLE 6: Opportunity Costs for REDD

Approach	Opportunity Cost Estimate	High	Low
Regional, empirical	\$2.51	\$4.18	\$0.84
Stern Review	\$5.52	\$8.28	\$2.76
Global models	\$11.26	\$17.86	\$6.77

Opportunity cost estimates and high-low ranges of opportunity cost/tCO_2 for the three approaches. Stern Review and global model values are for points on the supply curve that correspond to a 46 percent reduction in global deforestation; percent reduction for regional empirical models varies and in general is not known. The bases of the opportunity cost estimates are as follows: for regional empirical studies, the mean of 29 studies; for the Stern Review, the midpoint of the high-low range (from the 2006 version); and for the global models, the mean of the three models. High-low ranges are: for the regional empirical studies, the mean ± 3 · S.E.; for the Stern Review, the high and low values; and for the global models, the minimum and maximum of the three models.

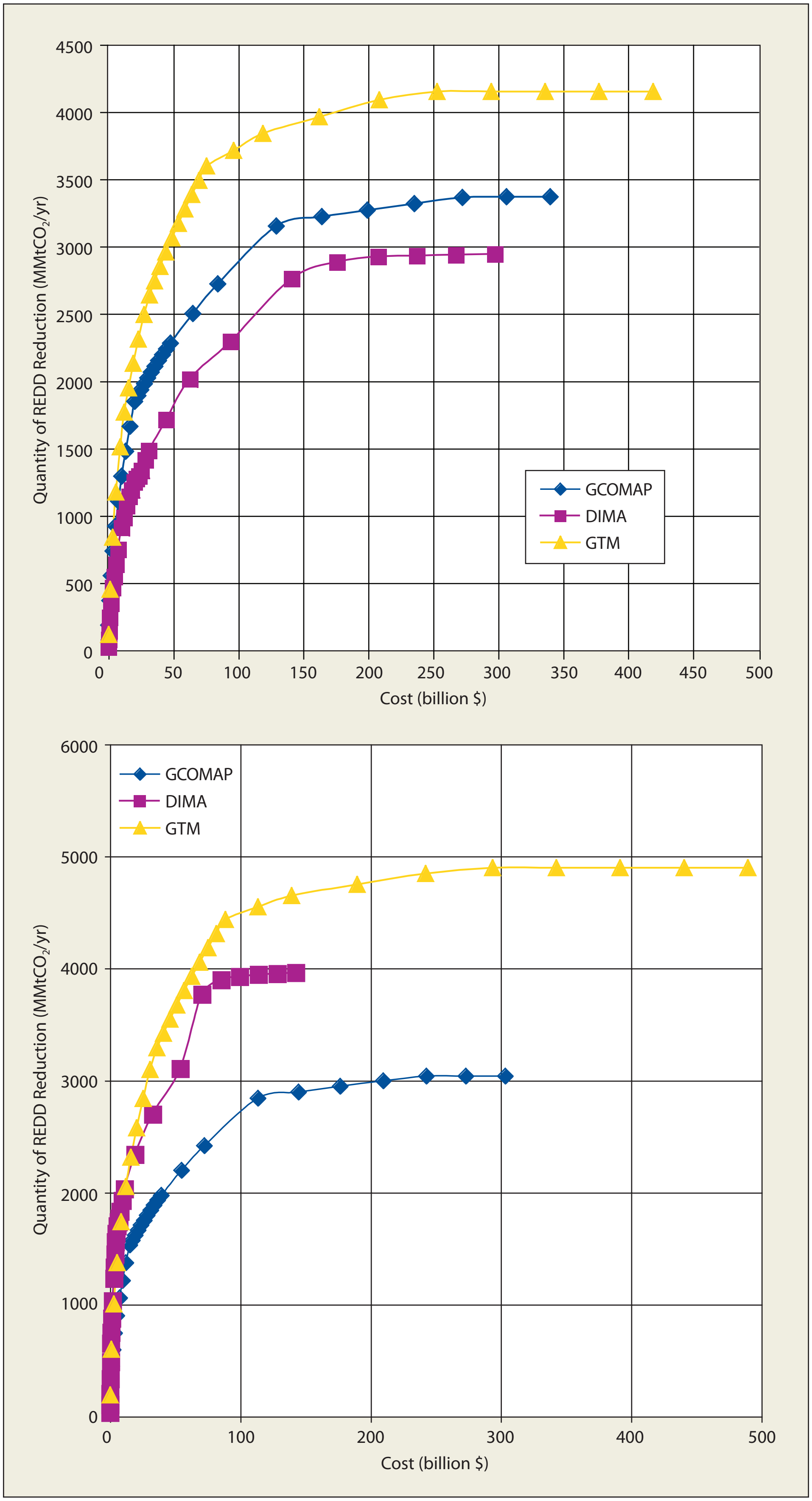


FIGURE 4:
Cost Curves for REDD in 2010 and 2020

Cost curves for REDD calculated from the GCOMAP, DIMA, and GTM models for two different years: 2010 (top) and 2020 (bottom). In each case, cost is plotted on the x-axis and quantity of emissions reductions on the y-axis.

estimates and the Stern Review, although, as argued below, the political-institutional constraints make it very unlikely that a global REDD system will actually exist then or even a few years after.)

In general, the GTM model tends to predict the most emissions reductions for a given cost (its curve is usually the highest) and the GCOMAP model the least, with DIMA in between. However, the curves do cross at a couple of points, so the most conservative predictions may be from GCOMAP or DIMA, depending on the cost range for which REDD potential is being estimated (Figure 5).

