Estimating the costs of REDD at the country level

Stefano Pagiola and Benoit Bosquet

Forest Carbon Partnership Facility, World Bank

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Please send any comments to the authors at spagiola@worldbank.org or bbosquet@worldbank.org

1. Introduction

1. Deforestation and forest degradation are among the most important single sources of emissions of greenhouse gases (GHG), contributing about 20 percent of total emissions annually, not to speak of the associated losses of livelihoods, biodiversity, environmental services, and cultural patrimony. To address this problem, efforts are underway to develop systems of payments for Reduced Emissions from Deforestation and Forest Degradation in Developing Countries (REDD). The Parties to the UNFCCC agreed in December 2007 in Bali to explore policies and financial incentives that could be implemented to encourage REDD after 2012.

2. As these negotiations get underway, the World Bank has launched the Forest Carbon Partnership Facility (FCPF) to build capacity and provide financial incentives for REDD. The FCPF will help up to 37 countries to achieve the following goals: (i) establish a national reference scenario for emissions from deforestation and forest degradation, based on historical and projected emissions; (ii) adopt a national REDD strategy based on their current forest and environmental legislation; and (iii) adopt a national system for monitoring, reporting, and verifying emissions from deforestation and forest degradation.

3. As countries embark on ambitious programs for REDD, they need information on the future costs and benefits of these programs. REDD payments will make many efforts to avoid deforestation attractive, but not all. The costs of some programs to reduce deforestation will exceed the benefits, despite the expected payments for REDD. Two key variables to determine the profitability of a REDD program will be the costs associated with the program and the payment per ton of emission reduction.

4. A number of studies have attempted to estimate the aggregate cost to the global economy of reducing emissions from deforestation. The Stern Review estimated the cost of avoiding deforestation entirely in eight countries collectively responsible for 70 percent of land use emissions at between US$1 to 2/t$CO_2$ (Stern, 2007, based on Grieg-Gran, 2006). Kindermann and others (2008) estimate that halving emissions from deforestation between 2005 and 2030, corresponding to a reduction in emissions of 1.7 to 2.5 billion tons of carbon dioxide (tCO_2), would require financial flows of US$17 to 28 billion per year to the developing countries responsible for these emission reductions. This would amount to a payment of US$10-21/t$CO_2$. A 10 percent reduction over the same period would cost between US$0.4 and 1.7 billion annually and US$2-5/t$CO_2$. These numbers were derived using three global models assessing the opportunity costs of reducing deforestation.

5. Individual countries considering participating in a REDD mechanism, however, need information on what it would cost *them* to reduce emissions from deforestation and forest degradation, and how to actually deliver those emissions reductions. Estimates of global average costs provide very little guidance in this regard, as in addition to the inevitable crude approximations that must be made in any such large-scale exercise, conditions within any given country may well differ substantially from the average.

6. This paper aims to do two things. First, it tries to clarify some very important conceptual issues. What exactly are we asking when we ask what the ‘cost’ of REDD is? What kinds of costs should be included? Second, it tries to highlight some of the issues involved in properly estimating the costs of REDD. Such estimates would help them to assess issues such as (i) how many emission reductions they might potentially be able to ‘sell’ to a REDD mechanism at given prices; (ii) how much the country would benefit from such sales; (iii) how they might be able to actually reduce deforestation so as to generate these emissions

reductions; (iv) how the costs and benefits of REDD would be distributed among different groups within the country; (v) what the budgetary implications would be for government agencies.

7. Estimating the costs of REDD is one thing; actually delivering those emission reductions is another. The two cannot be wholly separated, as part of the cost of generating emission reductions from REDD is the cost of the actions needed to actually avoid deforestation ('implementation costs'). This note does not attempt to indicate how to successfully avoid deforestation, but does show how a properly conducted analysis of the country-level costs of REDD can provide very important inputs into the development of such policies.

8. For a country, the benefit of participating in REDD would arise from the difference between the payments it receives for the emissions reductions resulting from REDD, and its costs of achieving it. Many governments are hoping to use REDD as a source of revenues to finance sustainable development. It is precisely from the difference between the costs of REDD and the compensation that countries receive for it that such financing may be generated. Whereas the amount and form of payments remains to be decided, the costs of avoiding deforestation depends largely on conditions within the country, and thus can be estimated even without knowing precisely how a REDD program will operate. Under either a market-based approach to REDD or a fund-based approach to REDD, countries need to know how much it would cost them to deliver emissions reductions.

9. We should make clear from the outset that there is no single numerical answer to the question of what the cost of REDD is for a country. Because agro-ecological, economic, and social conditions can differ substantially from place to place within a country, the costs of REDD can likewise differ substantially from place to place. Likewise, the cost and effectiveness of measures to reduce deforestation will vary. The results of the analysis of the costs of REDD will thus consist of a range of costs applicable to different situations or areas. It is quite likely that every country will find that there are many areas in which REDD would not be justified by any realistic payment per ton of emission reduction. Conversely, it is very likely that every country will find that it has many areas in which even quite modest payments for avoided emissions would render efforts to avoid deforestation attractive. The real issue is not whether REDD payments would be attractive at all, but how many emission reductions a country would find it attractive to provide at any given price per tCO_2 reduced.

2. What do we mean by costs?

10. In this section, we aim to clarify what is meant by the 'costs of REDD.' We begin by discussing the different categories of costs, and then examine who would bear what costs.

2.1 Categories of costs

11. Consider a hectare of forest. This forest sequesters a certain quantity of carbon. Cutting down the forest and converting the land it stands on to agriculture or pasture would release much of this carbon into the atmosphere, thus contributing to global climate change. It would also damage the biodiversity that the forest contains, perhaps cause other problems such as affecting downstream water flows, and deprive local people of traditional sources of livelihoods and access to ancestral grounds.

12. **Opportunity costs.** Deforestation, for all its negative impacts, can also bring benefits. Timber can be used for construction, and cleared land can be used for crops or as pasture. Reducing deforestation means foregoing these benefits. Similarly, forest degradation because of selective logging, fuelwood collection, or grazing of animals also brings benefits, and

avoiding this degradation foregoes these benefits. The cost of foregone benefits is known as "opportunity costs" and is usually the single most important category of costs a country would incur if it reduced its rate of forest loss to secure REDD payments. Estimating these opportunity costs is thus the central problem in estimating the costs of REDD. Estimating opportunity costs is also critical to understanding the causes of deforestation. Most economic agents do not cut down forests out of malice—they do so because they expect to benefit from it. Estimating the magnitude of opportunity costs gives a fair estimate of the pressures for deforestation. Understanding how opportunity costs are distributed across groups within society tells us who would gain and would lose from REDD, which is important both from a moral/ethical perspective (if losses would be borne by vulnerable groups) and from a practical one (if losses would be borne by politically powerful groups able to prevent adoption of REDD policies or resist their implementation). Estimates of the opportunity costs thus provide inputs not only into the costs the country would bear from REDD, but also into the causes and distributional implications of deforestation and, hence, the types of interventions needed to actually reduce deforestation and the potential need for mechanisms to avoid adverse social consequences.

