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Publication Date

2011-04-11

DOI

10.1017/S1355770X11000052

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LBNL Report

Emissions Scenarios, Costs, and Implementation Considerations of REDD Programs

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June 2010

LBNL's role in this work was supported by the Climate Economics Branch, Climate Change Division, US Environmental Protection Agency through the US Department of Energy under Contract No. DE-AC02-05CH11231.

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ACKNOWLEDGEMENTS

The authors would like to acknowledge the insightful comments provided by Steven Rose in his guest editorial capacity and other anonymous reviewers; the data and analysis produced by Juergen Blaser for the FIP program and shared by him for our use in generating table 6; and research assistance by Rajesh Koirala in revising table 4.

LBNL's role in this work was supported by the Climate Economics Branch, Climate Change Division, US Environmental Protection Agency through the US Department of Energy under Contract No. DE-AC02-05CH11231.

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ABSTRACT

Greenhouse gas emissions from the forestry sector are estimated to be 8.4 $GtCO_2$-eq./year or about 17% of the global emissions. We estimate that the cost for reducing deforestation is low in Africa and several times higher in Latin America and Southeast Asia. These cost estimates are sensitive to the uncertainties of how much unsustainable high-revenue logging occurs, little understood transaction and program implementation costs, and barriers to implementation including governance issues. Due to lack of capacity in the affected countries, achieving reduction or avoidance of carbon emissions will require extensive REDD-plus programs. Preliminary REDD-plus Readiness cost estimates and program descriptions for Indonesia, Democratic Republic of the Congo, Ghana, Guyana and Mexico show that roughly one-third of potential REDD-plus mitigation benefits might come from avoided deforestation and the rest from avoided forest degradation and other REDD-plus activities.

Please use the following citation for this report

Sathaye J., K. Andrasko and P. Chan (2011) Emissions Scenarios, Costs, and Implementation Considerations of REDD Programs. *Environment and Development Economics*, DOI:10.1017/S1355770X11000052.

Table of Contents

Table of Figures

Table of Tables

Emissions Scenarios, Costs, and Implementation Considerations of REDD Programs

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1 Introduction

Forest biomass plays an important role in the global carbon cycle. Forest vegetation sequesters carbon while at the same time deforestation and degradation of standing forests leads to release of stored carbon. The total forest cover has been declining globally. It stood at 3.95 Mha or about 30% of the global land area in 2006 (FAO, 2007). The gross deforestation rate is estimated to have declined between 2000 and 2005 compared to the decade of the 1990s, but it still amounted to a gross and net loss of 12.9 and 7.3 Mha/year, respectively (FAO, 2007). The often-cited reasons for this loss – expansion of settlements, unsustainable logging, and conversion to agricultural land – are well known and have been documented in many studies (summarized in, for example, Nabuurs *et al*., 2007).

This loss of forest cover and of carbon density per hectare due to degradation leads to significant emissions of greenhouse gases (GHGs), about 95% of which are carbon dioxide (CO_2) emissions. In 2004, forestry emissions were estimated to account for 17.4% of total GHG emissions of 49 $GtCO_2$-eq. Together with agriculture, the two land-use sectors account for about 30% of these GHG emissions. The 8.4 $GtCO_2$-eq./year of forestry emissions have increased from 5.9 $GtCO_2$-eq./year in 1990, and include those from deforestation, biomass decay, and more importantly from peat fires and decay of drained peat soils. Significant uncertainty still surrounds these estimates, as newer remote sensing studies produce results consistently lower than classic FAO (2007) values for key countries (e.g., Hansen *et al*., 2008, for Indonesia; van der Werf *et al*., 2009).

As the above statistics show, the large quantity and high growth rates of emissions from forestry are a cause for major concern. These lead to a double whammy – an increase in current emissions that are accompanied by reduced forest biomass cover – which leads to lower carbon sequestration in the future. It is thus imperative that emissions from forestry be slowed or eliminated in the future. Achieving such a change, however, is fraught with many challenges, starting with a lack of accurate data on the biomass and carbon density of tropical forests. The IPCC reported 19 sources of data on the annual carbon flux during the 1990s (Nabuurs *et al*., 2007, table 9.2). Global emissions were reported by some of these sources. Estimates based on land observations of the annual net carbon flux show a huge uncertainty band, for example, Houghton (2003) estimated these to be 3.3 ± 7.7 $GtCO_2$/year during the 1990s. The costs of emissions reduction are also highly uncertain because of the various drivers of deforestation that would have to be managed, and the potential for substitution from other forests not targeted for driver management programs.

In this paper, we report on recent estimates of the cost of reducing deforestation for alternative carbon prices using a new version (GCOMAP v.2) of the Generalized Comprehensive Mitigation Assessment Process (GCOMAP) model (Sathaye *et al*., 2005, 2006). GCOMAP is a partial equilibrium model that analyzes the cost of forestation and reducing deforestation globally by region. Its results were reported extensively in the IPCC assessment (Nabuurs *et al*., 2007). Subsequently, the model was used in several assessments to provide inputs on deforestation carbon economics. These include the (1) GLOCAF model used in the Eliasch Review conducted by the UK government (Sathaye *et al*., 2008), (2) ABARE model used in an analysis of the economics of climate mitigation conducted by the Australian Government (Commonwealth of Australia, 2008), (3) POLES model used in an assessment of the post-Kyoto potential for reducing emissions (Anger and Sathaye, 2008), and (4) BIOME4 model for an assessment of the impact of climatic change on net primary productivity and economic benefits of future forest growth in India (Ravindranath *et al*., 2010). The model results were also used in a report prepared for Greenpeace International on Reducing Emissions from Deforestation and Degradation (REDD) (Livengood and Dixon, 2009). The analysis for the Eliasch Review included an update of the deforested area, biomass density, and cost parameters for the four deforesting regions in the model. The analysis reported for Australia and for the European Union included an evaluation of transaction costs and in the latter case an evaluation of uncertainties in the historical baseline against which reduced deforestation is measured.

