Reducing Emissions from Deforestation and Forest Degradation +

Policy Analysis of REDD+ Via the Copenhagen Accord

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EXECUTIVE SUMMARY

The Copenhagen Accord is arguably the sole achievement of the United Nations Climate Change Conference in Copenhagen (COP 15) in 2009. Signed by 112 nations, it also provides testament to the endurance and importance of forest-based solutions to climate change. Though voluntary and legally non-binding, the Accord acknowledges the critical role that Reducing Emissions from Deforestation and Forest Degradation Plus (REDD+) initiatives must play in reducing greenhouse gas emissions to maintain global temperature increases below 2° C.

Since the onset of the industrial revolution, the concentration of greenhouse gases in the atmosphere, particularly CO_2, has increased exponentially due to anthropogenic activities such as fossil fuel burning and land use changes. This accumulation adversely impacts climate by increasing global temperatures. Deforestation and forest degradation contribute approximately 17% of total global greenhouse gas emissions (GHGs), making them the 3rd largest anthropogenic source.

REDD+ aims to reduce these emissions by maintaining standing forests, enhancing forest stocks and improving forest management. Forests sequester CO_2 via photosynthesis, converting it to energy and carbon biomass. This action not only removes CO_2 from the atmosphere, but also provides for its long-term storage. Though all forests are important, REDD+ is specifically targeted toward tropical forests. Nearly 77% of global deforestation occurs in tropical regions accounting for 95% of all forest-related greenhouse gas emissions.

The basic framework of REDD+ is simple. Developed countries will provide financial incentives to developing countries to maintain their forests. Initially, public and private financing will assist developing counties in creating capacity to achieve REDD+ goals. In the long term, developing countries will sell carbon credits (equal to the carbon sequestered by their preserved forests) to developed countries requiring carbon offsets.

Implementing REDD+ is far more complex than this simple framework suggests, however. Currently, public and private financing falls short of the resources needed to build the required capacity. In addition, though existing technology is capable of generating data of sufficient quality to produce credible measurements, the absence of international consensus regarding the definition of a forest and the selection of a standard methodology for creating globally consistent and comparable forest carbon inventories will prevent any meaningful future participation in international carbon markets.

Despite these obstacles, many pilot projects incorporating REDD+ components are currently underway, which should provide data useful in resolving these issues. Thus, as the international community looks toward the sixteenth Conference of the Parties (COP 16) in Mexico this November, it is imperative that both developed and developing nations prioritize REDD+ as a key climate mitigation strategy and strive toward finalization of a binding framework.

SUMMARY OF THE INTERNATIONAL AGREEMENT : THE COPENHAGEN ACCORD

The Copenhagen Accord is arguably the sole achievement to come out of the United Nations Climate Change Conference 2009 in Copenhagen (COP 15). Signed by 112 nations, it also provides testament to the endurance and importance of forest-based solutions to climate change. Though voluntary and legally non-binding, the Accord acknowledges the critical role that Reducing Emissions from Deforestation and Forest Degradation Plus (REDD+) initiatives must play in reducing carbon dioxide (CO_2) emissions to maintain global temperature increases below 2° Celsius.

Background and Evolution of REDD+
In 1992, the United Nations Conference on Environment and Development, informally known as the Earth Summit, established the United Nations Framework Convention on Climate Change (UNFCCC), with aims to stabilize greenhouse gas emissions at levels that will mitigate further anthropogenic interference with the world's climate system. Its main decision-making body, the Conference of Parties (COP), annually reviews the work of the UNFCCC. At its third meeting in 1997 in Kyoto, the COP adopted the Kyoto Protocol, a legally binding international treaty aimed at reducing the signatories' greenhouse gas emissions by 5.2% below 1990 levels by the year 2012. The seeds of reducing emissions from deforestation and forest degradation were planted in the Kyoto Protocol as well, but were not included due to the potential for carbon market leakage, in which halting deforestation in one area leads to devastation of forests elsewhere (Leakage 2008).

Over many sessions of the COP, REDD+ has evolved from two previous forms: Reducing Emissions from Deforestation (RED) and Reducing Emissions from Deforestation and Forest Degradation (REDD). At the 2005 COP 11 in Montreal, RED was put back on the agenda by the Coalition for Rainforest Nations[1]. In 2007, at COP 13 in Bali, the Bali Action Plan was adopted to focus discussions on reaching a new binding agreement by 2010, before the Kyoto Protocol expires in 2012. In terms of RED, the extra "D" for forest degradation was added to address problems of overgrazing and the degrading effects of deforestation on remaining forest systems. The Bali Action Plan marked an important crossroads for REDD, as it called for "the needs of local and indigenous communities" to be addressed, as well as "the role of conservation, sustainable management of forests and enhancement of forest carbon stocks," (IUCN 2009) two phrases that transformed REDD into REDD+.

In December 2009, the Conference of Parties held its 15th session in Copenhagen. Although the Parties did not reach a legally binding agreement regarding the Bali Action Plan, COP 15 took note of the Copenhagen Accord, a non-binding, voluntary agreement, in its report, of which REDD+ is a key element. Despite all of the disagreements regarding different agendas

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[1] Participating countries include: Bangladesh, Central African Republic, Cameroon, Chile, Congo, Colombia, Costa Rica, DR Congo, Dominican Republic, Ecuador, El Salvador, Fiji, Gabon, Ghana, Guatemala, Honduras, Indonesia, Kenya, Lesotho, Malaysia, Nicaragua, Nigeria, Panama, Papua New Guinea, Paraguay, Peru, Samoa, Solomon Islands, Thailand, Uruguay, Uganda, and Vanuatu

amidst REDD+, urgency and political will finally saw it signed in Copenhagen; it is important to note that mechanisms of REDD+ are still being discussed. In addition, although the Accord is considered an external document, it commits signatories to ongoing discussions regarding the definition of joint actions to address climate change. On this basis, the Copenhagen Accord may outline the core of a future legislation to be adopted at COP 16 in November 2010.

COP 15, the Copenhagen Accord and REDD+

Certain decisions of the COP 15 Report (1, 4, 10, 13) deal specifically with REDD+ and establish a contextual framework for past and future discussions. Principally, the COP 15 report states that developing countries should receive methodological and technical guidance related to REDD+ activities. Additionally, certain clauses of the Copenhagen Accord (2, 6, 7, 8, 10) identify REDD+ as a critical component of a broad strategy to address the problem of climate change. Key features of the Copenhagen Accord as relevant to REDD+ recognizes that:

Clause 2

Low-emission development strategies should be part of sustainable development.

Clause 6

Reducing emissions from deforestation and forest degradation, as well as the need to increase the amounts of sequestered carbon dioxide by forests, is extremely important to climate change mitigation.

Positive incentives are needed to achieve these goals. A mechanism will be established that includes REDD+ to enable the mobilization of financial resources from developed countries.

Clause 7

Various approaches will be pursued to promote mitigation actions, including the use of markets to increase cost-effectiveness.

Developing countries should receive incentives to pursue low-emission development.[2]

Clause 8

Developed countries collectively committed to provide new and additional resources approaching USD 30 billion between 2010-2012, split between adaptation and mitigation actions. Developed countries further commit to jointly raise USD 100 billion a year by 2020 to address the needs of developing countries with funding coming from a variety of sources. A significant portion of this funding should go through the Copenhagen Green Climate Fund *(see Clause 10)*.