13. **Implementation costs.** In addition to opportunity costs, there are also costs involved in implementing a REDD program. These are the costs directly associated with the actions leading to reduced deforestation, and hence to reduced emissions—for example, the cost of guarding a forest to prevent illegal logging, of relocating timber harvesting activities away from natural forests to degraded land scheduled for reforestation, of intensifying agriculture or cattle ranching so that less forest land is necessary for food production, of re-routing a road project so that less forest land is destroyed as a result of opening the road, of relocating a hydroelectric production project away from a natural forest, of delineating and/or titling land to traditional and indigenous communities so that they have an incentive to keep protecting the forest against conversion, and so on. All of these measures incur investment and recurring costs for the public and/or the private sectors, which need to be assessed and financed. Implementation costs also comprise the institution- and capacity-building activities that are necessary to make the REDD programs happen (including the expenses associated with the goods, training, research, and the political, legal and regulatory processes involved, including the consultations and government decision-making processes). These may be difficult to estimate, but they ought to be recognized.[1]

14. **Transaction costs.** Over and above opportunity costs and implementation costs, REDD also involves specific transaction costs, which are the costs that are necessary for the parties to a transaction involving a REDD payment (the buyer and seller, or donor and recipient), as well as external parties such as a market regulator or payment system administrator, to establish that the REDD program has indeed achieved a certain amount of emission reductions. The costs are incurred in the process of identifying the REDD program, negotiating the transaction, and monitoring, reporting, and verifying the tons of emission reductions. They are incurred by the implementers of the REDD program and third parties such as verifiers, certifiers, and lawyers. These costs are separate from implementation costs, as by themselves they do not reduce deforestation or forest degradation. They are nevertheless

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[1] Some governments have indicated a desire to use REDD as a source of revenues for financing more than forest protection in their countries. REDD is seen by some as an opportunity to finance sustainable development. This is a laudable goal, but does not imply that such sustainable development actions should be considered a *cost* of REDD; on the contrary, they are a *benefit* of REDD.

necessary to the transparency and credibility of the REDD program and thus add value to the whole process.

15. Boucher's (2008) review of 29 regional empirical estimates found mean opportunity costs of US\$2.51/tCO_2, with 18 out of the 29 estimates at less than US\$2/tCO_2, and 28 out of 29 at less than US\$10/tCO_2. The mean opportunity costs for Africa was US\$2.22/tCO_2, that for the Americas US\$2.37/tCO_2, and that for Asia US\$2.90/tCO_2.[2] Boucher estimates average costs of implementation and transaction costs together as being on the order of US\$1/tCO_2, or about 20 percent of opportunity costs. Grieg-Gran (2006) estimates implementation and transaction costs as reaching between 5 and 20 percent of the costs of avoiding deforestation in the countries with most forest cover.[3] Using a highest-altyernative value approach (see below), the opportunity costs of REDD in Guyana are estimated at US\$2 to US\$11/tCO_2e (Republic of Guyana, 2008). Thus opportunity costs seem to be the largest cost component of REDD in many cases. This will not necessarily be true in all cases, however.[4]

2.2 Accounting stance

16. Any discussion of costs must immediately address a critical question: costs to whom? Here a very important distinction must be made between (i) **costs to the country**, (ii) **costs to individual actors**, and (iii) **budgetary costs to government agencies**.[5] Each of these categories of costs is very important in its own right, but they are very different. Inappropriately mixing different categories of costs is an easy and common mistake, and can result in very misleading estimates of costs. The perspective from which costs are calculated is known as the *accounting stance*.

17. **Cost to the country.** The costs to the country as a whole include any costs that are perceived anywhere within the country, net of any benefits that are received anywhere within the country, omitting any costs and benefits that accrue outside the country. This is the perspective of a benevolent social planner seeking to maximize welfare within the country. Several important aspects of this perspective need to be emphasized:

- Any transfer from one party within the country to another is not a cost to the country. A payment made by the government to forest owners, for example, would be accounted as a cost to the government but as a benefit to the forest owner, and so would cancel out in the accounting from the country's perspective. The administrative costs of making the payment, however, would remain a cost for the country, as they would be an expense for the government but would not be received by the forest owners.
- Benefits or costs that accrue outside the country are not included in the country's accounts. This includes the climate change mitigation benefits of carbon

2 It should be noted, however, that Boucher found these differences across the continents not to be statistically significant

3 Using Grieg-Gran's 'realistic' scenario. Her estimated administrative costs would be 8-33 percent of her most conservative cost estimate, and 4-16 percent of her highest cost estimate.

4 This is trivially true, of course, in cases where there are no opportunity costs; see section 3.1 below.

5 The costs to the country are sometimes known as "economic" costs (Gittinger, 1982) or "social" costs (Monke and Pearson, 1989), while costs to individual actors are sometimes known as "financial" costs (Gittinger, 1982) or "private" costs (Monke and Pearson, 1989). We avoid these terms as they can easily lead to confusion. The term "social costs", for example, is often used to refer to non-economic impacts on society.

sequestration, as well as any biodiversity conservation the benefits of which are received primarily outside the country.[6]

18. **Costs to individual groups.** Individual groups within the country are likely to receive only part of the costs and benefits of any given land use. Indeed, a major reason for deforestation is that land users often perceive just a small part of all forest benefits, but stand to receive a large part of the benefits generated by alternative land uses. Opportunity costs often look very different from the perspective of individual groups and from that of the country as a whole. Individual groups only consider the specific subset of costs and benefits that are received by the land users. In general, such groups will not bear much of the costs of implementation or of the transaction costs involved in a REDD program.[7]

19. **Budgetary costs to the government.** The government itself is of course a particularly important individual actor within the country. Government agencies attempting to implement programs to reduce deforestations face costs to do so. The government will usually bear little or none of the opportunity costs, but it will often bear the bulk of the costs of implementation (although there can be important exceptions depending on how REDD programs are implemented) and of the transaction costs.

20. In general, the main difference between the different accounting stances is which costs and benefits are included. The country's perspective includes all costs and benefits that accrue within the country, while the perspectives of individual groups and of the government only include those specific costs and benefits that these groups perceive. The other major difference is that under the country's perspective, costs and benefits should also be valued at the social value of resources (their value in their next-best alternative use) rather than at their observed market prices. The social value of a resource may differ from that observed in markets either because of policy distortions (taxes, subsidies, import restrictions, and so on), or because of market imperfections. Conversely, costs to individual groups are valued at the prices that these groups actually pay, including any taxes. The difference between social values and observed market values was once very significant, as governments used to systematically distort the prices of agricultural inputs and outputs. As a result of reform processes, these distortions are now much smaller, though by no means non-existent. The discount rate used to assess costs to the country should be the social discount rate normally used by the government. In contrast, the discount rate used to assess the costs and benefits to individual group should reflect their rate of time preference. If the costs to all individual groups (including the government) were added up and re-calculated based on social value of resources rather than observed prices, they should equal the costs to the country.

21. Properly estimating the costs as seen from the perspectives of different users is vital for several reasons. First, it is important if costs are to be estimated appropriately. As noted, many costs and benefits received by individual groups may not be costs to the country, in that one group's costs are another group's benefits. This is particularly true of many kinds of government budgetary expenditures. Second, understanding the distribution of costs and benefits is extremely helpful in understanding incentives to cut down or degrade forests. A

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6 It is precisely for this reason that countries have very limited incentives to reduce emissions or conserve biodiversity, barring outside compensation through mechanisms such as REDD.