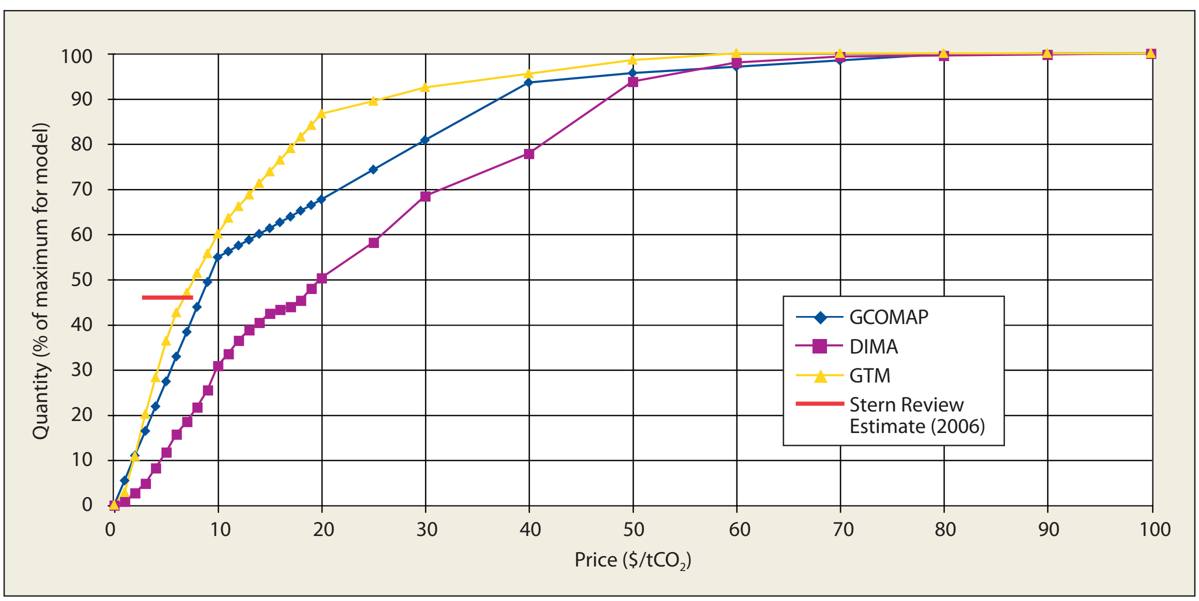
It is also notable that the curves for the three models plateau at quite different quantities of reductions. For 2010, for example, the GCOMAP curve levels off at just over 3,000 million tCO_2eq or three gigatons (Gt) CO_2eq, the DIMA curve at about 4,000 million tCO_2eq, and the GTM curve at nearly 5,000 million tCO_2eq (Figure 4, top). Thus the three models differ not only in their projections of how much emissions from deforestation can be reduced for a given cost, but also in how much could be achieved if unlimited funding were available.

Results of two other modeling approaches are worth mentioning here, although they are not presented in sufficient detail in the original publications to make them usable for deriving cost curves. Hyvarrnnin (2007) reported on the results of a Chatham House workshop at which choke prices from modeling were presented; under Chatham House rules these were not cited by the author and may well correspond to the models already considered here. The Vattenfall/McKinsey study (Vatenfall 2007, Enkvist et al. 2007) gave an estimate of 3.3 $GtCO_2eq$ of abatement potential from avoided deforestation up to 2030, at a marginal cost per ton of up to 40 euros. However, the data and methods of analysis were not presented in detail, making it difficult to compare these figures with others or use them to derive cost curves. Thus neither of these studies is considered further here.

Comparing estimates. Table 6 and Figure 5 compare the estimates from the three approaches, using the Stern Review's 46 percent as the quantity of reductions. The Stern Review (area-based) estimate gives a price range of \$2.76 to \$8.28, and the midpoint of this range is below the values for all three global models. The regional empirical price estimates are even lower than for the Stern Review, although the points on the supply curves to which they correspond are not clear. This may explain part of the differences.

We can also compare these results to those of the Intergovernmental Panel on Climate Change (Metz et al. 2007, Chapter 9), which estimated the potential of REDD for the year 2030. The IPCC's figures of

FIGURE 5: Relative Supply Curves for 2020



Relative supply curves for 2020 (relative quantity of emissions reductions, in percent, vs. price in 2005 \$) and Stern Review estimates of price based on a 46 percent reduction in deforestation at a cost of \$5 billion to \$15 billion/year (2006 version, without 2008 updating). Relative quantities of emissions reductions are calculated as absolute emissions reduction divided by the maximum emissions reduction (plateau height) for the model.

a potential 3,785 million tCO_2 from reducing deforestation in the tropics, of which 54 percent could be accomplished for less than $20/$tCO_2$, give an estimate of 2,044 million tCO_2 for the $20 price point. Applying the methods of this paper, the mean of the three global model estimates for that price point and year is 2,267 million tCO_2. The similarity of the estimates is not surprising, given that the IPCC's estimate is based in considerable part on earlier versions of the same global models.

Thus the global models give the highest prices—and consequently the least reductions achievable for a given cost—of the three approaches. A conservative approach should therefore estimate the potential of REDD using the global models.

Other costs. All three of the above approaches are essentially based on estimating the costs and potential of REDD from opportunity costs. But as mentioned earlier, several other kinds of costs are involved in REDD as well. Can we estimate these other costs and incorporate them into an overall cost curve?

Only a few studies have made such an attempt. Antinori and Sathaye (2007) found that transaction costs for forestry offset-project developers averaged $0.38/$tCO_2$eq (ranging from $0.03 to $1.23; n = 11), and forest projects generally had lower transaction costs than nonforest projects. As expected, transaction costs were lower for large projects than for smaller ones.

Implementation costs involved in REDD include measuring and monitoring, capacity-building, planning and goal-setting, and a wide variety of other kinds of costs that vary according to the drivers of deforestation and the REDD program adopted (e.g., confirming indigenous land rights, modifying plans for the road network, integrated conservation and sustainable development, and establishment of national parks). These costs overlap somewhat with transaction costs, and there is the additional issue of determining which ones represent real costs—as opposed to transfer payments among the citizens of a country, which should not be included (Pfaff et al. 2008). This report used implementation costs calculated from the proposal by Nepstad et al. (2007) for the Brazilian Amazon; this source offers the most comprehensive estimate and includes national as well as project-scale expenses. That estimate works out to $531.6 million annually for a program that reduces emissions by 917.5 million tCO_2, or $0.58/$tCO_2$, once it is fully implemented (year 10).