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[2] However, no incentive mechanism for mitigation efforts was clearly defined.

Clause 10

The Copenhagen Green Climate Fund shall be established as an operating entity of the financial mechanism to support mitigation activities in developing countries including REDD+, adaptation, capacity building, and technology development and transfer.

These clauses present REDD+ as a critical component of climate change mitigation efforts. To truly understand its potential, however, it is necessary to first examine the problem of climate change and the role of the forestry sector in exacerbating this critical issue.

THE ENVIRONMENTAL PROBLEM

Climate Change

Climate change is defined as the rise in average temperature of the Earth's atmosphere and oceans since the mid-20th century (Solomon et al 2007). In the natural radiative transfer balance, the sun emits heat in the form of shortwave radiation, a portion of which that is reflected and re-emitted in the form of longwave radiation. The greenhouse effect is a natural process by which certain gases in the atmosphere, such as carbon dioxide (CO_2), absorb and reflect longwave radiation, keeping much of that heat in the Earth's atmosphere and warming the planet. Anthropogenic activities have compounded the greenhouse effect by increasing the concentration of greenhouse gases (GHG) in the atmosphere, of which carbon dioxide is the most significant, (NASA 2010) consequently enhancing the greenhouse effect and causing additional warming of the planet. According to the 2007 Intergovernmental Panel on Climate Change (IPCC) report, 490-540 parts per million (ppm) of CO_2 is the maximum concentration allowable in order to prevent a global atmospheric temperature increase greater than 2o Celsius (Pachauri and Reisinger 66) and maintain environmental equilibrium. To put this in perspective, 2o Celsius is the difference between the temperatures of New York State today versus the temperatures able to sustain glaciers over most of the same land during the last ice age.

Deforestation and Forest Degradation

Deforestation is defined as the direct human-induced conversion of forested land to other land uses such as agriculture or mining. Increasingly, deforestation is employed to satisfy the global demand for products like beef, soy, timber, and palm oil. Forest degradation is a gradual (although still generally quite rapid) loss of forest quality due to human activity, including practices such as selective logging and understory fires, as well as the negative impacts deforested areas often have on the remaining nearby forests (such as soil erosion downstream). Forested land transitions often begin with degradation (Degradation 2009), which systematically lowers the forest's capacity to provide products, ecosystem services, and healthy habitats for biodiversity. In the context of REDD+, deforestation refers to a reduction in carbon density (Angelsen et al 2010).
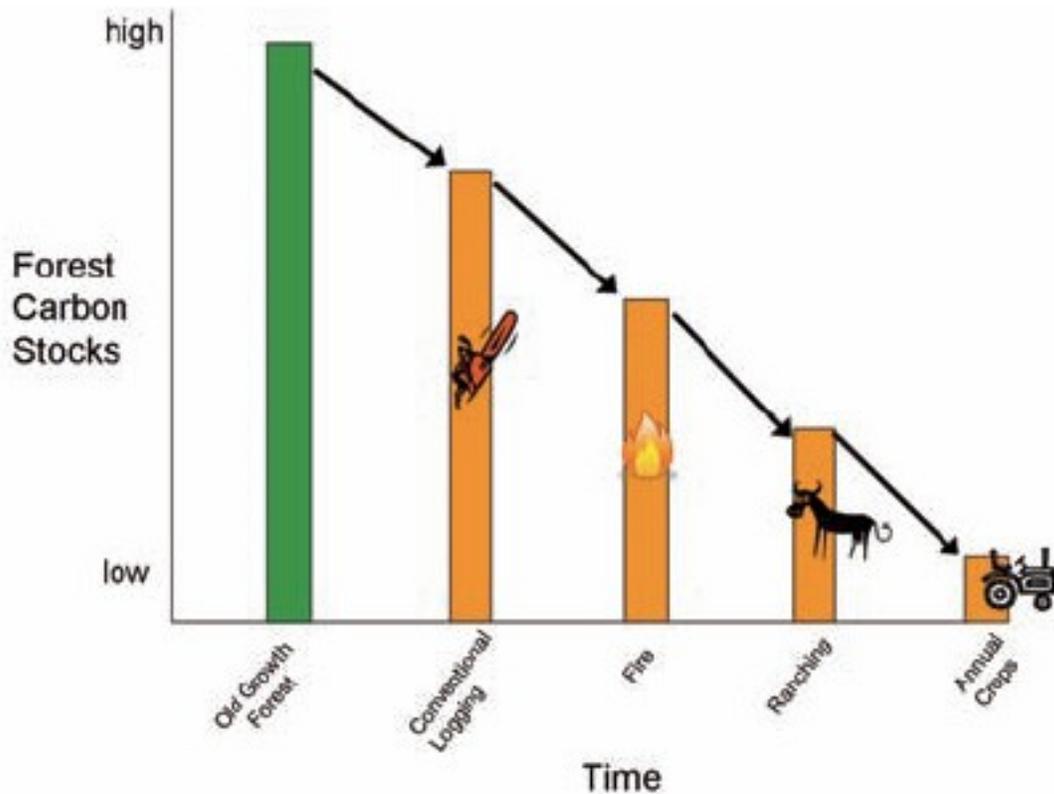
Figure 1: Relative impact of forest degradation, via various land uses, on forest carbon stocks (Degradation 2010)

Forests, if destroyed or degraded, release CO_2 to the atmosphere, significantly contributing to climate change. Accounting for more than 17% of global GHG emissions (Pachauri and Reisinger 36), these activities are the third-largest anthropogenic contributors to GHG emissions (Pachauri and Reisinger Figure 2.1) and second largest for CO_2. More than 95% of the global emissions from the forest sector are estimated to come from deforestation activities in tropical developing countries (Eliasch 1), where the majority of deforestation currently occurs. Deforestation and forest degradation activities produce an estimated 5.8 Gigatonnes (Gt) of CO_2 annually and will increase atmospheric CO_2 concentrations by an estimated 30 parts per million (ppm) by 2100 on its current course, or what is known as a 'business as usual' (BAU) scenario (Eliasch 1). It is worth reiterating here that current atmospheric CO_2 levels are at 390 ppm, and thus a 30 ppm increase from the forestry sector alone will bring us dangerously close to the lower boundary of the limits set by the IPCC necessary to avoid catastrophic climate change.
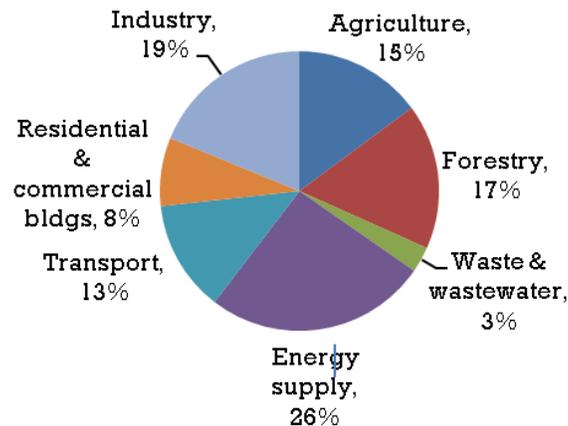
Global GHG Emission by Sector (2004)

Figure 2: Global Greenhouse Gas (GHG) Emission by Sector in 2004. Forestry ranks third in total emissions, releasing more GHG into the atmosphere than the entire global transport sector (Pachauri and Reisinger 36).

