Widening the scope of forest-based mitigation options in the tropics

The roles of forests in substituting for fossil energy sources and moving towards a greener economy

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Executive Summary

The purview of international deliberations over forest policy has expanded since the Kyoto Protocol was adopted in 1997. The initial focus of the United Nations Framework Convention on Climate Change (UNFCCC) focused almost exclusively on afforestation – the planting of new forest areas. This early preoccupation with forest carbon sequestration and storage inside of forests overlooked the fundamental reality that the most significant and enduring potential contributions that forests can make to climate change mitigation take place *outside* of forests themselves.

This potential can be achieved through three effects. The first is by substituting fossil fuels with renewable energy sources such as fuelwood and charcoal, an effect referred to as *direct substitution.* The second is by substituting construction and other materials such as aluminum and concrete that require large amounts of fossil fuels to produce with renewable, low carbon intensity materials that do not, an effect referred to as *indirect substitution.* And the third is through the carbon that continues to be stored over time in durable, long-lived wood products such as furniture and construction material. This material creates a large reservoir of carbon storage which lasts for decades after the material is removed from the forest, a stockpile of stored carbon referred to as the *forest products carbon pool.* With each harvest a new carbon stock is created outside the forest, while within the forest, re-growth after a sustainable harvest again begins to sequester additional carbon from the atmosphere. Together, these three effects carry significantly greater potential to mitigate climate change than either carbon sequestration or carbon storage through forest conservation.

The early fixation on carbon sequestration and storage also neglected the vital economic roles that forests play in providing local populations with subsistence and income, and in generating badly needed export revenues to developing countries that lack financial resources. In so doing, the dialogue on forests' roles both in terms of environmental services and economic development was often rendered self-limiting, and diminished both in terms of its relevance to the national policy priorities of developing countries and to creating greener economies. More fundamentally, the lack of focus on the socio-economic values that forests generate for local communities reduced the significance of this process in the eyes of the primary stakeholders.

Multiple wins from integrating the productive values of forests into a Green Economy

Considering the social and economic functions that forests fulfill alongside the environmental services they provide enables us to identify and capitalize on important multiple wins. These multiple wins represent outcomes in which a wider set of forest based mitigation options lead to both major global public goods in terms of emissions reductions and avoided emissions, and local benefits in terms of generating employment, improving livelihoods, and alleviating poverty. If managed sustainably forests have a significant potential to provide for the needs and livelihoods of forest-dependent people. The significance of the role that forests play as an economic asset is underscored by the findings of a number of recent local studies of job creation in Africa. For example, in Mozambique, about 15 percent of the population is involved in the production and trade of charcoal (Cuvilas et al. 2010). In Tanzania, one job is provided for every 520 kgs of charcoal produced. By World Bank estimates, Tanzanians consume some 1 million tons of charcoal annually, supplied by an industry that provides some 1.9 million jobs (Peter and Sander 2009).

Much depends on providing these local benefits, given that the active participation and commitment of local communities is likely to be the single most crucial factor in determining how sustainably forests are used. Their ongoing commitment is contingent on seeing the advantages of positive change and understanding the rationale behind more sustainable practices. Their commitment also relies on their voice, and decision making processes that purposefully address their priorities and concerns. Decisions which are presented to them as a *fait accompli* and which lacks legitimacy from their perspective are radically less likely to be carried out in practice. And, at the same time, if the integrity of the forest resource base is neglected, then whatever social and economic benefits that accrue to local populations are certain to be short-lived. These socio-economic and environmental considerations are both necessary conditions to making forests an essential pillar of greener economies. Both will be instrumental in bringing about the transition from a fossil fuel-dependent economy to a greener economy. And once achieved, both will remain vital elements in maintaining a green economy based on sustainably managed forests.

Multiple Benefits of Common Forestry Practices

Against the current background of rapidly dwindling forest resources in many developing countries major investments in fuelwood and in planted forests (including timber plantations) are needed in order to prevent a shift towards fossil energy sources that would emit very large volumes of additional greenhouse gases. Investments in sustainable renewable energy sources would reduce pressures on high conservation value forests. Such investments could also yield multiple benefits for the economy, livelihoods, safety nets, soil protection, and the environment. Experience to date suggests that realizing these benefits relies on inclusive, bottom-up planning and the active involvement of local stakeholders. On the demand side, major investments are also needed on the part of consumers who apprehend the important benefits of fuel-efficient stoves and other technologies that optimize energy efficiency.

Fossil fuel substitution and carbon storage

The three effects through which forests contribute to climate change mitigation after wood material has been harvested and removed from the forest warrant examining in greater detail. The direct substitution that takes place when fossil fuel energy is replaced by renewable bioenergy sources carries the greatest potential effect quantitatively. An overwhelming proportion of these renewable sources - some 95 percent - consist of solid biomass. Bioenergy from biogas, liquid biofuels, and biodiesel accounted for the remaining 5 percent in 2005. Much of the solid biomass is used as fuelwood and charcoal to supply household energy. Globally, about 2.5 billion people use fuelwood for cooking, a number projected to increase to 2.7 billion by 2030. This consumption of fuelwood releases more than two billion tons of CO_2 per annum into the atmosphere which, if not sustainably produced, is a net source of greenhouse gas emissions. Whereas bioenergy accounted for about 10 percent of the global total primary energy supply (TPES) in 2005, in Africa this proportion was 65 percent. It will remain the most significant source of energy in Africa well into the foreseeable future (Cushion, Whiteman, and Dieterle 2010).

Replacing it with fossil fuel-based energy, similar to energy consumption patterns seen in industrialized countries, would result in a huge additional release of CO_2 into the atmosphere. Against such a baseline it is therefore evident that sustainable production and use of solid bioenergy needs to remain a significant factor in the climate change mitigation dialogue in the longest term, well beyond 2050. The indirect substitution that takes place when fossil fuel intensive materials - materials that require high volumes of fossil fuel to produce - are replaced with materials that do not, represents another major potential reduction in greenhouse gas emissions. The reduction can be usefully expressed as the energy savings achieved by replacing building materials such as steel and aluminum, the production of which entails extremely high temperatures.

Development of carbon stock over time

The fate of harvested wood and subsequent carbon storage as wood products has major implications for the timing of atmospheric carbon emissions resulting from land use change. A study in 169 countries found that 30 years after forest clearance, up to 62 percent of the carbon removed from the forest remained stored in wood products and landfills - depending on what the harvested wood was used for. In tropical developing countries this share tends to be much smaller which means that much of the growing stock is lost after the harvest and eventually released as CO2 and methane into the atmosphere.

The need for fundamental changes in forest management

While the greatest positive impacts that forest products can have on climate change mitigation will take place outside the forest sector itself, these impacts will necessarily rely on the sustainability of the production methods employed within forests. The improvements necessary within the forest sector will require fundamental changes in silvicultural and forest management practices, and will require functioning and transparent markets that place a premium on products that have been sustainably produced – and that effectively impose prohibitive costs on products that have been produced unsustainably. These kinds of markets serve as the critical interface between the users of wood and wood products and growers in production forests, and will need to have independent, third party certification that the products have come from verifiably sustainable forest management planning and value chains which are socially and environmentally benign and in which local populations participated and were consulted and empowered. These markets are essential because the substitution effects that can be achieved once forest products have been harvested and removed from the forest will necessarily rely on the sustainability of the production base within the forest. Neither substitution effects outside the forest nor sustainable management within the forest can be considered in isolation from one another. Both are necessary conditions. And together, sustainable forest production and product use can not only lead to significant mitigation outcomes, but contribute to adaptation and social and economic effects as well.

Exploring the full potential of forest based mitigation options while building up a sustainable value chain

Maintaining forests in their ongoing capacity as carbon stores is a fundamental element of forest-based climate change mitigation. Retaining that stored carbon in forest soils and biomass, especially in high conservation value forests will necessarily remain an essential priority for forest mitigation strategies. Yet the conservation of stored carbon cannot be the only priority. Significant opportunities exist to promote more multi-functional and integrated patterns of forest use that combine conservation and the production of timber and other forest products that support livelihoods and provide for both social and environmental functions. These forms of systematically-managed forest landscapes represent important opportunities that relate directly to climate change mitigation and adaptation outcomes and constitute necessary additions to the current REDD+ structure.

Outlook 2050: The potential impact of mitigation options

Extrapolating from what is known about the status of forests in 2010, and from what is currently understood about the impacts of different forest management practices over time, it is possible to quantify the cumulative effects which these practices could have under optimal scenario projections by 2050. While these projections are somewhat tentative owing to the number of unforeseen factors that will come into play, they do provide a preliminary picture of the general scale of magnitude of forest-based mitigation options both inside and outside the forest sector. In 2010, about 2.9 billion tons of carbon were released into the atmosphere as the result of human-induced deforestation and forest degradation. Given an estimated annual rate of 1.72 billion tons of carbon sequestered through natural regrowth, this leaves 1.2 billion tons of net deforestation annually – effectively one and a half times the amount of carbon sequestered by planting trees (374 million tons of carbon) and the 317 million tons of fossil carbon currently substituted combined.

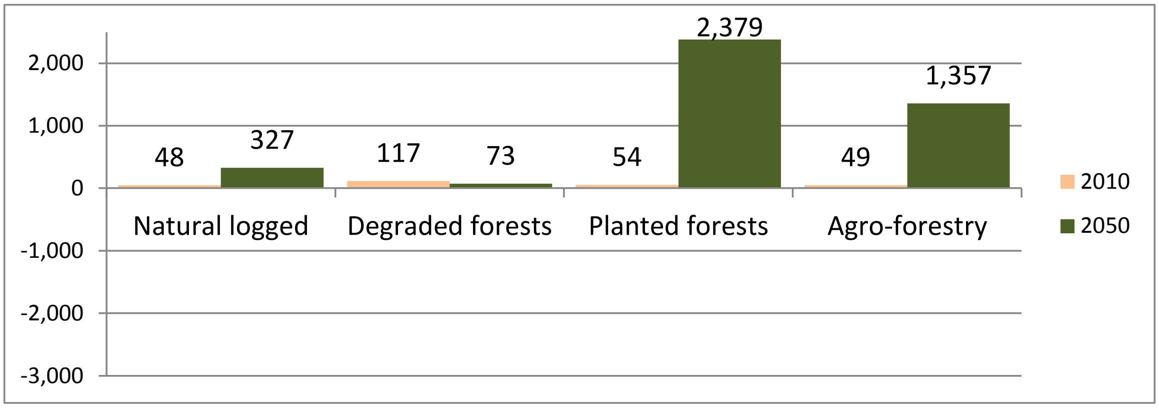
Given this ambitious scenario, the picture of 2050 reflects a fundamental transformation to green economies. Here, the uses of wood from permanent, sustainably logged forests, restored forests, reforested lands, and agro-forests make a pronounced contribution to climate change mitigation. In addition to the emission reductions achieved through improved forest management, the graphic also reflects high levels of substitution between the use of wood biomass and fossil fuel – the effects of annually replacing 4.88 billion tons of fossil-based carbon while sequestering 430 million more tons. The combined total of more than 4.8 billion tons of *neutral,* fossil fuel-substituting carbon and fueling green economies will be greater in 2050 than the gross amount of carbon that was released into the atmosphere by deforestation and forest degradation four decades earlier in 2010.

The great challenge that lay before the forest and climate change mitigation agenda is to strike an effective and workable balance between forest carbon conservation and the production of forest products – and using integrated landscape approaches that also include agricultural production. The analysis and arguments presented in this document find five areas in particular to hold significant promise in meeting both challenges.

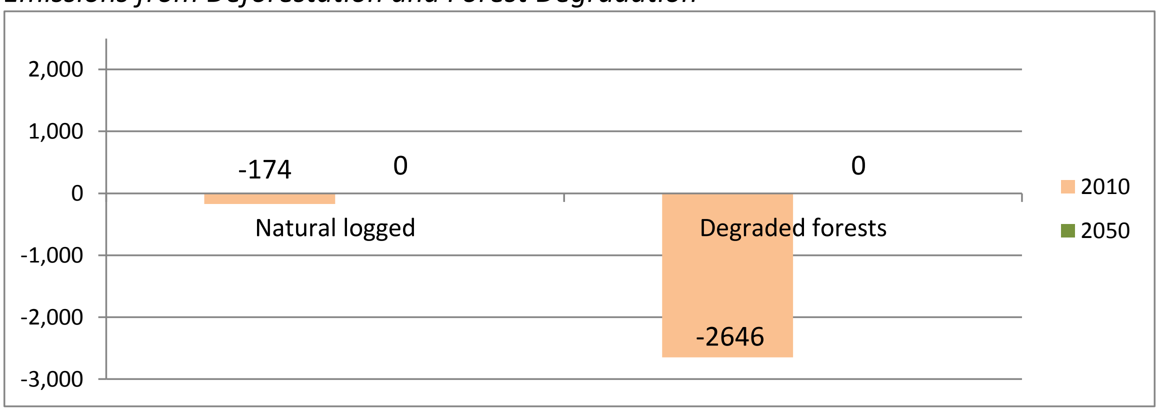
1. Extend reduced impact logging methods and related certification processes to all harvested forests, valorize more tree species, and both optimize and maximize the protection of existing primary forests.
2. Proactively promote agroforestry and plantation systems that a) increase food production; b) fuel green economies; and c) stabilize forest boundaries.
3. Finance the development of green economies with explicit provision for the sources of substitution these economies will cultivate and capitalize on as elements of sustainable forest management.
4. Elaborate forms of landscape governance that entail voluntary as well as compulsory land uses to satisfy multiple demands for forest products in both the present and the future, communicating REDD+ (which will be discussed forthwith) as a development opportunity for climate resilient green growth.
5. Promote efficiency and carbon life cycle assessment of the main forest practices and products from the forest source to the final user.

Figure 1: Fossil Fuel Substitution, Deforestation and Degradation, and Forest Carbon Sequestration in 2010 and 2050 (million tons carbon per year) [1]

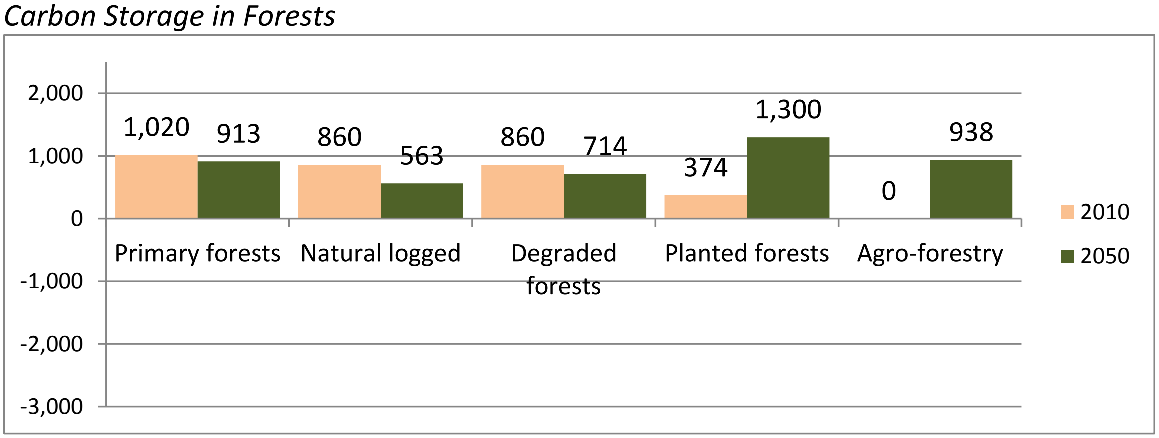
Fossil Carbon Substitution



Emissions from Deforestation and Forest Degradation



Carbon Storage in Forests



[1] Based on calculations by Michel de Galbert

Conclusions for policy makers and practitioners

Issues in the forest sector currently enjoy an unprecedented level of political prominence, both nationally and internationally. In many tropical countries REDD+ pilot projects have been initiated and policymakers are working on developing national REDD+ strategies. Current donor pledges on the order of US$6 billion in support of these strategies and initiatives reflect the significance the international development community attributes to forests as a vital asset in mitigating and adapting to climate change (REDD+ Partnership, 2012). While significant progress in redressing early shortcomings was seen at the 13th Conference of the Parties to the UNFCCC and at the 3rd Meeting of the Parties to the Kyoto Protocol in Bali in December 2007, the effects of forest-based climate change mitigation that take place after trees leave the forest need to be further incorporated into the calculus of REDD+. Until the scope of the forest dialogue is expanded further to address these contributions that forests make to climate change mitigation, the architecture of REDD+ will remain essentially incomplete.