Grieg-Gran (2006/2008) estimated that the administrative costs of REDD programs, based on eight countries and calculated per unit area, would range from $4/ha to $15/ha. These costs would overlap somewhat with the transaction and implementation costs and thus result in some double-counting if added to them; but the error involved would be small, as $4–$15/ha converts to just $0.01–$0.04/tCO_2 when expressed on a per-ton basis. The $3.80/ha estimate of Strassburg et al. (2007) for protection and management costs is even lower; here again, there is overlap with some of the other categories.

Da Fonseca et al. (2007) considered the issue of stabilizing the large amounts of forest carbon in high forest-low deforestation (HFLD) countries such as those of central Africa. Even though emissions from deforestation in these countries are low, they are important components of a global REDD plan because of the danger of "international leakage"—if they have no incentive for keeping their emissions low, timber companies and other drivers of deforestation could simply move from countries with REDD programs to these HFLD nations. This would increase their deforestation rates and cause a rise in emissions, thus partially neutralizing the reductions in the REDD countries from which the drivers of deforestation moved.

The global models give the highest prices—and consequently the least reductions achievable for a given cost—of the three approaches.

The estimate of da Fonseca et al. is that a strong stabilization plan for the 11 most important HFLD countries would cost $1.8 billion annually. Other estimates, covering 7 to 10 countries, would cost only $365 million to $630 million. Although these figures cannot be directly converted into measures comparable to those used for REDD (as they relate to keeping emissions constant, not reducing them), they are considerably less than the billions or even tens of billions estimated for opportunity costs (Figure 4).

Strassburg et al. (2008) take a different approach, developing a "combined incentive"—a single mechanism that would compensate both HFLD countries and REDD countries that reduce their deforestation rates. This system therefore does not require any separate funding for stabilization, and in fact it is financially attractive for countries spanning a wide range of deforestation rates. The resulting supply curves—calculated, using the combined incentive as the price variable, by two different methods—show low costs relative to the global models for equivalent levels of emissions reductions. Cattaneo (2008) presented a similar system, but based on stock and flow concepts that correspond more closely to standard financial definitions. Because these systems do not provide a separate estimate of stabilization costs, this report does not use them for estimating purposes, but the approach is worth consideration for its general applicability to all countries, whatever their levels of deforestation.

Adding the estimated per-ton costs—for transactions (\$0.38/tCO_2; Antinori and Sathaye 2007), implementation (\$0.58/tCO_2; Nepstad et al. 2007), and administration (\$0.04/tCO_2; Grieg-Gran 2006/2008)—gives a total of exactly \$1.00/tCO_2. Because the components overlap somewhat, adding them involves some double-counting and the sum is therefore conservative (it overestimates total costs and thus underestimates potential reductions at a given price). Stabilization costs cannot be expressed in per-ton units (\$/tCO_2), given that they apply to maintaining low emissions rates, not to emissions reductions. Therefore the author accounted for them separately, using the middle estimate of da Fonseca et al. (2007), \$630 million/year, to cover 10 HFLD countries.

The data available for estimating additional costs of REDD beyond the opportunity costs are very limited, as noted. However, the dearth of such data does not seem to be critical. Based on the above calculations, the opportunity costs would appear to make up the majority of the costs for an international REDD program.

THE DEVELOPMENT OF REDD: POLITICAL AND INSTITUTIONAL CONSIDERATIONS

The economic analysis, whether performed using regional empirical data, area-based estimates, or global models, and whether supplementing opportunity costs with other kinds of costs or not, still suffers from a fundamental limitation. It assumes the existence of a global REDD system.

This assumption is unlikely to be true at the beginning, however, and may take many years to develop. The reality is that not all countries may be able to participate initially, and not all that are able may want to. These possibilities apply both to the supply side (the tropical forest countries that can reduce emissions

Collecting soil samples, southeastern Nicaragua

by slowing deforestation) and the demand side (the industrialized countries whose funding will pay for these reductions). Thus it is vital to modify the calculated economic potential of REDD by taking political and institutional constraints on the system's development into account. For each of the relevant countries, we need to ask about its participation in a REDD system: Can it? Will it? And if so, when?

This may seem like a daunting task, as many dozens of countries, whether on the supply or demand side, are involved. But in fact there are only a few of each whose participation or nonparticipation would have a major impact on the dynamics of the system. The reason is that the distribution of sizes, among tropical forest countries and industrialized countries alike, is highly skewed.

Table 2, taken from the work of Hare and Macey (2007), shows this phenomenon clearly. Just two of the countries—Indonesia and Brazil—individually account for more than 10 percent of the total emissions from deforestation, and added together they are responsible for more than 50 percent. Fourteen other countries (Malaysia, Myanmar, Democratic Republic of the Congo, and 11 others) each contribute between 1 and 10 percent of total deforestation emissions, and collectively they bring the total up to 83.6 percent. Thus the top 16 countries—out of nearly 100 tropical forest countries in all—are responsible for nearly six-sevenths of all emissions from deforestation. This means that rather than having to consider each of the 100 countries when estimating a multilateral REDD mechanism's achievable reductions, it is sufficient to examine the capability and interest of only the largest.

The same is true on the demand side. Although in theory any country in the world could help fund emissions reductions, only a small number are likely to be sources of large amounts of money, no matter what kinds of REDD mechanisms are established. Further, many of these countries are members of the European Union, which can be considered a single entity. Thus for practical purposes it is the capacity and interest of the United States, the European Union, Japan, Australia, and perhaps a few other countries that will determine the extent of the funding for a future REDD system.

Capacity. Among the tropical forest nations, the capacity to participate in a REDD system varies widely. At one extreme is Brazil, the second-largest emitter of greenhouse gases from deforestation and the country that contains the majority of the largest single block of tropical forest in the world, the Amazon. Brazil has been monitoring its deforestation by remote sensing, in part through its own satellites, since the 1970s, and it now has a sophisticated system in place that can detect changes in deforestation rates within short periods. Although still a developing country, Brazil is an industrial and scientific power, with large numbers of universities, specialized research institutes, and highly trained scientists. Politically, it has a well-developed democratic system with considerable capacity to regulate land use, both at the federal and state levels. It ranks relatively high among tropical forest nations on governance indicators, such as regulatory quality and control of corruption (Estrada Porrúra et al. 2007).