Forests and Carbon Sequestration

Carbon sequestration is the process by which natural systems store carbon in different chemical forms. Plants, through the process of photosynthesis, incorporate CO_2 into their biomass by converting it into sugars, which they use for energy to carry out all of their metabolic processes (IPCC 16). They do this by fixing carbon molecules (binding carbon molecules to another chemical) in the branches, trunks, leaves and roots, and by storing it in the soil as organic carbon. Although part of the carbon in the soil and trees is released back into the atmosphere through different mechanisms such as respiration, a significant part remains in the biomass of the tree and soil (Feller et al 1).

Forests in particular absorb more CO_2 than they release, storing, on average, more carbon per hectare than any other type of land cover due to the fact that lignified tissues (i.e. wood) decompose more slowly than softer tissues. Forests therefore serve as natural carbon sinks (also known as reservoirs); 77% of the carbon in forests is stored in aboveground biomass and 39% of carbon is stored in soils (Eliasch 16-18). The current uptake of carbon on land worldwide is close to 9.5 Gt of CO_2 (Eliasch 17), and it is estimated that the current level of atmospheric CO_2 would be 10% higher without any forest sinks. The amount of CO_2 stored by trees depends on the geographic location (Eliasch 17), the genetics of the trees, and the fertility of the soils (Oren et al 2001). Furthermore, tropical forests sequester the amount of CO_2 stored by temperate and boreal forests combined (Eliasch 17), mainly a result of their longer growing seasons. As nearly 77% of current global deforestation occurs in tropical regions (FAO State of World Figure 1), reducing tropical deforestation is especially vital to combating climate change.

It is still important to reiterate, however, that boreal and temperate forests absorb more carbon than non-forest lands.
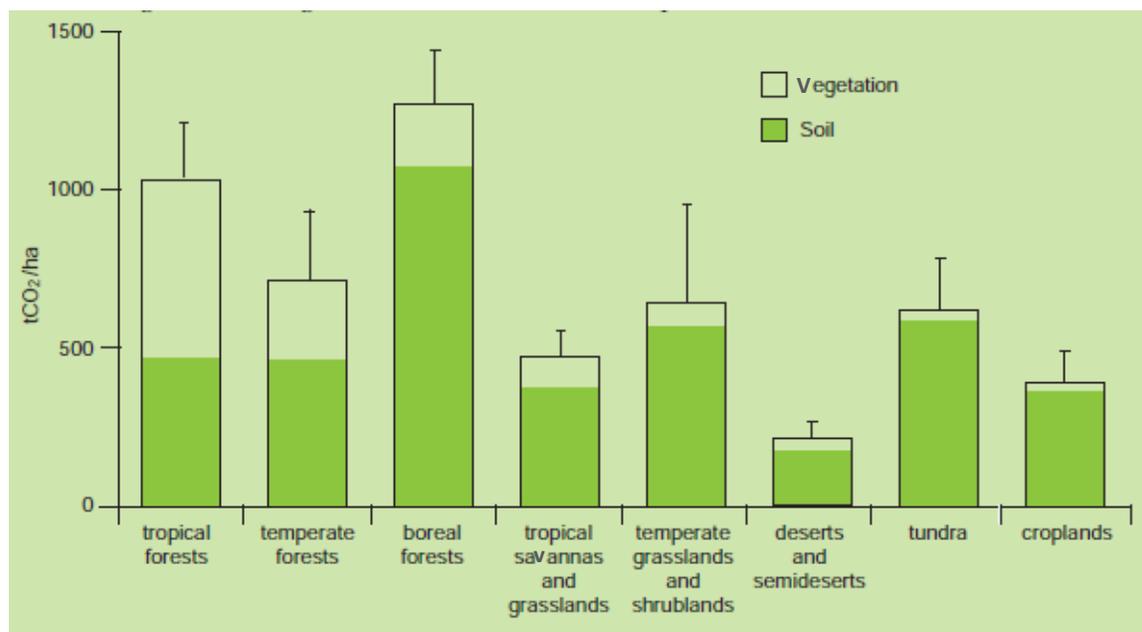

Figure 3: Average carbon stocks for different types of land cover. Please pay particular attention to amount of carbon stored in the vegetation, shown here in the unshaded portion of the bar graphs, in the tropical forests bar on the far left in comparison to temperate and boreal forests bars to its right (Eliasch 17).

Deforestation and forest degradation have a dual impact over the Earth's climate-related carbon cycle by not only destroying the natural carbon sinks, which prevents further CO_2 storage in the future, but by also releasing CO_2 and other GHG such as methane and nitrous oxide directly into the atmosphere. Net deforestation is estimated to have contributed between 22% and 43% of the total CO_2 rise from 1750 to 2005 (Forster et al 2). Forest biomass is particularly important to measure as it provides an indication of the amount of CO_2 that will be released if the forest is destroyed; it is estimated that half the dry weight of forest biomass is carbon (FAO Global Forest 31). Discerning the amount of carbon stored in forest and soil biomass is therefore critical to modeling potential CO_2 emissions from deforestation and forest degradation.

Biological and Human Ecosystems
As well as being an important carbon reservoir, forests play an important role in ecosystem functioning by regulating regional rainfall, enabling biodiversity, maintaining soil consistency, and reducing runoff, erosion, siltation, and flooding (Boyd et al 2). The loss and

degradation of these services and habitats threatens the livelihoods of the 1.6 billion people, almost a quarter of the world's population, who depend on the forest for their welfare in some way (Eliasch 15). Forests also contribute to the cultural, social, and religious identities of an even greater amount of people. As such, in addition to decreasing anthropogenic contributions to climate change, reducing deforestation and degradation has the potential to alleviate poverty and conserve important ecological services and biodiversity.

REDD+ AS PART OF THE SOLUTION

Reducing Emissions from Deforestation and forest Degradation (REDD+) will bring together a diverse set of stakeholders, including the governments of developed countries, industries, and non-governmental organizations (NGOs), who will provide financing, technology, and capacity-building to local forest communities and developing countries as incentives to maintain their forests. The causes of deforestation vary by region, and tropical countries are often faced with limited financial and institutional capacity and lack effective mechanisms that enable public participation in addressing the problem. Deforestation involves social, environmental, and governance issues that require collective action from different stakeholders and support from other nations. The aim of REDD+ is to develop a monetary value for standing forests that exceeds the opportunity cost of alternative land uses. This strategy has the potential to simultaneously alleviate issues of poverty and environmental degradation in the forested countries of the world.