7 There can be exceptions, of course. For example, land users participating in Costa Rica's program of payments for environmental services must pay for the preparation of a management plan, to fence and signpost areas under conservation contract, and for independent forest engineers to monitor their compliance (Pagiola, 2008). Thus some of the program's implementation and transaction costs are passed on to them.

group that would bear high opportunity costs from REDD is very unlikely to protect forests voluntarily. They must therefore either be compelled to do so or compensated for doing so. The distribution of opportunity costs thus provides important guidance on the formulation of policies to reduce deforestation and forest degradation. Third, the distribution of costs and benefits is important in its own right, as many stakeholders in forest issues are poor or vulnerable groups.

3. Estimating the costs of REDD

22. In this section, we discuss in more detail some of the issues that arise in estimating the costs of REDD. The basic building blocks of the cost analysis are estimates of returns to forest and to alternative land uses, and of their respective carbon stocks.[8] The difference between the returns to forest and those to the land use that would replace it indicates the opportunity cost of maintaining forests, while the differences in carbon stocks indicates the avoided emissions from doing so. This comparison will vary from area to area, depending on the nature of the forest, the agronomic suitability to different alternatives, the distance from markets, and many other factors, and thus must be conducted separately in different areas. The process thus involves three main steps:

- Identifying and mapping the forest areas at risk of being deforested or degraded, and the land uses which are most likely to replace them.
- Estimating the returns to both forest areas and alternative land uses, and the carbon stock under each (as well as other benefits, to the extent possible), so as to estimate the opportunity costs of avoiding deforestation or forest degradation.
- Using these data together to make projections of opportunity costs and carbon emissions reductions under alternative scenarios.

Note that efforts to estimate implementation costs are part of the third step; they rely on a prior estimation of opportunity costs, which would identify areas in which REDD would bring the highest benefits (because of low opportunity costs).

3.1 Opportunity costs

23. Preserving forests means foregoing the benefits that would have been generated by the alternative land uses that would have replaced the forests. If forests are cleared for agriculture, for example, then preserving forests means foregoing the benefits of crop production. The difference between the benefits provided by the forest and those that would have been provided by the alternative use is the opportunity cost of avoiding deforestation.

24. In general, the forests of interest to a REDD debate have on-site benefits that are lower than the potential benefits of alternative land uses. Forests that have high on-site benefits are generally not at risk of deforestation or degradation. Almost always, therefore, the opportunity costs of REDD programs will be positive.

25. The one notable exception may occur when forests are free-access resources. In that case, even very high on-site benefits might not save forests from degradation or destruction, because individual users have no incentive to protect the forests. Saving such forests would

[8] The discussion below applies to both deforestation and forest degradation, if ‘degraded forest’ is considered as a distinct alternative land use. Indeed, one could define several types of ‘degraded forest’, with different levels of degradation. We thus speak simply of the choice between forest and alternative land uses, rather than constantly repeating ‘deforestation and forest degradation.’

not, therefore, incur opportunity costs – indeed, it might generate net benefits to the country. In this case, the cost of reducing deforestation or degradation would consist solely of the cost of the measures necessary to change the free access nature of the forest.

26. Note also that many efforts to save forests act by increasing the benefits generated by forests. For example, eco-certification schemes attempt to generate a price premium for timber from sustainably managed forests. If these efforts are successful (without depending on on-going subsidies, trade protection, or other market distortions), they would convert positive opportunity costs to negative ones. In this case, as well, the cost of reducing deforestation would be limited to the cost of implementing the measures necessary to increase the on-site benefits of forests. On the other hand, an on-going subsidy to forest products (or a trade distortion that drives up the domestic prices of forest products) would *not* eliminate the opportunity costs – only hide them.

27. **Net vs gross values.** It is common to only consider *gross* values – for example, the value of crops that could be produced on land cleared from forest. This would tend to greatly overstate opportunity costs, however, as well as giving a mistaken impression of deforestation pressures. Producing crops, or livestock, or indeed any other economic activity, involves costs – for labor, for inputs, for working capital. What matters, then, is not the gross revenue that an activity might generate, but rather its *net* benefit.

28. **Change in values.** It is important to keep in mind that the opportunity costs of REDD are not given by the value of the benefits foregone from the alternative land use, but by the *difference* in net benefits between forest and the alternative land use. Forests can often generate a variety of benefits such as provision of fuelwood and other non-timber forest products (NTFPs) (Lampietti and Dixon, 1995; Bishop, 1999). In some cases, these benefits can be quite sizeable. If deforestation or forest degradation is reduced, at least part of these benefits would continue to be enjoyed. The proper measure of opportunity cost, then, is how much less benefit would be obtained by not switching to the alternative land use.

29. **Actual vs potential opportunity costs.** In computing opportunity costs, there are two possible approaches:

- Looking at actual land-use changes based on historic trends. These are not necessarily the highest-value land use changes.
- Estimating the highest-value alternative land uses. The report prepared by McKinsey for Guyana's president on the opportunity cots of deforestation uses this approach, for example (Republic of Guyana, 2008).[9]

The second method gives higher estimates of opportunity costs in per hectare terms, but not necessarily in per ton CO_2 terms because the loss of carbon may be higher than in an actual land use approach. If there are barriers to adopting the highest-value alternative uses, however, estimates based on the highest-value alternative use may bear little resemblance to the opportunity costs that countries actually face.

30. One relatively simple method of determining opportunity costs is to estimate the benefits generated by forests in an area, and comparing them to the benefits generated by

[9] The highest-value alternative approach, as used in the report prepared by McKinsey, gives an upper bound on the opportunity costs that a country would face. In most countries this upper limit is only theoretical, however—actual deforestation is typically to land uses that are much lower value (particularly if changes in co-benefits are included), and that would be a better measure of what the country is actually giving up.

non-forest lands in that same area. This approach has several problems, however. In particular, the land still under forest may not be comparable to the land that has already been converted to other uses. Farmers will first seek to convert the land that has the best soils, the most favorable topography, and is most accessible. Observed returns to land that has been converted to agriculture is thus likely to over-estimate the likely returns that land still under forest would generate if it were also to be converted to forest. This approach also only provides a static picture of opportunity costs, making it difficult to predict how they might evolve over time.

31. A more sophisticated approach involves developing models of returns to different activities, based on parameters such as yields, input use, and prices. These models could be relatively simple or relatively sophisticated, depending on data availability and analytical capacity.

- The simplest approach would be to use production budgets for the different land uses which break down in detail all the inputs and outputs, with quantities and prices for each.[10] By varying these values appropriately, estimates can be made of likely returns under different conditions. Areas with poorer soils, for example, would have lower yields, and hence lower returns – or higher costs, if additional fertilizer is used to compensate for the poorer soils. Areas further from the road would face higher transport costs.
- If data allow, a production function or profit function could be estimated econometrically.

32. **Spatial detail.** Opportunity costs are likely to vary substantially from place to place, depending on both agroecological conditions (for example, soil type, slope, and climate) and socioeconomic conditions (for example, distance to markets, availability of labor, and clarity of tenure rights). Average values may thus be very misleading. Efforts should thus be made to obtain opportunity cost estimates at the highest level of spatial detail possible. Geographic Information Systems (GIS) provide a valuable tool to organize available information and undertake the analysis.

