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Reducing greenhouse gas emissions from deforestation and forest degradation in developing countries: revisiting the assumptions

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Abstract The United Nations Framework on Climate Change (UNFCCC), at its thirteenth meeting in 2005 (COP-11), agreed to start a work program to explore a range of policy approaches and positive incentives for Reducing Emissions from Deforestation and Degradation (REDD). This process was further encouraged in the 2007 COP-13 with the explicit consideration of REDD activities as a means to enhance mitigation action by developing countries in the future. This paper outlines the context of this ongoing political process by reviewing the science indicating that land-use change is a key contributor of greenhouse emissions globally and the assumptions that REDD activities may be competitive—in terms of cost effectiveness—in comparison to other mitigation options. The paper then examines REDD proposals submitted by Parties before COP-13 and identifies key economic, technological, methodological and institutional challenges associated with their implementation. These proposals are discussed in the light of major drivers of deforestation and ongoing efforts to address deforestation. This reveals another set of challenges which, if not taken into account, may undermine REDD effectiveness. The paper aims to aid the policy process and contribute to the best possible design of a REDD framework under the future climate regime.

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1 Introduction

The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) underlines - as its predecessors - the need for immediate action to reduce the amount of anthropogenic greenhouse gases (GHG) emitted to the atmosphere in order to avoid a dangerous interference with the climate system (IPCC AR4 2007). The AR4 recognizes that no single technology or mitigation option has the potential to achieve this goal by itself; instead, a portfolio of alternatives offering enough flexibility to accommodate different national circumstances and interests will be required. Moreover, global participation will be paramount to effectively address climate change, which implies creating incentives and designing new avenues for developing countries (and possibly non-Kyoto Parties) to facilitate their participation in the international mitigation effort post-2012.

Reducing Emissions from Deforestation and Forest Degradation (REDD) in developing countries through positive incentives under the United Nations Framework Convention on Climate Change (UNFCCC) has been considered an opportunity to deal with many of these concerns. Deforestation in the tropics generates about a fifth of global GHG emissions (Houghton 2005) and, since project activities to reduce emissions from deforestation were excluded from the Kyoto Protocol's Clean Development Mechanism (CDM), obtaining support to address this source of emissions has been among the top priorities of developing countries in discussions about a future climate regime. Furthermore, this is seen as an opportunity for a "meaningful participation" of these countries in the international regime, one of the main demands of the United States to consider joining any international treaty imposing binding emissions reduction targets,[1] thereby providing Annex B countries with a political argument to urge non-Kyoto Parties to join international mitigation efforts and advocate for tougher national reduction targets in a post-2012 framework.

The importance of REDD activities in enhancing global mitigation action was acknowledged by the Convention at its 11th session (COP-11) in 2005. Since then, many Parties, non governmental organizations (NGOs) and research institutions, have made specific proposals on approaches to address GHG emissions from deforestation in developing countries. COP-13, held in Bali in December 2007, agreed to start a work program on methodological issues related to a range of policy approaches and incentives that aim to reduce emissions from deforestation and forest degradation in developing countries. This should consider, inter alia, outstanding methodological issues such as assessments of changes in forest cover and associated carbon stocks and GHG emissions, incremental changes due to sustainable management of the forest, demonstration of reductions in emissions from deforestation including reference emissions levels, estimation and demonstration of reduction in emissions from forest degradation, implications of national and sub-national approaches (including displacement of emissions), options for assessing the effectiveness of capacity building and technical assistance activities and of demonstration

[1] On July 25, 1997, during the negotiations of the Kyoto Protocol, the U.S. Senate unanimously passed by a 95–0 vote the Byrd-Hagel Resolution (S. Res. 98), which stated the sense of the Senate was that the United States should not be a signatory to any protocol that did not include binding targets and timetables for developing as well as industrialized nations or "would result in serious harm to the economy of the United States".

activities (Decision 2/CP.13). Additionally, REDD will be further considered by the Ad Hoc Working Group on Long Term Cooperative Action under the Convention (AWG-LCA) as part of the Bali Action Plan, together with the role of conservation, the sustainable management of forests and the enhancement of forest carbon stocks in developing countries. This paper reviews the conceptual basis of this ongoing negotiation by providing an overview of current and predicted deforestation rates in developing countries, and analyzing the mitigation potential and costs of REDD activities. It then examines existing Parties' REDD proposals and identifies key economic, scientific, technological, methodological, and institutional challenges associated to their implementation. The paper discusses these proposals in the light of deforestation drivers and previous conservation initiatives, thus illuminating a set of challenges which, if not taken into account, may undermine REDD effectiveness. By doing so, we expect to aid the policy process and contribute to the best possible design of a REDD framework in a future climate regime.

2 Emissions from deforestation in developing countries

According to FAO's 2005 Global Forest Resource Assessment, deforestation—mainly conversion of forests to agricultural land—continued at an alarming rate globally during 1990–2005, of about 13 million hectares per year (ha/year), with few signs of a significant decrease over time. The highest deforestation currently occurs in tropical America (4.5 million ha/year) and Africa (3.1 million ha/year), whilst tropical Asia has about 2.9 million ha/year. Nevertheless, deforestation rates vary greatly from one source of data to another depending on the methods used to estimate them (Table 1). For example, Hansen and DeFries (2004) used satellite data and reported rates higher than those reported by FAO (2001) in five out of six countries. These differences are difficult to resolve because the accuracy of ground-based estimates

Table 1 Average annual rates of deforestation (106 ha $year^{-1}$) in tropical regions

	1980s DeFries et al. (2002)	1990s FAO (2006)	1990s DeFries et al. (2002)[a]	1990s Achard et al. (2004)[b]	2000–2005 FAO (2006)
Tropical America	4.426	4.165	3.982	4.41	4.482
Tropical Africa	1.508	3.362	1.325	2.35	3.058
Tropical Asia	2.158	2.578	2.742	2.84	2.851
Total	8.092	10.105	8.049	9.60	10.391

The FAO rates are based on forest inventories, national surveys, expert opinion and remote sensing. The estimates of DeFries et al. (2002) and Achard et al. (2004) are based on data from remote sensing. Source: UNFCCC (2006a, b)
[a]Rates from DeFries et al. (2002) refer to gross rates of forest loss (not counting gains in forest area).
[b]Rates from Achard et al. (2004) do not include areas of forest increase.
Tropical America South America, Central America and Caribbean subregions in FAO estimates, to Bolivia and nine states in the Brazilian Amazon in DeFries et al. (2002) and to humid tropical forest biome of Latin America excluding Mexico and the Atlantic forests of Brazil in Achard et al. (2004); *Tropical Africa* Eastern and Southern and Southern and Western subregions in FAO estimates, to parts of the Democratic Republic of Congo in DeFries et al. (2002), and to the humid tropical forest biome of Guinea Congolian zone of Africa and Madagascar in Achard et al. (2004); *Tropical Asia* south and southeast Asia subregion in FAO estimates, to four Indonesian islands in DeFries et al. (2002), and to the humid tropical forest biome of Southeast Asia and India in Achard et al. (2004), including the dry biome of continental Southeast Asia

(such as FAO data) is not assessed, and estimates based on remotely sensed data are sensitive to the spatial variability of deforestation, that is, the size of clearings may be too small for a change in tree cover to be recognized in a 30-m resolution Landsat image. Consequently, it will continue to be difficult to accurately determine deforestation rates, at least until standard and validated methodologies exist which can be applied at a range of spatial scales (UNFCCC 2006a).

Forests account for almost half of the global terrestrial carbon pool, and if vegetation is considered alone (excluding soils) they hold about 75% of the living carbon. The total carbon content of forest ecosystems in 2005 was estimated at 638 Gt (FAO 2006). Thus, tropical forests play a particularly important role in the global carbon budget because they contain about as much carbon in their vegetation and soils as temperate and boreal forests combined (Melillo et al. 1993; Dixon et al. 1994; Field et al. 1998). Per unit area, tropical forests store on average about 50% more carbon than forests outside the tropics. Deforestation is typically associated with large immediate reductions in forest carbon stocks, through land clearing. Forest degradation—a reduction in forest biomass through non-sustainable harvest or land-use practices—can also result in substantial reductions of forest carbon stocks from selective logging, fire and other anthropogenic disturbances, and fuelwood collection (Asner et al. 2005).

As in the case of determining deforestation rates alone, estimates of *emissions* from deforestation are uncertain due to lack of standard methods, resources, capacity at national levels, and lack of data (WRI 2005). The IPCC estimates that, during the 1990s, global land use change emissions averaged 1.6 Gt C/year ± 0.8 Gt. Taking uncertainties into account, CO_2 from land-use change may be as little as 0.8 Gt C/year (12% of the world's emissions) or as high as 2.4 Gt C/year (28%), a difference of a factor of three. Houghton and Hackler (2002) and Houghton (2003) estimated emissions of 2.2 Gt C/year (26% of CO_2 in the 1990s), which is in the upper range of IPCC figures. According to Houghton (2005), considering CH_4 and N_2O and other chemically reactive gases that result from subsequent uses of the land, annual emissions from land-use change during the 1990s accounted for about 20–25% of total anthropogenic GHG emissions. The AR4 points out that land use change emissions grew 40% between 1970 and 2004, lower than the increase experienced in the energy supply sector (145%), the transport sector (120%), and industry (65%) in that period.