At the other extreme is the Democratic Republic of the Congo (DRC), which is representative of countries in which considerable capacity building will be necessary. ("Capacity" involves not only technical capacity but also the ability to plan, implement, monitor, and administer funding.) On almost all governance indicators, the DRC ranks in the lowest 10 percent and on some in the lowest 1 percent (Estrada Porrúra et al. 2007).

The other countries with major emissions from tropical deforestation show a range of abilities to participate in a global REDD system. Some of these countries will be able to enter almost immediately, but for others there will be a considerable delay while capacity is being built up.

Interest. There is a similar range, among tropical countries, of interest in participating in a REDD system. But just as important is the relationship of this interest to capacity. Brazil, as noted above, has relatively high capacity to join an international REDD system, yet its current negotiating position is that the national government does not support basing that system on the sale of credits in the carbon market. Rather, the nation continues to favor a fund-based approach predicated on contributions from developed nations. If a future REDD system were carbon-market-based, or if the system included the carbon market as one among several major elements, it is not clear at present whether Brazil would join it.

Other countries, at least at the present time, are more willing to join a REDD system. Papua New Guinea (PNG), for example, has led the Coalition for Rainforest Nations (CfRN) in pushing for the inclusion of REDD in the post-2012 climate agreement. Together with Costa Rica, it developed the CfRN proposal that REDD involve a "basket of approaches" with measuring and monitoring based

TABLE 7: Development of the REDD System

	Share of Emissions from Deforestation	Capacity	Interest	Timing of Entry
Indonesia	33.7%	2	2	Middle
Brazil	18.0%	1	2	Early
Malaysia	9.2%	1	2	Early
Myanmar	5.6%	2	3	Late
Democratic Republic of the Congo	4.2%	3	2	Late
Zambia	3.1%	2	3	Late
Nigeria	2.6%	2	2	Middle
Peru	2.5%	2	2	Middle
Papua New Guinea	1.9%	3	1	Middle

Potential development over time of the global REDD system, based on share of emissions and capacity and interest indicators: 1 = high, 2 = moderate, 3 = low.

on national baselines; this proposal led to a key breakthrough in the negotiations at Montreal in 2005. The PNG government has also been involved in negotiations with Australia and Indonesia to form a regional REDD system, which could go into force even before the post-2012 timetable. Thus PNG's interest in participating in future REDD systems is currently high; the limitation on when it might enter would primarily be a question of capacity.

For other major emitting countries, interest is also a potentially important factor in determining when they join a REDD system. Malaysia and Indonesia have given indications of their interest in REDD through membership in the CfRN (Table 3) and the Forestry Eleven group of countries that supported including REDD in the Bali Roadmap in the latter part of 2007 (Table 4), as well as through some UNFCCC submissions (Table 5).

Myanmar (Burma), the tropical forest country that ranks fourth in deforestation emissions, is a special case. It has shown little interest in REDD, is not a member of the CfRN, and is the largest deforestation emitter outside of the Forestry Eleven. Further, it is an important link in the illegal timber market involving China and some of its Southeast Asian neighbors. There is also considerable doubt, given Myanmar's poor record on democracy and human rights, whether it would be welcomed by other nations. Thus beyond its limited capacity and low ranking on governance indicators, Myanmar shows little interest in joining a future REDD system. Nor do other countries seem to be encouraging it to do so.

Predicting how quickly a REDD system could develop. It thus seems that the development of a global REDD system will take a considerable amount of time. Among the major emitters, some countries that have high capacity to participate have limited interest in doing so, at least with the kind of system that is likely to be implemented in the near future. Others are in the opposite situation, with high interest but more limited capacity. A few, such as Myanmar, are low on both dimensions (Table 7).

Translating these ordinal assessments into predictions about the rate of development of a future REDD system is difficult. Beyond the problem of translating somewhat subjective evaluations into specific dates, there is the fundamental problem of predicting the pace of development of a future system whose design, funding, mechanisms, and relation to industrial-nation emissions cuts is unknown. However, a few generalizations seem reasonable.

First, the world will not have a global REDD system, with all major tropical forest nations participating, at the beginning of the post-2012 period. Some countries will not have the capacity to participate by then; others will have the capacity but not the interest, and some will have neither.

Over time, the system can be expected to develop. One can hazard a prediction that Brazil and Malaysia may join relatively early on, perhaps followed by Indonesia and Papua New Guinea a bit later (Table 7).

Myanmar and the Democratic Republic of the Congo will take longer, perhaps more than a decade. Overall, given the skewed distribution of deforestation emissions (Table 2), a REDD system is likely to cover no more than half of worldwide emissions from deforestation by 2015, and it will probably take at least until 2020 to reach three-fourths or more. Certainly, in applying global models to estimate REDD's potential, the curves for 2020 are much more likely to be appropriate than those for 2010 (Figure 4).