33. **Variation over time.** In many cases, opportunity costs may vary over time. Land cleared from forest may initially be very productive, for example, but become gradually less productive until it is either left fallow to regenerate, abandoned, or switched to another use. In other cases, the alternative to forest may be a use with a particular time profile, such as a tree crop that only become productive several years after planting. Even if yields remain unchanged, their value may change over time as input and output prices change. These variations cannot always be predicted, but sometimes they can. Road construction or improvement, for example, can have substantial impacts on both input and output prices. Nepstad and others (2007), for example, project how planned road improvements in the Amazon will affect the profitability of different land uses and hence the opportunity costs of avoiding deforestation. In all such cases, a single snapshot view of costs and benefits would be misleading. Rather, the present value of the projected flow of costs and benefits should be estimated.

34. **Multipliers.** The economic impact of an activity can be wider than their returns indicate. Some activities can induce further economic activities through their effect on demand. If this impact were to be substantially different for forest to non-forest activities, then the estimate of opportunity cost should be adjusted accordingly. The range of estimated

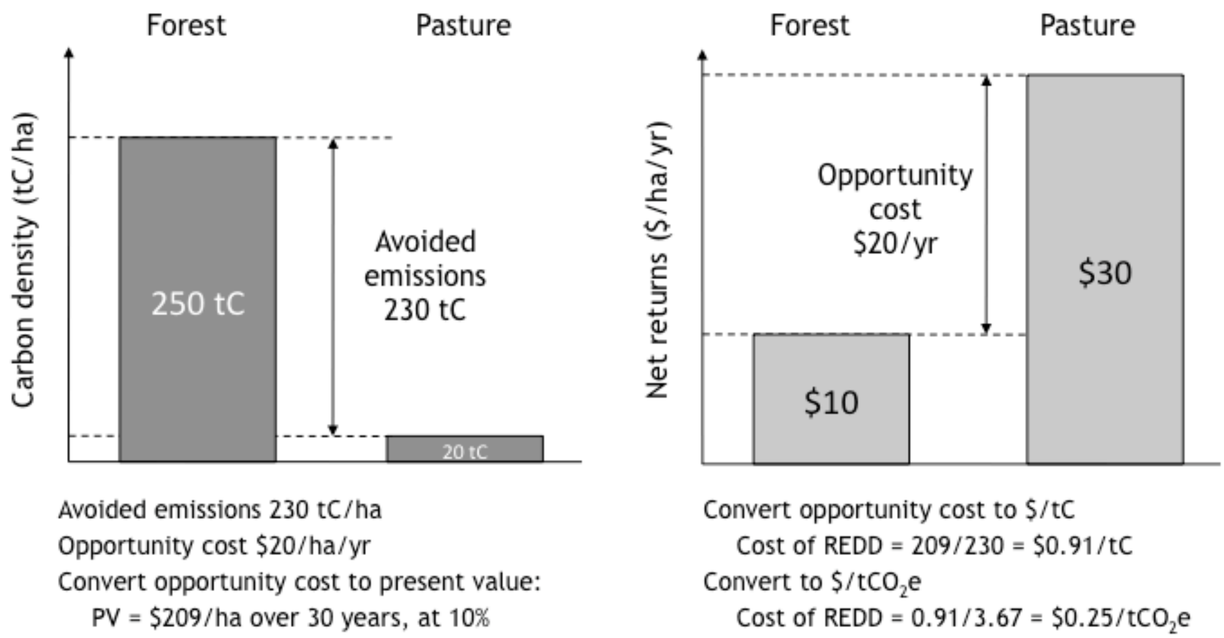
[10] Richards and Stokes (2004) call this the ‘bottom-up engineering approach’.

short-term multipliers is wide, ranging from 0.1 to 3.1, but most expenditure multipliers are in the range 0.6 to 1.4 (Hemming and others, 2002). These apply to government spending, however, rather than to individual economic activities.

3.2 Converting to per ton of carbon

35. Opportunity costs are generally estimated on a per hectare basis, as this is the form that data on returns from land uses are available in. To convert the opportunity cost of reduced deforestation per hectare into a cost per ton of carbon, information is also needed on the *difference in carbon density* between the forest and the alternative land use.[11]

Figure 1: Computing the costs of REDD



36. Figure 1 illustrates the computation of the costs of REDD. In this example, avoiding the loss of 1 ha of forest prevents 250tC from being emitted, but the alternative land use has a stock of 20tC, so the net emissions avoided are 230 tC.[12] Maintaining forest foregoes $30/yr in income from pasture. Given the $10/yr that forests provide, the opportunity cost is $20/yr. Because this land must be maintained under forest for a long time, this annual opportunity cost must be converted to present value terms. Using a 30 year time horizon and a 10 percent discount rate, this gives a cost of $209/ha. This is the value of the income foregone by maintaining forest on this land for this time period. To convert this opportunity cost in per hectare terms to one per ton of carbon terms, we divide by the net emissions reduction, in this case 230tC, and obtain $0.91/tC or, equivalently, $0.25/t$CO_2$e. This is the opportunity cost of REDD in this example. To arrive at the full costs of REDD from the country's

[11] It is not known whether REDD will require that estimates of this difference include changes in soil carbon; this may be elective, as it is for afforestation and reforestation activities under the CDM.

[12] If some of the timber harvested when forests are cut down is used for furniture or other long-lasting uses, the carbon it contains would not be emitted. Having to account for the fate of timber would add significant complexity to the calculations, however, and is unlikely to be required in a REDD program.

perspective, implementation and transaction costs must be added. If the implementation costs came to \$0.10/tCO_2e and the transaction costs to \$0.05/tCO_2e, then the country would be better of if it were paid any amount over \$0.40/tCO_2e to avoid deforestation. Individual land users would need to receive a compensation of at least \$20/yr to voluntarily forgo deforestation.