Countries with the largest emissions from land use change are Indonesia and Brazil, with 34% and 18% of the total global, respectively (Houghton 2003). Continued deforestation at current rates in these two countries alone would equal four-fifths of the annual reductions targets for Annex I countries in the Kyoto Protocol (Santilli et al. 2005). Some countries like Malaysia, Myanmar, and the Democratic Republic of Congo, which are not among the largest overall GHG emitters, also account for significant shares of global land use change emissions (WRI 2005). However, it must be noted that uncertainties for national-level figures are very high, in the order of ±150% Megatons (Mt) CO_2/year for large fluxes, and ±180% for estimates near zero. The World Resources Institute (2005) compared data from Houghton (2003) with official data submitted by governments to the UNFCCC and found that for large emitters and absorbers the estimates were significantly different, most notably in Indonesia and Brazil. In some cases, such as China, India and Argentina, data submitted by governments showed a negative source (that is, a net sink) of CO_2, whereas other sources reported a positive emissions source.

Assumptions of future deforestation rates are key factors in estimates of GHG emissions from forest lands and of mitigation benefits, and vary significantly across studies. Sathaye and colleagues (2007) foresee that deforestation rates will continue in all regions, at particularly high rates in Africa and South America, with a total of just under 600 million ha of forest lost cumulatively by 2050. Forests are most likely to be eliminated first in tropical Asia, where the rates are high and forest areas small, and then in West Africa (Houghton 2005). Using a spatial-explicit model coupled with demographic and economic databases, Soares-Filho et al. (2006) predict that, under a business-as-usual scenario, projected deforestation trends will eliminate 40% of the current 540 million ha of Amazon forests by 2050, releasing approximately 117,000 ± 30,000 Mt CO_2 to the atmosphere (IPCC AR4 2007). Furthermore, if droughts become more severe through more frequent and severe El Niño episodes (Trenberth and Hoar 1997; Timmermann et al. 1999), the dry season becomes lengthier due to deforestation-induced rainfall inhibition (Nobre et al. 1991; Silva-Dias et al. 2002), or there are rainfall reductions due to global warming (White et al. 1999; Cox et al. 2000), then substantial portions of the carbon pool stored globally in tropical forest trees could be transferred to the atmosphere in the coming decades.

3 REDD mitigation potential and costs

One of the principal arguments for REDD is the assumption that GHG mitigation through these measures can be cost-effective in comparison to other options, because REDD does not require the development of new technology, with the exception perhaps for monitoring (Stern 2006). In addition, it is usually assumed that forest-related mitigation options can be designed and implemented to be compatible with adaptation, and can have substantial co-benefits in terms of employment, income generation, biodiversity and watershed conservation, renewable energy supply and poverty alleviation (ibid.).

However, estimates regarding the mitigation potential and costs of REDD vary widely in the literature. Estimates depend on the geographical scale chosen for the analysis, the assessment approach applied and the assumptions (including, for instance, the characteristics of the interventions considered), and the data used. Whilst explaining and reviewing each of the approaches taken falls outside the scope of this paper, we discuss some examples of the mitigation potential and costs from selected studies to highlight the range of estimates and the assumptions they are based on.

Table 2 presents the averages of three global forest sector models with various specific strengths and weaknesses for different regions of the world (Sohngen and Sedjo 2006; Sathaye et al. 2007; Benítez et al. 2007). These results demonstrate a large potential for climate mitigation through forestry activities; the global annual potential in 2030 is estimated at 13,775 Mt CO_2/year (at carbon prices less than or equal to 100 US\$/tCO_2), 36% of which could be achieved at a price of 20 US\$/tCO_2. Reducing deforestation could contribute with 3,950 Mt CO_2/year, most of which (54%) could be achieved at prices equal or lower than 20 US\$/tCO_2. Most of this potential is in Central and South America with 1,845 Mt CO_2/year, and Africa (1,160 Mt CO_2/year), and to a lesser extent, in Asia. However, it must be noted that these global models cannot capture the context-specific dynamics of

Table 2 Mitigation potential of global forestry activities

Region	Activity	Potential at costs equal or less than 100 US$/ton CO_2, in Mt CO_2/year in 2030[a]	Fraction in cost class: 1–20 US$/ton CO_2	Fraction in cost class: 20–50 US$/ton CO_2
USA	Afforestation	445	0.3	0.3
	Reduced deforestation	10	0.2	0.3
	Forest management	1,590	0.26	0.32
	Total	2,045	0.26	0.31
Europe	Afforestation	115	0.31	0.24
	Reduced deforestation	10	0.17	0.27
	Forest management	170	0.3	0.19
	Total	295	0.3	0.21
OECD Pacific	Afforestation	115	0.24	0.37
	Reduced deforestation	30	0.48	0.25
	Forest management	110	0.2 0.	0.35
	Total	255	25	0.34
Non-annex I East Asia	Afforestation	605	0.26	0.26
	Reduced deforestation	110	0.35	0.29
	Forest management	1,200	0.25	0.28
	Total	1,915	0.26	0.27
Countries in Transition	Afforestation	545	0.35	0.3
	Reduced deforestation	85	0.37	0.22
	Forest management	1,055	0.32	0.27
	Total	1,685	0.33	0.28
Central and South America	Afforestation	750	0.39	0.33
	Reduced deforestation	1,845	0.47	0.37
	Forest management	550	0.43	0.35
	Total	3,145	0.44	0.36
Africa	Afforestation	665	0.7	0.16
	Reduced deforestation	1,160	0.7	0.19
	Forest management	100	0.65	0.19
	Total	1,925	0.7	0.18
Other Asia	Afforestation	745	0.39	0.31
	Reduced deforestation	670	0.52	0.23
	Forest management	960	0.54	0.19
	Total	2,375	0.49	0.24
Middle East	Afforestation	60	0.5	0.26
	Reduced deforestation	30	0.78	0.11
	Forest management	45	0.5	0.25
	Total	135	0.57	0.22

the forestry and agriculture sectors, and thus do not address implementation issues such as transaction costs (likely to vary across activities and regions),[2] barriers, and carbon market rules, which tend to drive mitigation potential downward toward true

[2]For instance, Benítez et al. (2007) considered political and financial risks in implementing afforestation and reforestation activities and found that the sequestration potential was reduced by 59% once such risks were incorporated.

Table 2 (continued)

Region	Activity	Potential at costs equal or less than 100 US$/ton CO_2, in Mt CO_2/year in 2030[a]	Fraction in cost class: 1–20 US$/ton CO_2	Fraction in cost class: 20–50 US$/ton CO_2
Total	Afforestation	4,045	0.4	0.28
	Reduced deforestation	3,950	0.54	0.28
	Forest management	5,780	0.34	0.28
	Total	13,775	0.42	0.28

Global model results indicate annual amount sequestered or emissions avoided, above business as usual, in 2030 for carbon prices equal or under 100 US$/t$CO_2$

[a] Results average activity estimates reported from three global forest sector models including GTM (Sohngen and Sedjo 2006), GCOMAP (Sathaye et al. 2007), and IIASA-DIMA (Benítez et al. 2007). For each model, output for different price scenarios has been published. The authors were asked to provide data on carbon supply under various carbon prices. These were summed and resulted in the total carbon supply as given middle column above. Because carbon supply under various price scenarios was requested, fractionation was possible as well. Two right columns represent the proportion available in the given cost class. None of the models reported mitigation available at negative costs. The column for the carbon supply fraction at costs between 50 and 100 US$/t$CO_2$ can easily be derived as 1—sum of the two right hand columns. Source: IPCC AR4 (2007)

market potential. Sathaye and colleagues' estimates for example, are based on a dynamic partial equilibrium model which simulates the response of forest land users (farmers) to changes in prices of forest land and products, and prices emerging in carbon markets (ibid.: 129). However, it does not consider the effect of increasing CO_2 concentration on the carbon cycle and its effect on biomass growth, nor does it take into account changes in capital markets between the reference and mitigation scenarios and their influence on interest rates, which in turn would influence the rates of return for different land use options. Furthermore, the authors recognize that the model is limited insofar as it only calculates the net social payoff or welfare gain in the forestry sector and does not contemplate other related sectors whose demand and supply may have also been affected, such as logging, agriculture and urbanization. Overall, this reflects how land use mitigation potential models are still to be refined and that figures need to be cautiously approached.

Other recent analyses have focused on the opportunity costs of REDD. Grieg-Gran (2006) estimated the costs of avoiding deforestation for eight countries with large areas of tropical forest responsible for 70% of global emissions from land use: Bolivia, Brazil, Cameroon, the Democratic Republic of Congo, Ghana, Indonesia, Malaysia and Papua New Guinea. Annual net forest loss in these eight countries equals 6.2 million ha, which, if avoided, would result in a 46% reduction in global deforestation. The total costs of avoided deforestation in the form of the net present value of returns from prevented land uses in these countries are approximately US$5–US$15 billion per year[3]—taking into account the legal, practical and market restrictions on logging. According to these results, direct yields from land converted

[3] It is assumed that the alternative to deforestation is forest conservation without any exploitation of timber and corresponding revenues.

to farming, including proceeds from the sale of timber, are equivalent to less than 1 US$/t$CO_2$ in many areas currently losing forest, and usually well below 5 US$/t$CO_2$. The opportunity costs to national GDP would be somewhat higher, as these would include value added activities in country and export tariffs (Grieg-Gran 2006). Costs would be even higher if governments were not able to identify and target areas with highest deforestation risk or were unable to prevent displacement of deforestation to other areas, as this would mean that a larger area would need to be compensated to achieve the desired reduction in deforestation.