Increasing and protecting carbon stocks in new and existing forests, which has up to now been the principal focus of international dialogue on forests and climate change, will without question remain an important part of the future climate change agenda. It cannot however be the exclusive focus of initiatives that use forests to mitigate climate change. This approach is too narrow. It not only tends to lead to the relative (and sometimes complete) neglect of social and economic functions, but it misses in its entirety the massive advantages of managing forests expressly for the purpose of displacing fossil fuels with alternative, low energy-intensive wood fuels and wood products. Bringing the substitution effects of forest products unequivocally into the carbon equation is the next major increment towards making enduring green economies a reality.

Widening the scope of forest-based mitigation option also requires a fresh look at the scope and synergies of ongoing international REDD+ financing instruments. Given the generally limited awareness of many of the facts presented in this document, the authors place a premium on concrete, practical examples of investments on the ground that should inform policy makers and practitioners. Several of these will reveal forests' contributions to climate change mitigation, economic development, and social values as being anything but trade-offs or mutually exclusive, but on the contrary, mutually reinforcing and interdependent. This suggests that longer-term change processes can benefit from practical bottom-up experience, and that the phased REDD+ approach adopted and promoted by UNFCCC in Cancun should not be seen in a linear way but rather in terms of synergies and convergence. This appears to be very much in line with the REDD+ Partnership's promotion of closer and more effective collaboration between internationally-supported initiatives, processes, and instruments. For instance, closer coordination or integration of Forest Carbon Partnership Facility (FCPF), UN-REDD Program, and Forest Investment Program (FIP) activities may represent a golden opportunity to revive, accelerate, and widen REDD+ goals and aspirations. Encouraging examples from the field clearly demonstrate that testing reforms on the basis of concrete pilots has provided the incentives necessary to maintain the momentum for change and to contribute to reducing the risk of failure of Readiness processes.

This document reviews the gradual expansion in the purview of the international dialogue on forests and climate change since Kyoto in 1997. It argues that the scope of the dialogue must continue to widen in order to capture both environmental services and economic needs – with particular emphasis on the needs of poor and vulnerable forest-dependent communities for whom forest resources are an essential source of livelihoods and basic needs. Addressing these social dimensions of forest management and forest use will entail dealing explicitly with fundamental issues of political economy, including local rights, land tenure, and community participation in decision making about how forest resources are managed. These need to be carefully negotiated and purposefully incorporated into national development plans and into the international agreement that evolves from the Kyoto Protocol. The document then presents a quantitative depiction of the climate-related impacts of different forest uses in 2010 and compares them with projected impacts that are achievable by 2050. While precise calculations of these impacts are not yet possible, there is sufficient empirical evidence from which to extrapolate preliminary estimates of the scale of magnitude these combinations are likely to have in sequestering and storing carbon and in displacing the use of fossil fuels by 2050.

The authors of this document hope that more policy makers can be persuaded to think along these lines in a more holistic manner, rather than looking upon forest carbon strictly in terms of conservation, or for that matter, strictly in terms of economics. The theoretical possibility of achieving an annual mitigation impact of 8 billion tons of carbon - a half of which is attributable to substitution effects - reinforces the epic importance of extending the purview of international dialogue beyond REDD and REDD+ to a larger, more comprehensive perspective that addresses the productive use and management of forest resources - including impacts that take effect outside of the forest sector.

I. The multiple roles of forests in environment and development

Forests are a critical resource for both the environment and for development. Their capacity to remove carbon from the atmosphere and store it makes them a vital asset to climate change mitigation, while their role as habitats of biodiversity make them a key to climate change adaptation. At the same time, the livelihoods of more than 1 billion people are directly supported by forestry and forest use. Of these, some 350 million people rely on forests nearly entirely for their income and subsistence, a substantial proportion of who rank among the poorest people on earth (FAO 2006; Martin 2003). This makes the economic role of tropical forests in developing countries a major priority, particularly for policies and programs that seek to reduce poverty. Balancing the use of forests as an economic asset for development with the need to capitalize on the local and global environmental services that forests provide is therefore a practical imperative. The results of a number of recent analyses suggest that there is substantial latitude for not only striking this balance, but for finding areas of significant convergence between environmental and economic objectives. These findings indicate that the largest effects that forests can have in mitigating climate change will take place outside of the forest sector itself - effects which substantially exceed those which can be achieved inside forests.

These extra-forest mitigation options include *substitution effects* which are achieved whenever fossil fuels are replaced with renewable forest-based energy sources, and when materials such as aluminum, steel, and concrete which require large volumes of fossil fuels to produce are replaced with materials such as wood which do not. By capitalizing on these substitution effects, forest-based materials can effectively reduce the volume of emissions from highly energy-intensive industries. A lesser, though still significant effect takes place through the carbon that continues to be stored for various periods of time in the *harvested wood products* that are removed from forests.

Growing demand

Demand for all types of wood and wood products will sharply increase until 2050 not only in developing countries but also at the global level (table 1). Most of this increased demand will be for wood energy sources. Today and in the foreseeable future renewable bioenergy sources of which solid biomass holds an overwhelming share (95 percent) will play an important role in global energy supply.[2] Traditional uses dominate in many developing countries but more modern applications are rapidly expanding in Europe and North America. In contrast, bioenergy from biogas, liquid biofuels and biodiesel accounted in 2005 for only 5 percent at the global level. Much of the solid

[2] Such replacements are considered "permanent" emission reductions under the UNFCCC stipulations. Some authorities consider this classification not only incorrect, but discriminatory against forest carbon stocks which are classified as "non-permanent."

biomass is used as fuelwood and charcoal to supply household energy. Globally, about 2.5 billion people use fuelwood for cooking, a number projected to increase to 2.7 billion by 2030, releasing more than 2 billion tons of CO_2 annually into the atmosphere.

Whereas bioenergy accounted for about 10 percent of the global total primary energy supply in 2005 (TPES), in Africa it accounted for 65 percent of TPES and will continue to for the foreseeable future. It is Africa's most significant source of energy (Cushion, Whiteman, Dieterle 2010). A replacement of this source of energy with fossil fuel based energy as seen in industrialized countries would therefore result in a huge additional release of CO_2 into the atmosphere. Against such a baseline it is therefore evident that sustainable production and use of solid bioenergy needs to remain a significant factor in the climate change mitigation dialogue in the longest term, well beyond 2050.

A particularly useful illustration of alternative outcomes by 2030 and 2050 is presented by the World Wildlife Fund (WWF) in its 2012 *Living Forests Report*. Using FAO figures from 2010 as its baseline, the WWF's Living Forests Model projects the contrast between two alternative scenarios in both 2030 and 2050: do nothing and bioenergy plus. The projected figures are borrowed from the International Institute for Applied Systems Analysis (IIASA).

Table 1: Projected annual rate of wood removals in 2030 and 2050

	FAO	LIVING FORESTS MODEL			
	2010	2030		2050	
		Do Nothing	Bioenergy Plus	Do Nothing	Bioenergy Plus
Saw logs & veneer logs	853	1,444	1,444	1,763	1,773
Pulpwood	527	754	754	905	893
Other industrial roundwood[19]	153	153	153	153	153
Energy wood	1,868	2,753	3,138	6,317	8,209
Household fuelwood		2,064	2,064	2,218	2,054
Total wood supply	3,401	7,168	7,553	11,356	13,082

Units: millions of cubic metres (roundwood equivalent)

Source: WWF 2012 – Living Forests Report: Chapter 4 – Forests and Wood Products[3]

[3] Bioenergy Plus Scenario: A scenario of the WWF Living Forests Model where bioenergy feedstock demand is based on the "global 2 Degree Celsius Scenario" derived from the POLES (Perspective Outlook for the long-term Energy System) model.

Two overarching challenges lay before the forest and climate change mitigation agenda: the need to satisfy demand for wood products both locally, in developing countries with tropical forests, and in industrialized, wood-importing countries. The other challenge is to strike an effective and workable balance between forest carbon conservation and the production of forest products – and using integrated landscape approaches that also include agricultural production. The analysis and arguments presented in this document find five areas in particular to hold significant promise in meeting both challenges.

II. The evolving approach to REDD+ in the international climate regime

Afforestation, Reforestation and Forest Restoration under the Kyoto Protocol.

In the Kyoto Protocol to the United Nations Framework Convention on Climate Change that was adopted in December 1997, forests are considered in terms of their impacts on the global carbon balance. In this balance, forests have three outstanding functions. As part of the global carbon cycle, forests store carbon in their constituent flora - a function for which they are referred to as *carbon stores* or "reservoirs."

When forests expand or become more biomass-dense, they sequester more carbon out of the atmosphere than they emit - a capacity for which they are referred to as *carbon sinks.* When forests are cleared or degraded or damaged by forest fires, disease, or pests, they become a *carbon source,* releasing large volumes of carbon and other greenhouse gases into the atmosphere. Accounting for each of these roles in the carbon cycle is essential when planning and designing forest-based climate change mitigation strategies (Houghten 2005). Project activities undertaken under the Kyoto Protocol's Clean Development Mechanism (CDM) sought to provide incentives to plant new forest areas (afforestation) and to replant deforested areas (reforestation).

Few if any incentives were initially provided to embrace wider concepts such as the restoration of degraded lands or the protection of carbon storage in standing forests.

Unfortunately, afforestation and reforestation (A/R) initiatives undertaken under the CDM achieved limited early success.[4]

[4] Their shortcomings were attributable in part to the complexities of applying CDM-approved methodologies to project design documents, delays in validating and registering those documents, and questions regarding the permanence of the carbon sequestration achieved. There was moreover often an inability to finance the required upfront investments. Uncertainties were also common over how to identify eligible lands and monitor for compliance to the concerned project design document. Areas that were deforested or degraded after 1990 were ineligible for CDM-A/R projects. Recognizing these problems, the Executive Board of the CDM, which certifies emission reductions, undertook to simplify methodologies and to develop more flexible emission credits. Initiatives are also underway to improve the technical and managerial capacity of project developers, and to reduce transaction costs (BioCarbon Fund 2011).

The Addition of Avoided Deforestation

While *mitigation by sequestration* remained on the international climate change agenda in the years following Kyoto, in 2005 another approach to forest-related climate change mitigation was introduced. This was *avoided deforestation* which for the first time focused on forests as carbon sources. Given the scale of global forest resources, which today cover about 4 billion hectares or 30 percent of the world's total land area, and the emissions associated with the rate of forest loss, avoided deforestation suggested itself as a natural priority. Land use change associated with the clearing of forests for agriculture, pasture, and other uses remains one of the largest anthropogenic sources of GHG emissions. In about 30 developing countries, deforestation and forest degradation are the largest sources of anthropogenic CO_2 emissions (European Commission Joint Research Centre and Netherlands Environmental Assessment Agency 2009).[5]

Deforestation was also recognized as a major development issue. More than half of the world's forest area, about 2.4 billion ha are located in the developing and transitioning countries of Africa, Asia and South-America (FAO 2010). It is in developing countries that most global deforestation is occurring (FAO 2011; FAO 2010; Carle and Holmgren 2008). Deforestation is especially acute in tropical and sub-tropical forests, which contribute heavily to local livelihoods and economic development, and which supply a variety of essential forest products such as fuelwood and food.

In November 2005, at the eleventh Conference of the Parties (COP 11) in Montreal, the governments of Costa Rica and Papua New Guinea, representing the recently formed Coalition for Rainforest Nations, requested the Parties to consider an agenda item on "reducing emissions from deforestation in developing countries." This brought Reduced Emissions from Deforestation (RED) into the international dialogue on climate change. The UNFCCC and the Kyoto Protocol were called upon "to take note of present rates of deforestation within developing countries, acknowledge the resulting carbon emissions, and consequently open dialogue to develop scientific, technical, policy and capacity responses to address such emissions" (Holloway and Giandomenico, 2009). The issue would be discussed at subsequent Conferences of the Parties, notably COP 13 in Bali in December 2007, where emissions from forest degradation were added to the agenda. RED was therefore expanded into REDD, Reduced Emissions from Deforestation and (forest) Degradation. A year later, at the December 2008 meeting of the Subsidiary Body for Scientific and Technical Advice (SBST) in Poznan, REDD was expanded further still, to REDD+, which includes conservation, sustainable forest management, and enhancement

[5] In recent years the relative contribution of deforestation and forest degradation to total anthropogenic CO_2 emissions has been declining because of the substantial increase in carbon emissions from fossil fuel combustion. The contribution of emissions from deforestation and forest degradation is now estimated to be about 12 percent and 15 percent when peat land emissions are included. See also Van der Verf et al. (2009) or Denman, K. L. et al.(2007)

of forest carbon stocks in the list of eligible activities under the UNFCCC (Box 1). REDD was originally formulated as a multi-level payment for environmental services (PES) scheme in which financial transfers between industrialized countries and developing countries are exchanged for emission reductions (Angelsen and Wertz-Kanounnikoff 2008).

Box 1: The Evolution of REDD+

Since the 2005 COP 11 in Montreal, a gradually expanding agenda for reducing GHG emissions through forestry have been discussed in international fora. This expanding purview is reflected in the progression of concepts from RED at COP 11, to REDD at COP 13, to REDD+ at the December 2008 meeting of the Subsidiary Body for Scientific and Technical Advice.

- **RED:** Reducing emissions from deforestation, in which only changes from 'forest' to 'non-forest' land cover types (gross deforestation) are included in forests in climate change equation.
- **REDD:** Reducing emissions from deforestation and degradation, in which lower carbon stocks in degraded forests are included in the equation.
- **REDD+:** Reducing emissions from deforestation and degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks. Restocking within and towards 'forest' is now accounted for.

Source: Van Noordwijk M and Minang PA. 2009. "If we cannot define it, we cannot save it" ASB PolicyBrief No. 15., Nairobi, Kenya.

Durban and Rio+20

At COP17 in Durban, South Africa in December of 2011, the Ad hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol considered a number of proposed changes to the carbon accounting rules for land use, land use change, and forests (LULUCF). One of the changes approved was a proposal to include harvested wood products – a reversal of the existing reporting practice of counting all harvested biomass as instantly oxidized (Ellison, Mattias and Petersson 2012). The change would theoretically provide strong incentives to capitalize on the substitution effects of replacing fossil fuel-intensive products with forest-based renewable ones.