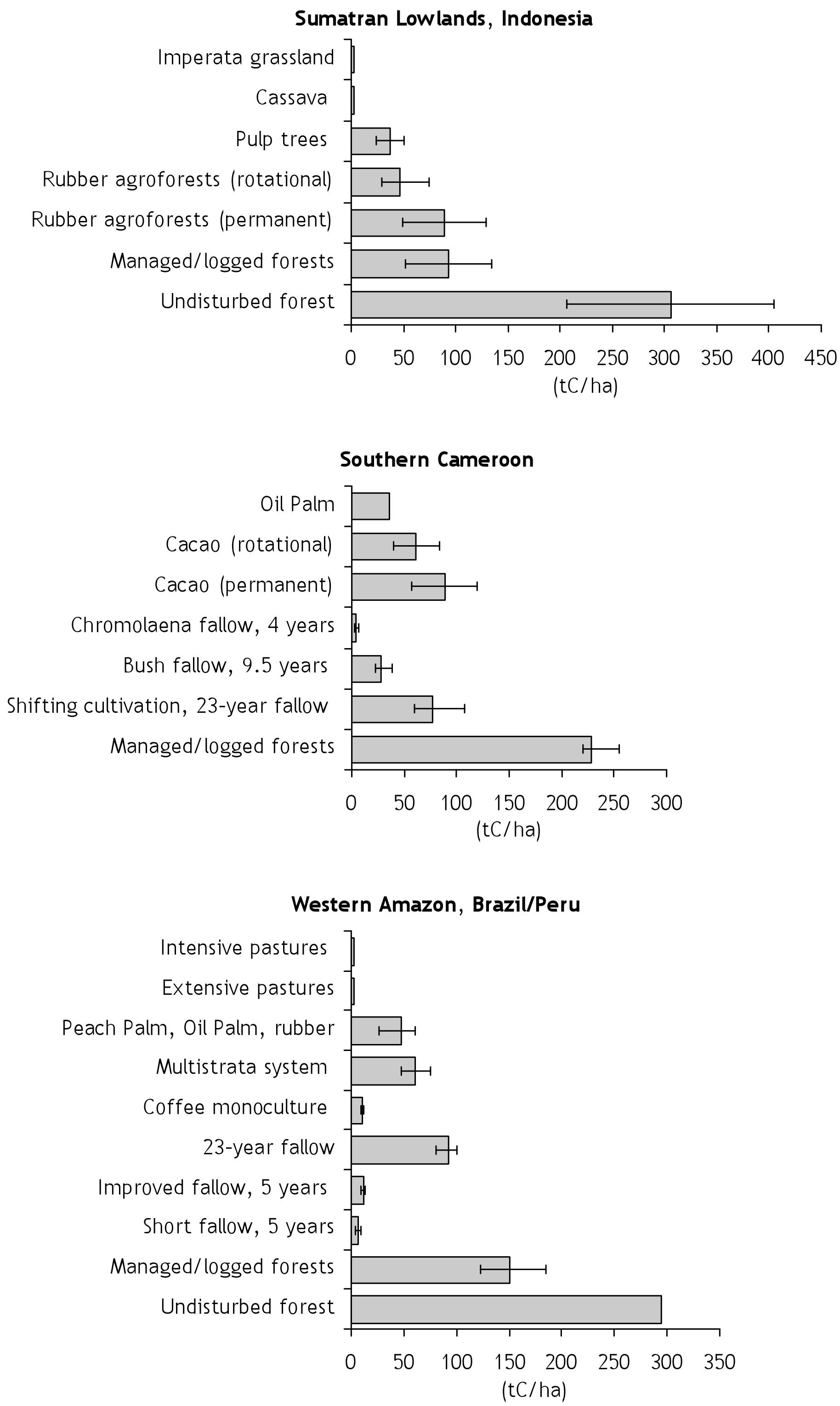
37. Note that here, too, what matters is how carbon density *changes*. Basing the conversion on the entire carbon stock of the forest would assume that it is all entirely lost upon deforestation. However, non-forest land uses can often sequester some amount of carbon, so using the entire stock would overestimate the actual reductions in emissions and underestimate the cost of achieving them. In the example above, if the carbon stock sequestered in pasture is ignored, the apparent avoided emissions would be 250tC/ha, and the unit cost of achieving it would appear to be \$0.84/tC instead of \$0.91/tC, or 8 percent less. The greater the carbon stock in the alternative land use, the greater the underestimation. If forests were replaced with agroforestry with about 100tC/ha, for example, the actual net emissions reduction would be 150tC/ha, at a unit cost of \$1.39tC, so basing estimates on gross carbon losses would underestimate the cost by almost 40 percent.[13]

38. Figure 2 shows examples of carbon density measurements for selected land uses at three sites studied by the ASB program. As can be seen, while forests hold substantially more carbon than alternative land uses at those sites, some alternatives can hold non-negligible amounts of carbon. Because carbon levels can vary over time in a given land use, these data are shown in terms of time-averaged carbon stocks. The ASB protocols for measuring carbon stocks and computing time-averaged carbon stocks are described by Woomer and Palm (1998). As a first approximation, the ASB program provides the following rules of thumb for carbon stocks in the humid tropics (Swallow and others, 2007):

- Natural forests contain about 250 tC/ha, and accumulate about 2.5 tC/ha/yr with a mean residence time of 100 years.
- Agroforests contain about 90-120 tC/ha, and accumulate about 3 tC/ha/yr with a mean residence time of 20-40 years.
- Fastwood plantations contain about 50 tC/ha, and accumulate about 5 tC/ha/yr with a mean residence time of 10 years.

13 Properly accounting for changes in carbon stocks also affects the relative cost of avoided deforestation and avoided forest degradation. The opportunity costs of avoiding forest degradation are likely to be considerably lower than those of avoided deforestation. Because the avoided carbon stock change is so much smaller, however, it does not follow that avoided degradation is necessarily cheaper in per tCO_2e terms.

Figure 2: Time-averaged carbon densities for selected land uses



Source: Based on data in Palm and others (2004).

39. A direct comparison between the carbon stocks of forest and an alternative land use becomes more difficult when their stocks vary over time. Consider the example of a standing forest that is cut down and replaced with an agroforest. Conversion would release the bulk of the carbon stock that the forest had contained but then, as indicated by the ASB data above, carbon stocks would gradually rebuild, eventually reaching as much as half the original level. In this case, the level of avoided emissions, and hence the cost per ton of emissions avoided, depends on how the comparison is made. Richards and Stokes (2004) find that previous estimates have used three main methods: (i) the 'flow summation' method, which sum the total tons of carbon captured over a given time horizon, regardless of when capture takes place; (ii) the 'average storage' method, which uses average carbon stored over one full management rotation[14]; and (iii) the 'levelization/discounting' method, which applies a discount rate to carbon sequestered at different times. As they demonstrate, these three methods can give very different results. We do not yet know how a REDD program would account for differences in carbon stocks over time.

3.3 Moving to the national scale

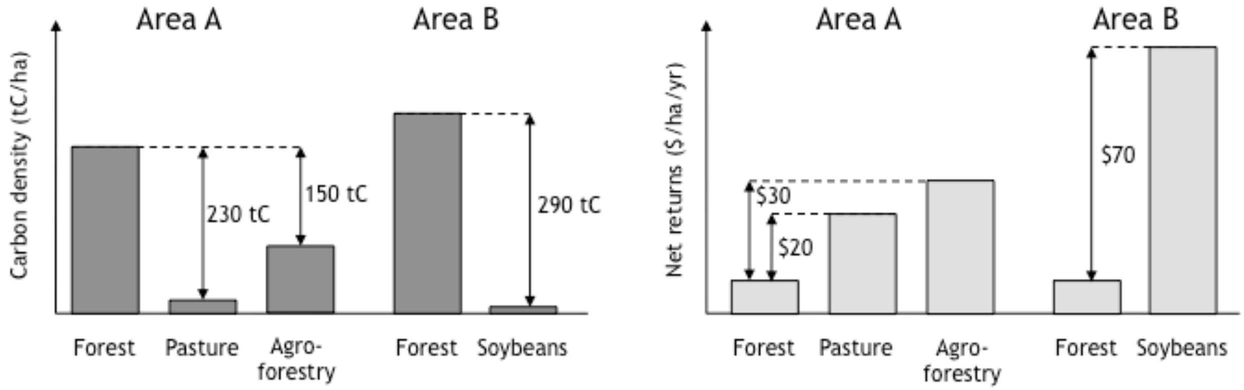
40. To obtain an estimate of the national costs of REDD, the estimated costs in any given area must be aggregated up, and combined with estimates from other areas. This is illustrated in Figure 3. The opportunity cost analysis is repeated for every relevant area threatened by deforestation, taking into account the various alternative uses to which converted forest land is put. In this example, deforestation affects two areas: area A, where 40,000 ha/yr are converted to pasture and 20,000 ha/yr are converted to agroforestry, and area B, where 20,000 ha/yr are converted to soybeans. The top part of the figure shows the net emissions in each case, and the net benefits that would be generated. Avoiding this deforestation would avoid these emissions, but forgo these benefits. The middle part of the figure converts the per hectare emissions and opportunity costs into per ton carbon terms (as in the previous example) and then computes total potential emissions reductions and costs. Thus halting all conversion of forest to pasture in area A would avoid 9.2 million tC of emissions, at a total opportunity cost of \$8.3 million, while halting the conversion of forest to soybeans in area B would avoid 5.8 million tC of emissions at a total cost of \$14.6 million. It is interesting to note that in this example, avoiding conversion to agroforestry is not much less costly in terms of cost per ton of carbon than avoiding conversion to soybeans, even though soybeans generates much higher returns per hectare. This is because agroforestry has relatively high carbon stocks, which partially offsets the difference in per hectare opportunity costs.