OVERALL ESTIMATES

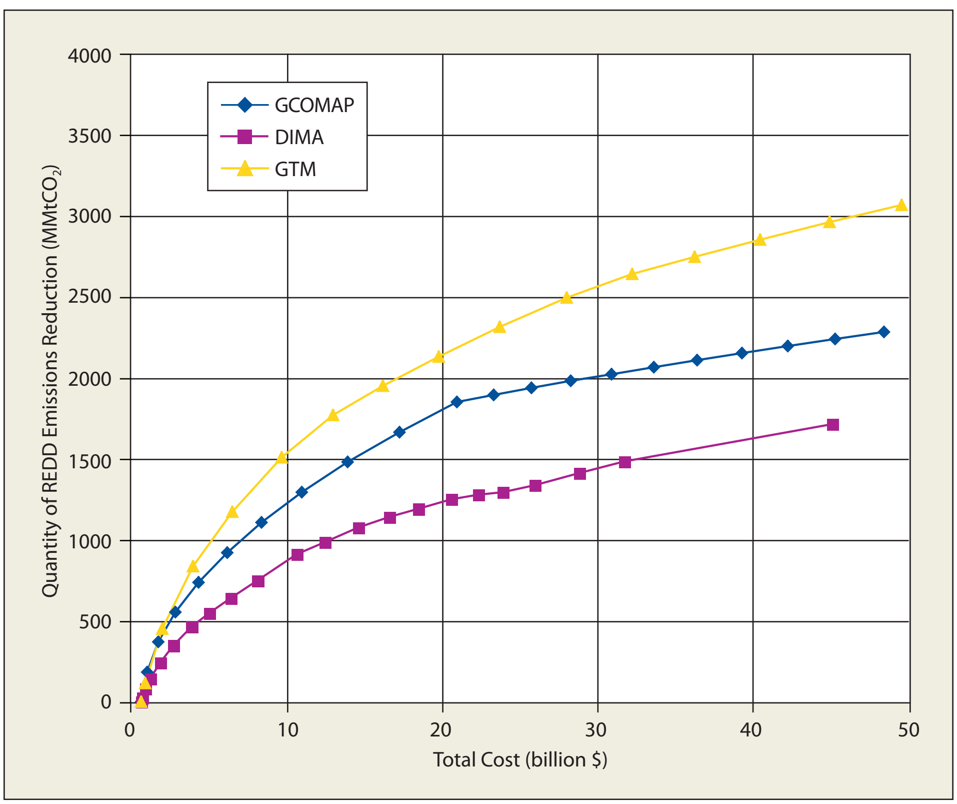
Combining all these costs and considerations, Figure 6 shows overall cost curves for REDD reductions according to the three global, partial equilibrium models. The curves include opportunity, stabilization, transaction, implementation, and administration cost estimates, and they are for a year (2020) by which the global REDD system may have enough participating countries for the curves to in fact be useful.

The text box on page 24 applies these cost curves to a real-world problem: estimating the potential REDD reductions that could have been achieved by the Lieberman-Warner Climate Security Act, a proposed climate bill debated in the U.S. Senate in 2008. The box shows how the estimation is done and compares the results both to U.S. overall emissions in 1990 and to estimated global emissions from deforestation in 2020.

The world will not have a global REDD system, with all major tropical forest nations participating, at the beginning of the post-2012 period.

Applying the method to other potential funding levels, the curves indicate that with \$5 billion in global funding, emissions from deforestation could be reduced by about 775 million tCO_2 (ranging from 550 to 975). With \$10 billion, the estimate goes up to about 1,175 million tCO_2 (850 to 1,500); with \$20 billion, up to 1,750 million tCO_2 (1,350 to 2,150). Finally, with \$50 billion in total funding,

FIGURE 6: REDD Total Cost Curve in 2020 for the \$0–\$50 Billion Range



REDD total cost curve in 2020 for the three global models. All costs, including opportunity, stabilization, transaction, implementation, and administration, are included. Only the initial part of the curve (x-axis range from zero to \$50 billion) is shown.

the estimated reduction would be just below 2,400 million tCO_2 (1,800 to 3,100).

To get a sense of the corresponding percentage reductions, consider first the estimates of total deforestation emissions in 2020—the plateau heights of the curves—from the three models. Because the average of the three is just under 3,500 million tCO_2 (ranging from 2,950 to 4,150), the $5 billion figure corresponds to just over a 20 percent reduction and the $20 billion figure to a 50 percent reduction.

Another way to view these curves is to consider the $2.6 billion in funding for REDD, over five years, announced by the government of Norway at the Bali UNFCCC conference in December 2007. In annual terms, this corresponds to 0.13 percent of Norway's GDP. If the other major industrialized nations allocated the same proportion of their GDP to the REDD effort, the total would be roughly $48.5 billion annually. This would be enough, according to the cost curves of Figure 6, to reduce global emissions from deforestation by 66 percent (ranging from 59 to 72 percent).

Estimating Potential Emissions Reductions from REDD under the Lieberman-Warner Climate Security Act

The Lieberman-Warner bill was the main climate proposal considered by the U.S. Senate during the 110th Congress (2007–2008). Proposed by Senators Joseph Lieberman (I–CT) and John Warner (R–VA), it represented a compromise among several other Senate bills. It was modified and passed by Senate committees in late 2007 and brought up for debate on the Senate floor at the beginning of June 2008. Tactics by opponents of the bill, including insistence on taking an entire day to have the clerk read the whole text out loud, led to its being withdrawn from consideration without a final vote. However, a test vote suggested that the bill could have gotten majority support.

Lieberman-Warner was a cap-and-trade bill, covering about 85 percent of the U.S. economy and reducing emissions of covered sectors 70 percent below 1990 levels by 2050. It contained two kinds of REDD provisions: market-linked funding for additional emissions reductions (beyond those made by the cap) related to "international forest protection," and direct carbon market funding from the potential for REDD credits to enter the U.S. market as offsets. Here, we estimate only the potential reductions from the market-linked funding (Title III, Subtitle H), using the version of the bill passed by the Senate Environment and Public Works Committee (S. 2191).

This market-linked funding came from the bill's provision that 2.5 percent of its emissions allowances be designated for international forest protection. The resulting revenue for REDD would compensate tropical countries for reducing their deforestation emissions, and it could also provide funds for related costs such as capacity building.

To estimate the potential emissions reductions that could be made using the market-linked funding for the year 2020, we first needed to calculate the amount of that funding. We took 2.5 percent times the number of emissions allowances available in that year (4,530 units, each equal to 1 $MMtCO_2eq$), which gave 113.25 $MMtCO_2eq$. Multiplying this number by the Environmental Protection Agency's estimate of the carbon market price at which these units would be auctioned ($28.31/$tCO_2eq$) gave a value of $3.2 billion. Subtracting the estimated $630 million needed for stabilization costs (da Fonseca et al. 2007) left $2.57 billion for all those costs that are estimated on a per-ton basis (opportunity, implementation, administrative, and transaction costs).