Durban also saw signs of a growing high-level recognition of the interdependence of forests and other elements of a broader landscape-based perspective, such as agriculture, water, settlements, and cities. These mutually-interacting issues had made the need for multi-disciplinary ("cross-sectoral") convergence a practical imperative and a major priority for the upcoming third Earth Summit the following June in Rio. This convergence was captured in the term "green economy," in which an expanded, more integrated, landscape-based, *climate smart agriculture* was to be an essential element.
The calls for inclusive green growth and natural capital accounting that were articulated at Durban became part of a framework of expectations about what could be accomplished at Rio, and hopefully in the form of high-level multilateral agreements or

conventions that directly address issues of environmental and social sustainability. These expectations about prospective ministerial- and executive-level accords proved to be inflated. In part this disappointment was the result of rather sensational public relations messages that promoted Rio+20 as the most significant opportunity to address these issues in a generation. More fundamentally however, the level of consensus for such intergovernmental agreements to be reached was clearly lacking.

While forests per se were not included among the Conference's seven priority areas (jobs, energy, sustainable cities, food security and agriculture, water, oceans, and disaster readiness), this in part reflected a determination among development agencies to overcome the division between forest-related and agriculture-related dialogue into separate and even mutually-antagonistic conversations, and to combine them purposefully into a more integrated landscape-based dialogue that encompasses water as well.

Rio+20 did see a number of relevant resolutions agreed upon in principle, including the need to dispense with fossil fuel subsidies. While such agreements in principle generated little enthusiasm in the press, away from the formal negotiations between government officials, the inclusive green growth agenda and the expressed eagerness to undertake *natural capital accounting* as a parallel (if not alternative) to conventional GDP accounting, both saw significant progress at Rio + 20. Within the green growth agenda, the "blue agenda"—the oceans agenda and the related fisheries, coastlines, and pollution issues it entails—was the focus of particular commitment, owing in large measure to the determination of the host Government of Brazil.

III. Mitigation Outside the Forest: Substitution and Carbon Storage in Wood Products and the Afterlife of a Tree

Both the role of forests as a carbon store and as a carbon sink warrant additional examination, with specific attention to the effects that forest products have on the climate *after* they are removed from the forest. Until fairly recently, these effects of forest-based climate change mitigation that take place after trees leave the forest were a glaring omission in the international dialogue on climate. Significant progress in redressing this omission was seen at the 13th Conference of the Parties to the UNFCCC and the 3rd Meeting of the Parties to the Kyoto Protocol in Bali in December 2007.

Table 2: Overview of forest-based mitigation options

	Reduction of GHG Emissions	Carbon Sequestration	Carbon Substitution
Mitigation Options	Reducing emissions from deforestation and degradation	Afforestation Reforestation	**Direct Substitution of fossil fuel use *** **Indirect Substitution of energy-intensive materials ***
Forest Management Options	Conservation forests Sustainable management of existing forests	Plantations Agroforestry Forest Restoration	Biofuel Plantations Charcoal, Fuelwood forest management Sustainable Wood Production NTFP management
	* Not yet included in UNFCCC		

Bringing wood use and its substitution potential explicitly into the REDD+ agenda

While REDD+ represents a substantially broader perspective of forest-based climate change mitigation than the earlier emphasis on afforestation and reforestation, another, highly significant option remains neglected. This is the use of wood, both as a construction material and as a source of bioenergy. The omission of wood use is a conceptual shortcoming that has important practical consequences for GHG reporting. The reporting framework that was established with the Kyoto Protocol classified all harvested wood as "emissions" because harvesting technically reduces standing forest carbon stock.

This technical definition ignores the fact that the carbon continues to be stored in the forest product, and that the product replaces alternative materials that are derived from non-renewable resources – many of which are highly fossil fuel-intensive to produce. This applies to timber in particular, in which the life of the product can last upwards of a century. The generation of new biomass replaces that biomass which was removed by harvesting, sequestering additional carbon from the atmosphere as it does.

Table 3: Fossil fuel energy used in the manufacture of building materials

Material	Fossil fuel energy		
	Megajoules / kg	*Megajoules / m3*	*Factor*
Rough-sawn timber	1.5	750	1
Steel	35	266,660	355
Concrete	2	4,800	6
Aluminium	435	1,100,000	1,467

Source: Ferguson et al. 1996

Omitting these important mitigation effects of managed forests and forest products places renewable forest-based resources at a serious comparative disadvantage in relation to non-wood materials. *And the use of these fossil fuels is the single largest human influence on the climate, accounting for 56.6 percent of GHG emissions* (IPCC 2007). Reducing these emissions from fossil fuels through the use of sustainably produced timber carries significantly more potential to mitigate climate change than either carbon sequestration or carbon storage through forest conservation. Standards for buildings and packaging impose additional barriers to the use of wood. As a result, perverse incentives implicitly favor more carbon intensive wood substitutes (Duncan, Mayer and Reid 2004). Biomass resources meanwhile supply just 10 percent of primary energy consumption globally (WEC 2010).

Incorporating product life cycle and the forest products carbon pool into the REDD+ calculus

Durable, longer-lived, wood products such as those used as building materials create a large reservoir of stored carbon for decades after they are removed from the forest. This creates a *forest products carbon pool* that includes wood used for construction and durable furniture, and that has an average life span of about 50 years (Kohlmeier et al., 1999; Platinga and Birdsey 1993). With each harvest a new carbon stock is created outside the forest, while within the forest, re-growth after a sustainable harvest again begins to sequester additional carbon from the atmosphere (Figure 2.).

While this re-growth has been captured in the carbon accounting calculations used for flexible mechanism projects under the Kyoto Protocol - the carbon that is stored for relatively long periods outside the forest has for the most part been omitted from models used to estimate emissions. For Earles, Yeh and Skog (2012), the “fate of cleared wood and subsequent carbon storage as wood products” has major implications for the timing of atmospheric carbon emissions resulting from land use change. Their study of 169 countries found that 30 years after forest clearance, up to 62 percent of the carbon removed from the forest remained stored in wood products and landfills - depending on what countries used the harvested wood for. In countries with temperate forests, managed forests are typically used to produce durable timber products that continue to store a substantial amount of their original carbon - more than 25 percent in 34 of the countries. In countries with tropical forests, forest materials are mostly used for fuel, pulp and paper, or are "non-merchantable," and far less of the materials' original carbon is retained - less than 5 percent in 90 countries 30 years after the forests are cleared. The significance of this for policy is that encouraging the production on longer-lived, "precious" timber products has important advantages in terms of contributing to the wood products carbon pool, unleashing a cascade of substitutions which are not achieved by producing fuel wood. These advantages warrant a balance between the production of precious timber products and the production of wood fuels and other shorter-lived products which are grown in shorter rotations - the succession of which wield a greater effect on direct substitution.

Capitalizing on direct fossil fuel energy substitution in its various forms, while making provisions for the risks it will entail

Direct substitution consists of replacing fossil fuels with renewable energy sources such as fuelwood and charcoal.[6] Fuelwood accounts for 67 percent of biomass-based energy sources (WEC 2010). Much of it is used to supply household energy. Globally, about 2.5 billion people use fuelwood for cooking, and this number is projected to increase to 2.7 billion by 2030, indicating that this is an issue in the longest term and will remain a major source of renewable energy well beyond 2050.

Table 4: Woodfuel production by region

Region	1988		2008		Average annual rate of change 1988 - 2008
	million m^3	*%*	*million m^3*	*%*	*%*
Africa	424	25	638	34	2.06
Asia	777	46	754	40	-0.16
Europe	134	8	152	8	0.65
North America	100	6	47	2	-3.74
South and Central America	230	14	286	15	1.08
Oceania	9	1	16	1	2.94
World	1674	100	1892	100	0.61

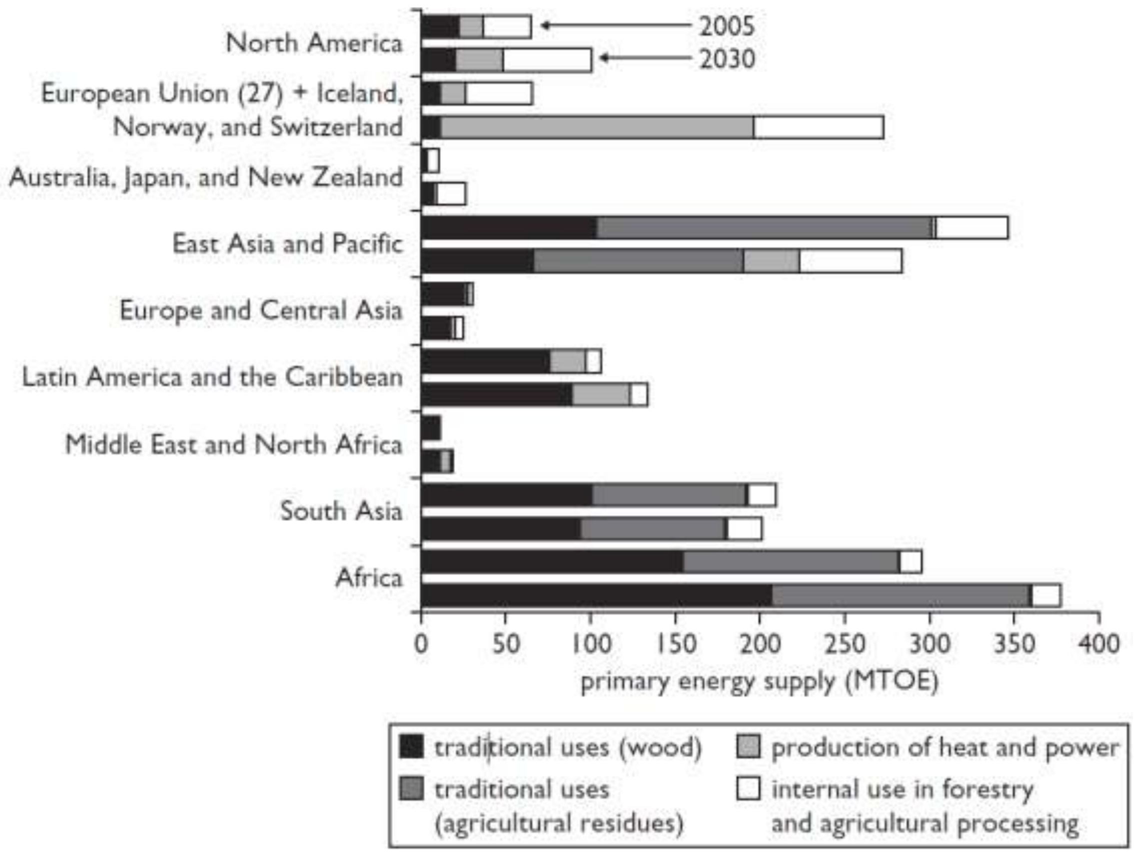
Source: What Woodfuels can do to Mitigate Climate Change? FAO 2010, from FAOSTAT

In Sub-Saharan Africa, an estimated 575 million people, some 76 percent of the total population relied on biomass for cooking fuel in 2009 (IEA 2009). Throughout much of the developing world, firewood remains the predominant form of wood energy used by households in rural areas, while charcoal use becomes more prevalent in urban households. Globally, wood fuel consumption ranged between 1.8 and 1.9 billion cubic meters during the last decade. Developing countries accounted for almost 90 percent of

[6] Such replacements are considered "permanent" emission reductions under the UNFCCC stipulations. Some authorities consider this classification not only incorrect, but discriminatory against forest carbon stocks which are classified as "non-permanent."

the world's fuelwood and charcoal consumption during this period (FAO 2008). The demand for fuelwood and charcoal will continuously increase, especially in Africa, Europe, Latin America, and Oceania over the next 20 years (Figure 1).

Figure 1: Projection of future global demand of "traditional" bioenergy (2005 vs. 2030)



Source: Cushion, Whiteman and Dieterle 2010

The potential for reducing emissions through biomass substitution depends on the fossil fuel being displaced - petroleum, coal, or natural gas - as well as on how sustainable the production of the biomass itself is. It also depends on the efficiency of converting this form of fossil fuel into useful energy relative to the efficiency of converting the particular form of biomass such as fuelwood, charcoal, crop residues, and dung.

While switching from fossil fuels to renewable biomass does not suppress all of the greenhouse gas emissions, findings regarding the actual rate of reduction that results from the switch varies widely in the scarce body of literature which has addressed the question. In Sweden for instance, the rate of carbon dioxide emissions reductions achieved by switching from fossil fuel to wood oil were found to be 40 percent between 1980 and projections for 2100 (Wibe 2010). In Switzerland, the carbon storage and substitution effects of an increased use of wood in buildings were preliminarily estimated at 97 percent (Werner et al. 2005). Because the biomass used for cooking in developing countries is generally less efficient than natural gas or liquid petroleum gas, substitution does entail some level of trade-off. Yet with modern energy conversion technologies, the efficiency of producing and using biomass is dramatically increased and pressure on scarce forest resources could be effectively reduced. Compared to open fires for instance, which convert about 10 to 15% percent of wood's potential energy into actual energy, modern wood pellet stoves and charcoal-based systems achieve about 80 percent efficiency for residential use (FAO 2008). In this area, we see an increasingly prominent role of existing voluntary standards systems. One of these, the Gold Standard® methodology for improved cook stoves and kitchen regimes, was used by the German non-profit Atmosfair to register cook stoves under the UN Clean Development Mechanism in July 2012.

The highly-efficient, locally-produced cook stoves reduce fuelwood usage by about 80 percent in a fuelwood-scarce region in which a large proportion of deforestation is attributable to wood collection. Atmosfair plans to disseminate as many as 100,000 such stoves over the next five years - leading to a savings of 250,000 tons CO2 equivalent annually (Atmosfair 2012).