41. The bottom part of the figure then uses this information to trace out the country's supply curve for REDD. It shows that the country could supply up to 18 million tC of REDD. If the country were offered a payment of, say, \$1.50/tC, it would only make sense for it to attempt to avoid conversion of forest to pasture in area A, where the opportunity cost is \$0.91/tC. If it succeeded in halting this deforestation, it would receive payments of \$14 million and face opportunity costs of \$8 million, leaving it about \$6 million better off (although some of this will be used to pay for implementation and transaction costs). If this deforestation was only reduced by half, on the other hand, both the benefit and the cost would be halved. Similarly, a payment of \$2.5/tC would induce the country to seek to halt all deforestation in area A, whether for conversion to pasture or agroforestry, but not to halt deforestation for soybean production in area B. By halting all deforestation in area B, the

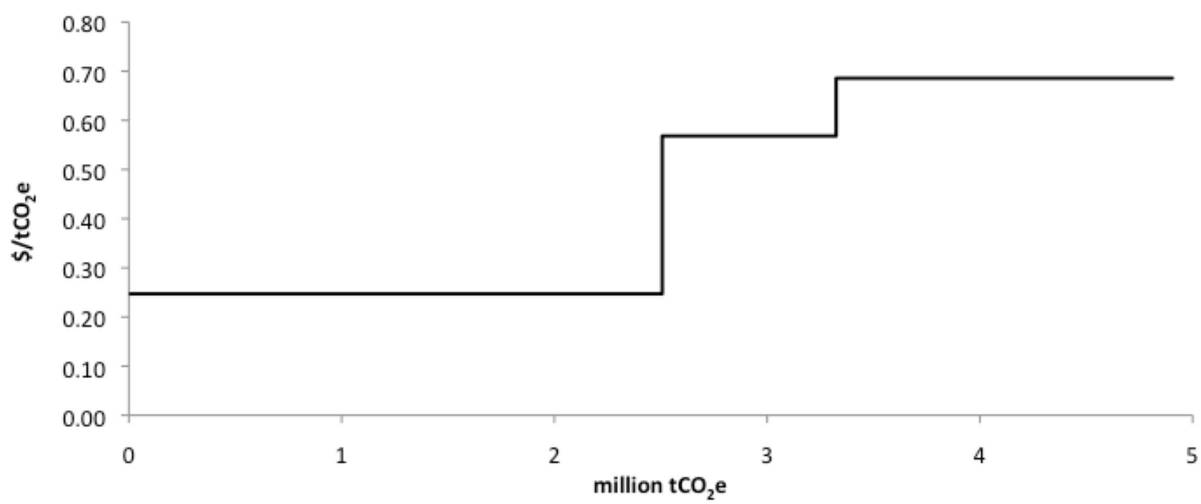
[14] ASB calls this method 'time-averaging' (Woomer and Palm, 1998; Palm and others, 1999).

country would receive $31 million and bear costs of $15 million, leaving it over $15 million better off (although, again, some of this would have to pay for implementation costs).

Figure 3: Deriving a national supply curve for REDD



	Deforestation rate (ha/yr)	Potential emission reductions (tC/ha)	Potential emission reductions (million tCO_2e)	Opportunity costs ($/ha/yr)	Opportunity costs PV ($/ha)	Opportunity costs ($/$tCO_2e$)	Opportunity costs (million $)
Area A							
Converted to pasture	40,000	230	2.5	20	209	0.25	8.3
Converted to agroforestry	20,000	150	0.8	30	313	0.27	6.3
Area B							
Converted to soybeans	20,000	290	1.6	70	730	0.69	14.6



42. Of course, implementation and transaction costs must still be added to these opportunity costs. But the supply curve as it stands can already provide considerable guidance. If the REDD payment offered were of $2.60/tC, for example, it would seem unlikely that seeking to avoid conversion of forest to soybeans in area B would be attractive for the country. Even though the payment exceeds the opportunity cost of $2.5/tC, it does not do so by much, making it likely that implementation costs will drive total costs above the payment.

Even if implementation costs were very low, there would be little net benefit to the country from making this effort. In fact, this supply curve can be used to determine the maximum implementation and transaction cost that would make efforts to reduce deforestation in an area attractive, for any given price of REDD. This supply curve can thus help prioritize national efforts to reduce deforestation, by identifying areas in which such efforts are most likely to bring net benefits to the country.

3.4 Co-benefits

43. In principle, the country's perspective should include *all* costs and benefits generated by a given land use that are perceived within the country. This would, in principle, include all on-site benefits (such as fuelwood and timber collection, recreation, and so on) as well as all off-site benefits (such as protection of water services, landscape benefits, and so on), except those that are received primarily outside its borders (such as carbon sequestration and biodiversity conservation). In practice, it has been common in the REDD debate to consider the on-site benefits separately from the other benefits, dubbed "co-benefits", of preserving forests. We follow this convention here.

44. When the co-benefits of forests are high, the costs of REDD from the country's perspective fall, and might in fact become negative. Consider a forest generating $10/ha/yr in on-site benefits, and which would generate $150/ha/yr if converted to cropland. The opportunity costs of avoiding deforestation in this area appear very high, at $140/ha/yr. Suppose, however, that cutting down this forest would cause $200/ha/yr in downstream damages such as sedimentation of reservoirs, or increased flood damage. Preserving the forest would avoid these damages. If the value of these co-benefits were to be included, the actual opportunity cost to the country would be negative: -$60/ha/yr.[15] In this case, it would be in the country's interest to seek to avoid such deforestation even in the absence of any REDD payment.[16] Omitting the value of co-benefits thus makes opportunity costs appear to be higher than they are.

45. In general, the value of co-benefits is very difficult to estimate and even more difficult to convert to per hectare terms, so they cannot usually be incorporated explicitly in opportunity cost estimates. It is, however, often feasible to identify areas or conditions under which co-benefits are likely to be particularly high. Pagiola and others (2006), for example, identify areas within highland Guatemala that are particularly important for water supplies, and prioritize them. Such information can then be used in conjunction with opportunity cost estimates to determine whether particular areas should be included in a REDD program. An area with high opportunity costs would generally not be attractive for inclusion in a REDD program, but if the co-benefits are likely to be high, this conclusion might be changed. In the example in Figure 3, a proposed payment of $2.5/tC would not have been sufficient to induce efforts to avoid deforestation in area B. But if part of the area that is threatened by conversion to soybean production were known to be in an important water supply area, such efforts might be justified—though perhaps targeted solely to the water supply area, rather than to all of area B.