The Carbon Market
Forests may be able to attain monetary value through their incorporation into regional and subsequently global carbon markets. Because greenhouse gases homogeneously mix once they are released into the atmosphere, reduction measures implemented in any part of the world will help mitigate global climate change. This principle underlies the existence of a global carbon market, where units of carbon that are measured in metric tons of CO_2or a CO_2 equivalent (a proxy which takes into account concentrations of other greenhouse gases) are traded. Carbon units are exchanged between market participants. Generally, two categories of carbon trading exist (Binello and Pearson 2007). The first is characterized by allowance-based transactions, where carbon credits are units that give the owner the "right to pollute" a certain amount. Under this system, credits are allotted to all emitters, allowing for some amount of CO_2emissions into the atmosphere each year. Businesses capable of emissions reductions are encouraged to sell their carbon credits for a profit to businesses that cannot reduce. Assuming that an emissions cap is set within the market as part of a global or regional cap and trade system, carbon credits will be highly valued by large emitters (potentially countries, industries, or individual companies)seeking to meet their emissions targets. Increasing demand for carbon credits will drive up credit prices; increasing credit prices will provide substantial incentives for abatement and should also fuel the innovation of new, cheaper emissions reduction technologies. Central to all proposed cap and trade systems for CO_2 is that as the cap is

progressively lowered and the value of carbon offsets increases, the financial burden of emitting CO_2 will also increase; firms that cannot adapt clean technologies in the long run will be driven out of the marketplace by the rising cost of carbon credits.

The second variety of carbon-trading category is a project-based transaction scheme, where carbon credits are generated by projects that offset emissions. Under this system, CO_2 emissions are "neutralized" in the sense that an emitter pays another party to avoid the release of CO_2 elsewhere in the world in exchange for the "credit," which allows them to emit the equivalent quantity of CO_2 saved, while still meeting their reductions goals. A current example of such a system would be the Clean Development Mechanism defined under the Kyoto Protocol; emissions reduction projects in the developing world offset industrial emissions in the developed world. The viability of the REDD+ framework is heavily dependent on its integration into whichever form of carbon market emerges in the future. Under most visions of REDD+ however, industries, primarily from developed countries, pay developing countries to keep the carbon sequestered in their forests intact.

Technological Instruments/Measurements for REDD+
The success of REDD+ depends on the monetary value of a standing forest exceeding that of a harvested forest. High quality measurements of forest carbon stocks that are consistent and comparable across nations are thus crucial to developing robust carbon markets that will drive REDD+ initiatives forward. The scientific methodology behind current forest carbon accounting is imprecise, but credible reference levels of emissions and removals can still be made using existing methods and technology (GOFC-GOLD 1.14). Moving forward, the certainty of these measurements will increase as expertise is gained (Parker et al 19).

Remote Sensing Imagery Techniques
Changes in forest coverage are typically assessed using remote sensing optical imagery techniques. One benefit of using satellite imagery is that access to many data sets is free and publically available, reducing an important economic barrier to developing countries. For example, all Landsat satellite data is archived at the United States Geological Service for free. A drawback of these techniques is that they only allow information related to land coverage to be obtained. Therefore, local field studies are still needed to derive land use estimates. Newer types of sensors, such as Radar and LiDar satellite sensors, hold particular promise for use in tropical regions because they reduce the limitations of optical data in regions with persistent cloud cover. Global Information System (GIS) techniques may also provide a valuable tool for compiling and managing forest data. Table 1 summarizes the technological instrumentation currently available to support the implementation of REDD+.

Technology	Actual/potential use
Remote sensing satellites: Landsat-5/TM, Landsat-7/ETM+, CBERS-2/HRCCD (GOFC 2.21)	Determination of baseline and future deforestation rates
Synthetic Aperture Radar (SAR)	Generation of images of earth-surface features Penetrate through haze, smoke and clouds thus, can be operated day or night (Gibbs 2007)
Light Detection and Ranging (LiDar) satellite sensors	Estimation of mean tree height, canopy cover or canopy density
Global Information System (GIS)	Capture, storage, analysis and presentation of data linked to a location Assessment of forest landscape changes over time, species distribution through various climatic and land-use scenarios, vegetation structure, forest functions and value (Snow and Snow 2008)

Table 1: Potential and widely used technologies that could be used to measure forest extent and carbon stocks , and thus implement REDD+.

Forest carbon accounting requires the collection and analysis of activity data and emissions factors data. Activity data relate to the aerial extent of forest lost or gained and are measured in hectares. Emissions factors involve the emission (e.g. deforestation and degradation) or removal (e.g. reforestation and afforestation) of greenhouse gases per unit area and are measured in tons of carbon per hectare (tC/ha).

Estimating Forest Carbon Stocks

Emissions factors are determined by estimating the amount of carbon contained in various forest-related carbon pools. This, in turn, provides estimates of the greenhouse gas emissions that might result from changes in forest coverage. The aboveground component of tree biomass is the major contributor to carbon stock changes related to deforestation, degradation, reforestation and afforestation activities. Forest stand tables, traditionally created to estimate the commercial value of forests, can be used to assess the aboveground carbon content of trees. These tables tally all trees in a series of diameter classes and estimate the biomass per average tree of each diameter (GOFC-GOLD 2.56). Weighing dry biomass also provides an estimate of carbon content (typically, half the weight of biomass) (Gibbs et al 3).

Tropical pine, broadleaf, woodland and mangrove forests vary considerably in their carbon stocks due to varying decomposition rates and periods of photosynthesis; even within a given forest, carbon stocks will vary with elevation, rainfall and soil type (GOFC-GOLD 2.44). Unfortunately, readily available and inexpensive remote sensors are incapable of distinguishing between different forest types and between disturbed and undisturbed forest. As a result, stratification is a useful and often necessary tool to estimate the type of vegetation affected by deforestation or degradation. Stratification involves the division of a landscape into strata based on the stock of carbon in the vegetation. Countries can be stratified by ecological zone using

global datasets (e.g. Holdridge life zones, WWF eco-regions, and FAO ecological zones) as well as other biophysical or anthropogenic criteria (GOFC-GOLD 2.50).

The carbon content of belowground biomass (roots) and additional carbon pools (dead wood, soil, non-tree vegetation) is measured in a number of ways. Roots are measured by using a root-to-shoot ratio, which is estimated to be 20% of the aboveground forest carbon stocks. The carbon stock of dead wood is estimated in a similar manner, and is equivalent to 10-20% of the aboveground carbon stock (Gibbs et al 3). Soil carbon content is determined by analyzing samples for bulk density and percent soil carbon. Non-tree vegetation can be collected and dried to determine biomass and carbon stock. Measuring emissions from biomass burning due to forest fires involves the use of satellite-based fire monitoring techniques that are able to detect active fires, map post-fire burned areas, and characterize the amount of energy of a fire in order to determine the biomass affected and resulting emissions.

Stratification Maps

Aerial maps of activity data created from remote sensing imagery can be superimposed onto stratification maps to identify the type of vegetation (and hence estimate the value of the carbon stock) affected by the net gain or loss. Ground sampling is often necessary to ensure an accurate determination of carbon estimates. Using these methods, a countrywide map of forest carbon stocks can be created and updated during monitoring events.

Once carbon data has been collected for a country, national look up tables can be compiled for use with stratification maps. In this way, national forest carbon inventories can be created, which will facilitate forest monitoring and valuation. Ultimately, the use of science to measure and assign monetary values to forests is crucial to the success of REDD+ initiatives. By taking advantage of existing methodologies and technologies, REDD+ programs can significantly mitigate climate change by providing incentives against deforestation and forest degradation and incentives for increasing reforestation, afforestation, and forest management.