The cost curves (e.g., Figure 4, bottom) were used to estimate the potential reductions for $2.57 billion in funding for each of the three models. These estimates were: for the GCOMAP model, 598 $MMtCO_2eq$; for the DIMA model, 396 $MMtCO_2eq$; and for the GTM model, 687 $MMtCO_2eq$, giving an average estimate of 560 $MMtCO_2eq$.

For comparison, this latter figure is equal to 9 percent of U.S. greenhouse gas emissions in 1990 (6,242 $MMtCO_2eq$). For another comparison, it is also equal to about 16 percent of the estimated emissions from deforestation in 2020, using the mean of the three models' estimates.

CHAPTER FOUR

Discussion

THE POTENTIAL OF REDD

Although the results of different quantitative approaches show considerable variation, and all leave out some costs and constraints, they are unanimous in indicating that REDD has great potential. Even using the most conservative of the three approaches (the global models) and estimating from the average of the cost curves of the models, the reductions that can be made for moderate cost levels are large. The costs of reductions in deforestation emissions compare quite favorably to those in fossil fuel sectors, and they are appreciably lower than current marginal prices for emissions reductions in the largest capped carbon market, the European Union's Emissions Trading Scheme.

The political analysis of the system's development does not change this overall conclusion, but it does show that the potential of REDD could take many years to be realized. None of the largest tropical forest countries fulfills both criteria: being capable of entering into a global system immediately, and having indicated a commitment to doing so. Of course, this will change over time as the outlines of the system become clearer, capacity is built, and countries take advantage of new opportunities. Nonetheless, we should not assume that any more than half of the emissions from deforestation will be in countries covered by a global REDD system in 2015, and inclusion of more than three-fourths of emissions will probably not take place before 2020. The situation is thus one of great potential in the medium and long terms but of limited potential in the near term.

For the purposes of making quantitative estimates of what can be accomplished with a defined amount of REDD funding, this report deliberately used conservative methods. What would be the most *likely* assessment of REDD's potential, however, as opposed to the most conservative?

To answer this question it is necessary to do a qualitative sensitivity analysis: what factors would tend to diminish or enhance the predicted results? On the "smaller" side (fewer reductions in emissions than predicted), some of these factors have been estimated, though based on limited data. They include several kinds of additional costs (e.g., measurement and monitoring, planning and administration, implementation). In addition, failures of governance could reduce the efficiency with which a system is run and thus its accomplishments—perhaps very substantially. International leakage, and the price/supply effects of increased land scarcity caused by the reduction of deforestation, could also reduce the potential of the system appreciably.

We should not assume that any more than half of the emissions from deforestation will be in countries covered by a global REDD system in 2015.

Capacity building, in all its forms, constitutes another cost. Beyond developing the ability to measure and monitor emissions, it includes fostering a trained and dedicated staff to use the acquired information to carry out an effective program. In this sense, money spent on capacity building might improve the efficiency of implementation and thus reduce the associated costs.

Negative quality effects, such as international leakage, lack of additionality, and difficulty of verification, will also reduce the accomplishments of REDD. Their scale, and the degree to which the system reduces or discounts for them, will depend on the specifics of the REDD agreement. Other factors include the degree of participation (how many countries are in the system) and the money spent on countering the negative effects. In this respect, the one or two billion dollars that were estimated by da Fonseca et al. (2007) as the annual cost of stabilizing the low deforestation rates of countries such as those in the Congo Basin would be money well spent.

The recent increase in world grain prices is another factor likely to raise the costs of REDD. Commercial soybean production in particular is an increasingly important factor in Amazon deforestation (Morton et al. 2006), and as soybean prices rise so does the value of land for their production—along with the opportunity costs of keeping land in forests rather than converting them to soybean fields. Although cattle ranching is still the major driver of Amazon deforestation, if soy and maize prices stay high the costs of REDD will be greater than those estimated here, which are based on periods during which world grain prices were considerably lower than they may be in the future. However, increases in other commodity prices, including those of energy, could have opposite effects, discouraging the expansion of industrialized export agriculture in the Amazon and other tropical regions.

A final factor tending to lower the potential of REDD is the degree to which future programs to reduce tropical deforestation will be any more effective than those of the past. The history of such efforts is replete with examples of programs and concepts that failed to realize their promise, including the International Tropical Timber Organization, Tropical Forest Action Plans, debt-for-nature swaps, extractive reserves, FAO programs, and others (Metz et al. 2007). This history does not provide grounds for optimism unless future REDD programs are implemented more effectively than these past efforts. There are reasons to think that elements of the new approach represented by REDD—payment only after reductions are made and verified, use of internationally available remote sensing data for monitoring, support for capacity building and leakage prevention, and a much larger scale of funding—will make a difference. But until it is implemented and shows its effectiveness, there are ample grounds for continued skepticism about whether REDD can realize its potential.

Given all these factors that would lower REDD's accomplishments below the estimates, it is worth remembering that there are several others that would tend to raise them. The first, of course, is that a conservative method was employed—taking the projections of the global models, as well as using the 2020 cost curves (which indicate higher costs than those for 2010), to take into account political-institutional limits on the rate of system development. Thus to the extent that reality is closer to the estimates of the Stern Review, REDD may be able to do better than these estimates suggest.

The political analysis may also be too conservative in that it bases its assessment of interest on current political positions. Once a REDD system that offers substantial financial benefits is in place, countries' positions could change significantly, and only a few nations would need to make such a decision to have an appreciable effect.

There are also three other factors that could lead to greater cuts in emissions from deforestation, though they should not necessarily be credited to REDD. These factors—changing opportunity costs as countries run out of forest to cut, the "forest transition," and efforts generated by the internal politics of tropical countries—are tendencies that would reduce deforestation even without international funding to pay the costs. Because they "would happen anyway," these tendencies should rightly be considered as part of the business-as-usual baseline against which the accomplishments of REDD are compared. In practice, however, it will be hard to separate the interacting effects.