In this paper, we report on the GCOMAP v.2 structure with the new data that were incorporated for the aforementioned Eliasch Review and Australian Government report, summarize the results of the above analyses and comment on some of the challenges to achieving the potential reduction in emissions from deforestation. The challenges and issues are described in the third section on implementation considerations and focus on key topics such as monitoring, reporting and verification of carbon stock and drivers of deforestation, engagement of indigenous and local communities, adequate compensation to deforesters, and governance infrastructure to accomplish the task.

1.1 Structure of the GCOMAP model

In this paper, we use our dynamic partial equilibrium global model, GCOMAP, to simulate the response of the forestry sector to changes in future carbon prices, in 10 roughly continental regions (Figure 1). The general equilibrium models mostly rely on a few global data sets. A major goal of GCOMAP is to make use of detailed country- or region-specific activity, demand, and cost data available to the authors on mitigation options and land use change by region (see Sathaye *et al*., 2006, for tropical country data). The model permits explicit analysis of the carbon benefits of reducing deforestation in tropical countries. However, it does not consider the impact of increasing CO_2 concentration (i.e., CO_2 fertilization) on changes in the carbon cycle, and its effect on biomass growth.

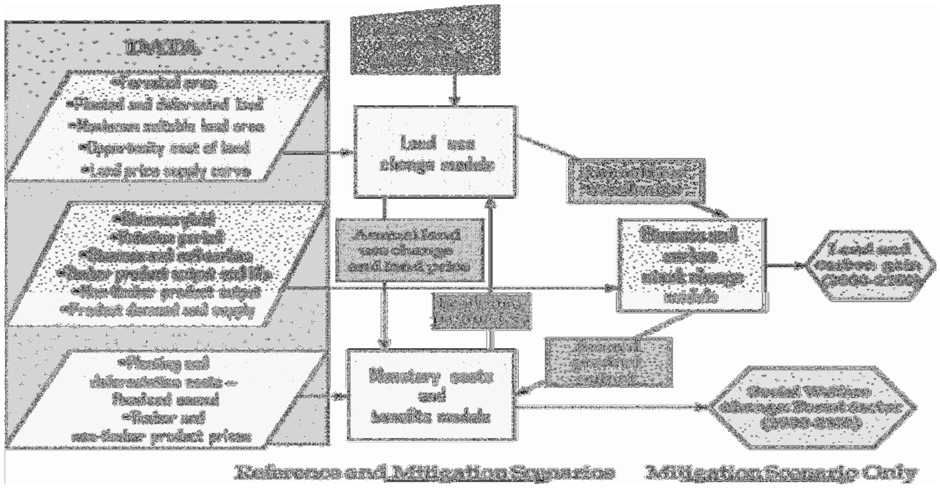

Figure 1: GCOMAP model structure.

The GCOMAP global model establishes a reference case level of land use, absent carbon prices, for 2000–2100. It then simulates the response of forestland users (e.g., farmers) to changes in prices of forestland and products, and prices emerging in carbon markets. The objective is to estimate the land area that land users would plant above the reference case level, or prevent from being deforested, in response to carbon prices. The model does not distinguish between public and private lands since the players in a carbon market may include public and private landholders.[1] The model then estimates the net changes in carbon stocks while meeting the annual demand for timber and non-timber products. More detailed description of the model structure, approaches, and data are presented in the model description (Sathaye *et al.*, 2005, 2006), including regional land use and carbon stock data, equations for the carbon accounting and financial modules, and other details.

The model analyzes three mitigation options globally: (1) short-rotation forestry, that is, new or replanted tree crops or forests managed on a rotation of growth and harvest between 6 and 60 years; varying by region and forest type; (2) long-rotation forestry, that is, planting and management for rotations between 20 and 100 years; and (3) avoided deforestation. In this paper, we focus on the option to avoid deforestation,[2] which is analyzed for four developing regions where deforestation is significant – Africa, Central America, South America, and Southeast Asia.

2 Deforestation mitigation potential and costs

The mitigation potential in forestry varies across countries, and over time. Significant factors that influence this potential include the availability and suitability of land for forestation, its carbon sequestration potential; current and future land use activities, including deforestation trends; and changes in the efficiency and use of forest products, including biomass dedicated for fuel.

The cost and carbon mitigation potential estimates from models are sensitive to several key parameters. These include the (1) carbon density of forests, (2) opportunity costs of deforested areas, and (3) future baseline deforested area estimates. We tested the influence of changes in more recent values on the first two of the three above-mentioned parameters, which are summarized below.

2.1 Updated carbon density values

Carbon density data were derived from the biomass and carbon density values published in the FAO (2005) global assessment of forests.[3] The carbon density values of forest stock include above and below ground living biomass, dead wood and litter, which vary by country. These average values were assumed to apply to deforested areas of the forests of each region.

African forest area and change-in-forest cover statistics are reported separately for North Africa, Eastern and Southern Africa, and Western and Central Africa by FAO. In North Africa, Sudan lost 589,000 ha of forest cover annually between 1990 and 2000, but the change in carbon stock was only about 13.5 MtC (49.5 Mt CO_2)/year (FAO, 2007, tables 2 and 3). On the other hand, the Democratic Republic of Congo lost 530,000 ha annually from 1990–2000, with an estimated change in carbon stock of about 92 MtC (337.3 Mt CO_2)/year. The other countries with significant forest and carbon loss in the region were Zambia, Nigeria, Code D'Ivoire and Cameroon. For the Africa region, an average value weighted by the deforested area of three subregions, Eastern and Southern, Northern, and Western and Central Africa was calculated.

In Southeast Asia, Indonesia accounted for about 1.9 Mha per year or about 68% of the forest cover change in the region from 1990 to 2005. Myanmar, Philippines, and Cambodia were the other major deforesting countries in the region. For this region, an average carbon density value was estimated by weighing country-specific data for forest cover and carbon density as reported in the 2005 FAO report.

For Central and South America, where Mexico and Brazil account for the bulk of deforestation, respectively, average carbon density values were available from the FAO report for each of the two regions, and these were used in the GCOMAP model.

Using the above FAO statistics, the resulting carbon densities were higher than calculated earlier using the 2000 biomass values for the three regions by the following margins: Africa – 33%, Central America – 75%, and Southeast Asia – 48%; however, carbon density was lower for South America by 13% (table 1). Higher carbon density values increase the total emissions in the base year and vice versa. Using these values, the global 2000 emissions estimate in GCOMAP v.2 increased by about 25% to 996 MtC (3,652 Mt CO_2). This value may be compared with the range of mean value estimates from De Fries at 3.3 Mt CO_2 and Houghton at 7.7 Mt CO_2 as reported in table 9.2 of the IPCC WG III AR4 report (Nabuurs *et al*., 2007). A significant consequence of the higher emissions is that at the same opportunity cost per hectare, the carbon price required to reduce emissions is lower compared to earlier GCOMAP v.1 runs reported by Sathaye *et al*. (2006).

Table 1: Carbon density values in GCOMAP v.1 and GCOMAP v.2

	Carbon density (tC/ha (tCO_2/ha))		
Region	*GCOMAP v.1*	*GCOMAP v.2*	*% change*
Africa	74 (271)	98 (359)	33
Central America	71 (260)	124 (455)	75
South America	142 (521)	124 (455)	−13
Southeast Asia	68 (249)	101 (370)	48

2.2 Updated opportunity cost estimates

The opportunity cost of deforested land consists of two components, net present value (NPV) of timber harvested prior to deforestation, and NPV of the revenue stream from agricultural crops, cattle ranches, and/or plantations. The GCOMAP v.1 data for the estimation of opportunity costs were reported in Sathaye *et al*. (2006). The updated cost and benefits data and information used in GCOMAP v.2 for each region are reported in Sathaye *et al*. (2008).

Unlike the data on area and carbon density, which are based on a common format and the data collection procedure used by FAO, the opportunity cost data are derived from many published sources for each of the four regions. A common methodology and procedure for collection of opportunity cost data is lacking. The data reported below are based on best available information and are not necessarily comprehensive for each region although because GCOMAP is not a subnational model we made an effort to collect data that would apply broadly to a large fraction of the deforested area in each region.

The data and information collected for each region were used to estimate the NPV figures that are presented in table 2. The net present value for different types of cropping and ranching (column 2) varies across regions but the variation is relatively small – limited to about 29% between the maximum and the minimum values.

Table 2: Opportunity cost of land: net present value (includes cost and revenue streams of products noted for each region

Region	*NPV[1] ($)*	*Deforested land use activities*	*NPV[2]*	*Deforested area harvested (%)*
Africa	169	Cocoa, palm, corn, and rubber	$126	10
Central America	158	Maize, chili pepper, and cattle ranching	$300	15
South America	184	Soy, rice, cotton, and cattle	$825	27.5
Southeast Asia	143	Timber, oil palm, rubber, and upland rice	$897	35

NPV[1]: Net Present Value (2000 US$ @20% over 10 years) per ha from agriculture without including revenue from timber harvesting.
NPV[2]: Net revenue (2000 US$) from harvested timber per hectare.
NPV values are held constant over time in the GCOMAP model.

In Latin America, the soil is rich enough to grow crops for the first couple of years and typically this is followed by ranching. Ranching offers a stable source of income that carries relatively lower weather and economic risk than growing crops (Sathaye *et al*., 2008).[4] Subsistence agriculture and shifting cultivation is practiced in some regions, which allows the deforested land to regenerate over time. Elsewhere, due to poor soil conditions land may not regenerate, leaving wasteland behind.

In our estimation of the opportunity cost of reducing deforestation, we include the cost of timber that might be harvested prior to removal or burning of the live and dead wood from the forested area, and the planting of annual or perennial crops, plantations, and cattle ranching. Roads constructed by logging trucks open access to parts of the forest. Open access permits deforesters to migrate to other parts of the forest that would otherwise be difficult to reach.

The proportion of deforested area that is harvested for timber varies by region. The values shown in table 2 are relatively conservative and range from a high of 35% for Southeast Asia to 10% for Africa. The value was assumed to be high for Southeast Asia because of the substantial illegal logging of timber in many countries, which is also documented in the REDD-plus proposals noted in section 3 (Smith *et al*., 2003). Illegal logging of prime species such as mahogany opens access to the illegal logging of other species and for broader deforestation of the neighboring regions. By its very nature, illegal logging is difficult to pin a value on. Studies report illegal logging to have ranged from 70–80% of timber production in Indonesia, up to 90% in the Brazilian Amazon, and between 34 and 70% in West Africa (Contreras-Hermosilla, 2001; Rhodes *et al*., 2006).

Many countries are taking regulatory actions to enforce existing laws to reduce illegal logging. Despite these actions, illegal logging driven by the domestic and international demand for timber continues to be a major impediment to reducing deforestation. While the illegal logging percentage is high in these regions, the extent to which this leads to deforestation is not known. Merchantable timber fetches a substantial value that can range from \$160–200/m^3 in the domestic market to \$700/m^3 or more at the point of export to the international market. Such high returns can significantly affect the carbon price needed to reduce deforestation. We have assumed relatively low percentage values in our analysis for total harvesting that includes illegal and legal quantities, which are shown in table 2. However, should these percentages be higher, the investment and carbon price needed to reduce deforestation would rise significantly.

The GCOMAP v.2 NPV values noted in table 2 for agriculture are lower than those used in GCOMAP v.1. In the previous version, the same cost figure (\$250 per hectare) was used for all regions, and the timber NPV value was same as in table 2.

2.3 Impact of updated data on reduction potential and costs

In this section, we report on the costs of reducing deforestation for the four study regions and the potential for minimizing the reduction in carbon stock and forested land area. We also estimate the investment needed for achieving this reduction and the role that carbon markets can play in providing carbon finance for this purpose.

Figure 2 shows the economic potential of constant carbon prices starting in 2010 in reducing deforestation for Africa, Central America, South America and Southeast Asia. The reference scenarios emissions in each region are almost stable or declining in the future except in the case of Africa where emissions are projected to increase until 2020 before beginning to decline. The effect of carbon prices on the mitigation potential varies across regions because of the difference in opportunity costs for agriculture and timber harvesting. In the case of Africa, the carbon price required to achieve the same magnitude of deforestation emissions reduction is lower than that for Central and South America. The corresponding carbon price is much higher in the case of Southeast Asia. A constant carbon price of \$60/tC (\$16/tCO_2) is high enough to virtually halt deforestation in Africa and the same is achieved at a carbon price less than \$100/tC (\$27/tCO_2) in Central America. In the other regions, a much higher carbon price will be needed to halt deforestation.

Box 1: Conceptual approach to estimated REDD-plus implementation costs

Conceptually, the eventual full costs of implementing REDD-plus in a country could be described as follows:

Total cost = (initial Readiness capacity building costs + transaction and implementation costs + investments for required alternative land uses and infrastructure + recurring annual costs + governance costs) − revenues from REDD strategy land uses − cobenefits of REDD strategies

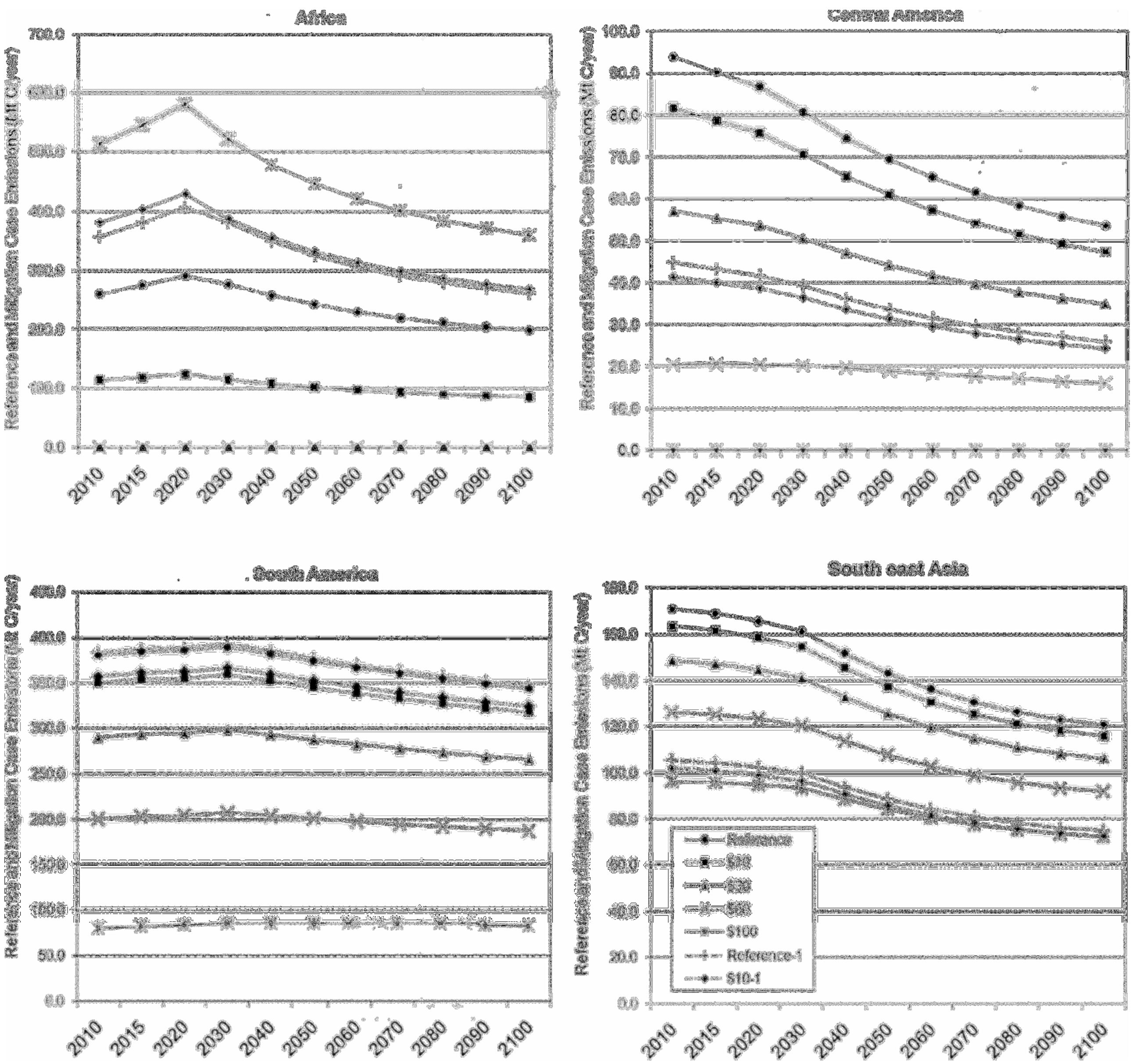

Figure 2: Reference and mitigation case emissions for the study regions of Africa, Central America, South America, and Southeast Asia (2010–2100), subject to constant carbon prices ($/tCO2)

Rising carbon prices offer lower mitigation scenario emissions in each of the four study regions. A constant price of $20/tC results in cumulative (2000–2100) combined carbon emissions in the four regions of 7 billion tC. This declines to about half the value or 3.5 billion tC if the price increases at 2% a year reaching $145/tC. The two dotted lines in each panel of figure 2 show the results using GCOMAP v.1 for a reference scenario and $10/tC ($2.7/tCO_2) mitigation scenario.[5] Consistent with the carbon data in table 1, the reference case has significantly lower emissions in each region except in the case of South America where the values are somewhat higher. The GCOMAP v.2 $10/tC mitigation scenario shows a 3 MtC/year increase, relative to the reference scenario in Central America, which is 300% higher compared to the mitigation result of GCOMAP v.1. While the percentage value is high for Central America, the difference in absolute values between the two sets of runs is significant only in the case of Africa where the mitigation carbon reduction is 35 tC (128 tCO_2) higher in 2020 in GCOMAP v.2.

3 Implementation considerations for national REDD-plus mitigation programs

The conceptual equation for full costs of REDD-plus implementation is shown in box 1. To date, there are few estimates of implementation, transaction, recurring, or investment costs and potential cobenefits, but the way forward is becoming more evident.

Global forest sector economic models, such as GCOMAP, are useful for estimating the quantity of land use response (e.g., the number of hectares of forestland converted or not converted to an alternative land use) to an economic stimulus or climate policy, and the price of carbon needed to affect a given response. However, most such economic models do not attempt to represent the complexity of implementing such a policy – how existing institutions, land use stakeholders, economic sectors, etc. will respond to a policy signal in a given country context. In other words, the models estimate the economic potential – but not the achievable potential, nor the related transaction costs and the lead time required for overcoming barriers and for implementing government programs or private sector investments.

Assessing how much REDD-plus could be implemented in practice in response to a carbon price signal and international climate policy regime is little explored in the literature. To advance such an assessment, we review potential elements of (a) national-scale REDD-plus activity implementation and the likely issues it would need to address and (b) a future REDD-plus implementation scenario for GCOMAP.

A few studies have assessed national or subnational implementation of policies for reduction of emissions from deforestation, and estimated carbon benefits and costs in detail (e.g., Nepstad *et al.*, 2007, for the Brazilian Amazon), or reviewed the range of potential implementation issues, infrastructure needs, reference case setting options, monitoring system and REDD-plus benefits delivery design (e.g., for Indonesia, the IFCA study, 2008). The Open Source Impacts of REDD Incentives Spreadsheet (OSIRIS) model is a free, transparent, accessible, and open source decision support tool developed to support UNFCCC negotiations on REDD-plus. OSIRIS enables comparison of global, regional, and country emissions reduction, deforestation and revenue impacts of alternative approaches to providing positive economic incentives for REDD-plus, and has been downscaled thus far to the national level for Indonesia (http://www.conservation.org/osiris/Pages/overview.aspx; Busch *et al.*, 2009).

Even fewer studies have considered the range of implementation barriers, costs, and opportunities in a global modeling framework and assessed the effect on the quantity, price, and timing of REDD-plus benefits available. Ebeling and Yasue (2008) performed early work that takes international leakage, permanence of emissions reductions, forest governance, and biodiversity and development cobenefits into account; and Benítez-Ponce *et al*. (2007) consider governance risk broadly as a discount applied to REDD-plus potential benefits.

Arguably the three most pressing questions for economic assessment of REDD-plus are, simply put: (1) How many tonnes of REDD-plus emissions reductions are available from tropical countries for climate change mitigation, from where, at what price, and when would they be available? (2) What is the quantity and timing of demand for emissions reduction programs in voluntary or any eventual regulatory programs? and (3) What percentage of such potential REDD-plus tonnes could be realized on the ground via implemented programs and policies, in the realpolitik of a given supplier country's political, socioeconomic, and governance context?

Table 3 provides a framework for a preliminary assessment of the effects of implementation on REDD-plus mitigation potential and timing of delivery. It summarizes key REDD-plus implementation issues that need to be addressed at the national and international level. These core policy issues include: development of a reference scenario at the national level; design of a monitoring, reporting, and verification system for REDD-plus; REDD-plus policy and program design; and key forest sector or other governance issues specific to REDD-plus (e.g., addressing ownership of carbon benefits on communally held lands). Considering the REDD-plus Policy and Program Design issue briefly, each country is reviewing its previous initiatives to manage land use, and beginning to identify alternative REDD-plus policies and practices to address specific drivers of deforestation. Indonesia, for example, is considering regulating and improving federal and provincial management of development of peat lands by coordinating government jurisdictions, and implementing land swaps; the Democratic Republic of Congo is assessing the potential to reduce the demand for firewood and to develop alternative energy sources through a national energy strategy focused on large urban areas and the eastern provinces undergoing rapid immigration; and Ghana is exploring ways to mitigate the effects of agricultural expansion (particularly of the dominant cash crop cocoa in the high-forest zone). (Table 5 offers additional examples.) Table 3 table synthesizes the feasibility of including each of these issues in REDD-plus modeling, concluding that it is feasible to develop an estimate or a proxy for each issue (though quantification of such estimates generally needs to be developed).

Table 3: Key REDD implementation issues at national and international scale

Implementation issue	*Key features of issue*	*Scale at which issue is likely to be addressed*	*Feasibility of inclusion in modeling*
Reference level establishment	Estimation of business as usual forest cover and carbon density trends without REDD interventions, using historic data on drivers of deforestation and/or future projections. UNFCCC climate regime rules eventually may provide guidance on time frame and methods.	Probably national, but consistent with global climate regime rules, and integrating subnational implementation reference scenarios	Critical, since REDD benefits estimated against reference case. Defining a country reference case is complex policy process, but can be simplified for modeling.
MRV system design (measurement, reporting, and verification)	Design of an integrated system of forest inventory, remote sensing, and/or modeling to REDD activities.	National, but consistent with global guidance and integrating subnational MRV methods and results	Possible to discount REDD benefit tonnes if high uncertainty.
REDD Policy and Program Design	Policies, programs and projects vetted with key stakeholders and proposed to achieve REDD and other benefits.	National and subnational	Feasible on policy scenario basis, in national or subnational models.
Key REDD governance issues	Begin work addressing key issues to facilitate implementation of REDD activities (e.g., define ownership of carbon commodities; establish equitable REDD benefits distribution).	Some national (e.g., forest concession policy); some local (e.g., specific land tenure issue).	Model which countries or REDD activities would lag in implementing REDD governance issues.

Two major international REDD-plus programs are in the early stages of supporting the conceptualization of REDD-plus national programs. The Forest Carbon Partnership Facility (FCPF, www.forestcarbonpartnership.org), with the World Bank as trustee, has a roughly $200 million Readiness Fund that is a REDD-plus capacity building partnership of 37 developing countries beginning to undertake studies and training to become ready to participate in REDD-plus, supported by 14 donors. The UN Collaborative Programme on Reduced Emissions from Deforestation and Degradation in Developing Countries (UN-REDD, www.un-redd.org) is using multi-donor trust funds to support capacity building for REDD-plus in at least nine countries in Asia, Africa and Latin America, supported by the government of Norway and other donors.

REDD-plus governance addresses the relative capacity of a country to administer forest sector and other programs efficiently, transparently and equitably, all relevant for land use change mitigation programs. However, only a few studies such as those by Ebeling and Yasue (2008) and Myers Madeira *et al*. (2010) apply global governance and risk indices to discount REDD-plus credits. Myers Madeira *et al*., for example, combine an estimate of the technical potential of RED mitigation (assessing avoided deforestation only, not degradation or other stock enhancement activities included in the broader REDD-plus term), calculated by their Forest Carbon Index, with a risk indicator that applies governance, ease-of-doing business, and REDD-plus Readiness factors based on quantified indices and globally available data. Additionally, they consider an exclusion or delayed discount that eliminates or delays countries' entry to a RED market based on the technical and political capacity of countries to supply REDD assets. These studies do not assume any improvement in governance and risk issues over the next decades, and so provide a static perspective on governance issues for REDD-plus; hence, more sophisticated analytical work is needed.

Studies of virtually all major issues are beginning to emerge (e.g., OAR Norway report on REDD-plus potential and issues; Meridian Institute, 2009). The Governance of Forests Initiative (GFI), for example, is developing a framework of indicator variables for assessment of forest sector governance, as a collaboration among World Resources Institute, Instituto do Homem e Meio Ambiente da Amazonia, and Instituto Centro de Vida. GFI's work is predicated on the assumption that transparent processes and capable institutions are necessary to address sustainable management of forests and reducing deforestation. Empirical analysis supports the finding that better governance results in better development outcomes, although the evidence of a direct effect of enhanced governance on reducing deforestation is weak (Kishore and Belle, 2004). GFI initially reviewed REDD-plus Readiness Proposals (R-PPs) drafted by Panama, Indonesia, and Guyana to participate in the FCPF, and the UN-REDD Joint National Program Documents (JNPDs) for Vietnam, Indonesia, Tanzania, Papua New Guinea, and the Democratic Republic of the Congo (DRC), and then the FCPF R-PPs and/or UN-REDD JNPDs for all subsequent countries. These reviews assessed law and policy development, land tenure administration and enforcement, forest management, forest monitoring, law enforcement, and forest revenue distribution and benefit sharing. The initial review found that the early readiness activities are addressing key governance issues at least generally, and do a reasonable job of providing a framework for measurement, reporting and verification (MRV) of REDD-plus, although more emphasis on governance and improved consultations with stakeholders is needed (Daviet *et al*., 2009).

However, actual experience to date in countries in implementing REDD-plus policies is limited. Early estimates of the potential cost of REDD-plus capacity building were generated by the FCPF and then the Eliasch Report, summarized in table 4, indicating capacity building costs for REDD-plus Readiness for an average-sized country such as Ghana or Panama (but excluding large countries such as Indonesia or Brazil) are about \$3.2–\$8.5 million (FCPF, 2008; Eliasch, 2008). More recent actual national proposals to become ready to undertake REDD-plus by eleven countries in the FCPF program request an average of \$13.6 million for capacity building, or four times the early FCPF estimates and 50% above the Eliasch high estimate. These estimates do not include the annual operating costs of an MRV system once it is in place. One estimate for REDD Readiness broadly, including addressing perceived governance issues, is \$13–92 million per country (Eliasch, 2008). New modeling is needed that would reflect such cost estimates in REDD-plus mitigation scenarios. This early estimate for achieving country readiness is a small fraction of the likely cost of many REDD-plus programs in a country, as evidenced by approximately \$3 billion in South America in 2010 alone with a carbon price of \$30/tC (\$8/tCO_2) in figure 2 (bottom left panel).

Table 4: Estimated cost of REDD capacity building for an average-size country

Components of REDD Readiness preparation proposals (R-PP)	*FCPF 2008 estimate (average, in 000) ($)*	*Eliasch 2008 estimate: High (in 000)[a] ($)*	*FCPF 2010 average estimates for 11 national R-PPs (in 000) ($)*
REDD management and consultations	890	2,000	$2,301
Develop REDD strategy	450	1,000	$4,062
REDD implementation framework	341	1,500	$877
Environmental and social impacts assessment	50	–	$377
Develop reference level	516	4,000	$1,457
Design REDD MRV system	1,008	–	$5,740
TOTAL (without annual MRV costs)	3,250	8,500	$13,661

Note: Countries with R-PPs assessed by the FCPF Participants Committee included in the FCPF 2010 estimates are as follows: Argentina, Costa Rica, Panama, Mexico, Guyana, Indonesia, Nepal, Ghana, Republic of Congo, Kenya, and Democratic Republic of Congo (available at FCPF Web site at forestcarbonpartnership.org).
[a]From Eliasch (2008).

Table 5 summarizes, for five FCPF countries with submitted Readiness proposals, the kind of potential programs and policies each country is considering for its REDD-plus strategy.

Table 5: Selected national preparations for REDD Readiness

Country	*Emerging REDD strategy elements (i.e., Selected early ideas of potential policies, programs, and alternative land uses to reduce deforestation and forest degradation)*
Indonesia:	• Protected areas management (Conservation Forests and Protection Forests): develop revised national conservation strategy, and confirm boundaries and legal gazetting. • Production forests: review effects of decentralized forest management; reduce the flow of illegal logs to the market, and reform the pulp and paper sector to substitute sustainable forest plantations for natural forest harvesting. • Consolidate policy and approval criteria for releasing government land for oil palm developments. • Regulate and manage development of peat lands by coordinating government jurisdictions, implementing land swaps, etc. *Source*: FCPF R-Plan, Component 3, Table 4, drawing on IFCA Consolidation Report: Reducing Emissions from Deforestation and Forest Degradation in Indonesia, Ministry of Forests, 2008.
Democratic Republic of the Congo	Three programs offer both high mitigation potential and relatively feasible implementation: • Afforestation and reforestation to restore forests, providing firewood and logging • Reducing the demand for firewood and developing alternative energy sources through a national energy strategy • Controlled intensive agriculture development through the rehabilitation of old and new savannah plantations. Source: FCPF R-PP Component 2.
Ghana	• Address unsustainable timber harvesting by supporting sustainable supply of timber to meet export and domestic/regional timber demand • Mitigate effects of agricultural expansion (particularly cocoa in the high-forest zone) • Implement policy measures and fuel efficiency initiatives projects that will reduce carbon emissions arising from charcoal and fuel wood use. • Policy and practical measures to address degradation caused by fire in the agricultural and livestock production cycles. Source: FCPF R-PP Component 2, Table 2a.
Guyana	• Utilization of non-timber forest products and services and expanding multiple uses of the forest • Reducing impact of logging and promoting added value processing to reduce waste • Reforestation of forest gaps, exploration of plantation activities, engaging communities in forest rehabilitation • Enhance enforcement of compliance by miners and mining companies with GGMC and EPA's requirement of reforestation on mined lands. Source: FCPF R-PP Component 2b, table.
Mexico	• Increase areas under forest management, via payment for environmental services (PES) and other approaches, and engaging communities in forest restoration. • Increase incentives and government assistance for production of high-quality forest products. • Develop forest-related economic activities in communities to address poverty. *Source*: FCPF R-PP Component 2b, table.

Notes: (1) Strategy elements are early ideas in the R-PPs or other documents as noted, likely to change as REDD preparation and studies continue. (2) Estimated scale of mitigation options is generally not yet estimated or very provisional.
Source: Country draft or full Readiness Preparation Proposals on FCPF Web site (www.forestcarbonpartnership.org).

Estimates of the mitigation potential of early REDD-plus strategies are presented in table 6 for five countries in the FCPF program that have developed Readiness Preparation Proposals. Deforestation carbon benefits are estimated here, very provisionally, to be only about 23.5–42.7% of total REDD-plus carbon benefits – illustrating the importance of countries and modelers addressing REDD-plus mitigation options beyond avoided deforestation.

Table 6: Selected country preliminary REDD-plus mitigation potential: carbon estimates

Country	*Deforestation per year, 2005 (000 ha)(000 tC)*	*Deforestation mitigation per year*[a] *(-50% scenario) (000 tC)*	*Degradation estimate (000 tC)*	*REDD-Plus activity estimate (SFM + Restoration +Afforestation, Reforestation) (000 tC)*	*Total REDD and REDD-plus mitigation potential 2011–2030 (000 tC)*	*Deforestation as % of total mitigation*	*Degradation and REDD-plus activities as % of total mitigation*
Indonesia	1,900 ha 127,000 tC	63,700 tC	57,000	28,400	149,100	42.7	57.3
DRC[b]	320 ha 28,800 tC	14,400	13,700	7,800	35,900	40.1	59.9
Ghana	115 ha 10,300 tC	5,200 tC	5,500	89,500	14,100	36.9	63.1
Guyana	13 ha 270	135 tC	NA	NA	NA	NA	NA
Mexico	260 ha 16,900 tC	8,400 tC	13,000	14,300	35,700	23.5	76.5

Sources: Adapted from data in FIP Expert Group (2010, table 3). Deforestation land area (hectare) from FAO (2007). Deforestation emissions are FAO ha multiplied by FAO C density/ha (e.g., Indonesia: 67tC/ha; DRC: 90; Ghana: 90; Guyana: 90; Mexico: 65), per FIP Expert Group (2010) tables. Degradation and REDD-plus emissions estimates are preliminary from FIP Expert Group (2010) (corrected to be 000 tC values, not 0000 tC as per FIP Expert Group (2010), table 3 title).

[a]Assumption that deforestation could be reduced by 50% by 2030.

[b]DRC degradation and REDD+ activity emissions scaled from FIP Expert Group (2010) COMIFAC 6-country estimates, where DRC is 57% of COMIFAC countries' area.

While preliminary REDD-plus Readiness cost estimates for capacity building and program descriptions are provided for Indonesia, DRC, Ghana, Guyana and Mexico, the full costs of REDD-plus implementation are not yet known – beyond the aforementioned Eliasch (2008) estimate of up to $92 million per country.

3.1 Modeling REDD-plus implementation

Given that global policy decisions are likely to dictate the general structure of REDD-plus programs, but implementation will be national or subnational, model implementation scenarios need to represent the most significant issues affecting each major REDD-plus mitigation region. Major new analytic and policy development work at the international and country levels is underway on virtually all of these issues. Therefore, modeling assumptions will be required about which of these issues will be adequately addressed. For example, such assumptions may include that emerging solutions in one country or study can be applied in other country contexts, and that the key issues that will remain limiting factors for REDD-plus in a country can be identified. Resolution of model results to large countries or subcontinental regions at a minimum, or for several hundred forest management classes (as in Sohngen and Sedjo's (2006) work using the Global Timber Model, would allow assumptions about each issue to be applied to major REDD-plus mitigation activity regions.

One set of analyses shows the impact of delays in implementation of REDD-plus programs on the mitigation potential (Commonwealth of Australia, 2008).[6] A delay would cause a reduction in the amount of avoided deforestation over a given period. For a constant carbon price of $100/tCO_2$, a delay of seven years from 2013 to 2020 in the initiation of a carbon market results in a reduction in carbon savings that start at a high value (94% lower than the savings without delay) in 2020 and gradually the difference between the two scenarios reduces to about 10% by 2100. (Myers Madeira *et al.*, 2010 also assess the effect of delays in implementation.)

Several alternate implementation scenarios could serve as simple proxies for the complex set of implementation issues, to assess the feasibility of deriving an implementable quantity of avoided deforestation mitigation over a policy-relevant timeframe such as 2020–2050. By making assumptions about which regions respond, to what extent, to REDD-plus incentives and policies, and how regions differentially advance work on the issues and barriers identified, it should be possible to generate new estimates of the quantity and timing of REDD-plus for mitigation purposes.

4 Discussion and conclusions

Slowing or avoiding deforestation will require that deforesters be compensated for their loss of monetary and other benefits. We provide estimates of the cost for reducing deforestation by region, but recognize that this estimate will prove complex to realize in developing country socioeconomic, institutional, and development contexts.

Countries undertaking programs to achieve emissions reductions will require extensive REDD-plus programs likely to include monitoring, reporting and verification of carbon stock and drivers of deforestation, participation by affected indigenous and local communities, adequate compensation to deforesters, and governance infrastructure to accomplish the task. Time delays caused by such issues are likely to be more critical in achieving significant avoidance of carbon reduction within a given time period than the transaction costs of overcoming these challenges.

However, programs are beginning in some countries to experiment with REDD-plus that should advance our thinking on what is required to undertake REDD-plus in a range of country settings, on what methods are needed and how to generate them, and on how to engage stakeholders so that they are active participants in the emerging REDD-plus country process. About 30 tropical countries are currently developing draft national plans to undertake studies, institutional arrangements, and governance work to lay a foundation for participation in any emerging post-Kyoto regime of positive incentives for REDD-plus. Presently, these countries are engaging in early consultations with key stakeholders on how REDD-plus Readiness should be undertaken, identifying key elements of programs or site-specific projects or policies that could slow drivers of deforestation and degradation. Preliminary costs of Readiness are contained in the country R-PPs, while program implementation costs and investment costs of large-scale REDD-plus programs are generally not yet known, although the latter are expected to be produced in the Forest Investment Program for about five to nine countries by around 2012.

New analyses are needed that (a) represent draft national programs to address REDD-plus, and reflect barriers and costs of implementation; (b) are spatially resolved, if feasible, to allow assessment of trade-offs across forest, agriculture, livestock, transportation infrastructure, urban expansion and other trends and sectors; (c) incorporate supply and demand for REDD-plus mitigation over time, based on feasibility of implementing REDD-plus programs differentially across countries and land use classes and governance regimes; and (d) reflect the major drivers of deforestation and degradation in given country socioeconomic and policy circumstances.

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Notes

[1] Some Forest Carbon Partnership Facility countries, the Democratic Republic of Congo for instance, have proposed that the national government will be the intermediary for all international carbon market transactions and carbon revenues will be shared with both public and private landowners.

[2] Managed and unmanaged forests are not treated separately in the deforestation component of the model.

[3] FAO data are uncertain but consistent, and since it is country–specific, it will help in the development of country-by-country evaluation of future scenarios.

[4] Cattle ranching occupied 60% of deforested land in 1990s. It varied from 80% in the 1980s to 65–70% in 2000–2005 (http://www.mongabay.com/brazil.html).

[5] Other values are not shown because the graph gets too occupied to decipher.

[6] Rose and Sohngen (2011) also model delays (and restrictions on eligible sequestration), finding large temporal leakage and reduced mitigation potential for REDD.