Likewise, Vera Diaz and Schwartzman (2005) calculated the carbon price at which conservation of standing forests becomes financially attractive for loggers and ranchers in the Brazilian Amazon (referred to as "breakeven price"). Their results indicate that benefits from deforestation captured by logging and cattle ranching come to US$1,699 per hectare, which translates into 11 US$/tC (3 US$/tCO_2), assuming a high timber potential scenario and 3 US$/tC (0.8 US$/tCO_2) in a low timber potential scenario. When deforestation benefits come from logging following cattle ranching, the breakeven price ranges from 1 US$/tC (0.3 US$/tCO_2) to 14 US$/tC (4 US$/tCO_2), whilst in the case of soybean cultivation it could go from 6 US$/tC (less than 2 US$/tCO_2) to almost 30 US$/tC (around 8 US$/tCO_2).

Similarly, Chomitz et al. (2006) compared, for selected land uses, profitability versus the carbon lost in establishing a new land use activity, finding a tremendous variability in the potential cost of "carbon conservation". At one extreme, traditional pasture management in the Brazilian state of Acre entails a loss of 145 t of carbon per hectare, but creates only 4 US$/ha in land value and 11 days/ha/year of employment. So the cost of conserving carbon, in principle, is just 0.03 US$/tC (or less than 0.01 US$/tCO2). Rubber agroforestry in Sumatra, as traditionally practiced, also yields virtually no land value, just managing to repay the opportunity cost of labor. The most profitable land use, oil palm in Cameroon, entails a carbon loss of 150 t/ha, confers a land value of US$1090, and provides 150 days of employment; here the theoretical cost of conserving carbon is 7.27 US$/tC (near 2 US$/tCO_2). Chomitz concludes that, at very low carbon values, it is socially preferable to keep land under forest rather than convert it to typical low-productivity pasture or annual cropping. At moderate values, carbon competes even with relatively high value plantation crops.

In addition to these direct mitigation costs (e.g. opportunity costs, compensation), reducing emissions from deforestation involves the costs of putting in place and operating compensation schemes and/or policies and measures. These costs would vary depending on a number of factors, including the scale of the intervention (i.e., project based, municipality, state, regional or national), its characteristics, efficiency and effectiveness, the existing capacities and the level of accuracy required in the measurement of emissions reductions. Based on the experience of existing payment for environmental services schemes in Central and South America,[4] Grieg-Gran (2006) estimates that annual administration costs associated with payment schemes

[4]From these schemes, a lower bound figure for annual administration costs of US$4/ha and an upper bound of US$15/ha were derived. These represent the likely range of operational costs of a compensation scheme employing a system of payments.

compensating for 6.2 million hectares of avoided deforestation (the annual average net forest loss in these eight countries over the period 2000–2005) would range from US$25 million to US$93 million. To maintain this reduced rate of global deforestation over time will thus require substantial increases in administration costs every year. In the second year, compensation payments would need to be initiated for another 6.2 million ha, and payments made for the other 6.2 million ha from the first year. By year 10, annual administration costs would range from US$250 million to just under US$1 billion. Fixed costs of monitoring deforestation (but not at a level of accuracy to monitor carbon), and considering an estimate of US$2 million per country (estimated by Chomitz et al. 2006), would be at least US$16 million.

In the light of everything said so far, measures to avoid emissions from deforestation indeed look cost-effective when their cost per avoided ton is weighed against observed prices in the international carbon market, which, in the case of the allowances of European Emissions Trading Scheme fluctuated from 24.70 US$/t$CO_2$e in 2005 to 22.10 US$/tCO_2e in 2006, whilst the CDM's Certified Emissions Reductions (CERs) saw average prices of 10.90 US$/t$CO_2$e (World Bank 2007a, b). The costs of reducing emissions from deforestation are also reasonable when compared to those of other mitigation options. For instance, they compete with the incremental costs of the technologies identified in the Energy Technologies Perspective (ETP) of the International Energy Agency (IEA 2006),[5] which are not expected to exceed—when these technologies are fully commercialized—25 US$/t$CO_2$e in all countries, including developing countries.

However, it would be wrong to believe that REDD activities are among the cheapest options in the mitigation portfolio available to 2030. According to McKinsey&Company (2009), around 15 Gt CO2e per year could be mitigated at zero or negative costs through, for example, energy efficiency measures, efficient technologies in the transport sector and wast recycling. Likewise, grassland management, second generation biofuels, degraded lands restoration and reforestation activities may be cheaper than reducing emissions from intensive land-use conversion (Fig. 1). This, together with the high administrative costs involved in the implementation of REDD activities, challenges the idea that REDD credits could "flood" the carbon market in the future, a concern commonly raised by some Parties and NGOs. Furthermore, it could be argued that such fears to date are the result of a "procedural failure" in the negotiations of the Kyoto Protocol, given that the emission reduction commitments (the demand) were defined before the activities eligible to meet them (the potential offer) were decided—something that may not happen in the post-2012 framework. As we show in the next section, cost-effectiveness and large-scale impacts of REDD activities need to be assessed in the broader context of the existing proposals, which entail methodological uncertainties and institutional-capacity weaknesses.

[5]The ETP was produced in response to the G8 leaders at the Gleneagles Summit in July 2005, which called for the IEA to develop and advise on alternative scenarios and strategies aimed at a clean, clever and competitive energy future. The technologies assessed included energy efficiency in buildings, industry and transport, clean coal and CO_2 capture and storage, electricity generation from natural gas, nuclear power and renewables, and biofuels and hydrogen fuel cells in transport.

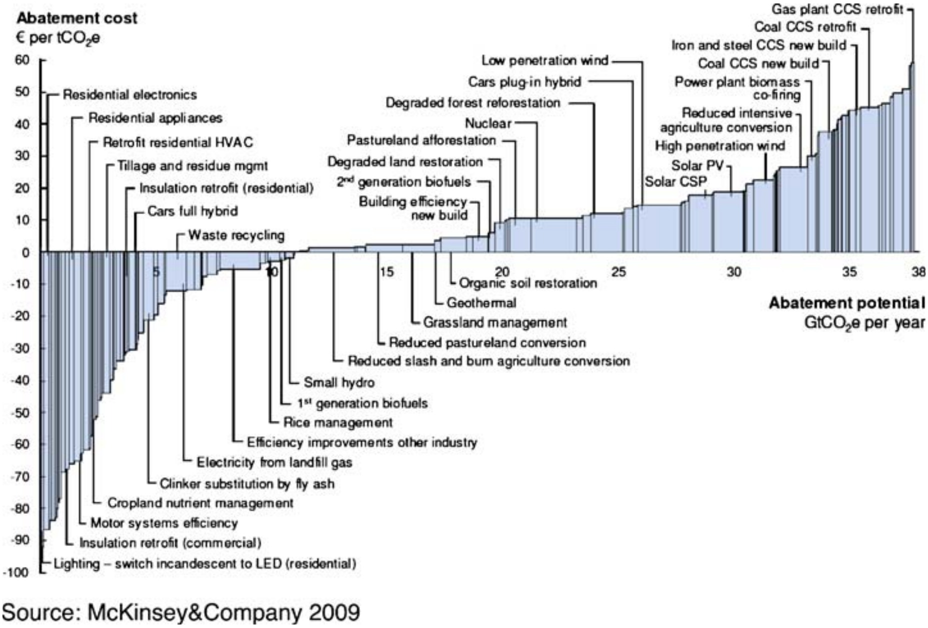

Fig. 1 Mitigation options and costs to 2030

4 Towards a REDD framework

4.1 Policy options: eligible activities and sources of funding

The type of forestry activities eligible under a REDD framework have important implications for technical aspects, particularly monitoring methodologies and costs, and for the likely future volume of emission reductions subject to reward or trade. Some Parties would like to ensure that REDD incentives apply not only to ongoing deforestation and forest degradation, but also to existing conservation efforts and promote the sustainable management of forests and enhancement of carbon stocks. Other Parties are more cautious and prefer that such incentives focus exclusively on activities reducing emissions from deforestation and forest degradation (UNFCCC 2009). At COP-13 in Bali, countries like India, Costa Rica, Indonesia and Bhutan openly supported the inclusion of conservation activities under a future REDD framework in order to ensure that those countries which have had a stable forest cover over time as a result of successful conservation and forest management programs can also benefit and strengthen such programs and further increase forest cover. This was opposed by Parties like Brazil and the European Union, which feared that conservation would be a potential source of “hot air” for REDD credits and it would reduce incentives for those countries who put efforts in halting ongoing land use change. The final decision adopted in Bali by the COP (Decision 2/CP.13) confirmed the need to take action against deforestation and forest degradation and thus requested the Subsidiary Body for Scientific and Technical Advice (SBSTA) to undertake a program of work on outstanding methodological issues related to a range of policy approaches and positive incentives for REDD. At the same time, positive incentives and policy approaches to REDD, together with the role of conservation, the sustainable management of forests and the enhancement of forest carbon stocks in developing countries, entered the more political discussions under the Bali Action Plan to be addressed by the AWG-LCA. As of March 2009, the size and characteristics of potential support schemes for these different options in a post-2012 regime are still under negotiation and will most likely not be defined before COP-15 at the end of the year.