The running-out-of-forest issue simply acknowledges that a country's emissions from deforestation are limited by its inventory of forest. As a country clears more and more of its forest, the supply of agricultural land will increase and that of standing forest will decrease. This increasing supply of already cleared land should lower the value of agricultural land and raise that of forest, other things being equal. At the extreme, once a nation clears all of its accessible forest, its deforestation emissions will drop to zero regardless of policy. Recent analyses have just begun to take these simple factors into account in examining the possible impacts of policy proposals, but as yet the baselines for REDD used by most analyses—including this report—implicitly assume that deforestation can continue at the same rate forever, even though forests are not infinite.

The forest transition is the name given by social scientists (Mather and Needle 1998, Rudel 1998, Mather et al. 1999, Rudel et al. 2002, Mather 2004, Rudel et al. 2005) to the reduction in deforestation, and eventually a change to net reforestation, as societies develop. Analogous to the demographic transition, its pattern over periods of several decades is that deforestation rates first increase, then decrease, and finally reverse. Part of the change is caused by the first factor just mentioned, that of running out of forest. But the fact that many countries seem to have made the forest transition when they still had large amounts of forest remaining proves that there are other causes and that alternative paths to "using it all up" do exist.

Mangrove swamp, Cairns, Australia

Most developed countries have already been through this transition, and several developing countries and regions have now shown the same turnaround from net deforestation to net reforestation. They include India, China, Costa Rica, the Dominican Republic, Cuba, Gambia, Puerto Rico, Bangladesh, and peninsular Malaysia (Rudel et al. 2005).

A third phenomenon, related to the first two, is the development of independent environmental movements and political pressures that lead to reductions in deforestation, whether the country joins a REDD system or not. This has been seen in recent years in many tropical countries, from small ones such as Costa Rica to large ones like Brazil; broad political efforts, including Brazil's "Zero Deforestation" campaign, have often resulted. Thus tropical countries are beginning to reduce deforestation for their own reasons, without waiting for the development of REDD mechanisms to fund the effort from abroad.

Clearly, these three phenomena—running out of forest, the forest transition, and the development of internal political movements to reduce deforestation—are connected in complex ways, difficult to separate out. Their relevance here is simply that we may expect them to bring about reductions in deforestation rates beyond those predicted from economic models based on REDD financing. They also can be important factors in reducing the political and institutional constraints that would slow participation in a global REDD system.

If these factors would be operating even without REDD systems, by rights they should be considered as part of the "business as usual" baseline against which REDD's accomplishments are compared. Thus strictly speaking they should not be discussed as reasons why REDD could accomplish more than predicted but rather as defining the "without REDD" case. However, although this reasoning is theoretically correct, in practice it is impossible to distinguish between the two cases.

Making such predictions in this arena—regarding changes in opportunity costs as the relative supply of cleared land grows, the course of the forest transition, the internal environmental and political dynamics of tropical forest countries, and even the timing of when they will "run out of forest"—is beyond our current abilities. Realistically, all we can do right now with any certainty is use current rates of deforestation as our baselines, even though they themselves are subject to considerable uncertainty (Ramankutty et al. 2007).

Thus there are reasons why the predictions of REDD's potential based on economic and political-institutional analysis may be too high, and other reasons why they may be too low. Better analysis can help determine which of these errors is larger, but fundamentally what we need is implementation of REDD and experience with its real-world accomplishments—and problems—in order to tell whether the current estimates of its costs and potential are overestimates or underestimates.

COMPARISON WITH THE EUROPEAN COMMISSION AND ELIASCH ANALYSES

In October 2008, just before this report was completed, two major new analyses of REDD were released. In a report to the government of the United Kingdom, Eliasch (2008) examined REDD policy; his project also commissioned several supplementary analyses, including an updating by Grieg-Gran of her original study for the Stern Review (Grieg-Gran 2006/2008, Stern 2006). And the European Commission released its recommendations on REDD to the European Union, including a detailed "impact assessment" that considered options for reducing emissions from tropical deforestation (Commission of the European Communities 2008). Here the author briefly considers these new analyses and compares their results to his own.

The most newsworthy aspects of these studies were the goals they put forward, which were essentially the same for both: to cut deforestation in half by 2020, and to reduce net deforestation (deforestation losses minus afforestation/reforestation [A/R] gains) to zero by 2030. Eliasch offers the estimate that for the 2030 goal, about 75 percent could be reached through reduced deforestation and the other 25 percent by afforestation/reforestation, while the 2020 goal refers only to gross deforestation without considering A/R.

The cost estimate for achieving these goals was quite comparable to that of this report. The European Commission (E.C.) estimated that to halve deforestation by 2020 the cost would be 15 billion to 25 billion euros annually, using a euro/dollar exchange rate of 1:1. Thus the midpoint of its estimate corresponded to U.S. $20 billion a year—the same as this report's estimate based on the global models. The Eliasch Review

Second growth (foreground) and the Palo de Mayo forest (background), southeastern Nicaragua

gives an estimate for 2020 of $18 billion to $26 billion ($7 billion from the carbon market plus $11 billion to $19 billion additional funding); again, very similar. The Eliasch Review thus predicts that about a third of the total would come directly from the carbon market.

The E.C. recommendation is that the principal funding through 2020 be generated by the auctioning of E.U. carbon allowances, with the proceeds being used to establish a "global forest carbon mechanism." Also, direct carbon market credits in the E.U. ETS could be tried out in a limited way in the short term, and if successful they could become an increasing part of the financing. Thus both studies see market-linked and voluntary financing as the predominant modes in the 2010s, with direct carbon market offsets becoming a larger component in the 2020s and beyond. This is very much in line with this report's analysis, as discussed above and presented in Table 1 and Boucher 2008b.

Therefore the two major new studies released in October 2008, and likely to form the basis of United Kingdom and E.U. policy on REDD, are very much in agreement with the major points of this report's analysis.