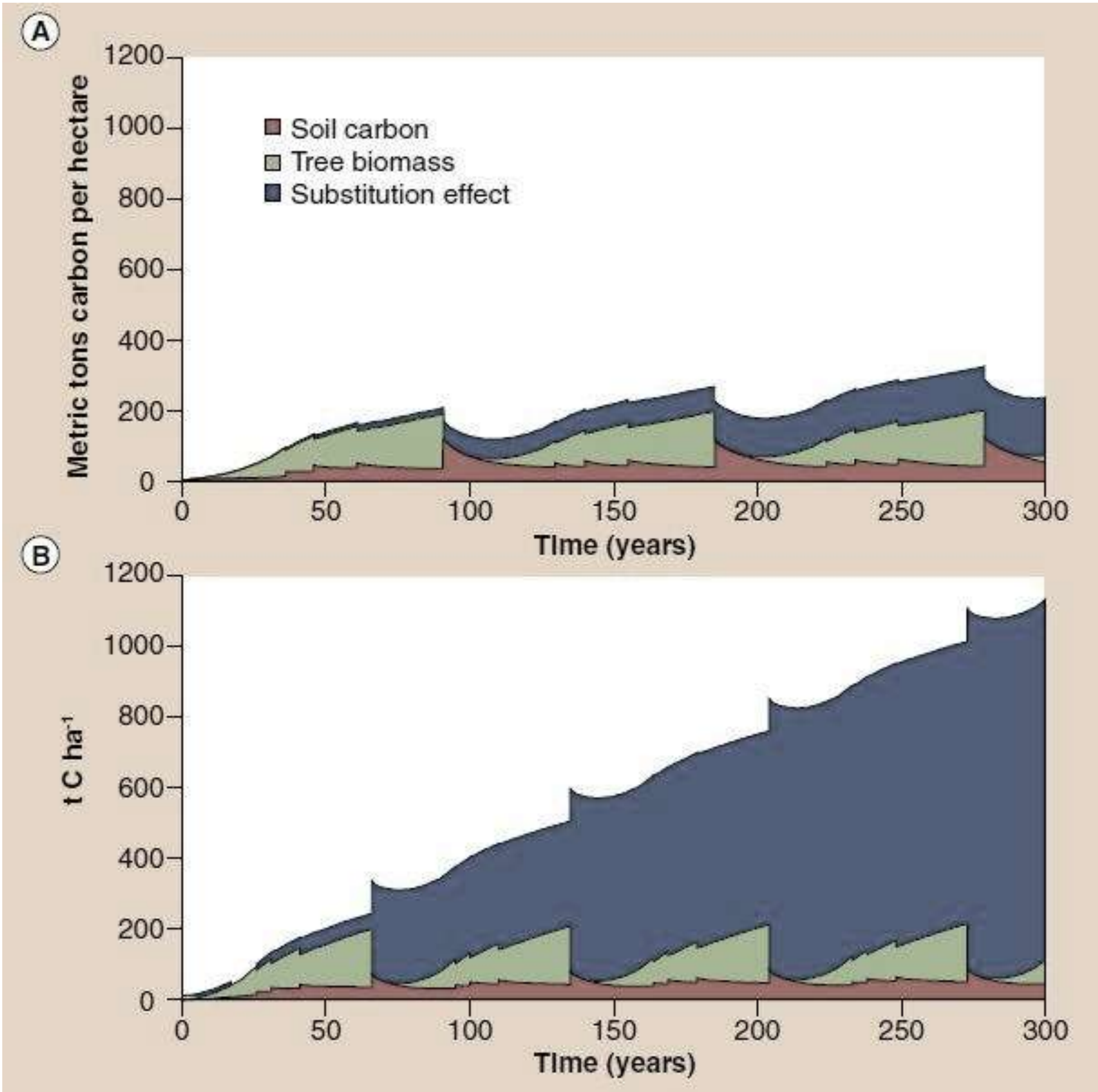
Cleaner and more efficient cook stoves also carry an important practical advantage in drastically reducing indoor air pollution, a major cause of health risk (particularly for women and small children) which is outside the purview of this paper, but which raises the issue to the attention of responsible public health agencies as well. While substituting fossil fuels with forest biomass sources in developing countries promises to both curtail GHG emissions and to satisfy energy needs, the transition will require careful management to ensure that it is both environmentally and socially sustainable. Particular care is warranted to ensure that the use of forest biomass does not lead to further deforestation and degradation from over-harvesting which otherwise would need to be counted as climate negative.

Box 3. Charcoal in Tanzania

In Tanzania, 90 percent of the population relies on charcoal and fuelwood for their energy needs. Charcoal is the largest and increasing source of fuel in urban areas. Between 2001 and 2007 the proportion of households using charcoal in Dar es Salam climbed from 47 to 71 percent. The total use of charcoal in Tanzania is about 1 million tons a year, of which half is consumed in Dar es Salam. This amount may double in 2030 (Peter and Sanders, 2009). The charcoal consumption is the main driver of deforestation in Tanzania, a country which is characterized by an annual deforestation rate of 1 percent. If the consumption of Dar es Salam was produced from improved kilns, the amount of wood needed, would be reduced by 3.6 million cubic meters per year, (a clear cut of 45.000 ha), and avoid the emission of one million tons of carbon per year.

Source: Christian Peter and Klas Sander (2009)

Figure 2: Development of carbon stocks over time with substitution effects



Development over time of the carbon stock of a periodically harvested forest, including cohorts of soil (organic matter with dead and decaying root biomass not removed) and living tree biomass (including live roots), and accumulated carbon emission reduction owing to product substitution - (A) for the combination of parameters giving the lowest reduction in net carbon emission, and - (B) for the combination of parameters giving the highest reduction in net carbon emission. Reproduced with permission from the Canadian Journal of Forest Research 37 (3) 2007

Figure 3 illustrates two highly significant points. The first is that carbon storage in a forest is limited to a particular place and that when the forest carbon stock reaches its maximum extent, then the climate benefits from additional sequestration end. The second point is that substitution options on the other hand achieve repeating climate benefits on a yearly and cumulative basis (see Annex). A too high level of storage in managed forests effectively prevents the optimal substitution effects from taking place.

Making indirect fossil fuel energy substitution a strategic priority

Indirect substitution consists of replacing materials that require high levels of fossil fuels to produce with renewable materials that do not. Fossil fuel emissions can be substantially reduced by using renewable material to replace conventional building materials - the production of which requires extensive use of fossil fuels that emit huge amounts of greenhouse gases (Schlamadinger and Marland 1996).

Materials like glass wool (or fiberglass insulation) and rock wool (or mineral wool), used to insulate buildings, are a case in point. The production processes that manufacture them require extremely high temperatures and are highly fossil fuel-intensive. Replacing them with wood-based cellulose as insulation would bring about substantial reductions in GHG emissions because the production of this material requires about 1/8 the energy that glass wool production requires (University of Massachusetts 2007). A wide variety of wood products compete with more energy intensive conventional materials.

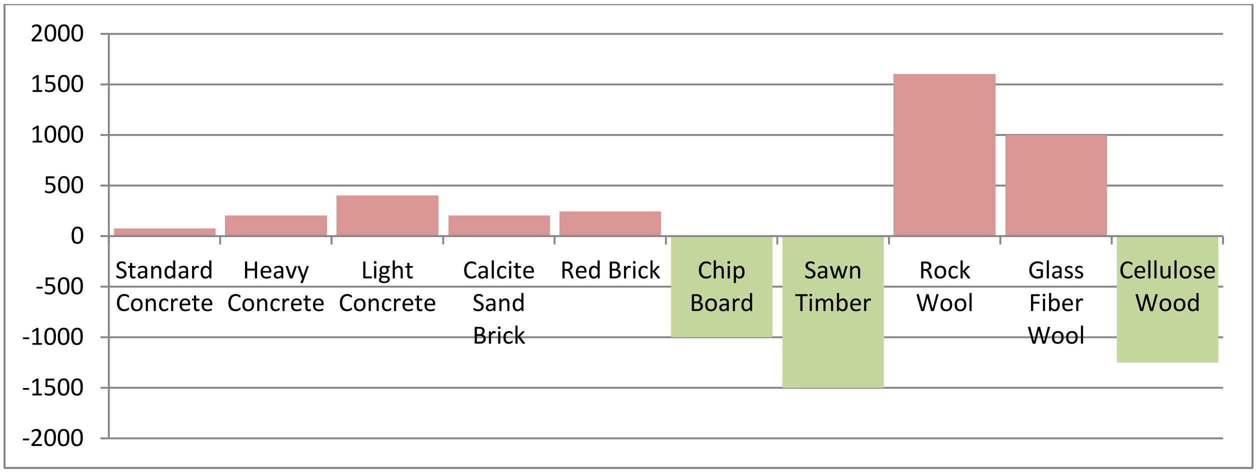
Table 5: Functionally equivalent building materials for construction and interior works

	Building element	Wood products	Competing product
Construction	Exterior wall Pillar Ceiling Insulation Roofing Underground engineering	Laminated timber board Gluelam pillar Ceiling of wood beams Wood fiber insulation panel* Unlined joist construction Wood palisade	2-layered brick wall Steel pillar Ceiling of reinforced concrete Mineral wool** Porous concrete pitched roof Concrete palisade
Interior works	Coverings of ceilings and walls Staircase Flooring Facade Furnishing Furniture	Profiled board Wooden staircase 3-layered parquet flooring Wood panels rough incl. supporting bars* Doorframe, particleboard Wood furniture, particleboard	Interior plasterwork Ready-made concrete staircase Ceramic tiles, enameled Exterior plasterwork** Doorframe, steel Steel furniture

*In a laminated timber board construction. **In a two-layered brick wall.

Source: RTS 1998-2001. Environmental Reporting for Building Materials and adapted from Werner et al. (2005)

Table 6: Net emissions from building material life cycles in grams CO_2 per kilogram of material



Source: RTS 1998-2001. Environmental Reporting for Building Materials and Reid et al. 2004.

Encouraging developing countries to move to carbon-neutral energy sources in their national energy strategies, based on the economic and public health advantages of doing so

In addition to the environmental benefits of capitalizing on the substitution effects of forest-based products, sustainably managed forests also provide for the needs and livelihoods of forest-dependent people. The significance of the role that forests play as an economic asset is underscored by the findings of a number of recent local studies of job creation in Africa. In Mozambique, about 15 percent of the population is involved in the production and trade of charcoal (Cuvilas et al. 2010). In Tanzania, one job is provided for every 520 kgs of charcoal produced. By World Bank estimates, Tanzanians consume some 1 million tons of charcoal annually, supplied by an industry that provides some 1.9 million jobs (Peter and Sander 2009).

Given the high demand for wood fuel in the tropics, its production is often unsustainable, leading to both forest degradation and growing shortages of the fuels themselves. In Africa, traditional forms of charcoal production cause some nine tons of CO_2 emissions for every one ton of charcoal used. This is a vitally important issue to address in national energy strategies because sustainably produced charcoal can be carbon-neutral (World Bank 2010).

Waste and human health impacts are also serious concerns. Used in their raw form, wood fuels are not only inefficient, but their combustion leads to indoor air pollution that poses a major health risk to households that use them (Cuvilas et al. 2010). Improving the sustainability of production and the use of primary bioenergy sources could therefore yield major development gains, particularly in poorer developing countries.

On the supply side, major investments in fuelwood plantations are needed in order to prevent a shift towards fossil energy sources that would emit very large volumes of additional greenhouse gases. Investments in sustainable renewable energy sources would reduce pressures on high conservation value forests. Such investments could also yield multiple benefits for the economy, livelihoods, safety nets, soil protection, and the environment. Yet experience to date suggests that realizing these benefits relies on inclusive, bottom-up planning and the active involvement of local stakeholders.

On the demand side, major investments are also needed on the part of consumers, including in stove and other technologies that optimize energy efficiency.

The combination of biofuel intensity in the manufacture of wood products, carbon storage, and fossil fuel substitution leave these products with a positive carbon balance - or a negative carbon "footprint."

The carbon that is released by burning wood residues and other renewable fuel sources is generally regarded as carbon neutral in that the carbon released has only recently been sequestered through photosynthesis. The US Forest Service provides a simple equation with which to calculate a product's carbon balance: The amount of carbon released during manufacturing (A), minus the use of biofuel (B), minus carbon storage in the product (C), minus the product's substitution effect (D) equals the total carbon footprint or credit (E). Applying this A – B – C – D = E formula to the life cycle assessment of different wood products, all the carbon footprint or "E" totals in the following matrix end up to be negative.

Table 7: Carbon balance of different forest products in the USA

Product			Carbon released during manufacture	Carbon from biofuel used in manufacturing	Carbon stored in the product	Substitution carbon	Total carbon footprint
			in kg CO2/unit				
Hardwood lumber	a	NE/NC region	0.9	0.6	1.8	2.6	-4.2
		SE region	1.1	0.8	1.8	2.6	-4.1
Softwood lumber	b	NE/NC region	1.8	1.2	6.6	7.0	-13.0
		SE region	3.9	3.3	8.4	7.0	-14.9
Hardwood flooring	c	Sold strip	1.1	0.7	2.1	0.0	-1.8
		Engineered	1.0	0.5	1.1	-0.1	-0.5
Doors	d	Solid wood	46.5	29.4	100.4	228.1	-311.5
Decking	e	ACQ-treated	5.2	1.7	16.1	11.9	-24.5
Siding	f	Western red cedar	37.7	6.0	77.7	20.4	-66.3
Wood-treated poles	g	PCP-treated	454.5	430.9	1160.4	1377.1	-1136.8
OSB	h	SE region	19.0	10.7	34.7	-	-26.3
Plywood	i	Pacific NW	5.7	4.1	25.5	-	-23.9
		SE region	10.1	6.5	30.9	-	-27.3
I-joist	j	Pacific NW	22.8	18.9	63.9	56.4	-59.9
		SE region	33.0	22.9	80.0	55.0	-70.0

a) One board foot, 12"x12".1" b) One 2"x4" stud c) 1 square foot d) One door
e) One deck board f) 100 square feet g) One 45 foot pole h) One 4'x8' sheet 3/8"
i) One 4'x8' sheet 3/8" j) One 16' long, 10" deep joist

Source: Bergman, Puettmann and Taylor 2011

IV. Mitigation inside the Forest – Getting Forest Management Right

While the greatest emission reductions are achievable outside of forests in substitution effects and in the forest products carbon pool, ensuring the integrity of the productive base within forests remains vitally necessary. The substitution effects and carbon that is stored in durable forest products after all rely entirely on ongoing production over time. Wood production therefore must necessarily be sustainable over time. Its sustainability in turn will rely on radically improved silvicultural and forest management practices and on functioning and transparent markets. These markets are the critical interface between the users of wood and wood products and growers in production forests. Independent third party forest certification based on forest management planning, meaningful consultation and participation of local populations is a good proxy to assure confidence in such markets and sustainable value chain. Substitution therefore cannot be dealt with in isolation from forest management and both together are a major untapped opportunity to expand the REDD+ approach.

Ensuring that forest conservation and forest carbon stocks are part of the *same* policy dialogue as forest use and forest management

Maintaining forests in their ongoing capacity as carbon stores is a fundamental element of forest-based climate change mitigation. Retaining that stored carbon in forest soils and biomass, especially in high conservation value forests will necessarily remain a priority for forest mitigation strategies. Yet the conservation of stored carbon cannot be the only priority. Mitigation strategies that focus exclusively on carbon storage through conservation have a potentially dangerous shortcoming in that there is no way to ensure that the forest carbon that is stored today will remain stored permanently. A significant part of this risk is political, for instance when changing government policies assign less priority to the environmental services provided by forests, or see the conservation of forest resources as an opportunity cost imposed at the expense of the country's economic development. The risk of policy reversals also increases when REDD payments are stopped or mismanaged to the point that they lose credibility. For these, among many other reasons, existing forests can be destroyed or become degraded at any given time, in which case they become a massive source of atmospheric carbon and, in addition to losing, their substitution capacity (Baral and Guha, 2004; Sedjo et al., 2004).

The opportunities that emerge to generate income by producing palm oil, soy, sugar cane, and other highly-profitable commodities are extremely attractive to land owners. These opportunities manifest powerful market-driven incentives that affect countless private decisions about what to produce and about how to use the forest one owns or has access to. Mobilizing funding from carbon markets or other incentive payment systems at a scale that is sufficient to make forest conservation a proportionately attractive alternative to them is now and will remain a formidable challenge, difficult to achieve for vast forest areas.