In addition to eligible activities Parties' REDD proposals up to COP-13 in Bali were sustained on a number of potential sources of REDD funding, including voluntary contributions, the carbon market and levies and taxes (Table 3). Based on the estimates by Grieg-Gran (2006) presented in the previous section, it could be argued that a "sufficient" source of funding would be that which provides at least US$5 billion per year, the minimum required to achieve a substantial reduction in emissions from deforestation. Taking into account that the total funding of the Global Environment Facility (GEF) devoted to climate change activities from 1991 to March 2005 reached only US$1.75 billion (Freestone 2009), and that the whole fourth GEF replenishment to fund operations between 2006 and 2010 amounts to just US$3.13 billion,[6] it seems clear that voluntary contributions are far below the necessary level of funding for REDD. Moreover, Official Development Assistance (ODA) fluctuates considerably over time and is unpredictable. On average, ODA volatility is four times higher than developing countries' GNP. This volatility can be attributed to budgeting procedures in donor countries, changes in priorities and policy-making or implementation delays. In most cases, it cannot be linked to objective and identifiable causes, hence it cannot therefore be anticipated (Mission Permanente de la France 2006).

A number of public funds have already been established to support the development of REDD activities, which as of March 2009 have been able to secure less than US$1 billion. The World Bank Forest Carbon Partnership Facility was established in 2007 to assist developing countries to reduce emissions from deforestation and forest degradation, and it expects to support 37 developing countries with a minimum of US$60 million or a maximum of US$300 million (World Bank 2007a, b). The fund's rationale is to support countries in preparing to participate in a future, large-scale, system of positive incentives for REDD, which includes preparing a national REDD strategy; establishing a reference scenario for emissions from deforestation and degradation, based on recent historical emissions and, possibly, modelling of future emissions; and establishing a monitoring system for emissions and emission reductions (ibid.). Once the REDD strategy has been designed and it is in place, the fund will also support the implementation of REDD activities in selected areas of each country. The first step before drafting the REDD strategy involves developing a Readiness Plan Idea Note (r-PIN) highlighting the main issues to take into account in the strategy and identify priority areas for funding (e.g., baseline preparation, capacities within government, land tenure programs). As of March 2009, 37 countries have already developed an r-PIN, but only two of them (Guyana and Panama) have presented their final Readiness Plan, which are still subject to approval.

Other funds established to support REDD in developing countries include Australia's International Forest Carbon Initiative (IFCI) (formerly known as Global

[6] http://www.gefweb.org/replenishment/replenishment.html

Table 3 Parties' REDD proposals in COP-13

Proposal	Source of funding for incentives	Incentives mechanism	Main features
National approaches			
Bolivia—joint submission[a]	Carbon and non-carbon market	REDD Mechanism—a system of positive incentives to support voluntary policy approaches	Incentives would be determined by calculating the estimated Reduced *gross* Emissions from Deforestation and Degradation (REDD), over an agreed upon past time period, evaluated against a Reference Scenario (RS) RS would be estimated through a reference emissions rate (RER) and taking into account a Development Adjustment (DA) factor (updated periodically)
Brazil	Financial voluntary incentives provided by Annex I countries	Provision of positive incentives for the net reduction of emissions from deforestation in developing countries, in relation to a Rate of Emissions from Deforestation (RED)	The positive incentives system is based on a comparison between the rate of emissions from deforestation (RED) for a certain past time period with the reference emissions rate (RER) RER is calculated on the basis of the emissions from deforestation in the last 10 years, and a minimum of 4 representative years need to be assessed. RER shall be recalculated every three years, only if it falls below the previous RER, as the average of the three last RED values If emissions from deforestation have increased, the difference is converted into a debit from future financial incentives RED monitoring shall be based on a transparent and credible system that reliably provides estimates of the annual emissions by biome
Congo Basin Countries[b]	Share of proceeds on REDD credits[c], taxes on carbon intensive products and services	Stabilization fund to support developing countries with low rates of deforestation	The share of proceeds could be distributed according to a number o criteria, such as total forest area, deforestation rate, forest area managed sustainably, and protected areas The selected criteria will especially recognize any effort in sustainable management beyond forest cover conservation

India	Not specified	Compensate countries for maintaining and increasing their forests	Incentives would be provided to developing countries which effectively expand or enrich their forests from a previously set baseline, that may be fixed at 1990 or other appropriate level
Vanuatu	Macroeconomic Ecosystem Services Market	A Direct Barter Approach—involves negotiating the exchange of an ecosystem service provided by one entity with something valuable provided by another entity, such as cash, debt cancellation, trading opportunities, employment, migration, technology transfer and education	The eligibility of forests for Direct Barter transactions would depend on the ability of such forests to demonstrably contribute to global carbon stocks protection
			Forests put forward by nations seeking Direct Barter transactions would register these forests as Direct Barter Assets (DBAs). The eligibility of DBAs and their categorization in a Direct Barter Asset Register could fall into two categories—a mandatory category (DBAm) and a voluntary category (DBAv) depending on their level of indirect co-benefits (socio-economic and cultural)
Sub-national, sectoral and community-based			
Costa Rica—joint submission[d]	Levy on ERUs or AAUs, tax on carbon intensive commodities and services and voluntary contributions	An Avoided Deforestation Carbon Fund (ADCF) to provide resources for the implementation of REDD activities	The activities financed through the ADCF could generate credits and provide participants with an entry to the carbon market (e.g. CDM), which would in turn entail additional funds and incentives
	Carbon market	CDM and other market instruments	Builds on CDM institutions and experience

Table 3 (continued)

Proposal	Source of funding for incentives	Incentives mechanism	Main features
Vanuatu	Carbon market 1	A Carbon stock mechanism that extends the principles of a voluntary emission trading to forest carbon reserves in developing countries	The carbon stock mechanism involves calculating the amount of carbon stock that exists in a country's forests; issuing credits representing the carbon stored in the above ground biomass of national forests; establishing a reserve over part of the national forest area, the size of which would be negotiated as part of the overall post 2012 negotiations or as a separate mechanism; approving eligible projects that commit to protecting forest area outside the reserve and periodically verifying the quantity of carbon stock being protected; and issuing a corresponding amount of tradable (temporary or permanent) credits to approved projects
	Carbon market 2	A sectoral crediting baseline approach covering carbon stock management activities within a geographic area defined by the country—known as Carbon Program Management Area—	The country voluntarily proposes a commitment of a C stock level in its program management area at the end of the management period, and this is accepted in the international negotiation process as the crediting baseline C stock Project proponents would enter into a contract with the host government and they would commit to increase the carbon stock levels within an identifiable project boundary inside the program area. They would receive tradable carbon credits upon achieving a higher carbon stock than the project baseline stock and could enter a forward contract sale of compliance-grade (temporary or permanent) credits to international carbon market buyers

Tuvalu	Bilateral ODA, corporate sponsorship, NGO and government contributions	A forest retention incentive scheme: a new funding arrangement under the Convention (alternative to carbon trading) to provide the necessary financial incentives to allow communities in developing countries to manage their forests sustainably	Communities that wish to reduce emissions from deforestation or forest degradation activities would seek funding to establish a Community Forest Retention Trust Account (CFRT Account) The funds received for the forest retention project would be put into the CFRT Account and the community could draw on a prescribed percentage of this Account to establish measures to combat deforestation and forest degradation Once the CFRT Account was established communities could apply for Forest Retention Certificates, which would be estimated based on emission trends at the commencement of the project compared with emissions at the end of a prescribed period (5–10 years) Independent auditing will determine the amount of certificates to issue to an international forest retention fund (fed by the special climate change fund, voluntary contributions from governments, International financial institutions, corporate donations and NGO contributions). The certificates could not be sold, transferred or traded

[a] Bolivia, Central African Republic, Costa Rica, Democratic Republic of the Congo, Dominican Republic, Fiji, Ghana, Guatemala, Honduras, Kenya, Madagascar, Nicaragua, Panama, Papua New Guinea, Samoa, Solomon Islands, Vanuatu

[b] Gabon on behalf of Central African Republic, Cameroon, Congo, Equatorial Guinea, Democratic Republic of the Congo and Gabon

[c] The Congo Basin Countries also suggested the creation of a REDD mechanism, identical to that proposed by Bolivia in its joint submission. The REDD credits mentioned here refer to those generated through that mechanism

[d] Costa Rica, Dominican Republic, Guatemala, Honduras, Mexico, Panama, Paraguay and Peru

Initiative on Forests and Climate), with an endowment of AUS$200 million—which includes US$10 million for the FCPF—which aims to support Papua New Guinea, the Philippines and Indonesia in REDD design and pilot activities, and the Brazilian Amazon Fund, which has already received contributions from Norway (US$110 million) and Germany (US$20 million), and with ambitious expectations of raising US$20 billion by 2020, including further donations from these and other countries, as well as private investors (Government of Brazil 2008). The United Nations has also established a multi-donor fund to support REDD, involving FAO, UNEP and UNDP, which has so far only received a contribution from Norway of US$50 million. In the light of an increasing proliferation of essentially public finance for REDD design and implementation, the FCPF, UN-REDD and IFCI programs are working closely to coordinate funding effectively.

The carbon market could thus be regarded as the most significant additional source of development finance, potentially exceeding US$50–120 billion/year in the long term (IEA 2005). In 2006, developing countries generated nearly 450 Mt CO_2e of CDM credits, representing an increase of 32% from 2005 volumes, for a total market value of US$5 billion (World Bank 2007a, b). However, for the carbon market alone to become a "sufficient" and predictable source of REDD funding, an agreement on more stringent emissions reductions beyond 2012, the inclusion of other project typologies under the CDM while maintaining adequate carbon prices, and the establishment of a long-term carbon goal will be essential. Additionally, simple rules and a broad market access for REDD activities will also be indispensable, especially taking into account that in 2006 carbon assets from afforestation and reforestation activities remained at only 1% of the total volume transacted in the CDM mostly due to complex modalities and methodologies and the exclusion of CERs from sinks projects from the EU Emissions Trading Scheme (World Bank 2007a, b).

In order to fund REDD activities, some Parties have proposed setting a levy (although they have not quantified it) on the Emissions Reductions Units (ERUs) issued or the Assigned Amounts (AAUs)[7] first traded in the carbon market, similar to the one imposed on CERs, as well as a tax on carbon intensive commodities and services in Annex I countries to feed an avoided deforestation carbon fund, which would support activities to reduce emissions from deforestation. In the case of ERUs, Point Carbon estimates that the potential offer in the period 2008–2012 could be around 200 MtCO_2e. Conservatively assuming a price of ERUs equal to its 2006 average (US$8.70) (World Bank 2007a, b), the total market value of ERUs offered in the first commitment period could be around US$1.8 billion (or US$360 million per year). For its part, the potential AAUs supply during that period has been estimated at 6.75 billion, but it is likely that in reality it will be limited to around 2.7 billion

[7]Each Annex I Party issues AAUs up to the level of its assigned amount. Assigned amount units may be exchanged through emissions trading. Emission Reduction Units (ERUs) are generated for emission reductions or emission removals from joint implementation projects. Certified Emission Reductions (CERs) are issued for emission reductions from CDM project activities. All units are equal to 1 metric ton of CO_2e (UNFCCC Website http://unfccc.int/essential_background/glossary/items/3666.php).

(Haites 2004). Assuming an average AAU price of US$5 per ton,[8] the total value of AAUs in the first commitment period could be around US$13.5 billion, equivalent to US$2.7 billion a year. Therefore, under the conditions expected until 2012, not even the sum of the potential annual value of both ERUs and AAUs together could attain the US$5 billion per year estimated by Grieg-Gran (2006) to reduce deforestation in a significant way. In fact, assuming a 2% levy on Joint Implementation or on Emissions Trading, the total annual market value of ERUs or AAUs would have to be around US$250 billion (nearly ten times the expected AAU market value from 2008 to 2012) in order to generate the required level of resources. Furthermore, a levy of this kind would depend on the existence of a sound long-term carbon market in order to produce a (to some extent) predictable flow of funds. Nevertheless, such levies, if linked to the carbon market by allowing funded projects to generate credits as proposed by Costa Rica,[9] could constitute a potentially sufficient source of funding, although politically difficult to negotiate.

Finally, it is not possible to estimate the likely volume of resources that a tax on carbon intensive commodities and services in Annex I countries could raise, since such commodities and services have not yet been specified by Parties. It is worth noting, however, that in the current context no international authority has the power to levy taxes. Consequently, an international tax such as the one proposed would have to be defined as a series of identical or similar national taxes, implemented by governments within a jointly agreed framework that would also cover the use of the revenue raised by each country.[10] This cooperative arrangement would need to be negotiated and legally formalized.

4.2 Technical issues

In addition to the question of which REDD activities become eligible and how to fund them, there are key technical issues which need to be resolved prior to establishing an international REDD framework. We acknowledge that some of these technical concerns are very much influenced by eligible activities. For instance, the type of satellite imagery and monitoring efforts required to assess changes in forest stocks, and the potential costs associated to them, from deforestation alone or deforestation combined with forest degradation, are very different. Forest degradation monitoring will require high resolution satellite imagery, which would need to be combined with ground based monitoring, thus increasing costs. Furthermore, new remote sensing technologies that may allow the estimation of changes in biomass will take some years to become routinely available for developing countries which in practice would result in a few countries with resources and expertise having advantage over others in early years of REDD implementation. If conservation were taken into account, the approach chosen to compare and reward REDD efforts

[8]According to the unpublished report "Options for a Green Investment Scheme for Bulgaria" (2004), by Charlotte Streck et al., a price range between US$4 to US$7 per ton of CO_2e in the AAUs market seems plausible based on current market indications.

[9]In a joint submission with the Dominican Republic, Guatemala, Honduras, Mexico, Panama, Paraguay and Peru (see Table 3 for more details on this proposal).

[10]A similar scheme has recently been proposed by France for the International Air-ticket Solidarity Contribution, aimed at addressing the public health challenges facing developing countries.

would have to be different for those countries with successful conservation policies in recent years (like Costa Rica; as well as those undergoing a "forest transition" (Rudel et al. 2005)), with currently low deforestation rates, and for those which have suffered and continue experiencing high deforestation rates (like Brazil); otherwise the former would either not be able to access any benefits or could generate "hot air".

The nature of technical issues will also differ depending on the scale at which carbon benefits are assessed and awarded. In this sense, mechanisms proposed by Parties (Table 3) can be divided into two main groups: exclusively national and from project to national (sub-national). The implications of these two approaches for the determination of emissions baselines, leakage, monitoring, permanence, and the geographical distribution of REDD activities is now discussed.

4.2.1 Emissions baselines

A number of Parties (e.g., PNG, Bolivia and Brazil) have proposed approaches that base incentives exclusively on the achievement of quantified emissions reductions from deforestation vis-à-vis national baselines or reference scenarios. Bolivia[11] and Brazil, for instance, propose a baseline-and-credit system where reference emissions levels are based on historic emissions rates. Brazil calculates such rates based on emissions from deforestation data of the last ten years, underlining that a minimum of four representative years needs to be assessed, whereas Bolivia has not specified a minimum period. The use of historic rates to establish baselines is similar to Annex I base year determination for emission targets, but it bears the same risk, namely the creation of excess emission allowances ("hot air"), particularly if there is evidence that deforestation is likely to decline in any of the large remaining tropical forest areas.

Deforestation rates can be related to the amount of remaining forests and their location: a slowing down of deforestation rates may reflect nothing more than the increasing cost of reaching what forest is left (Skutsch et al. 2006). Moreover, deforestation dynamics and the timing of deforestation differ greatly amongst countries and even within countries. It will make a great difference which reference period is chosen in order to estimate a baseline. If one particular base year or base year period was set for all countries wishing to conduct REDD activities, one group of countries will always be put at a disadvantage: those that had low deforestation rates in the base year or base period. These problems are further aggravated by the fact that land-use change and carbon stock data for most developing countries are very incomplete, which could undermine the expected environmental benefits of national approaches. Further, national baselines are also rejected by many developing countries on the basis that they could be a "back-door" way to coerce them into a regime of quantified emission reduction targets (Schwarze et al. 2002). As an alternative or complement to the establishment of baselines, Vanuatu proposes a carbon stock approach, through which a finite number of carbon credits is allocated to participating countries that

[11]In a joint submission with Central African Republic, Costa Rica, Democratic Republic of the Congo, Dominican Republic, Fiji, Ghana, Guatemala, Honduras, Kenya, Madagascar, Nicaragua, Panama, Papua New Guinea, Samoa, Solomon Islands, Vanuatu (see Table 3).

represent the tons of carbon stored in a country's forestry resources in a base year (UNFCCC 2007).

No standard methods currently exist to estimate avoided deforestation project baselines. Pilot projects that currently receive carbon credits have used a number of different approaches, amongst them: (a) extrapolation into the future of past trends; (b) hypothetical future scenarios; (c) prevailing technology or practice; and (d) simple logical arguments based on adjusting observed trends (De Jong et al. 2005). However, none of the methods allow an objective assessment of whether the baseline is appropriate to the area in question or provide a measure of how accurate the prediction is likely to be (ibid.). Spatial statistical models are considered appropriate to identify and evaluate the relationship between deforestation and spatially-explicit explanatory variables such as accessibility and pressure on land (e.g. Chomitz and Gray 1995; Cropper et al. 2001; Deininger and Minten 1996; Mamingi et al. 1996; Mertens and Lambin 2000; Nelson and Hellerstein 1997). These models are well suited for predicting where deforestation will occur and generally involve large samples and reasonably reliable data (Mertens et al. 2002). While such models say little about what tools are likely to be effective in preventing deforestation (Cropper et al. 2001), they suggest where deforestation will likely take place in the future if the spatially explicit conditions remain similar (De Jong et al. 2005).