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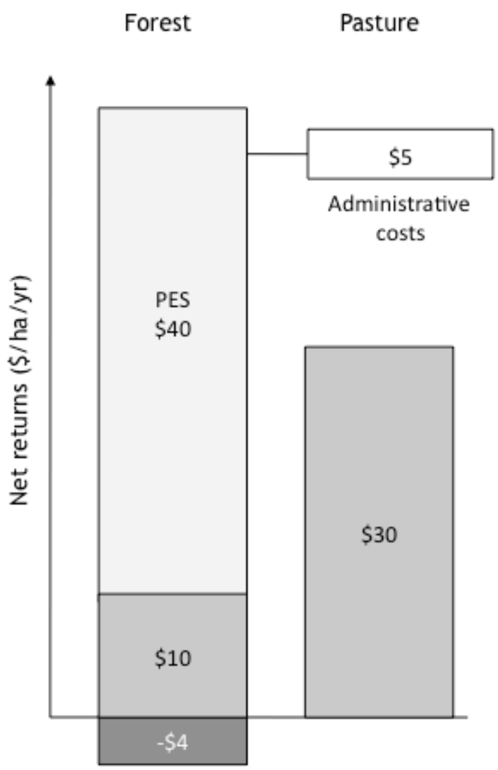
[15] Plantinga and Wu (2003), for example, find that the erosion and water pollution co-benefits of an afforestation program in Wisconsin (USA), would by themselves be sufficient to justify its costs. While this result cannot be generalized, it shows that in some cases co-benefits can be quite large.

[16] An important issue that will need to be resolved is whether avoiding deforestation in areas where co-benefits are sufficiently high to offset all opportunity costs would be considered to meet a REDD additionality criterion. Given the difficulty of measuring co-benefits, it may not be practicable in many cases to exclude such areas from eligibility for REDD.

3.4 Implementation costs

46. Actually reducing deforestation or forest degradation usually requires expending effort and resources. Most of the costs of implementation are likely to be budgetary costs for the government. Some costs, however, are likely to also be borne by others. Not all of these costs, however, are costs to the country. In particular, any transfer payments that compensate individual landholders for their opportunity costs are *not* a cost to the country.

Figure 4: Cost of REDD achieved using a payment mechanism



Cost to:	*Opportunity cost*	*Cost of implementation* Payment	*Admin*	*Net*
Government agencies		40	5	45
Individual land users	20	-40	4	-16
The country	20	0	9	29

Budgetary cost of REDD to the government:
$40 + $5 = $45/ha/yr = $0.56/t$CO_2$e

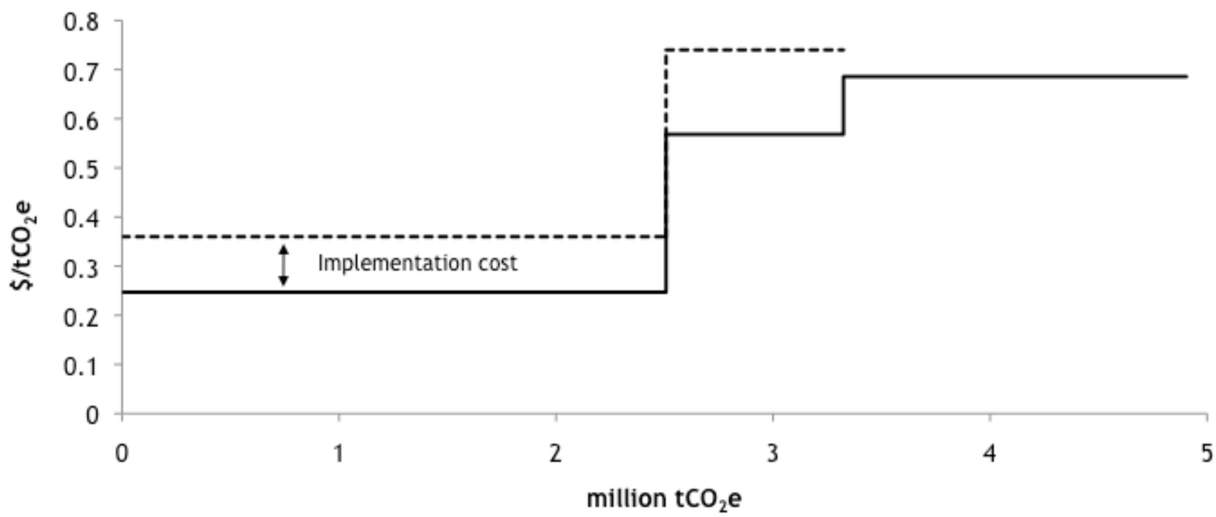
Cost of REDD to the land user:
($30-$10) - $40 + $4 = -$16/ha/yr
The land user is better off by $16/ha/yr

Cost of REDD to the country:
($30-$10) + $9 = $29/ha/yr = $0.36/t$CO_2$e

47. An example will illustrate (Figure 4). Suppose, as in our original example, that a landholder currently gains $10/ha/year from forest and would gain $30/ha/year from converting this forest to pasture. Thus the opportunity cost of preserving a hectare of forest is $20. Now suppose that the government institutes a program of payments for environmental services (PES) and offers payments of $40/ha/year to landholders who conserve their forests, and suppose further that administering the PES program costs the government $5/ha/year. Our landholder would find the payment attractive and enroll in the program, even if it imposes costs of, say, $4/ha/year (for example, to fence off the enrolled area). In this case, the budgetary cost to the government will clearly be $45/ha/year: that is what the government will spend. However, the cost of implementation to the country will actually be only $9, or the sum of the actual costs that the program imposes on the government ($5) and the participant ($4). The $40 payment itself is not a cost to the country: while it is a cost to the government, it is a benefit to the landholder, so that the two cancel out. The $5 in government administrative costs, on the other hand, is properly considered a cost of implementation. But any costs imposed on participants, such as the $4 in fencing costs of this example, are also costs of implementation, even though they do not appear on the government's books. In this example, the landholder is better off by $16/ha, as the payment offered exceeds their opportunity cost ($20) plus the implementation costs they face ($4). In

the national accounting of costs and benefits, the cost of this \$16 to the government is exactly offset by the benefit to the participant. The total cost of REDD to the country of achieving reduced deforestation in this way would thus be \$29/ha/year (opportunity costs plus implementation costs), which is equivalent to \$0.36/tCO_2e. Figure 5 revises the national supply curve for REDD derived previously to incorporate the estimated implementation costs of a \$40/ha/yr PES program. Note that this program would not succeed in avoiding conversions of forest to soybeans in Area B, as the payment offered is insufficient to offset the \$70/ha/yr opportunity cost that farmers face. Another approach, or a higher PES payment, would be needed to avoid deforestation in this area.