More than 460 million hectares of the world's 887 million hectares of primary intact tropical forest are designated as conservation forests to protect biological diversity, soil and water resources, environmental services, and in some instances cultural heritage (Blaser et al., 2011). This amounts to about 12 percent of the world's forests. Most of these forests are located inside legally protected areas (FA0 2010). Primary tropical forests store huge amounts of carbon in above- and below ground biomass, and it is in this role, as carbon stores, that they are assigned tremendous priority in climate change mitigation efforts. Restoring such high levels of carbon storage is almost impossible. Whether degraded through conventional logging, or transformed into tree plantations, secondary forests, or agroforestry systems, the new land use will never equal the original virgin tropical forest in its level of stock. Even the most sustainably managed forest has a much simpler canopy structure, lower leaf area index and density, lower biomass and lower ecosystem productivity (Soepadmo, 1993).

Box 3. The interdependence of mitigation and adaptation

Well-managed ecosystems such as forests can help societies to adapt to both current climate hazards and future climate change by providing a wide range of products and ecosystem services (Turner et al., 2009). Linkages between forests and adaptation is two-fold as forests play a role in the adaptation of broader society ('forests for adaptation') in addition adaptation is also needed for forests ('adaptation for forests') to accommodate a changing climate with increased drought periods and extreme weather events (e.g. see Amazon dieback study – World Bank, 2010.). For instance, the resilience of restoration plantings can be increased by planting native tree species instead of exotic ones and setting up polycultures, such as agroforestry systems, as an alternative to mono crop systems (Kanowski & Catterall, 2010). If policies aim at carbon conservation in forests as a method to mitigate climate change it is crucial to ensure that the carbon is not released.

Ecosystem-based adaptation (EbA) is a set of adaptation policies or measures aimed at reducing the vulnerability of ecosystems and their services to different threats, including climate change and land-use change. Such policies and measures also consider the role of ecosystem services in reducing the vulnerability of society to climate change in a multi-sectoral and multi-scale approach (Vignola et al., 2009). Mitigation should not be viewed isolated from other needs and the emerging EbA concept both in science and in international discussions on climate change and biodiversity, offers opportunities for both ecosystems and ecosystem-dependent communities to overcome the challenges of a changing climate (IUCN 2009).

Source: Locatelli and Pramova (2010*)*

Natural forests provide habitat to the highest and most complex biodiversity of any terrestrial land use.[7] This vast reservoir of biological diversity imbues the forest system

[7]. Ecosystems and Human Well-Being Vol.1: Current State and Trends, Millennium Ecosystem Assessment, (2005), pp.600-01.

with tremendous resilience against climate-related and other disturbances, and is instrumental in enabling the forest to adapt to climate change. Because it maximizes the probability that the carbon stored in the forest will continue to be stored over very long periods of time, this resilience is critical to the natural forest's role in the carbon cycle as well (Thompson et al., 2009). Resilience through biodiversity has become the focus of more integrated, ecosystem-based approaches to climate change that have gained significant traction in the operations of the World Bank and a number of other international development agencies over the last decade. Using conservation measures to prevent these forests from releasing carbon is necessarily a major concern in the international dialogue on climate change.

Yet significant opportunities exist to promote more multi-functional and integrated patterns of forest use that combine conservation and the production of timber and other forest products that support livelihoods and provide for both social and environmental functions. These forms of systematically-managed forest landscapes represent important opportunities that relate directly to climate change mitigation and adaptation outcomes.

Capitalizing on the many opportunities to increase carbon stocks in existing forests, with attention to other mitigation levers

The emphasis assigned to maintaining existing carbon stocks should moreover not detract from the important role of existing forests as carbon sinks – even mature forests which are in their or near their prime as carbon stores may continue to sequester some amount of additional atmospheric carbon. Increasing forest carbon stocks entails maintaining forests' role as existing carbon stores while, at the same time, enhancing their role as carbon sinks. This can be achieved by restoring degraded forests, by active regeneration of harvested forests, and by managing production forests to increase the volume of carbon captured through photosynthesis and to achieve permanently higher levels of carbon stock. Creating new carbon stocks by planting trees generates even greater net carbon impacts given the near zero baseline from which cultivation begins. The scenario changes from sequestering virtually no carbon to progressively larger volumes of carbon as the trees mature.

The results of two recent studies about the role of existing natural forests and old growth forests as carbon pools and carbon sinks indicate that not only do they store significantly more carbon than earlier assumed, but that they continue to serve as effective carbon sinks over long periods of time, until finally arriving at a diminishing incremental growth path (Mackey et al., 2008; (Luyssaert et al., 2008; Liao et al., 2010; Lewis et al., 2009). Their most critical roles however relate to biodiversity and carbon storage. One hectare of tropical forests in the Amazon for example, sequesters 1 ton of carbon per hectare per year (Brown 2002). Tropical timber plantations on the other hand can sequester up to 10 tons of carbon per hectare annually, depending on the stand, age, species and location (IPCC 2007). Nevertheless, because natural forests also do not add any carbon into the wood based product pool, forest conservation does not contribute to the substitution of fossil fuels or fossil fuel based products in any way.

Increasing demand for wood and wood products makes the management of production forests a necessary part of REDD+ policy options. The substitution outcomes described in this document will require transparent markets as well as some radical changes in silviculture and forest management. These markets provide the critical interface between producers and consumers, and they include international trade in wood products. Without sustainable wood production methods, substitution outcomes will be marginal or even negative, so ensuring the sustainability of wood production through independent third party forest certification becomes an important element in reassuring consumers that the wood products they buy have been produced the right way. Certification can also be used to ensure that local producers have been consulted and have participated in the production process in ways that protect their interests. This leads to confidence in the markets from the supply side and on the part of actors throughout the entire value chain.

The following key elements of forest management need to be covered for REDD+ to effectively address the role of production forests in a green economy.

1. Getting commercial forest management right.

In recent decades, the principles of sustainable forest management have evolved from managing forests to sustain production of a single commodity, mainly timber, to production of multiple goods and services. This shift from *sustained-yield* forestry to *sustained multiple-use* forestry was expanded upon with provisions for maintaining future options and not damaging other ecosystems. These were incorporated into the definition of "sustainable forestry management" in the UN Forest Principles in 1992.

State-of-the-art management of tropical forests is based on three fundamental elements. The first is the demarcation of a *permanent forests estate* to ensure the long-term sustainability of the forest in purposeful alignment with traditional rights and tenure systems. The second is the formulation of a *forest management plan* that balances the health and sustainability of the forest ecosystem with the development needs of local communities and other production purposes. The third element is a third party agent who supervises the effective implementation of the management plan, a capacity in which either government officials or independent auditors may be employed (Blaser et al. 2011; Pearce et al. 2003).

Since 1988, the area of permanent forest estate that is classified as being sustainably managed has grown from fewer than 1 million hectares to more than 25 million hectares, which is still less than 5 percent of the total estate. The International Tropical Timber Organization (ITTO), whose 59 member countries account for 80 percent of the world's tropical forests and 90 percent of tropical timber trade, estimated that the area of natural production forests designated as permanent forest estate was about 403 million hectares as of 2005. This represents 31 percent of the total area of tropical closed forest in the ITTO's producer countries. Of this total area, only an estimated 131 million hectares (32 percent of the total natural production PFE) are covered by management plans, 10.5 million hectares (4 percent) are certified by a recognized independent certification organization, and at least 30 million hectares (7 percent) are managed sustainably according to ITTO SFM criteria and indicators (ITTO 2011).

Private sector concerns about sustainable forest management, particularly in the area of foreign direct investment, were expressed in a series of Forest Investment Forums that were organized by the Program on Forests (PROFOR) and a number of its partner organizations beginning in 2003. A large number of firms that participated in the Forums expressed an unwillingness to invest in places where governance is weak and as a result investments in sustainable forestry were placed at a competitive disadvantage vis-à-vis investments in unsustainable practices that focused on immediate and short term returns. This represented severe opportunity costs in terms of many countries' ability to attract the types of investors who are interested in defending their corporate reputations and concerned with managing longer-term risks – namely the kinds of investors that policy makers should be interested in attracting. For the Collaborative Program on Forests (CPF), this left the potential for private sector investment to play an instrumental, even transformative role in accelerating economic growth, alleviating poverty, and protecting the environment badly underutilized. This is a critical shortcoming given that the scale of magnitude of investment that is required is far beyond the amounts that are available through official development assistance, but significantly more attainable through the exponentially larger volumes of investment capital that flow through private channels.

As of 2012, the World Bank, FAO, and a number of other members of the CPF were exploring possible ways to achieve a threefold increase in private sector investment by 2015 and a fivefold increase by 2020 – in large part through the formulation of an action plan that strategically addresses the specific constraints described by investors who participated in the Forest Investment Forums between 2003 and 2011. The action plan would also apply a set of criteria and indicators through which the economic, social, and environmental impacts of responsible private sector investment can be systematically measured and monitored. And it would include a detailed analysis of possibilities for investors to engage low income smallholders and communities in landscape-based approaches to restoring degraded forest and adjacent lands – including agroforestry farming systems that improve the fertility of nearby agricultural areas and that employ sustained-yield management within planted forests.

The focused conversations with private sector investors, civil society and non-governmental organizations, and environment and development agencies yielded a highly-informed series of recommended strategies, a number of which simultaneously encourage responsible investment and actively discourage irresponsible investment –

especially the perennial problem of illegal logging and trade. Together, the measures prescribed would extend the purview of forest law enforcement and standards compliance from the NGO community to local government, to exporting and importing firms, to the national governments of exporting and importing countries, and to companies with both the will and the capacity to engage in sustainable forest management – and that are adversely affected by the unsustainable practices of their less responsible counterparts. Most of these companies had already seen clear evidence of consumer demand for certified sustainable timber products. A number of measures will serve to get commercial logging operations right, including the following.

- Reform concessions, policies, and regulations, and terminate concessions in the case of noncompliance with regulations;
- Carefully plan roads and other infrastructure in the vicinity of protected areas;
- Use independent observers and log auditing;
- Adopt technologies that enable timber to be tracked from harvest through milling, thus ensuring that illegal wood does not enter the legal supply;
- Delineate boundaries between production forests/concession areas, protected areas, and indigenous and local community territories in transparent and participatory ways;
- Establish independent third party certification processes that track the chain of custody and that give importing countries the capability to reject illegally harvested timber;
- Increase investment in sustainable forest management (in addition to its environmental and other benefits, this also would motivate investors to prevent illegal forest management practices, as these distort market prices);
- Develop common standards for measuring and reporting forest crime; and
- Avoid timber harvesting in conflict zones, particularly from areas outside the control of recognized governments, and the ending of collaboration with companies that trade timber for arms.

Source: PROFOR 2004

2. Actively promoting Reduced Impact Logging

In sustainably managed forests, a variety of techniques associated with reduced impact logging are applied, including controlled tree felling, cutting vines before harvesting, and limiting the use of heavy machinery to avoid damaging soils and trees that remain standing. Reduced impact logging can minimize the proportion of the surrounding trees that are destroyed during logging by between 40 and 50 percent compared to conventional logging (Pinard and Putz, 1996; Sist and Bertault, 1997; Elias, 1999; Chabbert and Priyadi, 2000). Loggers typically harvest only a small number of selected, commercially valuable tree species. In some regions for instance, just 15 out of more than 2,500 woody species are harvested. Minimizing damage to unharvested trees dramatically reduces forest degradation and the carbon emissions associated with it. On the order of 1.6 to 2.1 tons of carbon per hectare per year can be saved compared with conventional logging (Swingland 2003). Globally, about 2.9 billion tons of carbon are currently emitted each year as a result of tropical deforestation (Y. Pan et al. 2011). The use of these improved forest management practices in tropical forests could retain *at least* 0.16 billion tons of carbon per year (Gullison et al, 2007; Putz et al. 2008). The greatest carbon savings from improved forest management can be obtained in the intensively logged forests of Asia, where the rate of emissions is the highest (Putz 2008). Significant savings can also be achieved by changing from conventional logging to reduced impact logging in the Congo Basin.

In addition to the benefits of reduced impact logging on the forest carbon store, the role of the forest as a carbon sink is also greatly enhanced. Because the stocking rate of improved tree crops is higher, post-harvest carbon sequestration rates are substantially higher than in conventionally logged areas (Pinard and Putz 1996; Boscolo and Vincent 1998). Sustained yields over time result in more timber production in the long term, so that the forest is providing renewable material that substitutes for fossil fuels and fossil fuel-intensive products at the same time that regeneration of harvested areas continues to sequester additional carbon out of the atmosphere. Sustainably managed forests provide an ongoing source of renewable materials (FAO 2002). The forest therefore has a continuous substitution effect, producing generations of timber and biomass, each of which replaces fossil fuels directly or which replaces building materials that require large volumes of fossil fuels to produce. This represents an enormous advantage over conventionally logged forests that often provide one or two harvests before being rendered unproductive and subsequently converted to other land uses.

Minimizing logging impacts and avoiding harvesting practices that create large openings in the forest canopy have important benefits for biodiversity by enabling forest biota that tolerates shade. A meta-analysis of six recent studies of biodiversity in forest concessions found that selectively logged forests retain 85 percent of bird species, 92 percent of the plant species, and all of the mammal and invertebrate species that are found in undisturbed old growth forests (Putz, 2011). This preservation of species richness significantly reduces the risk of pests and fires, and the massive releases of forest carbon associated with them. Reduced impact activities such as enhancing future timber yields through pre-and post-harvesting planning, including careful planning of access and skidding roads, minimizes erosion and simultaneously maintains vital environmental services such as the forest's watershed functions (Putz et al., 2008). Here too, in order to ensure equitable benefits, sustainable forest management and forest certification needs to include verifiable social inclusion, respect of terms and land rights, and safer and more secure employment opportunities.

Some forest ecosystems are highly sensitive and their biodiversity can be seriously affected by even the most careful reduced impact logging schemes (Pena-Claros et al., 2008; Putz et al., 2001). As such, many of them should be considered prime candidates for designation as protected forests and conservation buffer zones. Based on their value in terms of environmental services, biodiversity, or landscape functions, these areas should be classified as high conservation value forests (HCVFs). Certified sustainable forest management enterprises always dedicate a part of their forest area to HCVFs.

3. Providing incentives for loggers to transition out of conventional logging.

Conventional logging generally refers to managing forests to supply timber, typically with a preoccupation on maximizing short term profits. It often takes place without substantial government control or regulation, and in many cases involves informal chainsaw operators logging for domestic or local purposes. Experience shows that conventional logging in many cases leads to forest degradation, forest loss, and conversion to other, non-forest land use. As such, it is often used synonymously with poor management practices, and in contrast to sustainable forest management practices such as reduced impact logging (RIL). Because it assigns lower, if any priority to maintaining long-term timber supply or other forest benefits, conventional logging has a strong tendency to lead to lower returns from future investments in the same forest area (Rice et al., 2001). Owing to the higher returns that conventional logging achieves in the shorter term, loggers typically prefer it to sustainable forest management. As a result, conventional logging is the most widespread commercial use of tropical forests.

The high harvest intensity typical of conventional logging - between 30 and 110 cubic meters per hectare - causes a substantial decrease in forest carbon stocks, as much as 80 percent of the carbon stock of pristine forest (Butcher et al. 2002). While much of the carbon removed during the harvest is not released directly into the atmosphere, but rather flows to the wood products carbon pool where it continues to be stored, only about 30 percent of the carbon stored in a live tree will be permanently stored in the harvested wood. Much of the remaining 70 percent which is lost is attributable to waste and inefficiency in the harvesting process. The proportion of carbon that is stored and released depends in part on the level of mechanization in the wood harvesting and processing chain, which is commonly low in tropical countries (Winjum et al. 1998). This suggests itself as an important area of focus for development cooperation.