4.2.2 Leakage

Leakage is defined by the IPCC's Special Report on LULUCF as the unanticipated decrease or increase in GHG benefits outside of the project's accounting boundary (the boundary defined for the purposes of estimating the project's net GHG impact) as a result of project activities. When leakage is considered in national REDD approaches, the country-wide accounting of emissions from deforestation would mean that carbon losses outside the areas where REDD interventions are carried out would automatically be accounted for, since leakage would become part of the country's emissions from deforestation—in other words, the liability for leakage is transferred from the developer of a REDD activity at the sub-national level to the government. However, this does not entirely solve the leakage problem since the issue of international leakage remains. For instance, increased control over illegal logging in Indonesia with the aim to reduce deforestation and forest degradation could shift loggers to neighboring countries. For this reason, it has been argued that international leakage will be reduced if participation is incentivized (Skutsch et al. 2006). Nevertheless, we believe that widespread participation of developing countries in national REDD schemes in the short term is not likely due to lack of human resources and technical capacity which, as reflected in recent discussions by Parties and observers, need to be strengthened through a REDD "readiness" phase and additional financial support from multilateral agencies and other sources (UNFCCC 2009). Therefore, limiting the participation of such countries exclusively to national approaches could generate more international leakage than other more flexible approaches allowing for a wider participation even if at smaller scales. Likewise, the global environmental benefit of a flexible approach could be larger than that of a national scheme limited to a handful of countries with the required capacities in place.

It is often argued that REDD projects are more difficult to measure and monitor and have greater leakage of GHG benefits than energy sector projects. Nevertheless, a review of projects in the energy and LULUCF sectors assessed critical technical issues associated to projects, including baselines and leakage, and found that REDD and energy projects face parallel, comparable issues in measurement and in ensuring social and environmental benefits (IPCC 2000). Additionally, there is no concrete evidence that any one type of forestry project is more or less susceptible to leakage than others. In fact, it has been argued that there is no apparent and compelling reason to discard any one type of climate change mitigation option based solely on leakage (Schwarze et al. 2002). However, we acknowledge that REDD project-based or regional approaches do indeed face a relative risk of seeing how land-use change processes move towards areas where REDD programs are not being developed or where weak land-use governance predominates, such as regions with weak law enforcement and persistent land-use conflicts.

4.2.3 Monitoring

The ability to accurately quantify tropical deforestation is critically important for the generation of carbon credits from reduced deforestation. Key elements of a possible monitoring system include its ability to measure changes throughout all forested area within a country, use consistent methodologies at repeated intervals to obtain accurate results, and verify results with ground-based or very high-resolution observations (Herold et al. 2006). Nationwide monitoring of changes in forest or non-forest vegetation cover is required if accurate national accounting is to be attained. In particular, the full forested area of the country needs to be represented so as to account for leakage. For countries with a small forested/vegetated area, changes in forest cover may be tracked on the ground. However, when forest or non-forest vegetation areas occupy hundreds of thousands of hectares, then the costs of ground truthing are elevated and accuracy is lowered. For most nations, the only practicable approach for monitoring changes in forest and vegetation cover at the national scale is through the interpretation of remotely sensed imagery (including both airborne and satellite imagery). Furthermore, transition points from intact to non-intact forest are hard to determine by remote sensing as a canopy may still be closed, whilst the carbon stocks may well be reduced by 75% (UNFCCC 2006a). A variety of remote sensing methods can be applied depending on national capacity, available resources, deforestation patterns and forest characteristics. However, the key constraints in implementing national systems for monitoring changes in forest cover are cost and access to data at the appropriate resolution. Where cost is reasonable and/or the area to monitor is small, then wall-to-wall coverage with high resolution imagery such as Landsat or even with airborne imagery will provide a high level of certainty to estimate land use change (UNFCCC 2006a, b).

The alternative to satellite coverage is sampling. With respect to sampling remotely, one approach is to use a 'hierarchical nested approach' using medium to coarse resolution imagery (DeFries et al. 2002, 2006; Morton et al. 2005), whereby coarse resolution imagery is used to identify areas of rapid land use change that then become the focus of further study with higher resolution imagery. Furthermore, Chomitz et al. (2006) point out that there are economies of scale in sampling as the accuracy of the estimate depends on the size and representativeness of the sample, and not on the size of the population. Consequently, costs of monitoring deforestation at a rather coarse scale to pick up 25 ha patches would not differ so much by country and could cost around US$2 million per year. However, it is recognized that this would not serve for an accurate assessment of changes in carbon stock but would be an important part of an implementation strategy (Chomitz pers comm. cited by Grieg-Gran 2006). This lack of accuracy could, in any case, have important implications for including national approaches in the carbon market. Monitoring deforestation at national level is often assumed to be less uncertain than at the project level, yet many developing countries lack data on deforestation and corresponding carbon stocks. In these cases, it probably makes more sense to develop regional baselines at sub-national administrative levels (DeFries et al. 2005).

In contrast, the IPCC Special Report on Land-Use Change and Forestry (IPCC 2000) suggests that REDD projects are easier to quantify and monitor than national inventories because of the project activities' defined boundaries, the relative ease of stratification of the project area, and the choice of carbon pools to measure. Techniques and methods for sampling design and for accurately and precisely measuring individual carbon pools in REDD projects are based on commonly accepted principles of forest inventory, soil sampling, and ecological surveys. Moreover, the IPCC report (ibid.) also points out that, the error estimate in avoided deforestation projects (particularly in those with high carbon benefits) is likely to be small and similar to that obtained for carbon stocks in the forests. However, standard methods have not been universally applied to all projects, and methods of accounting for carbon benefits have not been standardized, thus resulting in some difficulties when comparing results across different projects.

In the light of these considerations, it seems evident that the costs of measuring and monitoring REDD projects will be a function of the desired level of precision (which may vary by the type of project activities), the size of the project, whether the project area is a contiguous or dispersed bundle of small landowners, and the natural variation within the various carbon pools. In cases like the Noel Kempff Project in Bolivia, the total cost was about $350,000 (IPCC 2000). The precision of the inventory, based on sampling error only, was ±4% with 95% confidence. Estimates of the revised carbon benefits from this project for its duration, based on additional measurements and data collection and the additional cost to collect this information, are in the region of US$0.10/tC. Moreover, future monitoring costs are likely to decrease because different sampling intensities will be used, project implementers can build on previous experience, and advances in technology will be available. In the Costa Rica's Private Forestry Project (PFP), the organization responsible for monitoring carbon sequestration and for acquiring remote-sensing information has an annual budget of US$200,000 (Subak 2000). Additional costs relate to the costs of monitoring forests and plantations on-site, including visits by forest engineers as well as more detailed audits of some sites (approximately a 5%). The labor costs for auditing are estimated to be US$10/ha/year, compared to US$1/ha/year for monitoring and US$2/ha/year for certification. The aggregate costs of project development, recruiting, and auditing are significant but they have not been judged to be excessive or to reverse the cost-effectiveness of the PFP.

4.2.4 Permanence

Parties have so far proposed mainly two options to deal with the permanence issue, applicable to approaches at any scale. Brazil requires countries to convert any increase in their emissions from deforestation above the reference emissions rate to a debit from future financial incentives. Although this may provide a simple solution to deal with permanence, it could also discourage the participation of countries with poor performance, particularly at initial stages when capacities would still be in the process of being established or strengthened. As a consequence, fewer countries may be able to effectively participate, and a smaller amount of emissions would be reduced globally in the short term. The second option to deal with permanence is the use of temporary Certified Emissions Reductions (tCERs), which would mean that the onus would be on the buyer of the carbon credits to renew them on a regular basis, as currently is the case of afforestation and reforestation projects in the CDM. Temporary credits however have an uncertain value, the only certainty being that they will be worth less than CERs (Schlamadinger et al. 2005), which has so far limited their attractiveness. The use of tCERs would, on the other hand, imply that REDD results in another Kyoto-type mechanism which does not lead to any further commitments by non-Annex I countries (ibid.). Table 4 presents a summary of the key characteristics of national and sub-national approaches.

4.3 Institutional concerns

The implementation of national approaches as an exclusive instrument to provide incentives to reduce emissions from deforestation in developing countries could have negative equity implications. These would arise primarily from the general lack of capacity in most developing countries to successfully implement REDD in the near future. The resources (including international support) and time that have

Table 4 Comparison of national and sub-national REDD approaches

REDD dimensions/ approach	National	Sub-national
Baselines	Deforestation baselines based on historic trends—selection of base year period critical— Viability potentially undermined by lack of data and capacities	Deforestation baselines will contain uncertainties associated with the models used
Additionality and leakage	Additionality difficult to determine in forest transition countries Leakage better controlled, but international leakage may remain if a majority of countries do not engage in REDD	Additionality assessed following similar rules to the CDM Leakage to be considered in the same way as for other mitigation projects
Monitoring and permanence	Effective monitoring subject to data availability, funding, and the existence of standardized evaluation methods across countries	Monitoring techniques need to be defined and standardized, and it may be easier to account for permanence due to well-defined project boundaries and carbon pools
Equity	Distribution eschewed in favour of skilled countries	Uneven distribution of REDD activities is also possible but increases the chances of participation by small countries with low deforestation rates

been required to put in place operational Designated National Authorities (DNAs) for the CDM in many developing countries—a relatively simpler institution than those required for controlling national GHG emissions from deforestation—provide an idea of the effort and time that would be necessary to establish the "carbon infrastructure" mentioned in Section 4.2.1. Likewise, under an exclusive national approach, countries with large forest areas and those currently suffering mostly from degradation would be in a disadvantageous situation, since they would require more expensive monitoring methods. Moreover, even though—as argued by countries supporting national approaches—the use of the IPCC Good Practice Guidance and Guidelines for National Inventories could facilitate the estimation of emissions from deforestation at the national level, those countries with less capacities would have to rely on default values, by definition conservative. Under a carbon market scenario, this might imply that these countries could receive fewer incentives (carbon credits) for the same reduction effort than a country with available data and country-specific carbon content values.

In contrast, allowing for a series of different approaches according to existing capacities would allow for a broader participation in international REDD efforts, yet their distribution could be still uneven, as demonstrated in the current CDM, where sub-Saharan Africa has been left behind (Boyd et al. 2009). Nevertheless, a more flexible REDD approach, allowing for sub-national initiatives, may potentially benefit a higher number of countries, putting in place projects that ensure poverty and pro-poor development benefits, with the use of simplified methodologies for small scale activities, and the creation of niche markets for ethically motivated projects where sustainable development is prioritized (Brown et al. 2004).

Regardless of the approach taken, selecting REDD pilot areas under a national scheme and defining a framework to transfer REDD incentives across scales, both for national/regional approaches and project activities, will be challenging processes. They are likely to generate tensions within countries and REDD participants and impact directly on the efficiency, effectiveness, equity and legitimacy of REDD schemes. For example, the early years of Mexico's program of Payments for Watershed Regulation Services disbursed payments across the country to secure equity outcomes and political fairness, regardless of the true benefits of selected projects in terms of river basin protection (Muñoz-Piña et al. 2008). Such poor targeting was addressed over the years but after a large number of rural communities benefited from the scheme. At present, Mexico is developing deforestation risk maps to identify target areas for REDD pilots under the World Bank's FCPF, thus trying not to repeat PES early outcomes. However, we would argue that this may have some political costs, particularly considering previous government programs where subsidies were granted in the form of payments for carbon sequestration, and it may thus generate discontent and create a perverse incentive in those forested communities located far from the identified deforestation hot spots (e.g. agricultural and urban frontiers).

The allocation of incentives across scales of governance in REDD pilot areas is also likely to be a difficult and time-consuming process, involving multiple stakeholders with competing interests (Trines et al. 2006). As it has also been shown in the PES literature, the negotiation of national-based payment systems has often taken at least 1 or 2 years and has involved lobbying by different parties, within and outside government (Corbera et al. 2009). The allocation of incentives for forest management and conservation need to take into account which actors have *de facto* and *de jure* rights over land and who is likely to benefit the most—and the least—from REDD. REDD incentives will also need to ensure that marginalized forest dwellers and farmers do not become worse-off as a result of the scheme and that their rights to sustain their livelihoods are not compromised (Corbera et al. 2007). It will be important to consider who is entitled to trade and receive carbon revenues and ensure that such revenues are not unfairly captured by private intermediaries and public institutions (Corbera 2008).

5 Discussion: governance challenges for REDD

So far our analysis reveals that a substantial reduction of emissions from land-use change over forthcoming decades can have critical climate benefits. However, the cost of achieving such reduction has been estimated around US$5 billion/year which is a substantial figure when compared to current GEF funds, ODA flows and carbon market investment volumes. Our examination of current REDD proposals has shown that these are characterized by several implementation uncertainties and challenges. Although these proposals will be further refined at the international policy level over the next few months and probably years—in order to come up with the most politically acceptable and environmentally effective framework—we argue that important efforts should still be made by individual countries to tackle the much broader political economy of deforestation. The act of clearing forested land and, subsequently, changing its use, is rooted in a set of complex social, economic, cultural and environmental realities, which operate over different spatial and temporal scales and vary in importance among nations and regions. Tropical deforestation, in particular, is not simply a forestry problem but one of land use, as most causes originate outside the forestry sector or the political domain of environmental ministries. Deforestation usually results from a combination of direct, immediate or proximate causes, indirect or underlying causes and other factors,[12] which in turn involve distinct stakeholders such as individuals, community groups, corporations, government agencies and development projects (Geist and Lambin 2001; Kaimowitz and Angelsen 1998; Brown and Pearce 1994).

The results of a study focusing on the causes of deforestation in 152 sub-national case studies (Geist and Lambin 2001) revealed that tropical deforestation is driven by identifiable regional variations of synergetic cause/driver combinations in which economic factors, institutions, national policies and remote influences are prominent. Economic and policy/institutional factors tended to be strongly interrelated and appeared as strong drivers of deforestation, while cultural, demographic and

[12] Geist and Lambin (2001) define underlying causes as broad forces that underpin proximate or direct causes. They include macro-level variables and policy instruments that are beyond the control of deforestation agents, and are divided into economic factors, policy and institutional factors, technological factors, cultural factors and demographic factors. Proximate causes of deforestation are those human activities that directly remove forest cover (e.g., agriculture, logging, infrastructure development), whilst the group of other factors associated with deforestation is composed of predisposing environmental factors (land characteristics, features of the biophysical environment), biophysical drivers and social trigger events.

technological factors were less so. Even though the expansion of cropped land and pasture was found to be the most frequently reported proximate cause of tropical deforestation, shifting cultivation was not to blame but rather the expansion of permanently cropped land for food production, often in hands of private companies. Further, in cases with high rates of annual deforestation, pre-disposing biophysical factors were at work or shaped the pattern of deforestation, namely low relief and flat topography in combination with good soil quality and high water availability. This complexity and interacting drivers need to be considered in designing any policies to stem deforestation.

Furthermore, evidence to date shows that countries' efforts to tackle deforestation, based on a combination of policies promoting conservation areas and sustainable forest management, have not been necessarily effective (Table 5). Across the developing world, total spending (including recurrent spending) on protected areas is roughly US$800 million/year (Chomitz et al. 2006), yet some of these areas remain constrained by insufficient staffing, poorly designed multi-stakeholder and institutional arrangements, lack of management leadership and undermining political environments (Stoll-Kleeman et al. 2006). Sustainable forest management programs have performed poorly because it is generally less profitable than alternative uses to individual actors or groups, and there is often a lack of secure land tenure or effective rights to forests, which may result in conflicts over land allocation. These conditions are worsened by the existence of illegal logging and trade networks, accompanied by lack of staff, equipment, training, as well as the presence and practice of corruption among government officers (ITTO 2005).

This shows that it may be too optimistic to assume that sub-national REDD initiatives can halt deforestation on their own, and that national approaches may be implemented in the short or middle-term. National, state and municipality level policies (environmental, agricultural, economic) should contribute to support and complement sub-national activities. The governance of land use change is a multi-sectoral issue, which requires coordination and institutional adaptation by all the agents involved. In this regard, lessons for REDD can be learnt from ongoing national systems of PES, which have also required the establishment of complex institutional frameworks and strong capacity-building efforts across government, civil society and service providers (Corbera and Brown 2008). In addition, financing national REDD approaches becomes more complex when wider governance issues are considered. Examining some governance indicators (government effectiveness, regulatory quality, rule of law and control of corruption, as defined by the World Bank) of the eight countries identified by Grieg-Gran (2006), it appears that most of them (with the exception of Malaysia and, to some extent, Brazil and Congo) are facing important governance challenges, which may hinder their capacity to implement effectively a national approach, at least in the short term. Moreover, many of the countries that could achieve the highest relative incomes through payments for avoided deforestation, such as Liberia, the Democratic Republic of Congo and Myanmar, may not have sufficiently effective governance capacities to implement effective land-use policies (Ebeling and Yasué 2008).

Davis et al. (2009) have reviewed 25 Readiness Plan Idea Notes (r-PINs) submitted to the World Bank's FCPF and highlight that most r-PINs lack emphasis on governance aspects, including an identification of the reforms and resources required to improve forest law, an in-depth discussion of carbon rights and land tenure

Table 5 Review of policies to prevent forest clearance

Policy	Description	Effectiveness
Reducing prices and demand for tropical agriculture and forestry products		
Policies for economic growth	Economic growth policies that concentrate less on agriculture and forestry are more likely to be effective on reducing deforestation rates. However, this is the case only when economic growth is accompanied by an equitable distribution of wealth (Ewers 2006)	Moderate (Kaimowitz and Angelsen 1998)
Policies to devaluate currency	They increase the relative price of tradable goods, thus making agriculture more profitable. Policies to control exchange rates could decrease deforestation rates if the export of agricultural goods is a major underlying cause of deforestation Governments are unlikely to adopt them as a means to control deforestation	Moderate (Kaimowitz and Angelsen 1998)
Policies that control the price of tropical goods	They apply to local production and consumption and include price ceilings and quotas, import restrictions and guaranteed minimum prices. Experiences in Central America show that price controls and other restrictions are likely to affect producers on lands that have already been converted and not to those on the agricultural frontier as these last have fewer alternatives to agriculture (Kaimowitz and Angelsen 1998). The same situation applies to logging, with the addition that decreasing prices and demand for wood can have negative effects on sustainable forest management	Ambiguous (von Amsberg 1998) Moderate (Kaimowitz and Angelsen 1998)
Policies that set export bans and taxes	They are implemented with the intention of decreasing supply and demand of agricultural products by increasing prices. However, such policies are likely to have negative side effects as they would discourage sustainable production, increase national consumption and increase illegal activities in countries with weak law enforcement	Moderate in the short run (Kaimowitz and Angelsen 1998)
Increasing the costs and risks associated with deforestation		
Policies that reduce subsidies for certain agricultural inputs	In an interest to promote agricultural activities, governments provide subsidies on fertilizers, pesticides and fuel, and credit for farming as well as for logging in the form of low stumpage prices and logging concessions. The literature has largely criticized these subsidies for the effects on forest cover. In general terms, market distortions that artificially make agricultural or logging activities more profitable have proven to be less economically efficient in the longer run as a consequence of ignored environmental costs (Grainger 1993; Kaimowitz and Angelsen 1998).	Moderate in the medium term. However, effectiveness is questionable (see examples from Brazil by Lele et al. 2000; Faminow 1998)

Policies to reduce technical support for agricultural activities	They may be difficult to implement given the political difficulties of stopping technical support for agricultural development in general. Some countries have effectively implemented policies that target lands not belonging to the agricultural frontier, as well as labor intensive practices, natural resource management and intensification of agricultural production	Low (Kaimowitz and Angelsen 1998)
Incorporating deforestation concerns into road and transport policies	Development of new roads increases deforestation in many different ways, for example, by opening new areas of forests and by increasing the profitability of agriculture through eased transport. Analyzing the implications of road construction for forest cover should be an essential component of any transport policy. This does not necessarily imply that fewer roads should be developed but rather changing their location, type and nature	Moderate in the medium term (Kaimowitz and Angelsen 1998)
Establishing protected areas	Although there are examples of efficiently managed protected areas, a report by IUCN reveals the lack of sustainable funding and shortage of funds to effectively manage them. It concludes that current levels of funding are inadequate, thus requiring the identification of new sources (IUCN 2006). Kaimowitz and Angelsen (1998) argue that deforestation has also been encouraged by restricting access to natural resources and by neglecting traditional management and protection of forested areas. Policies on land use zoning should provide for the involvement of local and indigenous communities. Only a couple studies explore reasons for variations in the effectiveness of protected areas. Bruner and others (2001) and Dudley and colleagues (2004) correlate management practices with self-reported measures of park conditions and find that guards are an important part of the transition from "paper parks" to working parks	Variable (Kaimowitz and Angelsen 1998)
Policies to reduce support for colonization	Few countries still support the colonization of forested areas	Generally moderate (Kaimowitz and Angelsen 1998)
Addressing land tenure		
Changes in land titling	There are also policies in place which require that a portion of natural forest in newly acquired lands remains intact. For example, the Brazilian government requires that, in the Amazon, public lands that become private shall preserve at least 60% of forest cover	Low, or even negative, resulting from weak implementation (Kaimowitz and Angelsen 1998)

Table 5 (continued)

Policy	Description	Effectiveness
Policies to establish common property regimes	They are applicable to indigenous and forest-dependent people and can have positive effects on deforestation as they transfer the management responsibility to a group of individuals that is in closer contact with the resource	Moderate (Kaimowitz and Angelsen 1998)
Zoning	Zoning has a sensible premise: efficient land allocation and management. There are at least two strands of technical planning, though in practice they may be combined (Chomitz et al. 2006). The legitimacy and effectiveness of zoning are closely linked to land tenure and depend on securing landholder consent and cooperation. Poor people can suffer if zoning is imposed on them without consent or compensation, while wealthier or more powerful interests may ignore the rules with impunity—or there may be no political will to impose zoning on anyone. For this reason, zoning has been problematic at the national level (Hoare 2006). Zoning and participatory planning has been used to resolve conflicts between forest dwellers and plantation interests in Papua province, Indonesia, and to delineate community boundaries in Vietnam. Successful applications have also been reported in Cameroon (Lescuyer and others 2001) and Madagascar (Cowles and others 2001)	Variable (Chomitz et al. 2006)
Taxes	They could be used to decrease deforestation by establishing tax concessions and exemptions on protected lands. Land taxes and capital gain taxes can discourage land speculation as they raise the cost of holding land as a mechanism to decrease inflationary risk. Related information is not available, however, Kaimowitz and Angelsen (1998) suggest that negative tax mechanisms are difficult to implement and enforce due to the high information requirements as well as the potential for tax evasion or avoidance	Variable/unknown (Kaimowitz and Angelsen 1998)
Increasing the profitability of sustainable forest management		
Policies to promote the marketing of forest products	They include forest certification and eco-labelling and use market forces to increase the profitability of Sustainable Forest Management (SFM). In most cases, such programs need government support because sustainable exploitation of forests would not pay for the opportunity costs of land. At the international level, forest certification has been promoted by ITTO and the Forest Stewardship Council. Certification through ITTO includes about 96.2 million hectares (27%) of "production" permanent forest estates (3.0%) and 1.77 million of plantations (3.9%)	Variable/moderate (Espach 2006)

Enhanced security of tenure	Such policies apply to forest dwellers as well as to long term logging concessionaires as they can reduce perverse incentives to clear cut as well as create incentives for the implementation of SFM. Transferability of tenure could encourage positive practices in forests as licenses for resources that are kept in better shape can be sold for higher prices in the future	High, however, depends on political changes, length of concessions and transferability of licenses (Kaimowitz and Angelsen 1998)
Payment for Environmental Services (PES)	PES schemes support the conservation of forests and SFM through transferring a payment from a beneficiary of a specific environmental service (e.g. watershed protection or carbon storage) to the provider of that service. The basic principle of PES is that beneficiaries are compensating forest owners because protecting forests entails a cost. (Mayrand and Paquin 2004) indicate that, by 2004, more than 300 PES schemes had been implemented globally. Most of these were designed for watershed and water conservation purposes, followed by biodiversity and carbon	Variable (Kaimowitz and Angelsen 1998; Corbera et al. 2006)
Integrated Conservation-Development Projects (ICDPs)	ICDPs aim to support development in forest communities, often those in or near protected areas. Researchers have concluded that ICDPs may only succeed only if there is a specific *quid pro quo* bargain—such as periodic payments to communities based on measured conservation outcomes (Ferraro and Kiss 2002). A recent review by the Global Environment Facility examined the impact on local incomes of 88 ICDPs projects, mostly in protected areas (but not all forests). Less than half of projects for which information was available succeeded in increasing incomes but financial success did not guarantee environmental success when new income-generating activities were unrelated to the natural resources at risk	Low (Chomitz et al. 2006)

Source: Adapted from UNFCCC (2006b), Chomitz et al. (2006) and other sources issues, and the identification of mechanisms to distribute REDD incentives and to ensure third-party verification of activities. These governance issues will need to be addressed in countries' definitive REDD strategies before the World Bank's FCPF or any other funding initiative disburse any implementation resources. To date, it is difficult to envisage that private investors would be willing to assume on their own the risk of potential policy failure by directly supporting government programs. In a system in which the allocation of funds and potential carbon credits takes place through host country governments, the political and legal risk of the mechanism will be considered too high as to attract private finance (Pedroni et al. 2007).

6 Conclusions

Deforestation in developing countries contributes to a significant share of global GHG emissions. However, specific mechanisms and incentives to address emissions from deforestation are currently lacking in the international climate change regime. Current negotiations under the UNFCCC for the creation of an arrangement to provide incentives and build capacities to avoid emissions from deforestation represents a fundamental step towards increasing mitigation options in the future. The process has so far resulted in a series of proposals on innovative sources of funding and incentives mechanisms applicable to different scales. The assessment provided in this paper, however, shows that these proposals face several design and implementation challenges which will have to be addressed so that REDD mechanisms can achieve their objective of reducing deforestation in the medium and longer term. These mechanisms will be complemented by methodologies and rules agreed by Parties, whilst the design and implementation of activities reducing emissions on-site should be left to each developing country according to its particular circumstances and interests.

However, REDD effectiveness will be subject to participant countries' ability to address the underlying drivers of deforestation and liaise with the agents involved in land-use change. We have shown that economic factors and policy frameworks constitute the main drivers of land-use change. In fact, misguided government policies and corruption have been among the major drivers of deforestation (in part because of the influence of large logging and timber trading companies), and even those governments willing to design and implement appropriate regulations tend to face severe capacity problems when it comes to their enforcement (Fuchs 2006). Therefore, in addition to strengthening developing countries' technical and institutional capacities, effectively addressing governance weaknesses will be paramount for the success of national scale REDD initiatives. Nevertheless, improving governance in developing countries implies a lengthy effort surpassing the climate change and even the environmental agendas, making it difficult to foresee massive emissions reductions from avoided deforestation in the short-term.

Further coordination among international and sources of funding for development and segments of the International Environmental Regime, including hard and soft legal instruments (e.g., the UNFCCC, the Convention on Biological Diversity, the UN Forum on Forests), and private certification instruments (e.g., Forest Stewardship Council), and across international governance regimes, such as the World Trade Organization, are needed. As Humphreys (2006) argues, unless a harmonization of the values and objectives behind forest and biodiversity conservation across international regimes takes place, it is likely that the interests of private corporations and developers will continue to prevail, thus rendering forest conservation a panacea. Placing excessive enthusiasm on an international climate policy framework to halt large-scale land-use change in the short term would be misguided, as governance issues remain the central challenge we should collectively address and reflect upon.

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