Figure 5: Adding implementation costs to national supply curve for REDD



48. **Effectiveness of implementation.** It is important to understand how effective a given measure will be at reducing deforestation. Ineffective measures would result in very expensive emission reductions, as their cost would be spread over only a few avoided emissions. Pfaff and others (2008), for example, estimate that Costa Rica's PES program has only reduced deforestation by about 1 percent. Conversely, Tattenbach and others (2006) estimate that PSA reduced deforestation by about 50 percent.

49. In the example above, suppose that there are ten participants in the PES program, each with 10 ha enrolled. Also suppose that five of these participants would have conserved forests even in the absence of the PES program, as in their case the benefits of conversion to pasture are less than the benefits that forests generate, for instance due to poor soils or long distance from roads. In other words, making payments to these five participants does not increase the amount of forest that would have been conserved: there is no *additionality*. Assume that the five others face opportunity costs of \$20/ha/year, as before. For these five participants, payments do result in additional conservation. For these five participants, the cost of implementation is \$9 as before, and the opportunity cost is \$20/ha/year, as before, giving a total social cost of reducing deforestation of \$29/ha/year. For the five participants that would have conserved forests anyway, there is obviously no opportunity cost. There is, however, a cost of implementation, as resources must still be devoted to signing contracts, monitoring compliance, making payments, and so on, while participants must also expend resources to comply with contract provisions such as fencing the enrolled areas. Thus the cost to the country of enrolling these five participants is \$9/ha/year. The total cost to the country of the program is therefore \$1900/year (\$29/ha/year over 50 ha and \$9/ha/year over 50 ha). Because this program covers 100 ha but is only avoiding deforestation on 50 ha, its average

cost to the country per hectare of REDD is \$38/ha/year (\$0.47/tCO_2e), or about 30 percent more expensive than a program that was able to target only land users who would have in fact cut down their forest. Similarly, the budgetary cost per hectare of REDD is \$110/ha/yr (=55x10/5), or double the \$55/ha/yr (=55x5/5) of a perfectly targeted payment program.

50. **Leakage.** Leakage would result in a similar reduction of efficiency. The displacement of deforestation from one area covered by the incentive payment to another area not covered by the payment must be taken into account when calculating the average cost of the program. Suppose for example that in the example above, two of the five participants with positive opportunity costs all clear an additional 10 ha elsewhere to replace the 10 ha of forest they have each enrolled in the PES program. In this case, the net deforestation reduction induced by the program is only 30 ha. The total cost to the country per hectare of REDD would be \$50/ha/yr (\$0.62/tCO_2e) because costs of implementation would now be spread over only 30 ha.

51. Implementation costs are not necessarily correlated with opportunity costs. For example, opportunity costs are likely to be quite low in forest frontier areas where farmers are cutting down free-access forest areas for subsistence farming, but the implementation costs of resolving the problem by establishing and enforcing clear property rights in such area can be quite high. Conversely, the implementation costs of a PES program implemented in an area of large farms producing commercial crops would be quite low thanks to easy accessibility, but opportunity costs would be quite high. Implementation costs will also not necessarily decline as the scale of implementation grows (unlike transaction costs, see below). On the contrary, it seems reasonable to expect that there would be diminishing returns to additional efforts to reduce deforestation, with some deforestation being quite easy to avoid, but then costs rising as additional reductions are sought.

3.5 Transaction costs

52. In addition to the opportunity costs and implementation costs of avoiding deforestation, countries will also have to bear transaction costs to document to buyers and REDD regulators that emissions reductions have been achieved. There is, at present, little data on how large these costs might be. Antinori and Sathaye (2007) find mean transaction costs of US\$0.38/tCO_2e in a sample of project-based CDM forestry projects.[17] A nationwide approach would likely have substantially lower average transaction costs, however. Indeed, Antinori and Sathaye find strong economies of scale in their sample of CDM projects. Likewise, Wunder and others (2008) find that national-scale PES programs tend to have lower transaction costs than watershed-scale programs.

53. An important aspect of transaction is they are likely to be largely fixed rather than variable. Their weight in the total costs of REDD, when expressed in \$/tCO_2e, will thus depend on how successfully the country reduces deforestation. The greater the reduction in deforestation, the greater the amount of emissions reductions over which these fixed costs will be spread, and the lower transaction costs will be in \$/tCO_2e terms.

4. Conclusions

54. The type of analysis discussed in this paper is meant to provide information to countries in developing their REDD programs: in determining what it would actually cost them to supply emissions reductions by reducing their national rates of deforestation and forest

[17] These are not REDD projects, however.

degradation. It is in the country's interest to carry out this analysis as accurately and objectively as possible. Overestimating the costs of providing emissions reductions would make reducing deforestation appear less attractive and result in a country undertaking a less ambitious REDD program than it might have. The country would thus be leaving money on the table, as well as missing out on any co-benefits that would have been generated by avoiding deforestation. Conversely, underestimating the costs of providing emissions reductions would make avoiding deforestation appear more attractive, and would result in the country providing at least some emissions reductions at a loss.

55. As part of their undertakings under the FCPF's Readiness Mechanism, developing countries should undertake their own analysis of the costs of REDD. This work is part of the process of adopting a national REDD strategy or adding to the existing set of laws and regulations to arrive at a legal and institutional framework for REDD. Economic rationale is one factor (not of course the only one) that should guide decision making. A country should know how much it costs to reduce emissions from deforestation and degradation so it is better prepared to decide how much to invest in which emission reduction program, and also to negotiate payments for REDD.

56. For the purposes of the FCPF, it is proposed that an independent Technical Advisory Panel will be set up to advise on the methodologies to be followed to estimate the costs of REDD, and then to encourage countries to apply this or these methodologies to underpin their national REDD strategy adoption process. The FCPF is developing a partnership with the ASB Partnership for the Tropical Forest Margins to provide training and support to participants in undertaking such analyses as part of their Readiness programs.

Glossary

Accounting stance – the point of view from which costs and benefits are calculated. Typical accounting stances in the REDD debate are that of the country as a whole, those of individual groups within a country, that of the government, and that of the global community as a whole.

Additionality – whether a program has an impact that would not have occurred in the absence of the program.

Implementation cost – the cost directly involved in implementing the REDD program; that is, the cost of the actions needed to reduce deforestation or forest degradation.

Leakage – the loss of forest and emission of greenhouse gases as a direct result of implementing a REDD program, which occurs in a different location than the REDD program itself.

Opportunity cost – the cost of the foregone benefits from one activity when an alternative activity is undertaken. In the context of REDD, the cost of foregoing the benefits that deforestation would have generated, such as timber and crop production.

Transaction cost – the cost of identifying the REDD program, negotiating the transaction, and verifying and certifying the emission reductions, so that the REDD payment can be executed and considered legitimate by the parties to the transaction and external parties, in particular the cost of monitoring, reporting and verifying the tons of emission reductions.

Acronyms and abbreviations

CO_2	Carbon dioxide
FCPF	Forest Carbon Partnership Facility
GHG	Greenhouse gas
Ha	hectare
NTFP	Non-timber forest product
PES	Payments for environmental services
REDD	Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
tC	Metric tonne of carbon (1tC = 3.67tCO_2)
tCO_2	Metric tonne of carbon dioxide (1tCO_2=1/3.67tC)
UNFCCC	United Nations Framework Convention on Climate Change

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