Figure 4: Eastern Brazilian Amazon Rainforest: a satellite map is used to identify forest land use (GOFC-GOLD 2.29).

Funding Sources for REDD+

In the discourse on REDD+, there are two sources of funding commonly discussed: public (i.e. governments, NGOs, etc.), which is too limited in scale to fund REDD+ indefinitely, and market (i.e. global carbon markets, private investors, corporations looking to offset their emissions), which is relatively abundant but not yet accessible to the forest nations of the developing world. According to the Eliasch Review[3], an effective REDD+ strategy must involve both public and private sources of funding. Public sources will allow forest nations to establish "readiness" in anticipation of participation in global carbon markets. As emissions reduction credits from REDD+ projects attract more private investment, the relative importance of public funds will decrease. The long-term goal is that REDD+ will be completely integrated into global carbon markets and will attract mainstream investors.

Timeframe	Strategy	Role of Public Investment	Role of Private Investment
Short Term	Capacity-building and closing the funding gap	Critical	Minimal
Medium Term	Increasing levels of access to carbon markets for forest nations	Important, diminishing over time	Increasing importance
Long Term	Full inclusion into global carbon market	None	Complete

Table 2: **The Role of Private and Public Funding During a REDD+ Implementation Timeline (Eliasch 126)**

While the net benefits of halving global emissions related to deforestation and forest degradation are estimated at $3.7 trillion, the funding necessary to accomplish that goal through 2030 is estimated to be between $17 and $33 billion a year, assuming that emissions reductions from REDD+ are tradable in carbon markets. The question of meeting the gap between the funding necessary to halve forestry emissions and the funding available through global carbon markets is critical to the successful launch of REDD+. An absence of private investment early on in the existence of REDD+ means that public funding will be the only significant funding source available for REDD+ and will need to sustain REDD+ until forests are completely integrated into the carbon markets. If carbon markets are expected to counter the operating costs of REDD+, the value of global carbon markets must increase dramatically, and soon. Currently, there is no truly global carbon market, nor is there a truly global cap-and-trade scheme to stimulate global demand for carbon credits in such a market. Without sufficient demand for carbon credits and sufficiently high carbon prices, REDD+ will continue to require public funding indefinitely rendering it unsustainable.

[3] The Eliasch Review, funded by the UK government, is an independent analysis of the role of international finance mechanisms to preserve global forests in tackling climate change.
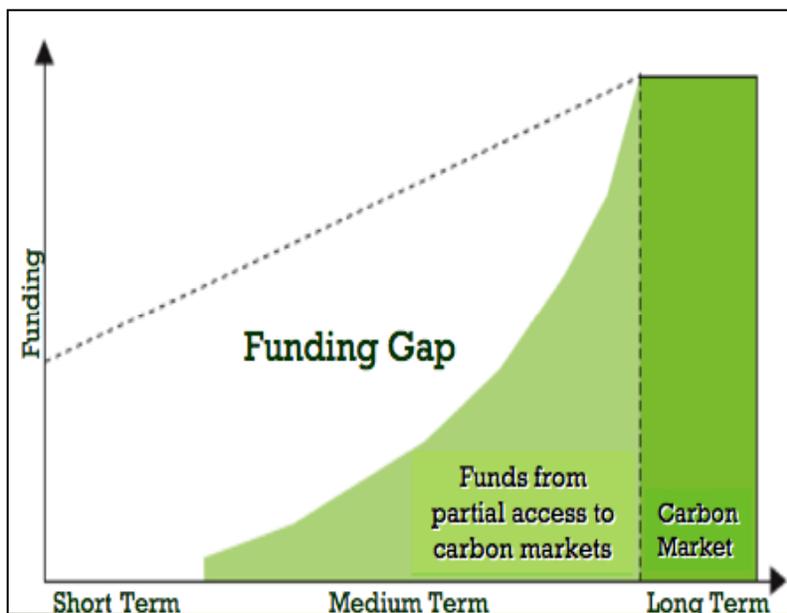
Figure 5: A potential transitional strategy towards global carbon market funding of REDD+ (Eliasch 126): In the short term, billions of dollars a year will need to come from public funding from developed countries. In the long term, funding will ideally be supplied by full access to the carbon market. However, in the medium term, a funding gap exists where REDD+ will heavily rely on public funding as it transitions into the carbon markets. The dotted line represents the amount of funds needed to halve deforestation.

MEASURING THE SUCCESS OF REDD+

Though REDD+ does not have a formal framework, many governments, international, and non-governmental organizations are creating tools to: 1) define the physical project boundary, 2) establish a baseline, also known as a reference level, for the project boundary, 3) create a unified carbon accounting system, 4) plan monitoring and verification processes and 5) measure the environmental and socioeconomic benefits of the REDD+ project.

Project Boundaries and Baselines
Defining accurate physical project boundaries requires a combination of as many of the following as possible: measurement techniques using technologies such as radar and satellite as discussed above, on the ground measurements, historical data, land deeds, and/or political boundaries. Ideally, these measurements will inform project managers whether REDD+ projects are reducing or increasing CO_2 emissions, and in what quantities, by comparing the measured emissions to a baseline. Baselines define an expected, or "business-as-usual," carbon emission level resulting from deforestation and forest degradation within the project boundary. It predicts the emissions that would occur in the absence of the project. A REDD+ project that produces emissions below the baseline represents a reduction in emissions within the project boundaries. At Copenhagen, UNFCCC Decision 4/CP.15 established a guideline for baselines, where it "recognizes that developing country Parties in establishing forest baseline emission levels and forest baselines should do so transparently *taking into account historic data*, and *adjust for national circumstances*, in accordance with relevant decisions of the Conference of the Parties." Though there are several ways to determine a baseline, all methods fall under these two basic categories; choosing the appropriate method is crucial for accurate carbon accounting.

There are various types of data available to build a region's future scenario when determining which baseline to use, and how to develop that baseline, including historic carbon emissions from deforestation and forest degradation activities, population trends, deforestation trends of nearby areas, present-day land-use contracts, timber projections, etc. If a region is experiencing steady deforestation rates, historical emissions are probably a good reflection of future emissions. If a country's rate of deforestation and forest degradation is decreasing due to drivers such as a bad timber market, then the baseline may need to be adjusted down over time to show that future business-as-usual emissions will most likely decrease over time. Similarly, if a country's rate of deforestation and forest degradation is increasing, the baseline may need to be adjusted up over time to account for this

Historic vs. Adjusted Baselines

Take two hypothetical project areas, A and B, each with 100 identical old-growth forest trees, that both use a historic baseline. In Area A, there has historically been a steady deforestation rate of ten trees a year, so the baseline predicts that next year ten trees will be cut down. Project Area B has the same historical deforestation trends of cutting 10 trees a year but a sudden increase in population due to an influx of refugees may imply that there will be increasing rates of deforestation. In this case, an adjusted baseline would be used to incorporate this population data, predicting a new adjusted deforestation rate of 50 trees a year. In both project areas, 99 old growth trees were conserved (perhaps one was illegally cut down). The carbon emissions from that one illegally cut tree would be subtracted from the baseline. In project Area A, where 10-1=9, 9 trees were prevented from being cut—which means that those trees' equivalent amount of stored CO_2 was prevented from being emitted into the atmosphere. In Project Area B, where 50-1=49, it is necessary to prevent 49 trees from being cut in order to have the same effect as Project Area A.
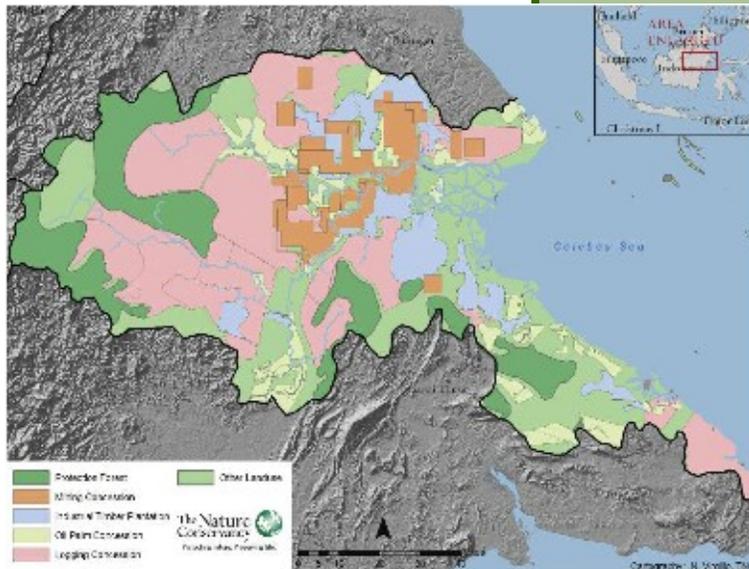

Figure 6: A map of land use in Berau including timber, mining, palm oil and logging concessions as well as protected forests. This information is used to establish a baseline (Fishbein 2010).

Protection Forest
Mining Concession
Other Land use
Industrial Timber Plantation
Logging Concession
Oil Palm Concession

increase. In any case, the baseline needs to reflect the future projected business-as-usual carbon emissions. Once a REDD+ project has been established and a baseline has been implemented, emissions from that REDD+ project can be measured. Of course, as project areas receive more accurate data, baselines should be adjusted overtime.

Carbon Accounting Systems

REDD+ projects aim to reduce carbon emissions by a measurable quantity. One ton of CO_2-equivalent emission reductions yields one carbon credit that, once verified, can be sold on the carbon market. An impediment to this process is the variable price of carbon that currently exists on the market. Today a carbon credit is worth a little more than €14 through the European Climate Exchange, but only about US$0.10 on the Chicago Climate Exchange. The monetary value of a REDD+ project is theoretically the number of verified carbon credits it produces multiplied by the price of a carbon credit on the market at a given point in time. The potential number of carbon credits for any given REDD+ project can attract or deter a country or region from implementing it. If the baseline of forest emissions is underestimated, and the number of carbon credits created from a project are too few, the REDD+ project will provide insufficient financial incentives to compete with the opportunity cost of alternative land uses (i.e. timber, mining or agricultural land-use projects) (Virgilio et al 2010). Additionally, accurate accounting of the carbon value of credits is critical to the prevention of market failure associated with the inflation or deflation of credit prices. One cannot pay for something that does not exist. Therefore, REDD+ carbon accounting systems need to be uniform at local, national and international levels.

Monitoring and Verification Systems

To ensure accurate carbon accounting, effective and efficient monitoring and verification systems must be implemented[4]. Although several frameworks for monitoring and verification exist, this paper will highlight the UNFCCC Good Practice Guidelines and the Voluntary Carbon Standard.

- **UNFCC Good Practice Guidelines**

   Every country that has signed the UNFCCC is committed to "develop, periodically update, publish and make available to the Conference of the Parties (COP)...national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol" (UNFCC 1992). The COP has decided that parties should follow the Good Practice Guidance for Land Use, Land -Use Change and Forestry (IPCC 2004), with the IPCC 2006 Inventory Guidelines to report emissions as a result of forest activities. Annex 1 countries are required to report annually in order to compare carbon stocks over time. Although developing countries are not technically required to report, they are encouraged to do so periodically (Krister 2009). Comparing changes from established baselines is more practical than repeating complete inventories for each country on a regular basis. However, periodic reporting in developing countries creates limited data and makes it difficult to analyze the extent of deforestation and its associated carbon emissions. At the Conference of the Parties in Copenhagen, it was decided to improve the methodologies behind measuring

REDD+ projects (Decision 4/CP.15), and that technical assistance should be provided to non-Annex I countries (where deforestation mainly takes place) "for the regular development of national GHG inventories…with a view to improving the accuracy, consistency and transparency of information in their national communications" (Decision 5/CP.15).

- **Voluntary Carbon Standard**
  The Voluntary Carbon Standard (VCS) is a joint project of International Emissions Trading Association (IETA) and the Climate Group to set standards for evaluating carbon emission reductions projects. Verification is undertaken through third party auditors in accordance with the International Organization for Standardization's ISO 14064-3:2006 (Validation and/or Verification of GHG Assertions). Currently, Avoided Deforestation Partners, a coalition of organizations within the forest carbon policy community, is developing a module-based methodology for REDD+ projects that will fit into the VCS. The new methodology divides individual REDD+ projects into a variety of specific carbon reduction modules, which will correspond to dedicated third party auditors (i.e. carbon stocks in leaf litter, carbon stocks in soil, above ground carbon stocks, below ground carbon stocks, etc.). This process of up-front carbon stock evaluation should be more cost effective and internationally comparable in developing assessments of carbon stocks than developing project-specific carbon methodologies (Avoided Deforestation Partners 2009). Once in place, independent auditors will be able to assess the baseline forest carbon levels at REDD+ projects around the world, under the common VCS methodology.

CONTROVERSIES SURROUNDING REDD+

The Copenhagen Accord was able to achieve general agreement on the importance of addressing emissions from deforestation as part a larger climate change mitigation strategy. However, there are many controversies surrounding the REDD+ program. The main issues center around how REDD+ will actually work; i.e. how actions to stop deforestation and forest degradation can be translated into reliable, verifiable carbon emission reductions that then would enable confident, consistent carbon credit trading on a global carbon market, and thus provide monetary incentives for such actions. There are several critical components necessary for REDD+ to function, which are currently under debate. International agreement on a global framework for REDD+ to work under, which is necessary for the long-term sustainability of the program, is still lacking. Additionally, in order to turn emission reductions from forests into a standardized, fungible commodity that can be traded on a carbon market, several preconditions still need to be fulfilled: there is not an agreed-upon definition of forests that is sufficiently detailed; there is no standard way to measure carbon stocks, or whether below ground carbon in soils should also be counted; and there is not enough information to support the long term viability of reforestation and afforestation measures to counter degradation.

Challenges with Finding International Agreement

One of the main reasons contributing to the lack of a formal agreement on how REDD+ should progress is the divergent economic interests and social priorities of the members of the international community. Although there is a general agreement on the crucial role forests play on the planet as carbon sinks and reservoirs, and as a source of biodiversity, etc., there is no single methodology used to measure and value the ecological and climate services the forests provide for us. One of the main reasons that has contributed to the lack of a formal agreement on how REDD+ should progress is the divergent economic interests and priorities of the international community. Although a general agreement exists regarding the crucial role of forests on the planet as a carbon sink and reservoir and a source of biodiversity, etc., methodologies to measure and value the ecological services forests provide have not been developed yet.

Challenges of Defining REDD+

Some challenges with REDD+ as it stands now deal with the various interpretations allowed by vague wording. Mention of incentives that "enhance forest carbon stocks" under REDD+ often implies practices that involve reforestation, the planting of trees in a location that was a forest prior to deforestation, or afforestation, the planting of trees in a location that was not a forest previously. In addition, while REDD specifically deals with "reducing emissions from deforestation and degradation in *developing countries*," REDD+ does not specify whether reforestation or afforestation practices that occur in developed countries are eligible for funding. Similarly, the United Nation's definition of a "forest" fails to distinguish between natural forests and tree plantations, allowing agribusinesses such as palm oil industries to cut natural forests and replace them with monocultures of non-native species. Additionally, nations could take advantage of REDD+ programs by claiming carbon funds for monoculture plantations or partially logged forests, landscapes that have emitted significant greenhouse gases due to forest clearing and suffered a loss in biodiversity (Hance 2010). In terms of creating new protected boundaries for forest conservation under REDD+, many countries do not have clear laws regarding property rights of indigenous people, which often lead to an inhumane expulsion from their long-settled homelands in lieu of an introduced sustainable management program. Environmental and conservation groups are lobbying the UNFCCC to change its definition of forests to address these critical ambiguities.

Palm Tree Plantation

Old Growth Rainforest

Figure 7: Two of the types of land cover that can be considered a forest under the current UNFCCC definition. Photo credits: Kimberly Lai

Controversies with the Science
In order to mitigate climate change, REDD+ provides incentives for avoiding deforestation and forest degradation as well as enhancing carbon stocks. This latter incentive is often interpreted as increasing reforestation and afforestation and the use of effective forest management. It is important to note that these mechanisms differ in their potential to reduce or prevent GHG emissions, and that "in the short term, the carbon mitigation benefits of reducing deforestation are greater than the benefits of afforestation" (Solomon et al 2007). In addition, the impact of deforestation on soil quality and local precipitation is not fully understood, making it difficult to assess the effect reforestation and afforestation will have in these areas. Due to these uncertainties, there is disagreement over the relative effectiveness and importance of these mechanisms in mitigating climate change.

- **Mechanisms that Enhance Forest Stocks**
  Afforestation, reforestation, and effective forest management are three mechanisms that are generally understood to enhance forest stocks. Afforestation and reforestation are similar in that they both involve planting trees in unforested regions. Afforestation is the establishment of forest plantations on land that was not classified as forest for the past 50 years (FAO Working Paper 2004). Reforestation involves planting trees on land that has been cleared of forest within the relatively recent past. Forest management refers to the process of planning and implementing practices for the stewardship and use of forests aimed at achieving specific environmental, economic, social and/or cultural objectives (FAO Working Paper 2004). In the context of climate change, it refers to the appropriate management of forests in order to achieve the maximum carbon stocks possible.

  Although these mechanisms do mitigate climate change, the scale of trees that would need to be planted to counter those lost through deforestation is extremely high, making afforestation and reforestation less than ideal alternatives. In addition, soil quality in tropical regions is lost rapidly after deforestation, further increasing the cost and reducing the effectiveness of these mechanisms (Islam and Weill 2000). Although reforestation and afforestation may have a positive impact in reducing atmospheric CO_2, large uncertainties remain in determining their potential carbon sink capacity. Even so, it is certain that their capacity for carbon sequestration is lower than that of primary forests (Czimczik et al 2005). Reforestation and afforestation activities also carry with them risks that old growth forests in tropical areas do not have, such as inadequate meteorological conditions, disease or other unforeseen events that can destroy the recently planted trees (Dutschke et al 2005). Furthermore, these new or replanted forests will not support the same level of complexity or ecosystem services as old growth forests (Parker et al 2008).

  The effectiveness of forest management at reducing GHG emissions is also uncertain, as the use of fertilizer causes nitrous oxide emissions and therefore reduces the potential benefits of carbon sequestration. In addition, the drainage of forest soils,

especially peatlands, may lead to substantial carbon loss due to enhanced respiration (Solomon et al 2008).

- **The Effect of Deforestation on Soil Quality and Precipitation**
  There is general scientific agreement that deforestation has negative effects on soil quality and precipitation. It is understood that deforestation leads to erosion and loss of essential nutrients in the soil. However, the responses of soil microbial communities to these land-use changes are not well understood. Changes in soil microbial abundance and community structure have consequences for nutrient cycling, carbon sequestration and long-term sustainability (Macdonald et al 2009). Thus it is uncertain if reforestation will be able to overcome the environmental challenges left behind from deforestation. This has important implications for the effectiveness and sustainability of reforested trees and their ability to act as carbon sequesters under the REDD+ program. In addition, there is a correlation between the moisture stored in soil (e.g. as result of irrigation) and the monthly average precipitation rate. In one such study in India, the areas of decreasing rainfall coincided with regions of agricultural intensive land use. This suggests that land-use change associated with agricultural intensification could be reducing the summer monsoon rainfall over certain regions of India. Thus, this also poses an environmental challenge to reforestation efforts as the re-introduced vegetation could be facing very different climate conditions and increased water stress, raising the uncertainty of the long-term sustainability of these efforts.

Due to the limitations and risks associated with afforestation, reforestation, and forest management, reducing deforestation and degradation have a greater, more certain positive impact on reducing GHG emissions and are therefore more effective at mitigating climate change. In addition to this crucial climatic benefit, primary forests support higher diversity and complexity, maintain vital ecosystem functions such as soil quality and water cycling and purification, and moderate local and regional climate processes, thus ensuring that the major hydrological, habitat, and climatic functions operate at an optimum level. Reducing deforestation and degradation should therefore be prioritized when implementing REDD+ projects in developing countries.

Measurement Problems and the Global Carbon Market
As stated before, the long-term aim of REDD+ is to be financially self-sustainable by using the mechanisms of the carbon market to back the monetary value of REDD+ emissions reduction credits. The scientific uncertainties related to REDD+ offer a potential threat to the success of the program's capacity to reduce carbon emissions. Currently, a scientific consensus does not exist that outlines how to measure the carbon stock of trees, not only due to the use of different methodologies but also to different assumptions made even when using the same methodology by different organizations. For example, The Food and Agriculture Organization's 1990 Forest Resource Assessment (FRA) of the forest extent of 90 tropical lands reported first 1,756 million ha, then 1,925 million ha, and finally 1,949 million ha of basic forest area (Grainger 2008). The variation in forest extent was due to different assumptions on what constituted a forest and involved variations in tree height, patchiness, etc. This illustrates

how estimates by the same international authority can change dramatically over the same year, causing uncertainties in the carbon accounting and limiting the capability to determine the certifiable benefits of a single REDD+ project. Discrepancies such as this can lead to obvious difficulties in determining the amount and value of emission reductions, and therefore the carbon credits issued for the given project. As private investors and large corporations – accustomed to investing in uniform and fungible physical commodities - do not appreciate uncertainty in the quality of a product, uncertainty in the frameworks applied in defining this imaginary commodity could ultimately prevent the transition of the REDD+ program into the final, market driven stage of the transitional strategy illustrated in Figure 4. Thus, reaching a consensus on what methodologies to use and standardizing measurements is crucial to establishing standardized baselines from which to measure the success of REDD+ and create viable carbon markets.

The Berau Forest Carbon Project

On the Indonesian island of Borneo, in the district of Berau, 75% of its 2.2 million hectares are forested, and only 17% of that land is under protection. Winrock International estimates the forest cover will decrease by a factor of ten in ten years (Fishbein 2010).

The Berau Forest Carbon Project (BFCP) spans the entire district of Berau and connects on-the-ground projects to a national REDD+ program. Its methodology and results will contribute to the current discourse regarding the various ways to implement REDD+ across a tropical forest state or country. This project is a collaboration of every level of government, multilateral expertise and funding, the private sector, NGOs, on-the-ground conservation, financial incentives, new governance, scientific monitoring and community involvement (Virgilio et al, 2010). The BFCP aims to slow the effects of climate change by reducing carbon dioxide emissions by 10 million tons in 5 years. Other goals include protecting watersheds and biodiversity as well as increasing economic opportunities for its local communities (Fishbein 2010). The project will also set aside protected areas and redirect plans for palm oil plantations from pristine forests to degraded or deforested areas (Virgilio et al 2010). It hopes to generate comparable amounts of income through carbon markets and sustainable forest management.

The project uses a combination of historical stratification maps, on the ground measurements and future land-use contracts to develop a baseline through high-resolution technology and field measurements (Fishbein 2010). The project is currently attempting to become accredited under the Voluntary Carbon Market Standard (VCS). A coalition of experts has developed standards for VCS carbon stocks, established a baseline, and created emissions, leakage and monitoring modules for REDD+. Measuring the success of the BFCP will be forthcoming, as the project is still in its early stages.

Photo Credit: OnAsia.com

CONCLUSION

In a world reluctant to modify its consumption of fossil fuels to levels sufficient to reduce greenhouse gas emissions to sustainable levels, it is critical that actions to reduce deforestation and forest degradation be pursued immediately. These activities are the third and second largest contributors of global greenhouse gas and carbon dioxide emissions, respectively. REDD+ provides a promising strategy that not only significantly cuts CO_2 emissions, but also protects ecosystems and acts to equalize the economic disparities between developed and developing nations. While international agreement on forest definitions and the scientific methodologies behind the REDD+ approach remain elusive, efforts to resolve these issues must remain a priority to ensure that an international framework that drives REDD+ forward is achieved in the near future. Once these obstacles have been removed, confidence in forest-based carbon credits should improve facilitating the creation of robust carbon markets, which should drive the widespread adoption of REDD+ initiatives. This, in turn, will pave the way for significant reductions in greenhouse gas emissions necessary to mitigating global climate change.

Photo credit: Kimberly Lai

GLOSSARY OF TERMS

Afforestation: the establishment of forest plantations on land that was not classified as forest for 50 years prior.

Annex I: nations that signed the Kyoto Protocol that are required to cap their emissions of greenhouse gases and are committed to emissions reduction targets. These are the 36 countries that the UNFCCC identified for emissions reductions.

Annex II: nations that signed the UNFCCC and are also members of the Organization for Economic Cooperation and Development. These nations have agreed to help developing nations combat climate change through technological and financial assistance.

Baseline: a baseline is the trend of carbon emissions based on a "business-as-usual" scenario. Baselines provide a framework for emissions reductions and a basis to assess the success of a REDD+ program.

Business-as-usual (BAU): a projected carbon emissions growth trend based on the assumption that there will be no reduction measures.

Biomass: plant matter that can be burned as a source of energy.

Carbon credit: a generic term reflecting a value assigned to the reduction or offset of greenhouse gas emissions. One carbon credit is equal to one ton of carbon dioxide.

Carbon price: the economic value of an amount of greenhouse gas emissions from anthropogenic causes.

Carbon reservoir/sink: a feature (natural or manmade) that absorbs atmospheric carbon dioxide (e.g. oceans, forests).

Carbon sequestration: the process by which natural systems store carbon in different chemical forms.

Copenhagen Accord: non-binding document signed at the 15th Conference of the Parties where signatories agreed to maintain global temperature rises below 2 degrees Celsius and sets up REDD+ as an effort to mitigate climate change through emissions reductions.

Conference of the Parties (COP): the signatories of the UNFCCC; the COP meets annually to dicsuss progress on dealing with climate change.

Deforestation: the conversion of forest land to non-forested land through human activity.

Degradation: human-induced long-term loss of forest, characterized by the reduction of tree

crown cover, but not yet considered as complete deforestation.

Greenhouse gases (GHG): gases in the atmosphere that absorb and re-emit radiation in the Earth's atmosphere, causing the warming of the Earth's atmospheric temperature that is known as the greenhouse effect. The primary greenhouse gases are water vapor, carbon dioxide, methane, nitrous oxide, and ozone.

Intergovernmental Panel on Climate Change (IPCC): Scientific panel of the UNFCCC that provides the UN with information on climate change.

Leakage: when efforts to reduce emissions in one area lead to an increase in carbon emissions in another area.

Reducing Emissions from Deforestation and Degradation (REDD): an initiative to cut carbon emissions by including "avoided deforestation" as part of the carbon market mechanisms. Through REDD, countries are incentivized to avoid deforestation.

REDD-plus (REDD+): an addition to REDD (see above) that includes sustainable forest management and incentivizes reforestation/afforestation in developing countries.

Reforestation: replanting or replenishing a previously forested area or a degraded forest area.

United Nations Framework Convention on Climate Change (UNFCCC): an international environmental treat originally signed at the United Nations Conference on Environment and Development (informally known as the Earth Summit) in 1992 that agrees to stablize atmospheric greenhouse gas concentrations at a level that would prevent dangerous anthropogenicly-forced climate change. The UNFCCC currently has 192 signatories.

APPENDIX

According to the UNFCCC website, the Convention divides countries into three main groups according to differing commitments:

Annex I Parties include the industrialized countries that were members of the OECD (Organisation for Economic Co-operation and Development) in 1992, plus countries with economies in transition (the EIT Parties), including the Russian Federation, the Baltic States, and several Central and Eastern European States.

Annex II Parties consist of the OECD members of Annex I, but not the EIT Parties. They are required to provide financial resources to enable developing countries to undertake emissions reduction activities under the Convention and to help them adapt to adverse effects of climate change. In addition, they have to "take all practicable steps" to promote the development and transfer of environmentally friendly technologies to EIT Parties and developing countries. Funding provided by Annex II Parties is channeled mostly through the Convention's financial mechanism.

Non-Annex I Parties are mostly developing countries. Certain groups of developing countries are recognized by the Convention as being especially vulnerable to the adverse impacts of climate change, including countries with low-lying coastal areas and those prone to desertification and drought. Others (such as countries that rely heavily on income from fossil fuel production and commerce) feel more vulnerable to the potential economic impacts of climate change response measures. The Convention emphasizes activities that promise to answer the special needs and concerns of these vulnerable countries, such as investment, insurance and technology transfer.

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