Although conventional logging may degrade forests to such an extent that what remains does not seem worth protecting, these degraded forest areas carry significant potential as carbon sinks. This potential disappears when the area changes over to other, non-forest land uses, which is a pattern that is quite typical throughout much of the tropics. In some instances, the spiral of degradation that conventional logging triggers is so severe that the land is ruined for other uses as well. When high harvest rates and destructive logging cause substantial canopy opening, susceptibility to fires and weed infestation increases. These developments can limit options for alternative land use considerably (Pearce et al. 2003). Conventional logging can lead to substantial habitat destruction and fragmentation and biodiversity loss, which in turn undermines the forest's capacity to adapt to climate change (Pearce et al., 2003; Rice et al., 2001; GFLP et al., 2008). Finally, conventional logging generally entails the construction of forest roads and trails which greatly facilitate further encroachment into adjacent forest areas.

In many developing countries, especially in Africa, poachers use the forest trails to hunt bushmeat, which is a highly demanded source of protein in many local communities. New concessions for conventional logging in pristine forests increase deforestation of adjacent forest area by up to 20 percent per annum (Hamilton, 1997).

The jobs created during the life of the logging operation, both inside the forest and in the larger forestry industry, tend to be low-wage and dangerous. In addition to the overwhelmingly negative effects that conventional logging has on climate and biodiversity, its local benefits are both scarce and short-lived. At present, 350 million hectares of tropical forests are dedicated as production forests and these forests are mainly exploited for timber. Given the growing demand for timber and increased access to forest area, logging is likely to expand well into the foreseeable future. Promoting the transition to *reduced impact logging,* which is associated with sustainable forest management, therefore warrants urgent priority.

Box 4: Sustainable natural forest management in Cameroon – The Wijma case

Wijma is a Dutch company that has been active in Cameroon since the 1960s. It was the first certified sustainable forest company in the Congo Basin. Wijma manages four forest management units in the southwest of Cameroon, covering a total area of 260,000 hectares.

Their environmental policy declaration includes the following points:

- High Conservation Value forests are dedicated to protect endangered fauna and flora species, in collaboration with NGOs and universities. Collaboration is also set with WWF for the conservation of the concessions boundary.
- Hunting and fishing are strictly controlled in the concession, and the company works with the local administration to fight poaching.
- Illegal logging and encroachment are controlled in collaboration with Cameroonian administration.

The company employs 500 people and harvests 80,000 cubic meters of timber each year. Each year Wijma undertakes a broad range of social services to support local communities. These include building houses and dwellings, schools, canteens, poultry breeding farms, roads, and bridges. They also include the provision of medicine, hospital renovations, and scholastic materials for 5,200 students in 59 schools annually. To ensure local ownership and sustainability, members of the local communities become project leaders, thus enlisting them as stewards of their own development.

Source: Michel de Galbert, personal communication with Sebastien Delion of Wijma Cameroun S.A.

4. Increasing carbon benefits from sustainably-managed planted forests

The ongoing process of carbon capture in planted forests can be augmented by using improved varieties of higher yielding tree crops such as better provenances. Some of these are faster growing and can be harvested in shorter rotations. Others are slower growing but produce harder, higher density wood that captures proportionately more carbon. These improved tree varieties can be introduced once it has been determined that their cultivation can be undertaken in compliance with certain social and environmental standards. In addition to the economic advantages of this more intensive production, it also has greater potential to displace fossil fuel, and at higher rates than less intensive forest management systems. Low cost technologies are available to process smaller trees and forest residues. This represents a volume of active "flowing" carbon in contrast to the less active, more permanent carbon stock that is stored in unharvested trees. The substitution effects of this flowing carbon are permanent, whereas the carbon stored in unharvested trees and wood products is time-limited and always reversible. And these substitution effects are achieved every time that biomass is used to replace fossil fuels, or that wood is used to replace materials that require large amounts of fossil fuel in their processing. These substitution effects are usefully classified as "direct" or "indirect."

5. Restoring degraded forest landscapes and enhancing existing carbon stocks

Some 1.64 billion tons of carbon are sequestered by degraded forests, which unlike deforested areas do maintain some level of production function, although with diminished productivity. Added to the 1.02 billion tons of carbon that is stored in intact tropical forests, this brings total annual carbon sequestration to 2.66 billion tons – nearly as high as the 2.82 billion tons gross deforestation (Y. Pan et al. 2011). Effective landscape restoration strategies can transform these into vital, high-value assets within a few years. Much of the restoration could be achieved through assisted natural regeneration which entails substantially reduced investment costs. Based on satellite analysis, the Global Partnership on Forest Landscape Restoration (GPFLR) estimates that up to 950 million hectares - or one half of the world's degraded forests and forest landscapes - could be restored globally. 85 percent of this area is situated in the tropics (GPFLR 2011).

The African continent has the greatest potential for landscape restoration with more than 650 million hectares of degraded forests - about one third of the world's tropical degraded forests. *Wide-scale restoration* could be applied in sparsely populated areas where pressure from competing land-uses is relatively low. *Mosaic restoration* is applicable in areas with higher population density and other land uses such as agriculture. *Protective restoration* can be introduced in altered and densely populated landscapes where most land is used for food production and settlements.

The amount of carbon that can be sequestered through the restoration of these areas exceeds the amount that continues to be stored through avoided deforestation, and much of its potential relates to the carbon substitution effects that restoration would have if periodically harvested. While a wide range of restoration options exists, two such options are discussed here to illustrate the multiple benefits that landscape restoration scenarios could bring: restoration through *timber plantations* and through *agro-forestry.* In both instances it is important to qualify that the positive impacts described refer to plantations and agro-forests on previously degraded or deforested lands, and not on cleared primary forests.

Timber plantations on afforested, reforested, and restored forest areas are a prospectively important element of REDD+. Between 2000 and 2010, the global area of planted forests increased by about 5 million hectares annually, 3.6 million in the tropics. This brings the area of planted forests in the tropics to 151 million hectares. China in particular assumed a leading role in afforestation, planting about 1.9 million hectares per year on lands which were not forested in recent history. (Although it warrants qualifying that much of this area is planted with monocultures that provide limited ecosystem services). Although timber plantations represent about 7 percent of forested area globally, they accounted for 35 percent of round wood produced in 2000 (Varmola and Carle 2002; FAO 2010).

Just over half of the global plantation area is used for the production of industrial wood. Most of the rest is used to produce wood fuels. Tropical regions account for over 80 percent of the global fuelwood harvest and only about one-third of industrial roundwood production (Bowyer, 2004). 46 percent of industrial round wood production in 2050 is projected to come from plantations (FAO 2010).

Yields on timber plantations are very high. Some species, such as Eucalyptus species and *Acacia Mangium* can yield as much as 40 to 60 cubic meters of wood per hectare annually, containing between 11 and 17 tons of carbon (IPCC 2007). At 20 cubic meters per hectare (total aerial biomass), this represents some 11 cubic meters of merchantable volume per hectare annually (Whittaker 1972; IPCC 2006). Yet the existing literature on this point for tropical forests is curiously scarce.

The high yields seen on tropical plantations have important practical implications for the direct substitution effects of using forest residues and products to replace the use of fossil fuels. These promise to become still more pronounced with the emergence of innovative, second generation biofuel technologies such as the pyrolysis process, which directly replaces fossil fuels in both electricity production and transport.

While the rate of timber growth in plantations exceeds that in managed tropical forests in general, returns from the initial investments take longer to materialize than returns from sustainably managed natural forests. They also entail high up-front capital investment costs. Commercial timber harvesting on plantations usually begins when the plantation operation is between 7 and 15 years old – a significant waiting period before investors see their first returns.

The total carbon stock that is stored in plantation ecosystems is about 28 percent lower than that of natural forests. Plantations however *sequester* significantly higher volumes of carbon dioxide - particularly when trees are young and growing rapidly (Liao et al. 2010). This rate of sequestration can be increased in the short term (under ten years) by using fast-growing species that enable shorter harvest rotations (Redondo-Brenes 2007; Redondo-Brenes and Montagnini 2006; Kraenzel et al., 2003). Slower-growing tree species on the other hand carry important advantages in terms of carbon storage in the longer term, owing in part to the high specific gravity of hard woods. These hardwood species also add more carbon to the wood product carbon pool because they are processed in long-lived wood products, such as furniture or construction material, rather than into short lived products like paper. Because they yield more timber than sustainably managed forests, the substitution effect of timber plantations is greater, although it varies depending on which tree species are grown.

At the end of their use, wood products can be recycled, and if used as fuel, substitute for fossil fuel use. The ultimate impact of production needs to be gauged not only in terms of the production process itself, but taking into the fullest account the life of the product in terms of carbon storage and substitution. Although timber plantations are generally lower in biodiversity value than natural forests, they can be designed to optimize their forest biodiversity and to fulfill critical ecological connectivity functions (GIZ 2011).

6. Assigning greater priority to agro-forestry and management of dry forests

Agroforestry refers to land use systems and technologies in which woody perennials such as trees, shrubs, palms, and bamboo are purposefully planted on the same land management units as agricultural crops and/or fodder plants and livestock. These may be arranged spatially or sequentially. When defined as agricultural land with tree cover greater than 10 percent, traditional agroforestry accounts for more than 1 billion hectares globally, some 46 percent of agricultural land (Zomer et al. 2009).

These systems remain grossly undervalued in REDD+. Agroforestry systems can simultaneously produce timber, wood fuels, non-timber forest products, agricultural and horticultural crops, and fodders. These multiple roles make them particularly effective in providing livelihoods, reducing poverty, and improving development outcomes more broadly. They can also simultaneously sequester and store carbon, improve water management, reduce soil erosion, and increase biodiversity. They can increase carbon stocks by more than 50 tons per hectare compared to agricultural land. While agroforestry systems typically store between 15 and 30 percent of the above-ground carbon stock of dense tropical forests, they sequester and store substantially more carbon than agricultural systems without trees (Pandey 2007). (According to Pandey (2007), carbon stocks in agro-forestry systems averages 95 tons per ha, but those that replicate some elements of natural forests structure such as cacao- or rubber agroforests store much more carbon.) Fertilizer tree systems in particular can increase carbon sequestration (Albrecht and Kandji 2003) even further.

Investments in agroforestry over the next fifty years could result in 50 billion tons of additional carbon dioxide being removed from the atmosphere. This alone is a major proportion of the world's total carbon reduction challenge (Garrity and Verchot 2008).

Agroforestry systems also improve ecosystem functions in ways that build resilience against droughts, pests and climate-related threats. Integrating agroforestry and tree farming systems in landscape restoration can provide food, fuelwood/timber and income to local farmers, while increasing carbon stocks and making agriculture more resilient to climate hazards.

Both ecological and economical interactions take place between the different components of agroforestry systems (ICRAF 1993). Long-term research in Africa has shown that fertilizer tree systems (nitrogen fixing trees such as *Faidherbia* trees intercropped with maize for instance) can boost crop yields up to four times. Without having to buy chemical fertilizers or to invest in irrigation systems, farmers can reduce the amount of labor and farm investment by intercropping trees. Agroforestry can thus maintain or increase crop production and overall farm productivity and substantially raise the returns from farm investment (ICRAF 2009).

Using wood or wood fuels from agro-forests can reduce both the pressure on natural forests and the need for fossil fuels, though the substitution effect of producing wood energy has yet to be taken into account in international dialogue. Agroforestry systems that include indigenous species in the package of plant species cultivated can have an especially large positive effect on biodiversity. They can therefore contribute to biodiversity outside of protected areas, unlike agricultural and other land use systems that rely on only a small number of cultivated species. The variety of plant and animal species produced ensures a constant flow of goods and services.[8]

A wide variety of agroforestry systems exist, but the degree of environmental services depends on the species used. For example, some tree species may only recycle nutrients from soil depths, other than nitrogen fixing trees that add new nitrogen into soils. Trees can also play an important role in watershed management, with some species that help regulate water flows.

Management of dry forests. Recent research findings from the *Cerrados* in Brazil indicate that the importance of these landscapes for carbon mitigation is grossly underestimated – and can reach the overall carbon content level of tropical rainforests of the Amazon. However, a main difference between the two ecosystems is that in the *Cerrados*, about 2/3 of the carbon is stored in the soil, and only 1/3 in the above-ground vegetation (Brazil Investment Plan for the CIF/Forest Investment Program; March 2012).

[8] See Michon and de Foresta (1995).

Box 5: An agro-forestry success story from Niger

In 1990 forest regulations in Niger were relaxed to allow farmers to cut down trees on their own farms for timber and fuelwood. This provided farmers with an incentive to plant trees in-between their crops. As a result, farmer-managed natural regeneration began to accelerate rapidly and *Faidherbia* agro-forests now cover more than 5 million hectares of sorghum and millet farms in Niger.

The farmers planted up to 200 trees per hectare and claim that since then their crop yields and livelihoods have improved. The trees protect the crops and the land from wind and water erosion and provide fodder for their cattle and goats during dry seasons. In the past the barren plains of Niger where characterized by infertile soils, dust storms, droughts and shortages of fodder and fuel-wood. Agroforestry transformed these landscapes into productive landscapes again and enabled the establishment of a sustainable fuel-wood market.

Where conventional reforestation projects failed despite large investments, local farmers succeeded in addressing environmental degradation and poverty by applying an agroforestry method known as farmer managed natural regeneration (FMNR).

Source: Tougiani, Guero and Rinaudo, 2009.

V. Widening the Scope of Forest Based Mitigation Options - The Prospective Contributions of Tropical Forests to Climate Change Mitigation by 2050

Extrapolating from what is known about the status of different forest areas in 2010, and about the potential impacts of different forest management practices over time, global projections of these impacts by 2050 depend on many factors and are therefore difficult to quantify. However, it is possible to quantify the impact of different forest management systems available already today and to extrapolate the cumulative impacts. These are general projections of the overall scale of magnitude of the carbon effects of using forests and forest products in different ways over the next four decades that are essential for addressing climate change. The wood products carbon pool is not included in the calculations because the methodologies that will be used to calculate the wood product benefits are still being developed. A preliminary glance at the contrast between the 2010 baseline and the more ambitious prospective changes by 2050 warrants the reader's attention (see figure 1 in executive summary).

In 2010, about 2.8 billion tons of carbon was released into the atmosphere as the result of human-induced deforestation and forest degradation. Given an estimated annual rate of 1.72 billion tons of carbon sequestered through natural regrowth, this leaves 1.2 billion tons of net deforestation annually – effectively two times the amount of carbon sequestered by planting trees (374 million tons of carbon) and the 267 million tons of fossil carbon currently substituted combined.

Given this ambitious scenario, the picture of 2050 reflects a fundamental transformation to green economies. Here, the uses of wood in permanent, sustainably logged forests, restored forests, reforested lands, and agro-forests make a pronounced contribution to climate change mitigation. In addition to the emission reductions achieved through improved forest management, the graphic also reflects high levels of substitution between the use of wood biomass and fossil fuel - the effects of replacing 3.8 billion more tons of fossil-based carbon while sequestering 1.3 billion more tons annually. The combined total of more than 4.1 billion tons of *neutral,* fossil fuel-substituting carbon and fueling green economies will be greater in 2050 than the gross amount of carbon that was released into the atmosphere by deforestation and forest degradation four decades earlier in 2010.