UNANSWERED QUESTIONS

As indicated above, there are many unanswered questions, which limit the possibility of making predictions about REDD until more real-world data are available and incorporated into further modeling. These questions include:

- What is the relative potential for funding from the carbon market, from voluntary assistance, from mixed market-linked systems such as Greenpeace's TDERM and CCAP's "dual markets" approach, from auction proceeds, and from allowance allocations?
- How effective will the quality controls (e.g., on leakage and additionality) be in practice?
- How much will the willingness of countries to participate in a REDD system depend on the system's details or its funding, and how likely is that dependence to vary as governments change, social movements grow, and internal and international political dynamics develop?
- How closely will REDD commitments be linked to the depth of the emissions cuts undertaken by developed countries?

These kinds of questions, though vital to the success of REDD, can only be answered with any degree of certainty once we have had some actual experience with REDD systems. There are other questions, however, on which further analysis and discussion—beginning now—could lead to progress much sooner. Among them are:

- Why do the estimates of costs vary so much between regional empirical studies, the area-based estimates of the Stern Review, and the output of the global models? Is it because the global models include the highest-value uses of tropical land (e.g., Southeast Asian commercial logging), and thus are at the "top right-hand end" of the cost curve? Are there additional reasons?
- How does this difference among estimates square with the idea, going back to Adam Smith, that wider markets should lower costs, not raise them?

The two major new studies released in October 2008, and likely to form the basis of United Kingdom and E.U. policy on REDD, are very much in agreement with the major points of this report's analysis.

- What are the best estimates we can make of some of the "additional costs" that are not included in the current analysis for lack of quantitative data? For example, how much should we allow for measuring and monitoring, or for capacity building? Are any of these costs so low that they could reasonably be left out?
- Can we replace the qualitative and partly subjective estimates of the political and institutional variables (capacity and interest) with generally acceptable quantitative measures?
- Can the political-institutional analysis be connected to reliable predictions about the time it will take for various countries to join a REDD system?
- What will be the impact on a REDD system if the countries participating account for a total of only 50 percent of tropical deforestation emissions? Or 75 percent? Is there some level (e.g., 85 percent) at which the dynamics of the system are essentially the same as if there were 100 percent participation? Do the answers to these questions depend on which countries are in and which are out, or just on the percentages?
- Can empirical approaches that provide full supply curves but do not depend on global modeling

(Swallow et al. 2008, Strassburg et al. 2008, Cattaneo 2008) become a fourth major approach to estimating the cost of REDD? According to recent studies, these empirical approaches would seem to combine the virtues both of regional and area-based analyses with those of global models, providing detailed cost curves but not requiring the many assumptions—and thus the difficulty of interpreting differences in results—of the global models. Though they do not take into account the global feedbacks that would change prices and costs as a REDD system develops, they may be an important step toward more solid predictions.

REDD is not only a way to confront the challenge of global warming but also part of a new path toward sustainability for rich and poor nations alike.

Thus we would seem to have an ample supply of questions to constructively occupy our time, even before REDD systems are established and begin to provide us with real-world experience.

CONCLUSION: DEVELOPMENT WITHOUT DEFORESTATION

These questions place the analysis of REDD in a broader context. Reducing emissions from deforestation is part of the needed pattern of development, in industrialized and tropical forest nations alike, for limiting dangerous climate change as well as for providing the basic necessities of life—including food, shelter, health, and education—to all of the world's people.

The vision, in other words, is that these two historic transformations can be supported by a path toward development without deforestation. Success will require financing (from the wealthy countries of the world) that offers not only the possibility of cutting a major source of greenhouse gas emissions but also the potential to provide a substantial transfer of resources from north to south for sustainable development. It is not too much to expect that by 2050 we will have reduced developed-nation emissions by 80 percent, reduced emissions from tropical deforestation to zero, and ensured that every child born on Earth will be able to live a life of security and dignity.

Different countries will contribute in diverse ways to these efforts, with options for reducing deforestation that include parks and preserves, confirmation and enforcement of indigenous land rights, revision of road-building plans, and cracking down on illegal logging. Even programs in urban areas (e.g., improvements in health care, building schools) can alleviate the pressures on forestlands and thus reduce deforestation. Similarly, the contributions of developed countries can be made through a variety of mechanisms including the carbon market, official development assistance, international lending institutions, the proceeds of allowance auctions or carbon taxes, and the allocation of allowances.

Although development without deforestation is just one aspect of the struggle to avoid the worst consequences of climate change, it transcends that struggle. REDD is not only a way to confront the challenge of global warming but also part of a new path toward sustainability for rich and poor nations alike. It represents a new phase in the history of the planet.

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APPENDIX

Sources of the Data for This Report's Regional Empirical Estimates of Opportunity Costs

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OUT OF THE WOODS

A REALISTIC ROLE FOR TROPICAL FORESTS IN CURBING GLOBAL WARMING

Reducing emissions from deforestation in developing countries (REDD) can not only help avert the worst consequences of global warming but also contribute to international efforts to preserve biodiversity and promote sustainable development. In this report, the Union of Concerned Scientists shows that REDD could substantially decrease the severity of climate change at a relatively low cost: even using a conservative approach, we estimate that $5 billion in annual funding could reduce heat-trapping carbon emissions from deforestation more than 20 percent in 2020, and $20 billion could reduce such emissions by 50 percent.

The development and implementation of a system that will make REDD a goal of governments around the world will no doubt face obstacles in the form of political and institutional constraints. Our analysis suggests that REDD is not likely to be pursued by all of the countries with the largest amounts of tropical forest (i.e., those responsible for three-fourths or more of total deforestation emissions) until 2020 at the earliest. Nevertheless, REDD clearly can and should be a central element of the worldwide effort to prevent global temperatures from rising 2°C over pre-industrial temperatures (the level that scientists agree would trigger potentially catastrophic climate changes).

National Headquarters
Two Brattle Square
Cambridge, MA 02238-9105
Phone: (617) 547-5552
Fax: (617) 864-9405

Washington, DC, Office
1825 K Street NW, Suite 800
Washington, DC 20006-1232
Phone: (202) 223-6133
Fax: (202) 223-6162

West Coast Office
2397 Shattuck Ave., Ste. 203
Berkeley, CA 94704-1567
Phone: (510) 843-1872
Fax: (510) 843-3785

Website www.ucsusa.org **Email** ucs@ucsusa.org

Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions