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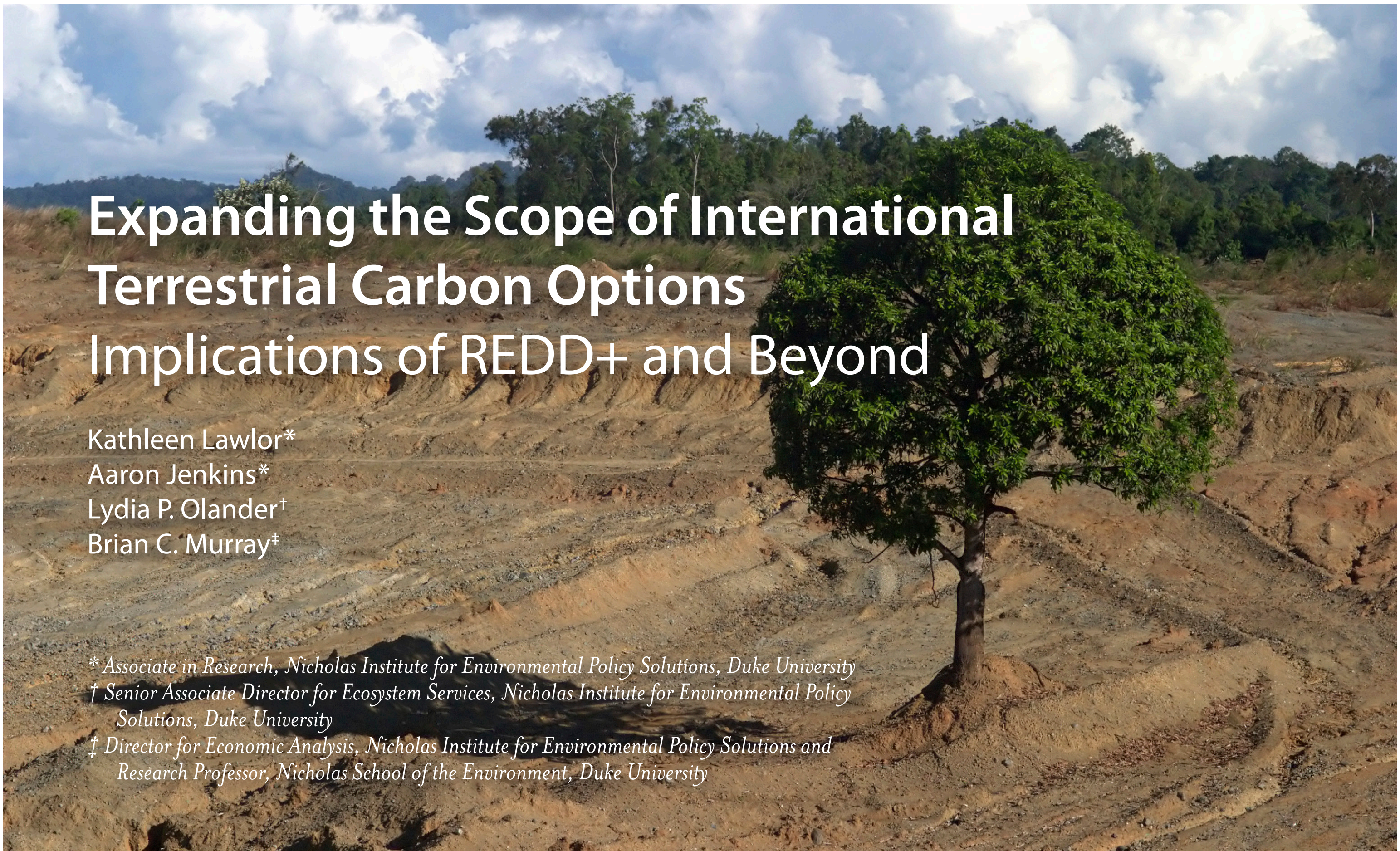

Expanding the Scope of International Terrestrial Carbon Options
Implications of REDD+ and Beyond

Kathleen Lawlor*
Aaron Jenkins*
Lydia P. Olander†
Brian C. Murray‡

** Associate in Research, Nicholas Institute for Environmental Policy Solutions, Duke University*
† Senior Associate Director for Ecosystem Services, Nicholas Institute for Environmental Policy Solutions, Duke University
‡ Director for Economic Analysis, Nicholas Institute for Environmental Policy Solutions and Research Professor, Nicholas School of the Environment, Duke University

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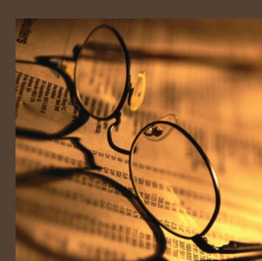

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[1] Associate in Research, Nicholas Institute for Environmental Policy Solutions, Duke University, USA, and corresponding author; klawlor@duke.edu.
[2] Associate in Research, Nicholas Institute for Environmental Policy Solutions, Duke University, USA
[3] Senior Associate Director, Ecosystem Services, Nicholas Institute for Environmental Policy Solutions, Duke University, USA
[4] Director for Economic Analysis, Nicholas Institute for Environmental Policy Solutions and Research Professor, Nicholas School of the Environment, Duke University, USA

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Executive Summary

Programs for reducing emissions from deforestation and degradation ("REDD") in developing countries through climate policy enjoy wide support. Indeed, this support is affirmed by the Copenhagen Accord, which notes the importance of reducing emissions and enhancing carbon removals in forests. And while important implementation details have yet to be decided, the Copenhagen Accord also pledges to immediately establish a mechanism and mobilize financial support from developed to developing countries to undertake such actions in their forests. By noting that this finance will support a "REDD+" system, the Accord also seems to support the notion of expanding the scope of land-use accounting and policy incentives beyond just reducing deforestation and degradation.

But what exactly does "REDD+" mean? Terminology is still evolving in the international forest and climate policy sphere and there is some confusion regarding terms commonly used to describe program scope. While "REDD+" is commonly used to describe programs that include activities additional to reducing deforestation and degradation, the specific activities it would encompass (and how the scope would differ from that of "REDD") remains unclear.

Activities that could come under the scope of a broader program include restoration and improved management of forests to enhance carbon stocks; reduced-impact logging; afforestation and reforestation; avoided conversion of peatlands, wetlands, and grasslands; and sustainable management of croplands and rangelands. Accounting for activities that manage or restore forests to increase carbon stocks is often described as "REDD+" and therefore somehow distinct from forest degradation (REDD) accounting. However, we note that because these activities require the same measurement and monitoring techniques and because forest regrowth starts as soon as degradation stops, it seems more appropriate to consider degradation and forest carbon stock enhancement accounting as two sides of the same coin. Yet here it is important to distinguish between restoration of degraded forests and tree-planting on nonforested lands. We also note the importance of considering programs that encompass activities in nonforest biomes, such as agricultural systems, wetlands, peatlands, and savannas. We therefore offer that it might provide more clarity to align program scope definitions more neatly with the four possible types of land uses and land-use changes that could be measured, and thus accounted for, in a system: (1) avoided conversion of forests to nonforests; (2) activities in forests remaining forests; (3) conversion of nonforest to forest and (4) activities in nonforest remaining nonforest.

Expanding scope to incentivize reduced emissions and increased sequestration across all terrestrial ecosystems could yield significant benefits to society in the form of climate change mitigation, given that land use contributes around 30% of global emissions. Expanding scope beyond deforestation should also create more opportunities to protect and restore ecosystem services and reduce poverty. However, in order to realize these benefits, we must acknowledge and address risks of nonnative species replacing natural forests, tree-planting leading to short-term carbon-water tradeoffs, and carbon interests overriding rural communities' traditional land tenure regimes. Potential impacts on carbon markets (e.g., concerns about terrestrial carbon offsets "flooding" cap-and-trade markets and devaluing allowances) will also need to be considered. Further, the rules governing expansion of scope beyond deforestation, and the sequencing of these scope changes, could have considerable influence on the overall environmental integrity of the system. How forests are defined—in terms of both crown cover and nativeness—also has important implications for ecosystem services, the climate, and biodiversity.

In this paper, we examine the implications of expanding the scope of carbon accounting on representative countries' crediting potential. We pay particular attention to the question of whether sequencing scope expansion in a phased manner, rather than bringing all terrestrial ecosystems and land uses initially under the purview of carbon accounting, complicates the system's ability to achieve optimal outcomes.

To illustrate how different countries might fare under different accounting scopes, we quantify crediting potential for selected countries that represent a range of circumstances (Brazil, Cameroon, the Democratic Republic of Congo, Ghana, Indonesia, and Peru). Crediting potential is presented both in terms of maximum biophysical potential and the amount of avoided emissions/sequestration we might expect to see at moderate carbon prices.

These examples highlight a few key points. First, estimating the crediting potential for activities in forests remaining forest (reduced degradation and enhancement of forest carbon stocks) at the country level is challenging due to a lack of data and systematic monitoring of carbon changes in forests. Current efforts to improve countries' forest carbon stock inventories will make future estimation easier. Second, some countries gain more than others from expanding the scope beyond deforestation, given differences in historical deforestation trends, forest carbon stocks and logging intensity, extent of nonforest areas, and agricultural practices. Third, if scope expansion is voluntary, then some countries may choose not to account for forest degradation if they find that the costs of reining in degradation activities (e.g., logging, fuelwood collection) outweigh the carbon revenues that could be earned from reducing these emissions. If accounting for changes in forest carbon stocks is not initially required or allowed to phase in voluntarily at a later program stage (as in current drafts of U.S. legislation), then this may create perverse incentives for degradation activities such as logging to *increase* during the early years of the program before they come under the accounting scope. Given that degradation emissions can be significant, those designing terrestrial carbon programs should carefully consider how to manage these risks. Finally, many countries have strong afforestation/reforestation (A/R) potential, thereby expanding economic opportunities for engaging in GHG mitigation, but also warranting careful attention to possible ecological and hydrological tradeoffs.

To assess the environmental integrity of the system and to lay the long-term groundwork for addressing the 30% of global emissions from land-based activity, the scope of land use/land-use change accounting should initially be as broad as possible. The IPCC provides guidance with tiered accounting approaches, which should allow all/most countries to provide at least rough estimates in a standardized manner. This can be implemented even if crediting methodologies and financial mechanisms initially address a more limited range of biomes (i.e., just forests). Policymakers therefore have some important decisions regarding: (1) the initial scope of the program; (2) whether scope expansion should be voluntary or binding; (3) the specific activities that constitute "REDD+"; in particular, the position of A/R; (4) if A/R is included, the specific rules that would govern its implementation; (5) how often baselines should be adjusted, and what reference years such adjustments should be based on; and finally (6) how forests are defined.

1. Introduction

Forest loss accounts for a significant share of global greenhouse gas (GHG) emissions. Recent estimates put the figure between 12% (van der Werf et al. 2009) and 17% (IPCC 2007a). Most of these emissions are due to the clearing of tropical rainforests in developing countries. Movement to include deforestation reduction efforts in climate policy has gained considerable traction since 2005, when the Coalition for Rainforest Nations proposed establishment of a mechanism called "Reducing Emissions from Deforestation in Developing Countries" the United Nations Framework Convention on Climate Change (UNFCCC). Since 2005, development of programs to reduce emissions from deforestation ("RED") through climate policy has advanced rapidly at the UNFCCC and at other governance bodies, such as the U.S. Congress. The general idea behind such programs is to address the challenge of global climate change while providing countries with positive financial incentives for reducing emissions from their forest sector.

1.1. Policy evolution: Moving from RED to REDD to REDD+ to AFOLU

Since 2005, there has been considerable interest in expanding the scope of RED beyond deforestation to also include incentives for reducing emissions from forest degradation (REDD) as well as preserving and increasing forest carbon stocks (some call this "REDD+"). Indeed, at the 13th Conference of Parties (COP) in 2007, parties committed in the Bali Action Plan (UNFCCC 2008) to work towards climate change mitigation efforts that include:

> Policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries.

The activities following the semicolon are commonly considered to be the "+" part of REDD+.[5] This push towards expansion of scope has gained considerable traction, enough so that the Copenhagen Accord uses the term "REDD+" (rather than "RED" or "REDD") to describe the international forest carbon policies under development at the UNFCCC. Further, the AWG-LCA text (UNFCCC 2009a)[6] released at Copenhagen (though still draft text under negotiation at this writing) seems to place the "+ activities" on equal footing with the "REDD activities" by listing the forest sector mitigation actions developing countries will take as follows:

> (a) Reducing emissions from deforestation;
> (b) Reducing emissions from degradation;
> (c) Conservation of forest carbon stocks;
> (d) Sustainable management of forest;
> (e) Enhancement of forest carbon stocks;

However, the term "REDD+" and the additional activities it is supposed to encompass ("…conservation, sustainable management of forests and enhancement of forest carbon stocks…") currently lack clear definitions and have contested meanings. On the technical side, it is debatable whether, given measurement and monitoring realities, accounting for reduced degradation can be done separately from accounting for enhancement of forest carbon stocks. Further, listing "conservation" as somehow distinct from activities that reduce forest loss is confusing since presumably conservation already falls within the scope of reduced deforestation and degradation programs. While inclusion of the word "conservation" here may be a call-out to those countries with little historical

[5] For example, this is the definition used in The Little REDD+ Book (2009) as well as in materials from the Terrestrial Carbon Group.

[6] "AWG-LCA" stands for the "Ad hoc Working Group on Long-Term Cooperative Action under the Convention." This UNFCCC body has been negotiating the text that would outline the policy architecture for a REDD/REDD+ system. The Subsidiary Body for Scientific and Technical Advice (SBSTA) is tasked with producing measurement and monitoring guidance for a REDD/REDD+ system at the UNFCCC. The SBSTA text released at Copenhagen (UNFCCC 2009b) also makes reference to stabilizing and enhancing forest carbon stocks, in addition to reducing forest emissions.

deforestation and degradation to reduce (e.g., Guyana), listing "conservation" here still seems superfluous since these countries could indeed receive incentives for forest conservation under a REDD policy (through either construction of forward-looking baselines that project future forest loss or extension of "leakage prevention" payments). Sustainable management of forests is a well-accepted principle in forestry, but it is somewhat unclear how this fits uniquely into the carbon context separately from reduced degradation and enhancement of carbon stocks. Finally, it is also not clear whether "enhancement of forest carbon stocks" includes afforestation and reforestation (A/R) along with activities that increase the carbon density of existing forests (since A/R involves the conversion of nonforests to forests).

On the political side, which activities would/should be eligible for REDD+ remains controversial. For example, some observers are concerned that conventional selective logging could be eligible, with some arguing that no logging activities, not even those using reduced-impact logging (RIL), should be eligible for REDD+ credits (Humane Society International 2009). There are also concerns that pursuit of carbon credits from a wider range of forest activities might lead to the conversion of natural forests into faster-growing tree plantations with corresponding loss of biodiversity. This concern stems from the fact that the definition of "forests" currently used by the UNFCCC makes no distinction between plantations and natural forests.[7] How A/R is treated is also a contested topic in the negotiations because if it does come under the purview of REDD+, then this would have implications for the Clean Development Mechanism (CDM), which currently oversees crediting for A/R. Many tropical forest nations have stated that a REDD+ mechanism should be in addition to and not compete with or limit the CDM (Papua New Guinea 2009).

More recently, many countries (developing as well as developed) countries, along with civil society observers and technical agencies, have been calling for the scope to be expanded beyond REDD+ to also include carbon and other GHGs on agricultural and other nonforest lands (Papua New Guinea 2009; FAO 2009; and Terrestrial Carbon Group 2008). Such expansion of scope is often referred to as "AFOLU" (Agriculture, Forestry, and Other Land Use). And while many parties note that agriculture can only be brought into the accounting scope once appropriate measurement and monitoring methodologies are developed, some parties, particularly African countries, are pushing for agriculture to be included in the post-2012 agreement (African Ministers of the Environment 2009) as this may provide their best opportunity for participation in land-based mitigation.

1.2. Why expand the program scope beyond deforestation?

Expansion of program scope beyond deforestation is critical for achieving climate goals. One reason is the matter of degradation (reduction in forest density), which produces significant carbon emissions. Because the UNFCCC defines "forest" as an area with minimum crown cover of 10%–30%,[8] forests can be significantly degraded (lose up to 90% of their crown cover) before they are considered "deforested." Forest degradation in the tropics is caused by selective logging, fuelwood collection, charcoal production, grazing, and fire (Murdiyarso et al. 2008). While systematic estimates of degradation emissions across countries do not exist,[9] one study found that accounting for selective logging in the Brazilian Amazon increases the region's forest sector emissions 25% beyond a deforestation-only estimate (Asner et al. 2005).

A second reason for broader scope is the potential for leakage, or the shifting of deforestation activities (e.g., cultivation of oil palm, soy; cattle ranching) and emissions to countries or nonforest biomes outside the scope of accounting and incentives provided by the program. Expanding the program scope to provide countries that have historically conserved or recently increased forest cover with incentives to continue such positive trends can help guard against leakage. And including wetlands, peatlands, and grasslands in the scope can help prevent

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[7] See Decision 11/CP.7 of the Marrakesh Accord (2002) and Decision 19/CP.9 regarding CDM forestry activities under the Kyoto Protocol (2004).
[8] See Decision 11/CP.7 of the Marrakesh Accord (2002).
[9] This is in large part because the UN Food and Agriculture Organization (FAO), which produces country-level estimates of deforestation, does not have an agreed-upon definition for degradation and thus does not ask countries to report on this type of forest loss.

deforestation drivers from simply shifting to these nonforest biomes (or at least ensure accounting of carbon emissions from any such land-use changes). The world's wetlands store significant amounts of carbon (202–535 gigatons[10] [Gt]) (Mittra et al. 2005), and half of the world's wetlands are reported to be in the tropics (Neue et al. 1998).[11] Tropical peatlands may contain as much as 2,850 tons of carbon per hectare (tC/ha) in the peat layer alone (Parish et al. 2008)[12]—vastly more than the 193 to 225 tC/ha stored in the biomass of tropical equatorial forests (IPCC 2006; Gibbs et al. 2007). Recently revised estimates of carbon emissions from forest loss and peatlands reveal that deforestation and forest degradation account for about 12% of global GHG emissions, and that when emissions from degraded Southeast Asian peatlands are considered, this share rises to 15% (van der Werf et al. 2009). Avoiding the draining of peatlands in such places as Indonesia and Malaysia is therefore important for reducing global GHGs.

A third reason for scope expansion is the potential to maximize the climate contributions from the land-use sector by not only reducing degradation emissions but also (a) increasing carbon accumulation in degraded forests through restoration; (b) increasing carbon sequestration through reforestation and afforestation; and (c) reducing emissions from agriculture, through agroforestry and other techniques. Agriculture accounts for about 10%–12% of global GHG emissions, with about 70% of the technical mitigation potential in developing countries (Smith et al. 2007). Reducing use of nitrogen fertilizers and reducing livestock herds and altering their feed offers climate benefits, but carbon sequestration in soils accounts for the vast majority (89%) of the technical mitigation potential in the agricultural sector (Smith et al. 2007).

Expansion of scope may also be critical to the success of reduced deforestation schemes. Because the world's population is increasing and demand for food and wood products will continue to grow, it will be hard to relieve pressure to clear forests unless societies find ways to increase the amount of food and wood that can be produced per unit of land area. There are also political benefits to expanding the scope of the program beyond deforestation, since this provides incentives for more countries—no matter their point on the forest transition curve or their forest type—to gain from inclusion of positive incentives to reduce emissions and/or sequester more carbon.

1.3. Just what is the "+" in "REDD+"?

In this paper, we discuss the impacts and implications of expanding the accounting scope beyond deforestation to other land uses. However, this discussion is complicated by ambiguous definitions for some terms commonly used to describe program scope. As noted, there is currently a lack of clarity and consensus surrounding the term "REDD+," including how this scope would differ from what is already covered by "REDD." Therefore, we seek clarity by using terms that distinguish scope by the four types of land use and land-use changes that could be accounted for in a program:

1) avoided conversion of forest to nonforest (or, avoided deforestation) (abbreviated as **RED**),
2) activities in forest remaining forest (abbreviated as **Forest→Forest**),
3) conversion of nonforest to forest (abbreviated as **Nonforest→Forest**), and
4) activities that reduce emissions or increase carbon stocks in nonforest remaining nonforest (abbreviated as **Nonforest→Nonforest**)

We show how the terms and definitions used in this paper to describe accounting scope stack up against the more commonly used terms and definitions to describe program scope in Figure 1. Ideally, each program scope term should neatly overlap with one or multiple accounting scopes, so that differences in the former are distinguished by

[10] The term *ton* (abbreviated *t*) as used in this report refers to the metric ton (1 ton [or *tonne*] = 1,000 kg = 2,204.62 lbs). Hence, the abbreviations *Mt* and *Gt* refer to the megaton (1 million metric tons) and the gigaton (1 billion metric tons), respectively.
[11] Estimating just how much carbon the world's wetlands store is complicated due to uncertainty over not only their carbon content, but also their area of distribution (Mittra et al. 2005). This latter uncertainty is due, in part, to different interpretations of what constitutes a "wetland." Mittra et al. (2005) note this is a particular problem for the tropics where the boundary between "wetland" and "peatland" is frequently blurred.
[12] The total carbon content of tropical peat forests (both the peat and the forest biomass) is, on average, 3166 tC/ha (Parish et al. 2008).

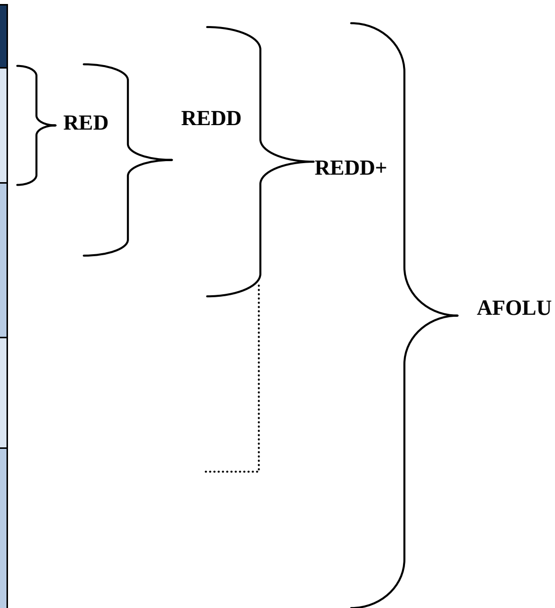
differences in the latter. However, as Figure 1 shows, there is some discordance here, revealing that clarity is needed regarding which land-use changes are included in the program scope terms commonly used. While the wording of the Bali Action Plan has led many to describe activities that sustainably manage and enhance forest carbon stocks as "REDD+," we find it somewhat contradictory to think of these activities as somehow under a different scope than those activities that reduce degradation. When measurement and monitoring realities are considered, avoiding degradation and managing/restoring carbon stocks in forests are really two sides of the same coin. These points have also been noted by Skutsch (2009). The scope of REDD+ is also confused by the ambiguous position of afforestation and reforestation, as the figure shows.

Figure 1. Land-use change accounting and common program scope terminology: Concordance and discordance.

Accounting scope:
Terms and definitions used in this paper

Land-use change accounting scope	Potential activities
RED (avoided conversion of forest to nonforest)	activities that avert deforestation
Forest→Forest (activities in forest remaining forest)	activities that avert forest degradation (e.g., RIL) and sustainably manage and enhance forest carbon stocks (e.g., restoration of degraded forests)
Nonforest→Forest (conversion of nonforest to forest)	afforestation and reforestation
Nonforest→Nonforest (activities that reduce emissions or increase carbon stocks in nonforests remaining nonforests)	improved agricultural and animal husbandry practices; avoided conversion of grasslands, wetlands, and peatlands

Program scope:
Commonly used terms



Further, it must be emphasized that incentives for conservation of forest carbon stocks in countries with low deforestation rates could be provided under any of these accounting scopes. Such incentives could take the form of crediting based on reductions below an established baseline. There has been much discussion about which baseline methods are most appropriate for determining compensable reductions in a REDD(+) scheme and it is beyond the scope of this paper to summarize that debate.[13] However, one approach consistent with compensating only real additional reductions relies on a projection of how much forest loss would occur in the absence of the program. Establishing such a baseline for countries that have no or little historical forest loss is tricky, but not impossible. Baseline methodologies that consider the forest stock, along with the historical and projected rate of forest loss, are one possibility (see Cattaneo 2009 and Strassburg et al. 2008). Baselines can also be established for these countries by modeling not only expected changes in in-country drivers of forest loss, but also the potential impact of REDD-induced leakage from other countries. "Stabilization" or "leakage prevention" payments are another possibility.

[13] See Griscom et al. (2009) for a quantitative comparison of some of the more widely discussed proposed baseline methodologies.

1.4. Three dimensions of program scope: Accounting, crediting, and financing

It is important to distinguish between the three elements of program scope—the extent of land uses and land-use changes (1) accounted for, (2) credited (e.g., against a baseline or reference scenario), and (3) financed through a climate program or market. A "one-size-fits-all" scope strategy is neither feasible nor necessarily desirable for all countries and all land uses. The accounting scope and crediting scope do not necessarily have to be the same and parallel financing mechanisms are possible.

For example, one possibility is to start with a system that requires broad accounting, encompassing biomass and soil pools, CO_2 and non-CO_2 GHGs in both forest and nonforest biomes in order to gauge total GHG impact of land use. However, the system might initially only measure, report, and verify (MRV) credits for carbon changes in forests, where measurement and monitoring methodologies are better developed and more certain. This may also occur if countries are free to select the scope of MRV/crediting and some determine that tracking only forests better serves their interests. Financial incentives could operate at a scope that is different from what is accounted and credited, in that what is paid for could be a subset of what is measured (or measurable). For example, a market mechanism could use land credits as part of a broader offset system or through a fund where compensated forest reductions are supplemental to developed country commitments. The decision regarding which land activities are included in the market or fund could either be determined by the central administrative authority (e.g., UNFCCC or a national government running its own emissions trading system) or could be left to the discretion of the forest countries supplying the credits. Countries with historically high deforestation rates may be able to demonstrate a high reference level of deforestation emissions and greater crediting potential in a market-based offset system for RED (as opposed to REDD or REDD+). Alternatively, countries with historically low deforestation rates may find themselves in a better position to seek a fund-based mechanism that compensates for stabilization and enhancement of all forest carbon stocks. In such a system, avoided emissions and enhanced carbon sequestration in nonforest biomes could still be incentivized directly through a fund-based mechanism focused on leakage prevention or indirectly by discounting a country's forest sector credits for any observed or estimated leakage driven to nonforest areas. Once measuring and monitoring methodologies for changes in nonforests improve, these activities could be credited at a greater level, through either fund or market mechanisms.

2. Potential Impacts of Scope Expansion on Ecosystems, Rural Populations, and Carbon Markets

2.1. Potential impacts on ecosystems and rural populations

Programs that widen the scope beyond RED may produce both positive and negative social and ecological impacts, with varying implications for communities' climate change adaptation capacity.

2.1.1. Activities in forest remaining forest (Forest→Forest)

Activities that reduce forest degradation typically have positive ecological impacts. For example, RIL techniques harm fewer trees than conventional logging and when they seek to minimize the impact of roads and skid trails they can reduce erosion, avoid harming watersheds, and protect biodiversity by avoiding wildlife corridors (Putz et al. 2008). However, some fear that if logging activities are able to receive credits for managing and enhancing forest carbon stocks, then forest managers may apply treatments to suppress the growth of small tree species and non-arboreal plants (e.g., lianas), thereby reducing floral diversity and threatening the fauna that depend on these plants (Putz and Redford 2009).

Crediting for reduced degradation and forest enhancement would create new development opportunities for the dry tropics, where many poor live (Skutsch 2009; Campbell 2009). Positive social impacts could result if communities are involved in and benefit from activities to restore and manage forests that have been degraded through shifting agriculture, fuelwood collection, and charcoal production. However, if states try to reduce degradation by limiting small-scale fuelwood collection and agricultural activities, and do not provide rural communities with adequate compensation or assistance in developing alternative energy and livelihood strategies, these same communities could be harmed.

2.1.2. Activities that convert nonforest to forest (Nonforest→Forest)

Afforestation and reforestation (A/R) have potential for both positive and negative ecosystem impacts as well. Impacts will largely depend on (1) whether the tree-planting is done on lands that were originally forested, lands that have been converted to agriculture, or on natural grasslands and (2) whether a diverse mix of native species or a monoculture of native or introduced species is used. In general, A/R could potentially yield long-term benefits for regional hydrology if the newly forested areas attract precipitation (McAlpine et al. 2007; Makarieva et al. 2009). And conversion of agricultural lands to forest may improve water quality by reducing fertilizer use and thus nutrient loading (Pattanayak et al. 2005). Further, tree planting on degraded lands can reduce erosion, protect watersheds, and increase biodiversity—if a diverse mix of species is used (IPCC 2000). But when the species are nonnative, planted in a monoculture, and grown on grasslands, risks of negative impacts on hydrological systems and biodiversity are high. While tree plantations can increase groundwater recharge, they can reduce stream flow considerably and increase the acidity of soils and stream water (Jackson et al. 2005; Jobbagy et al. 2006). Afforestation in dry regions using nonnative species can yield even more severe hydrological impacts. For example, grassland plantations of eucalyptus, a popular nonnative plantation tree in many parts of the dry tropics, has been found to reduce runoff by 75% and in some cases dry up streams completely (Farley et al. 2005; Jackson et al. 2005).

Where A/R activities do not harm ecosystem services and are implemented with the informed participation of rural communities as project beneficiaries, such activities could advance development objectives by creating sustainable wood energy supplies and new revenue streams. But large-scale tree-planting projects could also have negative social impacts. First are risks to both urban and rural communities of decreased water supplies, which will already be stressed due to climate change. Second are risks to rural communities of displacement, given that many may not possess legal ownership or management rights to lands they have customarily occupied and used. Traditional agricultural practices often involve rotating crops between parcels of land, with tired land left fallow for 20-40 years. Such lands may appear to be "unused grasslands," and if taken over for tree plantations, land-use conflicts and food security problems could result.

Ensuring that A/R activities work for ecosystems and people may be essential for taking pressure off of natural forests, and thus realizing deforestation and degradation emissions reductions.

2.1.3. Activities in nonforest remaining nonforest (Nonforest→Nonforest)

A wide range of activities could be undertaken to avoid emissions from and enhance sequestration in landscapes outside forests, many of which could yield positive impacts on ecosystems. In agricultural lands, activities that avoid N_2O emissions by reducing or making more efficient use of nitrogen fertilizers and other agricultural chemicals should also improve water quality (Pattanayak et al. 2005). Agroforestry systems that use leguminous species can decrease fertilizer need by 75%, while doubling crop yields (Sileshi et al. 2008), storing significant amounts of carbon, and benefiting biodiversity (Swallow et al. 2007). Further, planting tree species commonly used for fuelwood and construction on farms and household lots can help relieve forests from harvesting pressure.[14] Improving pasture management to reduce the area subject to grazing, burning, and soil compaction by cattle can not only decrease emissions but also fight desertification (Smith et al. 2007), reduce erosion, and encourage biodiversity. And protecting wetlands mitigates flooding and maintains water quality and biodiversity.

Potential for the rural poor to benefit from carbon activities on nonforest lands is high since so many in these communities are engaged in agriculture. Further, activities that enhance the resiliency of farms to adapt to a changing climate could yield high human adaptation benefits, given that those dependent on rain-fed agriculture, particularly in Africa, are predicted to be especially hard hit by reductions in precipitation (IPCC 2007b). Activities to address overgrazing could benefit rural livelihoods as well, especially where farmer-grazer conflicts are escalating. However, the potential for the poor to tap into new revenue streams for sustainable agriculture may be limited by economic realities: if the transaction costs for dealing with large numbers of smallholders are too high, large agricultural operators may attract most of the carbon investment.

2.2. Potential impacts on carbon markets

2.2.1. Concerns about market flooding

Inclusion of offsets in a cap-and-trade regime can help lower overall GHG mitigation costs. Early estimates (such as those from the 2006 Stern Report) showing that emissions from tropical forests could be reduced at a much lower cost than reductions in other sectors attracted much interest in including RED offsets in climate policies. Some have expressed concerns that the supply of RED offsets could be so large and so cheap that these credits would flood the allowance market, weakening the carbon price signal and discouraging or deferring development and deployment of clean energy technologies in other sectors. These concerns may heighten should there be an expansion in program scope, and thus in *potential* offset supply. However, these concerns may be overstated. First, implementing RED will likely be much harder and more expensive than initial estimates suggested, both because of shortcomings in the methodologies and a lack of institutional infrastructure to deliver the reductions. Second, recent studies find that investment in energy intensity R&D would decline only 8%–10% when either RED offsets or RED plus other forest carbon offsets are included (Tavoni et al. 2007; Bosetti et al. 2009). In either case, the majority of long-term abatement in developed countries meeting stringent targets would still come from other sources in the energy and industrial sectors (Murray et al. 2009). Third, flooding concerns can be addressed by policy design. For example, increasing the offset supply could be matched by a commensurate tightening of the cap. Placing quantitative limits on offsets is also an option; this is the approach taken in the climate bill passed by the U.S. House, which limits international offsets to 1–1.5 billion tons CO_2e annually.

[14] Many smallholders in the developing world already practice agroforestry to some extent, by planting and maintaining trees on their farms and household lots (Zomer et al. 2009). Because agroforestry involves the planting of trees on nonforests lands remaining nonforest, it is not entirely clear whether carbon incentives for expanding agroforestry practices would be part of a REDD+ system, or if they would only become creditable activities if the scope is expanded to AFOLU.

2.2.2. Competition between forest conservation and other land-use activities

There is some risk that including nonforest lands in the program could attract investment away from forests. While forests suffer from open-access problems and tenure is often unclear, croplands are by definition managed and may thus be more attractive to investors. Large international firms have recently been acquiring vast tracks of agricultural land in developing countries (Cotula et al. 2009) and investors may find that engaging in carbon deals on these lands carries less risk and is more cost-effective than engaging numerous smallholders in forest-agricultural mosaics. However, forests may still be more attractive due to their high carbon content. The mitigation potential in the forest sector (RED, A/R, and sustainable forest management) is estimated to be 2.4 to 3.4 times greater than in agriculture in 2030 (IPCC 2007a). But since afforestation would generally take place on agricultural land, such tree planting could draw investment away from protection of natural forests.

3. Measurement and Monitoring Requirements for Each Accounting Scope

As the scope expands to encompass more land-use changes and activities, countries' overall crediting potential will increase. The measurement and monitoring requirements for each accounting scope are detailed in Table 1. For each land-use change activity group, data on area change and emissions/removals factors (carbon stocks) will be required. But getting accurate data on these two components will be more difficult for some land-use change activity categories than others. Therefore, establishing baselines as well as measurement and monitoring will be more challenging (and more expensive) for some activities. Measurement and monitoring for RED and A/R can be done now, though both the area change and forest carbon stock estimates for RED could be improved for many countries (UNFCCC 2009). Measuring and monitoring degradation and other activities in forest remaining forest is more complicated, given the lack of data on historical degradation trends and the need for forest carbon stock estimates that are more precise (IPCC Tier 2–3)[15] than what is currently available for most countries. Measurement and monitoring tools for agriculture and other activities in nonforests are not as advanced but are being developed by various organizations.

Efforts are currently under way in many countries to improve forest carbon stock estimates. New techniques for measuring forest carbon stocks remotely are also developing rapidly. Researchers at the Carenegie Institution for Science's global ecology department in Stanford, California, for example, are developing techniques that combine satellite imagery with laser-based LIDAR instruments to map and detect changes in forest carbon stocks. These techniques would improve not only the precision of current forest carbon stock estimates, but would also facilitate regular monitoring of changes in forests remaining forests by replacing the laborious measurement of trees in numerous plots that is now required with analysis of satellite and LIDAR imagery. The researchers plan to make the software they have developed freely available for countries to use, and employing it currently costs as little as 10 cents per hectare (Tollefson 2009).

[15] According to the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (2003), IPCC Tier 1 methods are simplest and produce crude estimates by using available default values to estimate carbon stocks. IPCC Tier 2 methods are similar, but produce estimates that are a bit more precise because they use default values that are country-specific. IPCC Tier 3 methods are more complex, and the most precise, using models to with country-specific parameters to estimate forest carbon stocks.

Table 1. Measurement and monitoring requirements for different accounting scopes.

Land-use change accounting scope	Potential eligible activities	Measurement and monitoring requirements
RED (avoided conversion of forest to nonforest)	activities that avert deforestation	area change: remote sensing, aerial photography, or ground inventories C stock: can be done initially with IPCC Tier 1 default values, but estimates will be uncertain and inaccurate; to improve estimates and move to IPCC Tier 2–3 (UNFCCC 2009), countries can undertake ground-based inventories using stratified sampling approach based on forest type or use new techniques (satellite + LIDAR)
Forest→Forest (activities in forest remaining forest)	(1) activities that avoid or reduce degradation: reduction in area planned for logging, reduction in area affected by fuelwood harvesting, use of reduced-impact logging techniques (2) activities that restore degraded forests	area change: remote sensing can track logging; other degradation activities may require ground-truthing, though new satellite + LIDAR techniques may work as well C stock: requires IPCC Tier 2–3 level estimates and regular inventories; ground-based measurements will likely be required for measuring regrowth in degraded forests
Nonforest→Forest (conversion of nonforests to forests)	afforestation and reforestation	area change: remote sensing, aerial photography, or ground inventories C stock: established estimates for carbon accumulation by species, though missing allometric equations for many species
Nonforest→ Nonforest (activities that reduce emissions or increase carbon stocks in nonforests remaining nonforests)	(1) no/reduced till, agroforestry, other improved agricultural and animal husbandry practices (2) avoided conversion of wetlands, savannah, and peatlands	area change: remote sensing can track some land-use changes now (e.g., savanna burning) and approaches are under development for other nonforest activities (e.g., certain agricultural practices) C stock: uncertainty remains regarding the carbon effects of many changes in practices, as well as the depth of the soil profile that should be considered in these estimates other GHGs: estimates exist for some practices (e.g., N_2O emissions from fertilizer application) but substantial gaps and uncertainty remain

4. Implications for Crediting Potential and the Accounting System

4.1. Shifts in baselines and crediting potential as scope expands

As more land uses are brought into the scope of accounting and incentives, countries' overall crediting potential will increase. We use the term "crediting potential" to describe the absolute biophysical potential, though clearly, for economic reasons, realizing this full potential may be infeasible. We discuss these economic factors further below.

For activities that involve emissions reductions (such as avoided deforestation), maximum crediting potential will usually equal the baseline (the threshold under which emissions must be reduced) that is agreed upon by parties. In general, baselines are supposed to reflect a counterfactual scenario (the amount of emissions that would occur in the absence of new conservation incentives). Baselines may be based on simple extrapolation of historical emissions trends (assuming they are expected to continue) or on forward-looking projections, where projected changes in deforestation and degradation drivers are considered to model or estimate future forest loss rates. Baselines may also be influenced by policy decisions that mandate certain changes. For example, draft U.S. climate legislation requires that countries have declining baselines in order to earn credits so that forest loss does not simply get pushed off into the future (American Clean Energy and Security Act 2009). Baselines may also take into account the existing forest stock in countries, as in the "Stock-Flow" methodology proposed by Cattaneo (2009) and the "Combined Incentives" methodology proposed by Strassburg et al. (2008). By establishing a global deforestation reduction goal and weighing each country's slice of the pie by its forest carbon stock, these approaches would increase the crediting potential for those forest countries with low historical deforestation rates (e.g., Guyana), while decreasing the crediting potential of those countries with historically high deforestation rates (e.g., Indonesia). Crediting potential for low deforestation rate countries may also not be determined by projecting forward-looking, stock-weighted baselines, but by some other process.

It has been noted that establishing baselines for activities in forest remaining forest (avoided degradation and restoration of carbon stocks) is not possible for many countries, since a lack of data on historical trends precludes both business-as-usual projections as well as modeling future trends (Skutsch 2009). This is not necessarily a problem, as accounting for changes in forest remaining forest is primarily a matter of measurement and monitoring, and therefore, will be dealt with by improving countries' forest carbon stock estimates and regularly updating inventories. Accounting for changes in forests' carbon stocks will require that they are estimated at both time 1 (T_1) and time 2 (T_2) so that the change in carbon density becomes a variable rather than a fixed factor. This is represented by the following equation:

$$\textit{Net Emissions} = [\textit{Forest Area } (T_1) \times \textit{Forest Carbon Stocks } (T_1)] - [\textit{Forest Area } (T_2) \times \textit{Forest Carbon Stocks } (T_2)]$$

A positive change indicates net GHGs emitted, while a negative change indicates carbon sequestered. Calculating emissions from forest loss in this way, instead of using default carbon stock estimates, would automatically expand the accounting scope beyond deforestation only to also encompass changes in forest remaining forest (Gibbs et al. 2008).

For activities that increase carbon sequestration by converting nonforest to forest (that is, A/R), determining crediting potential can be a bit more complicated. As a starting point, one can estimate A/R's maximum crediting potential as the carbon removals that would occur if all nonforest lands were converted to forests. This maximum biophysical estimate then needs to be pared back in accordance with policy rules (i.e., in order to be eligible for a CDM reforestation project, the land must have been converted from forest to nonforest prior to 1990) and also to reflect economic and institutional constraints, which make conversion of all eligible nonforest lands to forests infeasible. Further, notions of additionality and baselines may apply to A/R as well (e.g., rules may only credit tree planting that is above and beyond "common practice," trees that would have been planted anyways), which would further reduce estimates of A/R crediting potential. However, any such additionality tests for country-level A/R crediting are not yet certain and current and projected business-as-usual (BAU) levels of A/R may be so low that subtracting out "BAU" A/R would not significantly alter estimates of A/R biophysical and economic potential.

Before examining a quantitative example of how scope expansion will affect countries' crediting potential, it is important to note that in reality, economic factors will constrain how much of the biophysical crediting potential is actually realized. While the crediting potentials shown below may present countries with significant revenue generation opportunities, countries will weigh these benefits against the costs of implementing the emissions reduction or carbon sequestration activity. These costs will include opportunity costs, the costs of measuring and monitoring, other transaction costs, and management costs. Costs will vary amongst countries. It is beyond the scope of this paper to compare these costs and benefits for each country, but where costs are high, most biophysical potential will not be realized unless carbon prices are also high. Institutional factors will limit the realization of this full biophysical potential as well.

4.2. Shifts in crediting potential as scope expands: Quantitative examples

4.2.1. Maximum biophysical crediting potential

In order to compare how different countries might fare under different accounting scopes, we provide *very coarse estimates* of the absolute crediting potential for selected countries under accounting scopes that include (1) just RED; (2) RED as well as activities in forest remaining forest (Forest→Forest); and (3) RED as well as Forest→Forest activities plus conversion of nonforests to forests (Nonforest→Forest). These are first-order estimates of the maximum biophysical potential for each scope, under the assumption of very high carbon prices. Our examples do not extend coverage to the crediting potentials for activities in nonforests remaining nonforests (AFOLU). While estimates of crediting potential in the agricultural sector do exist at the continental level (see Smith et al. 2007), reliable country-level estimates are more difficult to come by. The EU Joint Research Centre's EDGAR Emissions database provides estimates of agricultural and savanna-burning emissions at the country-level,[16] but these sums do not include the potential that may be realized through activities that increase carbon sequestration in soils, which could be substantial.

In order to reflect an array of country circumstances, we selected six forested countries that represent divergent historical land-use change trajectories, using the categories developed by The Nature Conservancy and TerraCarbon (2008): (1) Peru, a High-Forest Low-Deforestation (HFLD) country; (2) the Democratic Republic of the Congo (DRC) and (3) Brazil, both High-Forest Medium-Deforestation (HFMD) countries; (4) Indonesia, a High-Forest High-Deforestation (HFHD) country; (5) Cameroon, a Medium-Forest Medium-Deforestation (MFMD) country; and (6) Ghana, a Low-Forest Low-Deforestation country.

The average annual crediting potential is shown (in $MtCO_2e$) for each country in Figures 2 and 3 as follows:

RED: Avoidance of 100% of annual deforestation emissions, estimated using the product of:

- Area change: average forest area lost annually between 2000 and 2005, as reported by FAO (2006)
- Carbon stocks: region-specific average of IPCC's (2006) regional-level forest biome estimates of above- and below-ground biomass (soil carbon not included)

Because remote-sensing studies' estimates of historical area change differ from those of FAO and are likely to be more accurate, we also estimate what RED potential might be for Brazil according to the area change reported in a study by Hansen et al. (2008b). We combine Hansen et al.'s (2008b) deforestation area estimates with the carbon stock estimates used in our calculated examples. Availability of data in the literature on both deforestation *and degradation* emissions limits this comparison of methods to just Brazil.

[16] Data available at http://edgar.jrc.ec.europa.eu/index.php.

Determining which forest carbon stock estimates to use for countries is tricky. A wide range of biome-specific carbon stock estimates exist. These estimates can be combined with maps of vegetation type to develop country-level estimates. However, these estimates don't capture variations within biomes or the extent to which forests have already been degraded. Until ongoing efforts to improve countries' forest inventories are complete (and sustained to capture changes in biomass over time), carbon stock estimates will simply have a high degree of uncertainty. Whether (and how much) soil carbon is included in the estimates makes an important difference as well. When soil carbon is included, estimates of forest carbon stocks are considerably higher (see Table 2); this is particularly true for Southeast Asian peat forests.

Table 2 shows the regional forest carbon stock estimates used in this paper to calculate deforestation emissions. Gibbs et al. (2007) convert biomass estimates from IPCC (2006) to come up with carbon stock estimates for each tropical forest biome (equatorial, seasonal, dry) for each region (e.g., sub-Saharan Africa, Latin America). In this paper, we use a simple average of the Gibbs et al. (2007) carbon stock estimates for the three tropical forest biome types for each region. To show the range of possibilities, we also include in this table some of the forest carbon stock estimates presented in other sources and policy proposals.

Table 2. Forest carbon stock estimates (tC/ha).

Estimates used in this paper to calculate deforestation emissions

Source		Sub-Saharan Africa	Latin America	Insular Asia	Soil carbon included?	Comments
Gibbs et al. (2007)	Tropical equatorial	200	193	225	NO	biomass values reported in IPCC (2006), Table 4.7, converted to carbon stocks
	Tropical seasonal	152	128	169		
	Tropical dry	72	126	96		
	Average (applied in this paper)	**141**	**149**	**163**		

Estimates from other sources and policy proposals (not applied in this paper)

Source		Sub-Saharan Africa	Latin America	Insular Asia	Soil carbon included?	Comments
Gibbs and Brown (2007a 2007b)	Tropical equatorial	99	–	164	NO	takes into account land use and population to estimate anthropogenic degradation
	Tropical seasonal	38	–	142		
	Tropical dry	17	–	120		
Terrestrial Carbon Group (2009a)		186	194	206	YES (25%)	25% of soil carbon projected to be emitted during deforestation
Interim Financing Proposal (2009)		countries with mainly moist forests = 100 countries with mainly dry forests = 60			NO	conservative default values proposed for early efforts only, while measurement and monitoring capacities and the accuracy of estimates improves

Forest→Forest: Avoidance of 100% of net annual degradation emissions associated with legal logging using conventional logging techniques, estimated using:

- Area change: 1/30th of the natural forest area zoned for logging in 2005,[17] as reported by ITTO (2006), assumed logged each year
- Carbon stocks: region-specific per-hectare estimates of conventional logging net emissions, developed by Putz et al. (2008)

Putz et al. (2008) derive annual emissions estimates for conventional logging by modeling the net emissions that would occur over a 30-year time period, which is the typical logging cycle in the tropics. It is important to note that these are the *net* (rather than *gross*) emissions associated with legal logging potential; that is, these estimates account for the carbon that trees sequester during regrowth. Because the Putz et al. estimates are specific to a 30-year time period, we assume that 1/30th of the area zoned for legal logging is harvested each year.

Table 3 shows the estimates of carbon stocks lost during conventional logging versus reduced-impact logging (RIL). Only the estimates for conventional logging are used here to estimate biophysical potential; the RIL estimates are applied later in section 4.2.4. Economic crediting potential

Table 3. Estimates of net carbon lost during logging: Conventional vs. reduced-impact techniques (Putz et al. 2008).[18]

Region	tC/ha (over 30 years)	
	C loss due to conventional logging	C loss due to reduced-impact logging
Sub-Saharan Africa	19	12
Latin America	19	12
Asia	108	78

We also show estimates of degradation emissions for Brazil using numbers reported in a remote-sensing study by Asner et al. (2005). These estimates reflect observed historical emissions, whereas our estimates use the area currently zoned for logging to project how much logging we might expect to see without a carbon policy. The remote-sensing estimates also have the advantage of capturing both *legal and illegal* logging, whereas our projections estimate only possible future *legal* logging.

Nonforest→Forest: Average amount of carbon sequestered annually if 100% of land eligible for A/R is planted over 30 years, estimated using:

- Area change: country-specific A/R eligible area estimates developed by Zomer et al. (2008b), where 1/30th of area is assumed to be planted each year
- Carbon stocks: for simplicity, 100tC/ha used for all countries, where the 100tC is assumed to accumulate linearly over 30 years[19]

Zomer et al. (2008b) estimate the amount of land available in each country for CDM A/R projects by considering various biophysical factors and policy constraints. They deem land unsuitable for A/R if it is too high, too dry,

[17] The ITTO report provides the most up-to-date zoned area data that was available at the time of publication. Most data is from 2005, and the rest from within a few years of 2005.

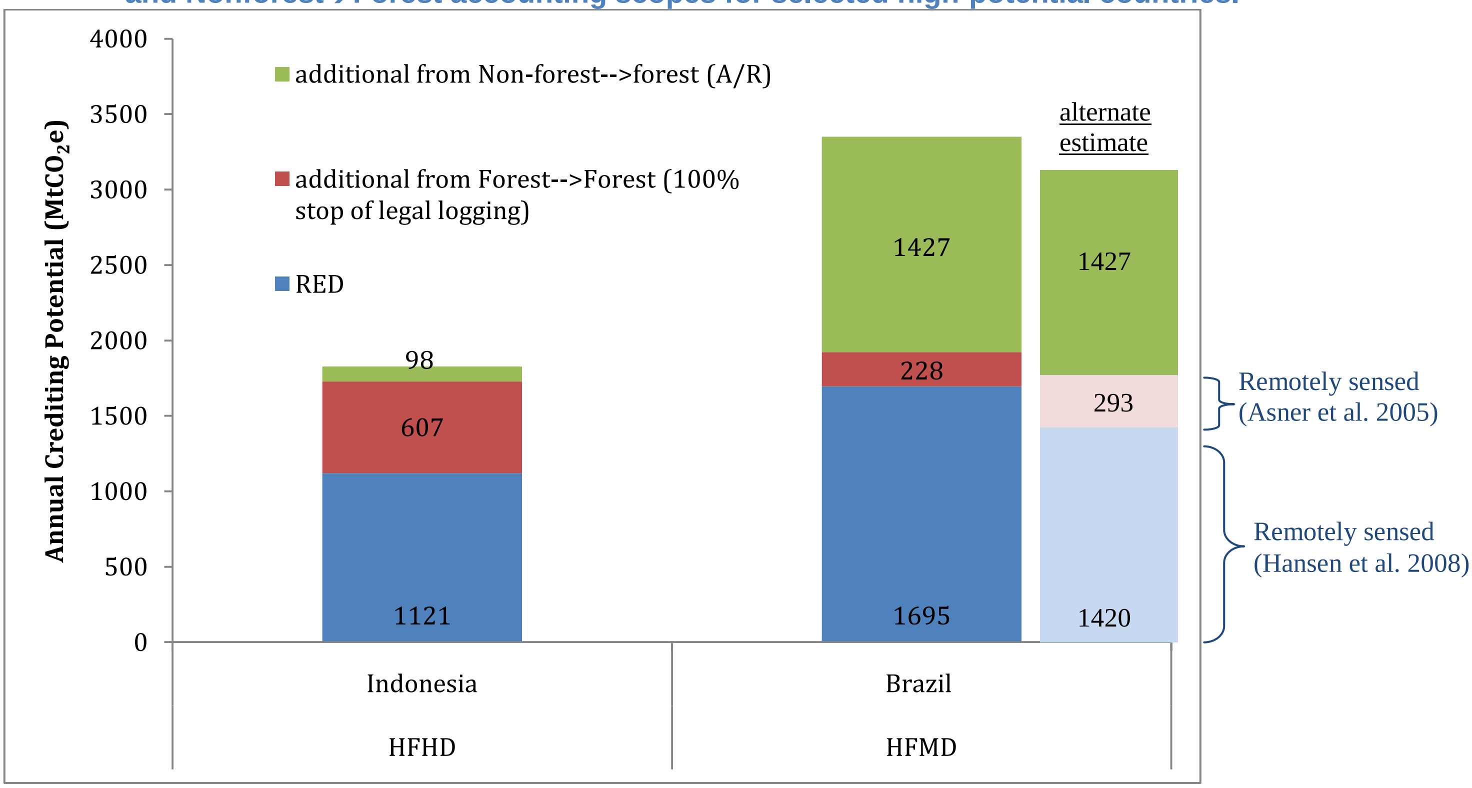
[18] These estimates are based on field data collected in Para, Brazil and Sabah, Malaysia. Data was modeled to estimate conventional logging emissions, assuming 30-year logging cycles and factoring in regrowth. The Sabah estimates are applied to Asia; the Para estimates are applied to both Latin America and sub-Saharan Africa, since forest biomass and timber densities are similar on the two continents.

[19] Accumulation of 100tC/ha over 30 years (3.33 tC/ha/year) is a conservative estimate. A/R projects certified by the Climate, Community and Biodiversity Alliance standard project accumulation of ~125tC/ha for reforestation plots in both dry and humid ecosystems in Nicaragua. Zomer et al. (2008a) report that 4–8tC/ha/year is the average of estimates of tropical tree plantation carbon accumulation rates found in the literature.

classified as an urban area, irrigated or under intensive agricultural production, or if the land was converted from forest to nonforest after 1990 (per CDM's exclusion rule). Zomer et al. also considers the forest definition used by countries, since countries can choose how much remaining canopy cover (anywhere between 10% and 30%) defines a land as "forest" and this affects how much land is available for A/R. For the countries considered in this paper, Peru, DRC, and Brazil have all chosen 30% as their minimum crown cover; Ghana 15%; Indonesia and Cameroon have yet to indicate. We use the tree cover percentages elected by the countries and assume that Indonesia and Cameroon each choose 30%.[20]

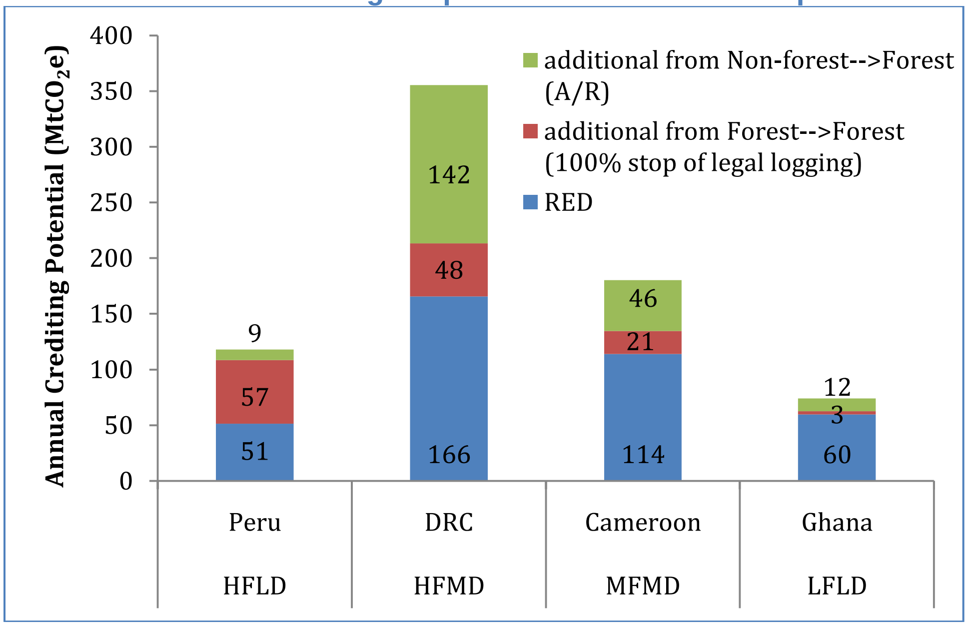
Since A/R projects frequently estimate their carbon accumulation over a period of 30 years, we also consider a 30-year time period and assume that countries plant about 3% of their available area each year. These sums are then annualized.

Figure 2. Maximum biophysical crediting potential for RED, Forest→Forest, and Nonforest→Forest accounting scopes for selected high-potential countries.



[20] Forest definition parameters of participating countries are available at http://cdm.unfccc.int/DNA/index.html.

Figure 3. Maximum biophysical crediting potential for RED, Forest→Forest, and Nonforest→Forest accounting scopes for selected medium-potential countries.



Figures 2 and 3 present our estimates for biophysical potential by program scope for the highest-potential countries (Brazil and Indonesia) and the medium-potential (remaining) countries in our sample. Before proceeding with a discussion of these results, we introduce a number of caveats to consider.

4.2.2. Caveats and assumptions

It is important to emphasize that the intent of Figures 2 and 3 is to facilitate comparisons of circumstances across countries and accounting scopes, rather than develop precise estimates of crediting potential. In order to make these comparisons, we use data from studies that present their analysis in a consistent fashion across countries. However, these data sources are likely *not* those that will be used to construct countries' actual emissions reference scenarios. Further, to develop our simple comparison scenario, we make certain assumptions that may not necessarily hold in reality. A few caveats are therefore in order.

First, for RED, remote-sensing studies have revealed that the deforestation area estimates reported by FAO greatly overstate forest loss for many countries (Achard et al. 2002; Hansen et al. 2008b; van der Werf et al. 2009). Therefore, our use of FAO area change data may lead to overestimates of RED crediting potential. On the other hand, our use of conservative emissions factors that do not include soil carbon may lead to underestimates. It is also important to note that RED baselines (and thus potential) may be informed by historical data, but not necessarily wed to it (as assumed in our analysis), as baselines may be established by modeling projected future relationships between deforestation drivers and forest loss and may take into account countries' existing forest stocks.

Second, for the Forest→Forest accounting scope, the proxy we use to estimate crediting potential (net emissions from conventional logging) is likely a serious underestimate of the emissions reductions and carbon removals that could result from the numerous activities that could take place in forest remaining forest. Our numbers account only for emissions from *legal* logging and exclude such other important sources of degradation emissions as *illegal* logging, small-scale agriculture and understory fires, fuelwood collection, and charcoal production. Our estimates also exclude the crediting potential that could be realized by restoring degraded forests. Including estimates for these other sources of emissions and removals is precluded by a lack of data. Estimates of illegal logging vary and are subject to considerable uncertainty, but the problem is believed to be significant. According to one report, illegal logging accounts for 85% of the wood harvested in the Brazilian Amazon, 51% in Indonesia, 50% in Cameroon, and 34% in Ghana (Smith 2002). While we aim to control for bias by using a proxy indicator of degradation that underestimates REDD potential across countries in a *consistent* fashion, our proxy is still biased if one of the excluded emissions sources is a more important emissions source in one country than in another. For example, because we know that small-scale agriculture and fuelwood activities are more widespread in the Congo Basin forests than in the intact parts of the Amazon (Hansen et al. 2008a; Zhang et al. 2005), our proxy may be downwardly biased for DRC and Cameroon.

Third, for our Nonforest→Forest estimates, it is important to note that countries may not actually plant trees on all hectares eligible for A/R. The biophysical potential may be limited by additional policy rules not considered in our analysis as well as the economic factors addressed further below. For example, the CDM currently allows A/R to account for no more than 1% of total certified emissions reductions; one study finds that if this cap remains, then A/R will be limited to just 2% of its biophysical potential (Zomer et al. 2008a). Further, realizing the maximum biophysical potential for A/R is likely not desirable, as it will significantly reduce runoff and disrupt hydrology in the more arid areas and grasslands (Trabucco et al. 2008). It is also important to note that the carbon gains occur less quickly for A/R than they do for activities that reduced emissions, like avoided deforestation and degradation activities. While emissions can be stopped as soon as the activity begins (though not to say that takeoff and implementation will be easy), accumulating carbon in planted trees takes time—not just for the trees to grow, but also to plant the trees. We account for this progressive accumulation by assuming that just 1/30th of the total carbon that could be sequestered over 30 years is sequestered each year. Though, in reality, planted trees do not accumulate carbon in a linear fashion. Rather, carbon accumulation tends to be low in the early years within the first decade, grows exponentially higher after that, and then tapers off as forests approach their biological maximum. Depending on the species, however, this biological maximum may be well after 30 years.

Lastly, the carbon stock estimates could be made more precise for all of the accounting scopes considered. For RED and activities in forest remaining forest, site-specific forest inventory data could be used. For A/R, use of species-specific estimates that account for variability in growing conditions across sites within a country would yield more realistic estimates of A/R crediting potential. The Appendix describes in further detail the data and methods used to produce the figures in this paper.

4.2.3. Discussion: Biophysical potential

Caveats aside, our analysis finds about 50% of total crediting potential for all countries in our sample coming from RED. As expected, the analysis shows crediting potential increasing for all countries as the land use accounting scope expands, with Brazil having the highest potential in each scenario. However, some countries benefit more in relative terms than others from policy expansions past RED. For instance, as the scope expands to include activities in forest remaining forest, Peru’s crediting potential more than doubles and Indonesia’s increases by over 50%, while also netting the largest absolute gain among the countries. In Peru, the strong gains are due to a low historical deforestation rate, contributing to a low crediting potential for avoided deforestation, as well as to the relatively large amount of the country’s forests that are zoned for logging. In Indonesia, the large increase is heavily influenced by the emissions factors, as the per-hectare emissions from logging are about six times greater in Asia than in Latin America (108 vs. 19 tC) due to the greater abundance of commercial timber trees per hectare and, to a lesser extent, the higher carbon stocks of these forests (Putz et al. 2008). This means that while Brazil has twice as much area zoned for timber as Indonesia, potential emissions from legal logging in Indonesia are 2.6 times as great as in Brazil. A policy that includes activities in forest remaining forest could therefore be attractive to other southeast Asian countries for this same reason. As scope expands to include A/R, Brazil and DRC, and to a lesser extent Cameroon, have the most potential benefit to capture, because of all their nonforest land.

These results indicate that countries may have different incentives regarding scope expansion. These incentives may play out in a few different ways. On the one hand, those countries with the largest percentage gains in crediting potential may be those who would benefit the most from policy expansion. Consider that by expanding the scope from just RED to also include Forest→Forest and A/R, Peru, DRC, Brazil all would experience crediting potential gains of about 200% or more, whereas Indonesia and Cameroon would only see an increase of around 60% and Ghana only 24%. Thus, Ghana may not be interested in expanding scope beyond RED, since it would in some sense lose comparative advantage to the other countries who gain so much, while both Peru and Indonesia may favor scope expansion to include degradation, though they might be relatively indifferent to including A/R. On the other hand, the absolute gains in crediting potential, rather than the percent gains, could be a more important part of the story. While Brazil shows only small percentage increases as scope expands to include activities in forest remaining forest, in absolute terms, it gains much more than other countries. Likewise, when scope expands to include A/R, Indonesia gains only 6%, though its absolute potential is the third highest, after DRC and Brazil.

The comparison of methods for the Brazil case affirms a couple of assumptions. First, when remotely sensed data is used, historical deforestation is shown to be less than what is estimated by FAO. Second, the remote-sensing study shows larger degradation emissions than our calculated estimate. This may be due to the ability of this study to capture both legal and illegal logging, though it is important to note that comparing these results is complicated by the fact that Asner et al. (2005) use different carbon stock estimates; namely, they report *gross* emissions, whereas the estimates we use from Putz et al. (2008) report *net* emissions after forest regrowth.

4.2.4. Economic crediting potential

The full biophysical potential essentially measures what could be made available if money were no object. But economic realities, driven by the cost of forgone opportunities as more land is devoted to GHG mitigation and away from other uses, and institutional barriers will limit countries' realization of the full biophysical crediting potentials depicted in Figures Figure 2 and Figure 3. An extremely high carbon price would be needed for standing forests to outcompete commodities in many settings. Even with a high price on carbon, some continuation of forest clearing and logging can likely be expected, given expected increases in populations, which will translate to rising demand for food, wood, and minerals. And where governance is weak, halting illegal activities will remain difficult, even with a strong price signal. For A/R, the value of agricultural land is often quite high and luring that land into forest can be expensive in some cases. Concerns about carbon-water tradeoffs that can accompany tree planting could also make realization of A/R's maximum biophysical potential undesirable.

Therefore, it is useful to consider some scenarios that capture the tradeoffs with these economic factors and to recognize that landowners will not simply forgo extractive activity at all costs to supply carbon credits. These scenarios assume timber harvesting continues (but uses more sustainable techniques), some forest clearing continues, and some of the land that could be potentially afforested/reforested remains in a nonforest state. To this end, we illustrate in Figures Figure 4 and Figure 5 what countries' "economically feasible" crediting potential might be by estimating just the amount of avoided deforestation and A/R we would expect to see at moderate carbon prices ($20/tCO_2e$) and the amount of logging emissions that could be avoided through use of reduced-impact logging (RIL) techniques. We estimate this economic crediting potential for each accounting scope as follows:

RED: The fraction of the full biophysical reduced-deforestation potential (shown in Figures 2 and 3) that is expected to be achieved at a moderate carbon price of $20/tCO_2e$. We adapt the fractions reported by Nabuurs et al. (2007) by assuming that 80% of biophysical potential can be realized at $100/tCO_2e$ and that a certain percentage of this amount can be achieved at $20/tCO_2e$, according to Nabuurs et al.'s continent-specific fractions. Because these fractions are continent-specific, they reflect the differences in opportunity costs across regions. Africa is thought to have lower opportunity costs than other regions and, consequently, a higher fraction of the biophysical potential may be achieved there at lower carbon prices. However, because these estimates do not also include transaction and management costs, they may overstate what is "economically feasible," given that transaction and management costs may be high where property rights and governance systems are weak. Table 4 shows the fraction of their RED biophysical potential that each country is expected to achieve at a moderate carbon price of $20/tCO_2e$.

Table 4. Percent of biophysical RED and A/R potential realized at moderate carbon prices ($20/tCO_2e$).

Country	Percent of biophysical potential achieved at $20t/CO_2e	
	RED (avoided deforestation)	Nonforest→Forest (A/R)
Brazil	37.6%	31.2%
Cameroon	56%	56%
DRC	56%	56%
Ghana	56%	56%
Indonesia	41.6%	31.2%
Peru	37.6%	31.2%

Based on fractions reported in Nabuurs et al. (2007).

Forest→Forest: RIL techniques allow for the same volume of timber to be harvested, but with less carbon emissions (as well as other increases in environmental benefits). To estimate avoided emissions due to RIL, we subtract the amount of emissions that would be produced through RIL from those that would be produced from conventional logging techniques (shown in Figures 2 and 3). Estimates are again derived using 1/30th of the natural forest area zoned for logging in 2005, as reported by ITTO (2006), and region-specific per-hectare estimates of net emissions from conventional logging and RIL, both developed by Putz et al. (2008).

Nonforest→Forest: The fraction of the full biophysical A/R potential (shown in Figures 2 and 3) that is expected to be achieved at low carbon prices of $20/tCO_2e. Nabuurs et al. (2007) report fractions for both RED and A/R; we adapt and apply these fractions to A/R as described above for RED. As for RED, these fractions are continent-specific and thus reflect differences in opportunity costs across regions, but may not fully capture regional differences in transaction and management costs, which will be influenced by the strength of property rights and governance systems. Table 4 shows the fraction of their A/R biophysical potential that each country is expected to achieve at these low carbon prices.

Figure 4. Estimated economic crediting potential for RED, for Forest→Forest, and Nonforest→Forest accounting scopes for selected high-potential countries.

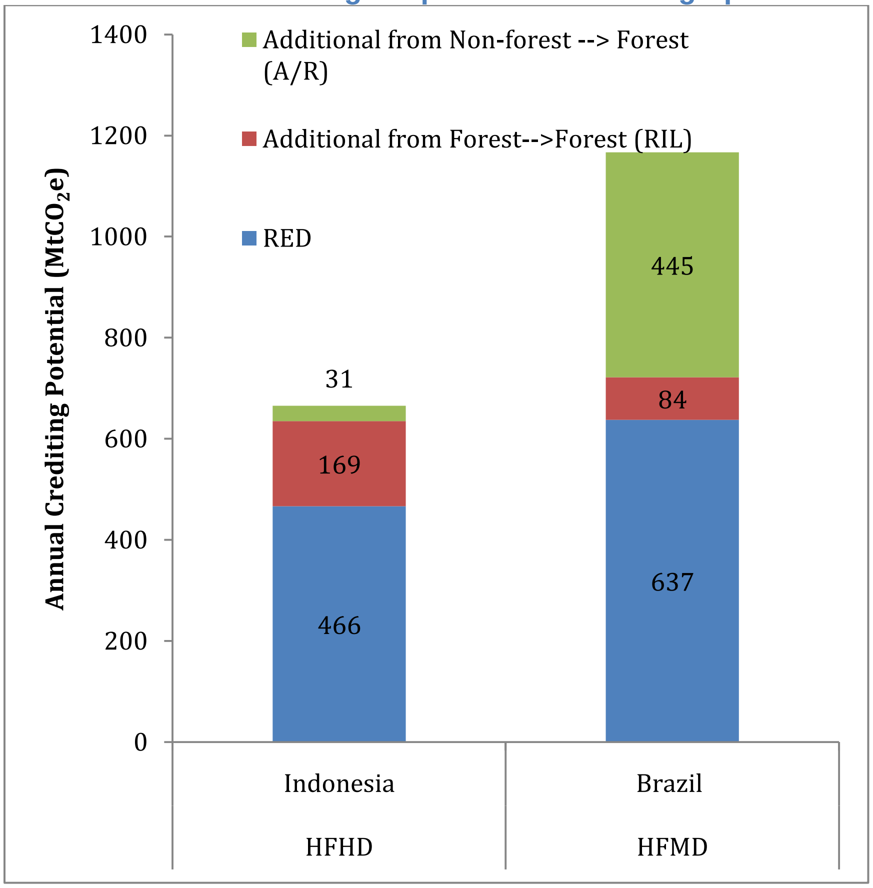
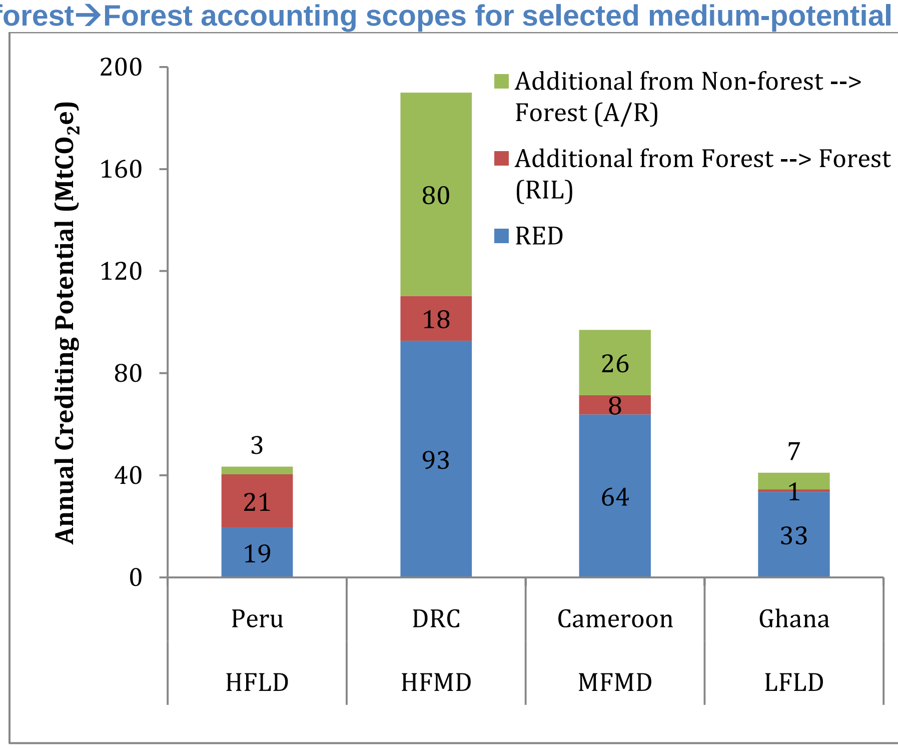


Figure 5. Estimated economic crediting potential for RED, Forest→Forest, and Nonforest→Forest accounting scopes for selected medium-potential countries.



4.2.5. Discussion: Economic crediting potential

Despite the differences among countries regarding the fractions of biophysical potential estimated to be realized at moderate carbon prices, the general ordering of countries (in terms of who gains the most, who gains the least under the accounting scopes considered) remains consistent with the results discussed in section 4.2.3. Discussion: Biophysical potential However, the absolute magnitudes of potential reported here might be viewed as more realistic estimates of countries' crediting potentials.

For activities in forest remaining forest, the results show that continuing logging (and using RIL techniques) reduces crediting potential considerably for all countries—as compared with the potentials reported in Figures 2 and 3 from completely stopping logging. The crediting potential for the African and Latin American countries under the RIL ("economic") scenario is 37% of what could be earned by a complete halt of legal logging ("maximum biophysical scenario"). For Indonesia, the RIL scenario yields 28% of the logging moratorium scenario. However, Indonesia could still earn a significant amount of credits in the RIL scenario. This is again due to the higher density of commercial timber and forest carbon per hectare in southeast Asian forests, which means that the potential for avoided carbon release is higher. Although crediting potential decreases for all countries in the RIL scenario, net costs for realizing this potential may be much less, and thus more profitable and more feasible, since opportunity costs of employing RIL over conventional logging are minimal because the RIL estimates used assume that harvesting yields remain constant and thus timber revenues are not forgone. Implementing RIL techniques on legally logged forests may also minimize the unintended consequence of boosting illegal logging that a logging moratorium might create. Continuing timber production volumes apace may therefore yield environmental gains as well.

Averaged across all the selected countries, total economic crediting potential would be 45% of the maximum biophysical potential. Results vary somewhat among the three regions represented. Economic potential relative to biophysical is highest in the African countries at about 54%, compared with about 36% for Brazil, Indonesia, and Peru. Lower opportunity costs are the main reason that a greater percentage of the African countries' potential appears more economically feasible.

4.3. Implications for policy design

4.3.1. Implications of voluntary scope expansion and sequencing

While the Copenhagen Accord affirms that going forward the international forest carbon system will be a "REDD+" system, many of the questions regarding how scope expansion should be sequenced and whether such expansion should proceed on a voluntary basis remain pertinent. This is because we still lack clarity regarding which specific activities will be considered eligible for "REDD+" financing and whether accounting will initially cover degradation and forest stock enhancement as well as deforestation. Despite the "REDD+" language used in the Copenhagen Accord, it is quite possible that initial efforts may still start up as a RED-only system, with the expressed goal of eventually including other accounting and crediting.

As financing programs for national REDD+ move forward post-Copenhagen, policymakers have several options to consider regarding the scope of activities that will be accounted, credited, and financed. One option is to initially start with just a RED system that tracks and credits reduced deforestation and uses very rough carbon stock estimates (IPCC Tier 1). Another option is to start with a fuller REDD system that uses updated forest carbon stock estimates and requires reporting of changes in forests remaining forests. And, of course, a third option is to begin with a REDD+ system that clearly delineates the specific activities included in the system. While ongoing forest carbon inventories and improved remote-sensing technology and methods should allow for initial start as a REDD system, there is some discussion of an interim approach[21] that would use rough carbon stock default values and require accounting of only deforestation. If forest carbon programs are set up initially as RED-only systems that

[21] See the Interim Financing Proposal (2009) from the Interim Working Group on REDD.

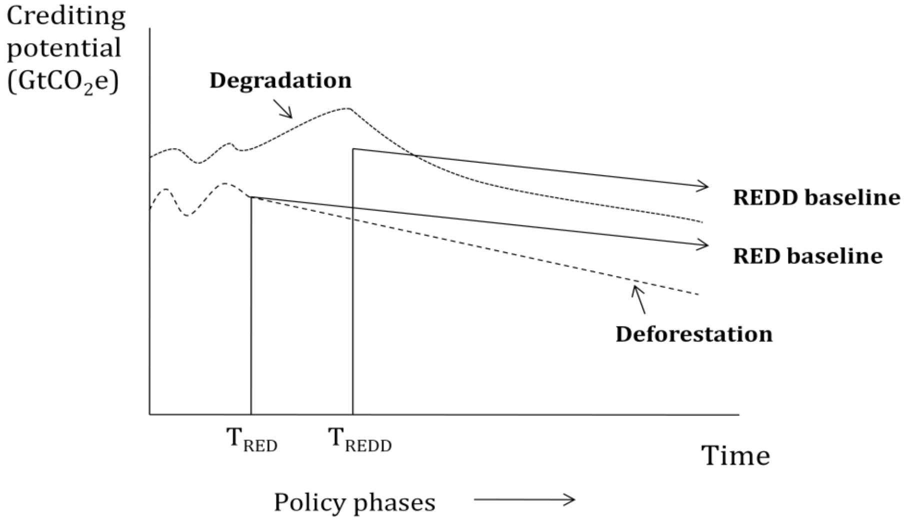
permit countries to voluntarily opt into degradation and other land-use accounting, then consideration needs to be given to a few important issues.

If the system is set up so that expansion of accounting scope beyond RED is voluntary, there is a risk that some countries may choose not to account for degradation if they find that the carbon credit benefits do not sufficiently outweigh the costs associated with accounting for activities in forest remaining forest—especially if countries believe it will be difficult for them to control illegal logging and therefore claim the credits or if they perceive the opportunity cost of stemming the activity that leads to degradation (e.g., logging, firewood collection, shifting cultivation) would be too high. To wit, Brazil's current RED proposal does not include degradation accounting (Parker et al. 2009).

Second, while some types of degradation do progress to deforestation and would thus eventually be accounted for, some degradation activities never progress to losses in forest cover beyond the 70%–90% deforestation threshold and would thus go unaccounted (Skutsch 2009). Differences in land-use change trajectories will depend on the drivers in that particular landscape, which vary by region. For example, while logging along roads in the forest frontier in Indonesia and the Amazon may enable agriculture and thus deforestation, logging in the Congo basin may not be followed by forest clearing for large-scale agriculture, given relatively less infrastructure, population pressure, and foreign direct investment in this region. Changing the forest definition to have a higher deforestation threshold could help to address part of this problem. While criticisms of the forest definition are prominent (Sasaki and Putz 2009), the likelihood of the definition being changed is not clear.

Third, some countries might choose to expand the accounting scope to include A/R, and even agriculture, before they would include degradation. Demonstrating additionality might be easier for A/R projects and protecting the planted stands may be less challenging than reigning in degradation. But the attractiveness of A/R will be determined by other issues as well, such as agricultural policy/subsidies, commodity prices relative to carbon offset prices, and growing food demand in countries with increasing populations. Here, the issue of land tenure may be important. Where there are a fair amount of agricultural and/or A/R-eligible lands managed or owned by private entities, implementing these activities may be viewed as more feasible than reducing deforestation and degradation, since forest loss often takes place in (and is the result of) open-access regimes, where land ownership is ambiguous. Even if expansion of scope to include degradation is required and not voluntary, the timing of policy phases could be critical. The possibility of perverse incentives would be real during a period in which a policy on RED is in force but degradation falls outside of its purview. For example, there may be perverse incentives for RED producers (countries or landowners) to increase timber harvesting (resulting in degradation) during this time in order to replace the revenues lost from forgone agriculture or to maximize the returns from logging before a policy that requires tracking of changes in forests remaining forest comes into force. Figure 6 presents a stylized depiction of such a scenario, where the level of degradation rises when a RED policy comes online and then begins to decline once the accounting scope is expanded to cover degradation.

Figure 6. Shifting of crediting potential and land-use change trends in response to the timing of accounting scope expansion



4.3.2. Policy design considerations

To ensure the environmental integrity of the system, the scope of land use/land-use change accounting should initially be as broad as possible. This can be implemented even if crediting methodologies and financial mechanisms initially address a more limited range of biomes (i.e., just forests) or GHGs (just CO_2). This goal should be the driving principle for all countries, including Annex 1.

Recognizing this principle, decision makers therefore have a number of key policy design issues to consider:

1. Initial scope of crediting and incentives

Should the incentives program be started narrowly at RED or more expansively at REDD+? RED is simplest, but as the paper shows, leaves out critical GHG components that would remain outside of the scope of incentives until the program was expanded. This could mean valuable time lost, especially given the time necessary to reverse some of these carbon losses. It could also result in increased degradation until it is brought under the system's purview.

If there is an initial interim period of a RED-only system, then it will be prudent to use conservative carbon stock estimates because some forests may already be degraded and degradation may continue and even accelerate during a RED-only policy. Using conservative carbon stock estimates can guard against over-crediting, which is crucial to preserve the environmental integrity of the system. Developed countries could further help guard against risks of sustained or increased degradation during this interim period by reducing their imports of illegal tropical timber and adopting and enforcing policies similar to the Lacey Act, recently enacted in the U.S.

2. Rules for expanding program scope

Should countries be allowed to select their preferred scope and its timing or should an international agreement (or donor-funded program or offset buyer) determine what is binding and the timing of scope expansions? In keeping with the Kyoto Protocol, developing countries' responsibilities are differentiated from those of developed countries (the Berlin Mandate), and this has manifested itself in a regime where developing countries do not have binding obligations to reduce GHGs. This tends to favor giving developing countries full control over the scope of their program involvement. However, it is clear that this could create perverse incentives and internal leakage from in-scope activities to out-of-scope activities. This is not unprecedented within the Kyoto Protocol framework, where countries can determine the scope of the land management activities applied to them under Article 3.4 of the Kyoto Protocol. Efforts will be necessary to ensure that flexibility and responsibility are adequately balanced.

With an expanded scope, there may be competition between activities in forests and activities in nonforests, such as A/R. While this may not matter from a GHG perspective, if protection of existing forests for biodiversity and the many noncarbon ecosystem services (e.g., regulation of precipitation and weather; provisioning of water, food, and medicine; conservation of cultural and aesthetic values) that forests provide is also a goal of the REDD+ program, then certain incentives may need to be put in place so funds continue to be directed towards forests. Competition between activities in forests and nonforests will be determined by each activities' revenues (the higher carbon content of existing forests, as compared with newly planted forests or plantations, should allow RED(D) to earn more per hectare) and costs (startup, MRV, and implementation costs may be lower for some A/R activities).

3. Specific activities that constitute "REDD+"

The evolution of language in the negotiating texts at the UNFCCC (from the 2007 Bali Action Plan to the 2009 AWG-LCA draft released at Copenhagen) indicates that there is now broad consensus that the scope of REDD+ should include "reducing emissions from deforestation; reducing emissions from degradation; conservation of forest carbon stocks; sustainable management of forest; and enhancement of forest carbon stocks." But there is still a lack of clarity regarding the specific activities that would be included under these five categories. In particular, it is not clear (1) what is meant by "conservation" and why incentives for such activities would not already be included by efforts to reduce deforestation and degradation, and (2) whether "enhancement of forest carbon stocks" includes A/R. Clarification of the specific activities that constitute "REDD+" is therefore needed. Here, it might provide more clarity to align program scope definitions more neatly with the four possible types of land uses and land-use changes that could be measured, and thus accounted for, in a system: (1) avoided conversion of forests to nonforests; (2) activities in forests remaining forests; (3) conversion of nonforest to forest; and (4) activities in nonforest remaining nonforest.

4. Rules for afforestation and reforestation (A/R)

As noted, the position of A/R is still unclear: Does the expanded REDD+ scope indicate that forestry activities will move from the project-based CDM system to the REDD+ sectoral system? If not, will the CDM be reformed and issue only sectoral-level credits? There are many possible advantages of bringing A/R into a REDD+ system (as A/R has gained little traction under the CDM). First, this presumably would allow A/R to produce long-term credits (rather than temporary credits), and thus attract more investment. Second, having A/R subject to the same rules as REDD(+) would lower transaction costs for project developers and countries, many of whom will likely want to implement both types of activities—especially considering that some tree planting is already a component of most early REDD projects. Third, scaling up A/R activities may be integral to the success of REDD activities, as planting new forests and plantations is critical for satisfying a rising population's demand for wood products, while taking pressure off existing forests.

However, blurring the line completely between A/R and REDD does present some risks that need to be addressed up front. As discussed in this paper, depending on which species are used and where the trees are planted, A/R can present risks to local water supplies and biodiversity. Rules may be adopted to guard against these risks. Another issue that will need to be addressed if A/R becomes a sectoral activity and comes into a REDD+ system is what additionality tests will be required (if any). Guarding against conversion of existing forests to newly planted forests or plantations is another important issue (see #5 below).

5. How forests are defined

Two aspects of the forest definition require further examination: (1) the lack of distinction between existing forests and newly planted forests or plantations and (2) the issue of crown cover, where a forest may lose up to 70%–90% of its original crown before it is considered deforested. The current definition of "forests" used at the UNFCCC does not distinguish between existing forests and newly planted forests or plantations. This may create incentives for REDD credits being issued for areas that have been converted from existing forests to newly planted forests or plantations. If such conversion is not counted as deforestation, this could be problematic because this land-use change could produce significant carbon loss and degrade the ecosystem services provided by existing forests. Thus crediting this conversion as if it were avoiding the full loss of carbon on existing forests would overestimate the carbon benefits, as well as undermine broader ecosystem value. To guard against unaccounted carbon emissions and the other negative impacts that might result from converting existing forests to newly planted forests or plantations, policymakers may need to either revise the definition so that only existing forests are considered "forests" or put in place safeguards against conversion. Here, it is worth noting that the CDM in fact includes such safeguards for A/R: "afforestation" is defined as planting trees on lands that have not had forests within the last 50 years and "reforestation" is defined as planting trees on lands that have not had forests since 1990.

Reconsideration of the deforestation threshold (where only a decrease below 10%–30% of original crown remaining pushes lands from the "forest" to "nonforest" category) could yield benefits as well. For example, if the definition of forests is revised so that the deforestation threshold is higher, then this may help prevent continued or accelerated degradation during a RED-only policy, since some of this degradation would instead be viewed as deforestation.

6. Baseline criteria as scope evolves over time

To what extent can activities undertaken during an initial phase (e.g., RED only) affect baselines established for an expanded program later on? For instance, should degradation estimates be included from a RED-only phase when establishing a baseline for a REDD (Forest→Forest) or more comprehensive program? These questions also raise the general issue of how often should baselines be adjusted, regardless of scope.

Appendix

Notes on methods to calculate Nonforest→Forest (A/R) potential

Zomer et al. (2008) develop country-level estimates for land area eligible for CDM-A/R. This study considers the variable impacts of forest definition for each country by providing estimates for forest crown cover thresholds ranging from 10% to 30%. Recently, tropical countries have been adopting forest definition parameters (minimum tree cover, minimum area, and minimum tree height) for participation in UNFCCC. Of the countries considered in our paper, Peru, DRC, and Brazil have each chosen 30% as their minimum crown cover; Ghana 15%; Indonesia and Cameroon have yet to indicate. We use the tree cover percentages elected by the countries and assume that Indonesia and Cameroon each choose 30%.

Zomer et al. deemed land unsuitable for A/R if it met the following characteristics:

- high-elevation areas, above 3500 m and/or tree line
- dry areas, as determined by an Aridity Index (AI), where threshold is lower than AI 0.65
- areas classified as urban, water bodies, or various types of tundra
- areas classified as irrigated or "under other intensive agricultural production" (unclear if small-scale agricultural lands are included or excluded)
- areas deforested after 1990, according to the USGS Ecosystem Land Characteristics Database (1993)

The CDM distinguishes between afforestation and reforestation as follows:

- **Afforestation:** establishment of trees on land that has not had forest on it for more than 50 years

- **Reforestation:** establishment of trees on land that has had forest on it during the last 50 years, but is not currently forested

Under CDM rules, in order to be eligible for reforestation, the land must not have contained forest on it on December 31, 1989.

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for more information please contact:

Nicholas Institute for Environmental Policy Solutions
Duke University
Box 90335
Durham, NC 27708
919.613.8709
919.613.8712 fax
nicholasinstitute@nicholas.duke.edu
www.nicholas.duke.edu/institute