Three forest uses in particular warrant additional treatment as areas of especially high impact.

Restoration of logged and degraded forests by 2050

In 2010, logged and degraded tropical forests took up an estimated 806 million hectares globally (GPFLR 2011). That these degraded forests continue to produce wood and sequester carbon distinguishes them fundamentally from deforested or what are sometimes referred to as "barren lands." On average, this area yields an estimated 2 cubic meters of wood per hectare annually, bringing total annual production of degraded forests to about 1.6 billion cubic meters - some 1.3 billion cubic meters as fuelwood, and 0.3 billion cubic meters as roundwood.

Together, these substitute for about 165~~145~~ million tons of carbon in fossil fuel equivalents.[9] Some 1.72 billion tons of carbon are stored in degraded forests in the tropics (Y. Pan et al. 2011). This carbon is divided about equally between about 403 million ha in logged concessions and about 404 million ha in other degraded areas (ITTO 2011; WRI 2009). Given the rate of tropical deforestation in 2010 at 7.45 million ha per year, and assuming that this rate will level off at zero in 2050, the average rate of deforestation during the 40 year period would be 3.72 million ha per year. The 3.72 million ha per year multiplied by 40 years leads to a 149 million ha reduction in the overall tropical deforestation, bringing the 806 million ha of logged and degraded forests to 657 million ha in 2050.

From 2010 to 2050, the area of degraded forests assigned to concessions is projected to remain stable at 403 million ha, assuming that appropriate policy frameworks are introduced and effectively administered. This projection assumes that appropriate policy frameworks are established and that concessions are no longer being established in primary forests. Productivity increases have raised yields to 3 cubic meters per ha per

[9] While this analysis limits itself to forests, expanding this area to include degraded lands in general, there is significant potential to restore some 2 billion hectares (WRI 2011).

year, bringing the total annual harvest to 1.2 billion cubic meters. 900 million cubic meters of this harvest go to biomass production for energy purposes. 300 million cubic meters go to roundwood production. And the rate of regrowth is reduced from 860 million tons carbon to 563 million tons.

The degraded forests outside concessions, including wide scale and mosaic-type area, are much more vulnerable to illegal logging and other activities associated with deforestation. Council and community-based sustainable management is only beginning; all the efforts of REDD+ need to focus on these area and the surrounding lands in order to lower and stop once the land-use change.

These degraded forest areas without concession have also leveled off at 254 million ha by 2050. Total harvesting in these non-concession degraded forests is 840 million cubic meters, of which the great majority - 770 million cubic meters - is used for fuelwood. This leads to 73 million tons in carbon savings, added to the theoretical regrowth of 714 million tons of carbon on 254 million ha.

In addition to their significance for climate change mitigation through carbon sequestration and storage, degraded forests are also important areas for biodiversity conservation - and therefore climate change adaptation. For the Convention on Biodiversity (CBD), much of this importance is measured in a shorter timeframe than 2050 - namely in the Aichi Biodiversity Targets set for 2020.

Among these, Target number 15 applies in particular: “By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.”

Planted forests by 2050

As of 2010, an estimated 151 million hectares of plantation forests were used in the production of some 158 million cubic meters of roundwood. Projections to 2050 expand this area to 500 million hectares and diversify production into wood fuel and biomass in addition to roundwood for a total of 10 billion cubic meters of wood. 1300 million tons of carbon is stored annually in planted forests, compared to 374 million tons in 2010. Still more significantly, 2.4 billion tons of fossil carbon is replaced, compared to the 54 million tons that was replaced by the substitution effect in 2010.

Agroforestry by 2050

Agroforestry is projected to be practiced on 750 million hectares for a total of 6 billion tons of wood. Together with plantations, it can durably offset at least 40 percent of the increase in the needs of energy of non G7 economies, possibly in the form of electricity (Hawksworth 2006). At this scale, agroforestry is also an essential element of agricultural sustainability through its effects on soil fertility. (Mitigation through storage, which is estimated at up to 36,000 tons of carbon by Y. Pan was not included in the simulations.)

Outlook

The 2.8 billion tons of annual carbon emissions that is targeted by REDD in 2010 represents more than 40 percent of the forest mitigation challenge globally, that is the global reduction and offset of the greenhouse gas emissions. More than one and a half of the forest mitigation challenge can be met by sustainably managing degraded forests, planting trees on barren lands, and avoiding waste. The ongoing substitution effect of plantations is almost two times higher than their one-time storage effect. In China, 2 million hectares of forest are planted each year, and even though these plantations would benefit from more sustainable practices, the potential scale of magnitude this points to is massive. If all tropical countries planted trees at this pace, then 20 million hectares would be planted annually.

The agroforestry scenario described above would add an additional 13 million hectares of agro-forests to these 20 million hectares of plantation forests annually. When such tree and agroforestry plantations are purposefully integrated into their surrounding landscapes and efficiently linked to energy-producing plants and consumer markets, they can be instrumental in meeting energy and food needs while at the same time they remove pressure from natural forests.

Figure 3: Surface Land Use (millions hectares)

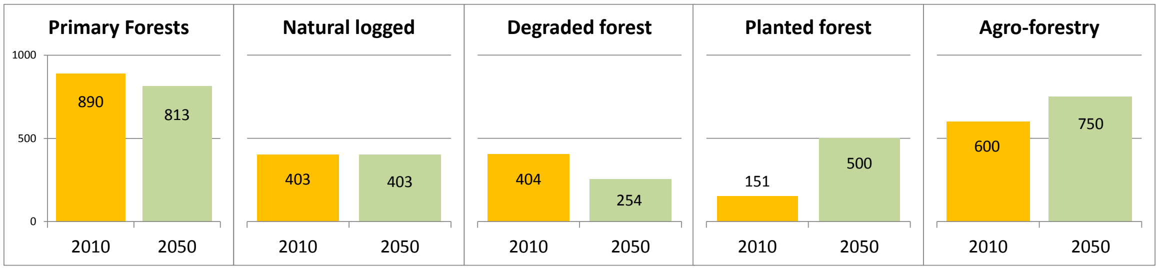


Figure 4: Harvest Yields (square meters per hectare per year)

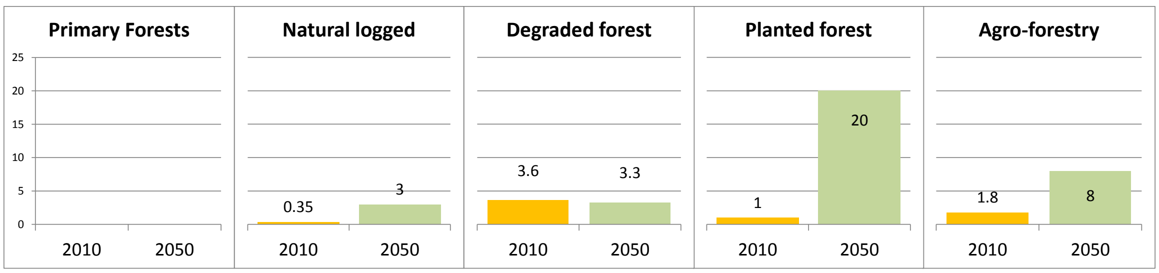


Figure 5: Fossil Fuel Substitution (millions tons carbon per year)

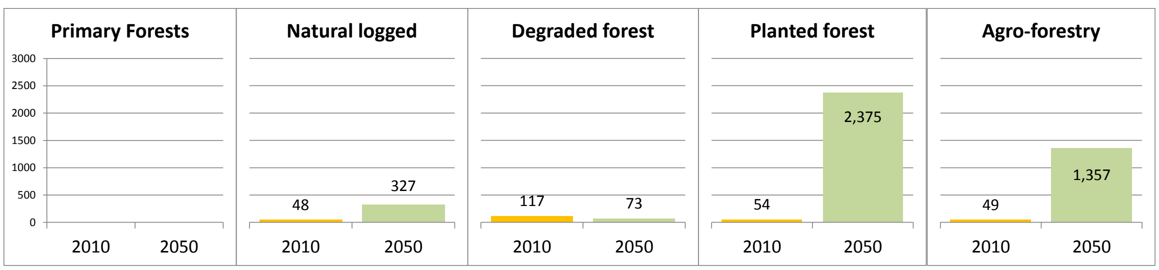


Figure 6: Carbon Storage in Forests (millions tons carbon per year)

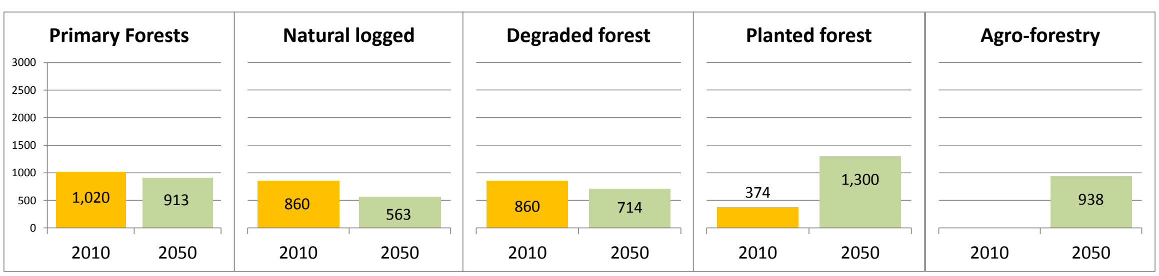
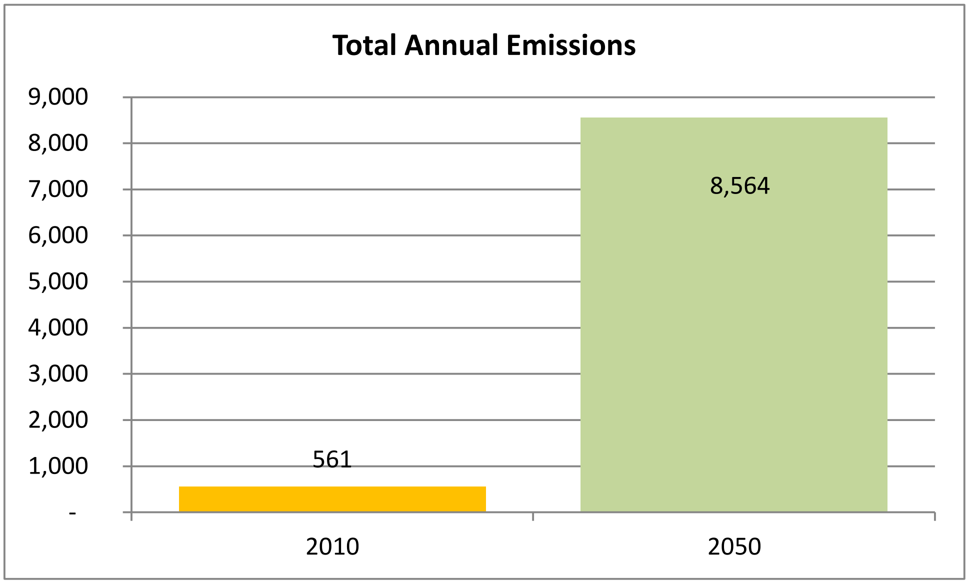


Figure 7: Total Offset and Avoided Emissions (million tons carbon per year)



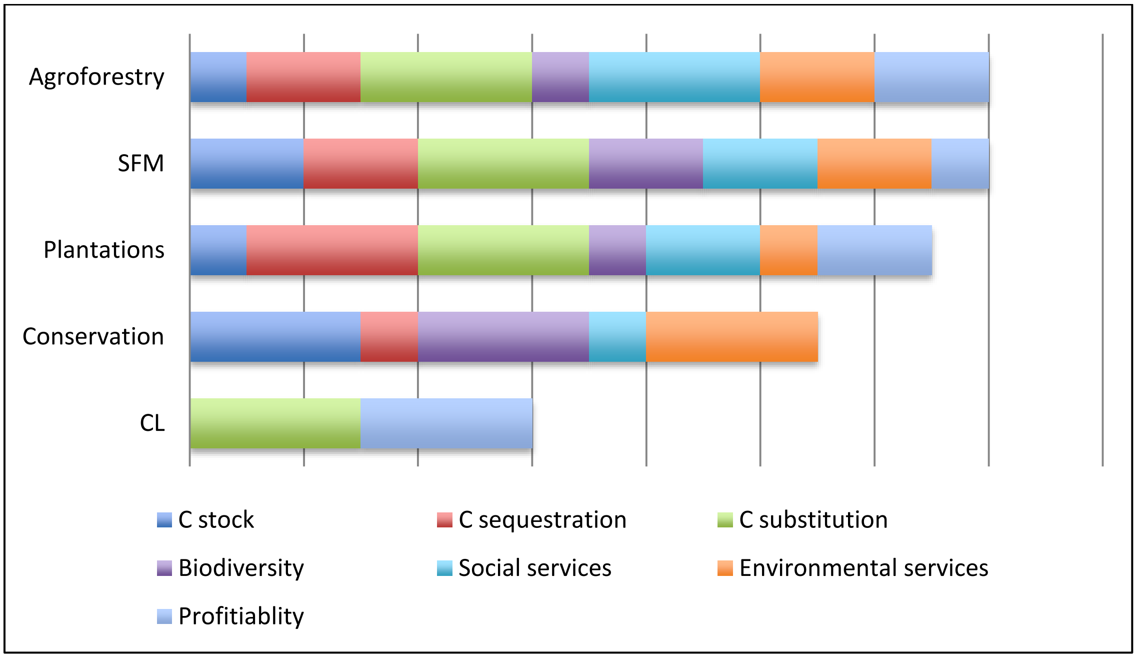
(See detailed table in annex 3)

VI. Trade-offs and Multiple Wins

The environmental services that forests provide must be considered alongside the important social and economic roles that forests play as well. At the end of the day, the changes prescribed in this document for increasing the number of forest-based mitigation options will need to generate important benefits for local communities in terms of jobs, livelihoods, and poverty alleviation in addition to environmental services such as carbon sequestration and the conservation of critical biodiversity. Turning forests into an essential pillar of a greener economy, maintaining and capitalizing on the full suite of services they provide locally and globally, and managing them sustainably will not only lead to more efficient mitigation of anthropogenic GHG emissions, but also to the creation of jobs and livelihoods, the alleviation of poverty, and the conservation of critical biodiversity. These need to be considered together, as do the balances and trade-offs between shorter term and longer term objectives.

Doing so reveals a more complete picture than considering one practice in isolation from others. A rudimentary qualitative representation such as the one presented in the Figure 3 can be useful in this regard. In it, each management practice entails strengths and weaknesses. Conventional logging for instance has a high potential to add a large volume of carbon to the forest products carbon pool and generates significant profits for investors. Its costs in terms of other criteria are however very high. Sustainable forest management and agroforestry on the other hand yield multiple benefits, albeit with drawbacks in terms of economic profitability.

Figure 8: Multiple Benefits of Common Forestry Practices



Considering the advantages and disadvantages of the respective forest uses gives rise to a calculus in which both trade-offs and multiple "wins" become apparent. Forests can be managed to simultaneously provide multiple benefits, even though a single management objective often determines how a forest is used - for instance profit motive in the case of conventional logging and timber plantations. If the way forests are used can be determined by multiple and trade-offs benefits, including those which apply in the longer term, then different and more rational combinations of forest use are likely to become preferred. Sustainable forest management and agroforestry in particular emerge as forest uses that generate multiple benefits - the so-called "triple win" of improving livelihoods, mitigating climate change, and increasing resilience to climate change. Timber plantations are also likely to produce multiple benefits when certain considerations are taken into account. These include what the land was previously used for, which tree species were planted and in what kind of arrangements, and how socially inclusive the operation will be in terms of employment generation or outsourcing to smallholders to produce on their own land (outgrower schemes).

The area under sustainable forest management in the tropics is slowly expanding. Properly informed decisions and policies can build upon this early progress and accelerate it. These can continue to make poor forest management practices like conventional logging less attractive, while further improving incentives for operators to adopt sustainable forest management practices. Certification schemes and systems to verify the legality of timber sources are on the rise.

However, without a major pull from international consumer markets, it would be difficult to provide strong incentives for quick changes in approach on the producer side. In the European Union, the Illegal Timber Law and the Forest Law Enforcement, Governance and Trade Action Plan, as well as a number of public and private sector procurement policies have become important elements of an overall strategy to make conventional logging less attractive in international markets. In the United States, the Lacey Act serves a similar purpose.

Despite these positive developments, more than 90 percent of tropical forests are still managed poorly or not managed at all according to the ITTO's *Status of Tropical Forest Management 2011.* Sustainable forest management in the tropics remains less profitable in the short term than competing land-uses like agriculture or mining. Confusion over ownership and land and tree tenure, and a lack of clear market signals, continue to be a major barrier to sustainable forest management throughout much of the tropics. Forest governance and the capacity to enforce forest laws are often weak among local governments. Awareness of opportunities and risks in the forest sector is often very limited among public officials, and capacities to create enabling conditions for more sustainable forms of forest use are limited (SCBD, 2008).

The increase in forest area in many developing countries that has resulted from the establishment of new planted forests warrants qualification as well. Many timber plantations for example established in the 1980s failed owing to poor management and lack of local and community ownership. The rate of success of timber plantation ranges from 61 percent in Africa, to 45 percent in South America, to 40 percent in Asia, (FAO, 2010). Successful management of tropical tree species on plantations relies heavily on intensive and timely silvicultural interventions (Kanninen et al., 2004).

Improved forest management of these timber plantations would lead to positive climate impacts by increasing the overall plantation growth. In the long term, it is likely that the demand for tropical hardwood produced on plantations will exceed supply. Tropical hardwood plantations will therefore have to produce increasing volume during the coming decades. The excellent market potential implicit in this scenario represents a major opportunity to both increase income and returns on investment, and to replace fossil fuels with wood substitutes (Varmola and Carle, 2002). Effectively seizing upon this opportunity can dramatically increase the incentives for investors to ensure that production on the plantation is sustainable (Ince, 2010).

The combination of declining forest resources and increasing demand for forest products on the part of growing populations with rising incomes, in addition to growing competition from other land uses, is making both national and international dialogues about forest resources and the climate increasingly urgent. And as the pressure to find solutions intensifies, arguments that discount or dismiss either forest's roles in human well-being or in protecting the environment may become more widely recognized as intrinsically unworkable.

Site-specific decisions about how forests are to be used need to be informed by more comprehensive information and balanced logic. By widening the focus of how we deal with forests, seeing them embedded in multi-functional landscapes in which markets attribute real economic value to ecosystem services, important opportunities can emerge to align economic and environmental imperatives.

The notion that human well-being and the quality of ecosystem services are positively correlated has found powerful validation in recent research findings (Zhongwei, Lin and Yiming. 2010). In developing countries in particular, where a significant proportion of economic growth relies directly on the natural resource base, improving the management of those resources to ensure the flow of ecosystem services is a priority that may find increasing leverage.

If societies' dependence on those natural ecosystems is neglected and the resource base is allowed to decline, the window of opportunity to capitalize on forest use alternatives that generate multiple benefits will begin to close very quickly, as will the consequences for development, both economic and human development. And nobody will be more exposed to those consequences than the rural poor (OECD 2008). Given the rate of the depletion of stocks in natural resources and the unsustainable patterns of economic growth throughout many parts of the developing world, the immediacy of these human risks are acute (Arrow 2010).

The relatedness of poverty and natural resource loss and degradation is by now empirically validated. International development agencies with a commitment to achieving the Millennium Development Goals regard investment in natural capital as an intuitive part of their missions and agendas. In the larger global economy however, in which development agencies account for a miniscule proportion of the investment capital that flow between countries, markets have been slow in internalizing values associated with public goods.

Expanding forest-based climate change mitigation to encompass carbon substitution effects and carbon storage in wood products not only makes for a fuller and more complete accounting of how forests affect climate, it establishes forests as the centerpiece of a new green economy. Our vision of what a green economy will look like becomes clearer and more complete, and our vision of the path that takes us there does as well. In this vision, the bridge to a green economy is made largely out of wood.

VII. Conclusions

Issues in the forest sector currently enjoy an unprecedented level of political prominence, both nationally and internationally. In many tropical countries REDD+ pilot projects have been initiated and policymakers are working on developing national REDD+ strategies. Current donor pledges on the order of US$6 billion in support of these strategies and initiatives reflect the significance the international development community attributes to forests as a vital asset in mitigating and adapting to climate change (REDD+ Partnership, 2012).

The authors of this document hope that more policy makers can be persuaded to think along these lines, rather than looking upon forest carbon strictly in terms of conservation, or for that matter, strictly in terms of economics. Both are highly selective perspectives which have limited the scope of how many governments and international agencies have looked at the roles of forests in mitigating climate change. Embracing a more expansive perspective opens policy planning to a far more complete menu of options.

These include policies and activities that can encourage the use of recycled materials (especially recycled wood and paper products). They include public procurement policies, wood fuel plantation programs, and other initiatives that specifically encourage substitution effects in products and energy sources. They include technologies such as energy efficient wood stoves which promote efficiency. They include the use of carbon life cycle assessments of different forest management practices - a direction of research that is profoundly promising.

And very importantly, it includes the communication of these types of initiatives as *development opportunities* in a context in which many developing countries perceive reduced emissions from deforestation and forest degradation as a series of constraints and proscriptions.

While achieving a mitigation impact of 8 billion tons of carbon annually - a half of which is attributable to substitution effects - is theoretically feasible, it represents an approximate theoretical maximum. In practical terms, a great many things would have to “go right” to make this happen. Yet achieving some substantial proportion of that sum total would also bring about major benefits. From the perspective presented in this paper, REDD+ appears as a promising, albeit intermediate step towards this wider purview, which is a logical expansion of REDD+.

For this expanded REDD+ to achieve its full potential, it must be instrumental in bringing about the transition from a fossil fuel-dependent economy to a greener economy. Its funding mechanisms must effectively support *both* benefits to local peoples *and* positive impacts on the global environment in order to remain tenable over time.

Strategies that address environmental issues but that omit or neglect social issues (and vice versa), need to be discredited, and ultimately discarded. And as many people as possible - and forest-dependent people in particular - need to understand why, given that their active participation and cooperation is likely to be the single greatest factor in determining how sustainably forests are used. This requires legitimacy from their perspectives, and the purposeful acknowledgement and incorporation of their priorities and concerns. Decisions which are handed down to them by decree and which appear to them as arbitrary are dramatically less likely to be carried out in practice.

If the livelihoods of millions of forest dependent people are disregarded or neglected, then the social relevance of interventions will be undermined to the point that they are unworkable. If environmental services and the integrity of the natural resource base are neglected, then whatever livelihoods forests provide are likely to be at best short-lived.

Increasing and protecting carbon stocks in new and existing forests, which has up to now been the principal focus of international dialogue on forests and climate change, will without question remain an important part of the future climate change agenda. It cannot however be the exclusive focus of initiatives that use forests to mitigate climate change. This approach is too narrow.

It not only tends to lead to the relative (and sometimes complete) neglect of social and economic functions, but it misses in its entirety the massive advantages of managing forests expressly for the purpose of displacing fossil fuels with alternative, low energy-intensive wood fuels and wood products.

Bringing the substitution effects of forest products unequivocally into the carbon equation is the next major increment towards making green economies a reality.

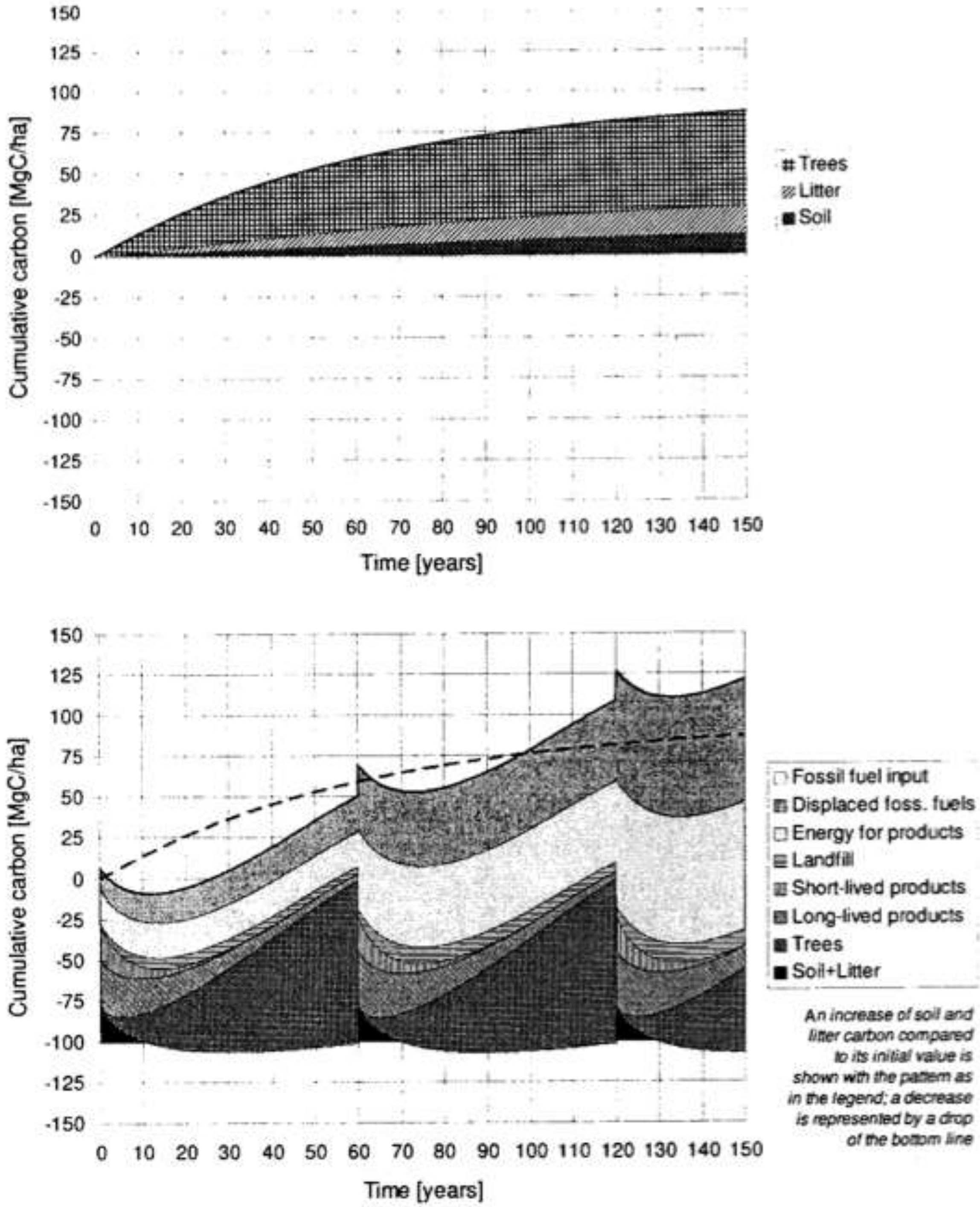
Annexes

Annex 1. Comparison of Conventional and Reduced Impact Logging Schemes Applied in the Congo Basin.

	Conventional Logging				Reduced Impact Logging									
	a		b		a		b		c		d		e	
	Low	Per year	High	Per year	Harvest	Per year	Harvest	Per year	Harvest	Per year	Harvest	Per year	Harvest	Per year
Harvesting (m^3)	10	0.33	20	0.67	10	0.33	20	0.67	10	0.67	15	1	20	
Roads (% of stock)	1.5	0.05	1.5	0.05	1.3	0.04	1.3	0.04	0	0	0	0	0	
Damages (%) (3)	7	0.23	14	0.47	4.2	0.14	8.4	0.28	4.2	0.28	6.3	0.42	8.4	
Total Damages (%)	8.5	0.28	15.5	0.52	5.5	0.18	9.7	0.32	4.2	0.28	6.3	0.42	8.4	
Heads (in m^3) (4)	7	0.23	14	0.47	7	0.23	14	0.47	7	0.47	10.5	0.70	14	
Fuelwood (in m^3) (5)	74	2.47	136	4.55	50.5	1.68	90.6	3.02	40.2	2.68	60.3	4.02	80	
Total Felling (in m^3)	84.2	2.8	156.5	5.2	60.5	2.0	110.6	3.7	50.2	3.3	75.3	5.0	100.4	
Fuelwood / Timber	7.4	7.4	6.8	6.8	5.0	5.0	4.5	4.5	4.0	4.0	4.0	4.0	4.0	
	30 Year Rotation								15 Year Rotation					

Source: Calculations by M. de Galbert in cooperation with B. Cassagne from Forest Resources Management.

Annex 2. Comparing the mitigation effect of total conservation and managing a forest



Source: Marland and Schlamadinger, 1997.

While carbon storage in the forest does more to mitigate climate change in the short term, after a certain period of time the total mitigation effects of sustainable forest management options come to make the most substantial and enduring contributions to mitigation.

Annex 3

FOREST MITIGATION POTENTIAL IN THE TROPICS										
LAND-USE	**YEAR**	**SURFACE AREA USE**	**HARVEST YIELD**	**CONSUMPTION & POTENTIAL**			**FOSSIL CARBON SUBSTITUTION**	**DEFORESTATION &DEGRADATION**	**STORAGE IN FOREST**	**TOTAL OFFSET & AVOIDED EMISSIONS**
				Rnd Wood	**Fuel wood**	**Biomass**				
		Mha	M3 /ha	Mm3	Mm3	Mm3	MtC	MtC	MtC	MtC
Primary forests	2010	890						-	1,020	1,020
	2050	813						-	913	913
Natural logged	2010	403	0	140	-		48	(174)	860	734
	2050	403	3	300		900	327		563	890
Degraded forest	2010	404	4	154	1,310		117	(2,646)	860	(1,669)
	2050	254	3	70	770		73	-	714	787
Planted forests	2010	151	1	158			54		374	428
	2050	500	20	250	770	8,980	2,379		1,300	3,679
Agro-forestry	2010	600	2		1,000		49			49
	2050	750	8		770	5,230	1,357		938	2,294
										All totals
TOTAL	2010	1,848		452	2,310		267	(2,820)	3,114	561
	2050	2,720		620	2,310	15,110	4,136	-	4,428	8,564
PROGRESS		872		168	-	15,110	3,869	2,820	1,313	8,002
PERCENTAGE of PROGRESS							48.4	35.2	16.4	

Almost half of the mitigation progress can be achieved by plantation and agro-forestry, 35 percent by preventing deforestation alone, and only 16 percent by storage, which is a temporary effect.

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