W W F   N O R W A Y

THE LINK BETWEEN REDUCING DEFORESTATION AND FOREST DEGRADATION

Netaholic13, courtesy Flickr

AND BIODIVERSITY CONSERVATION

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Executive Summary

While there exists a growing amount of peer-reviewed literature and high-quality information assessing the potential for REDD+ to stem carbon emissions, little exists documenting how biodiversity fares under REDD+. Reducing carbon emissions from deforestation and forest degradation, conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries is often referred to as "REDD+."

First, we explore the overlap between carbon-rich and biodiversity-rich forests worldwide. Section 2 summarizes the affect of deforestation and degradation on biodiversity, and offers examples of how complex the responses of natural systems are to disturbance. Section 3 explores how human disturbance affects forests, their storage of carbon and ability to maintain biodiversity. Our purpose in consolidating findings from selected studies from the tropical regions of the world, that quantified the affect of human disturbance on biodiversity by forest type and land use type, is to offer a range of numerical estimates of the impacts of *degradation* and how biodiversity responds to this gradient of land-use impacts. Furthermore, in assembling these study outcomes, we compliment our quantitative estimation in Section 4 of the affect of deforestation on biodiversity loss, the probability of REDD reversing those trends, and the gains for biodiversity under a REDD scenario.

Section 4 applies an economic model (OSIRIS), utilizing an historical-adjusted reference level, to estimate the affect of RED (the model is limited to deforestation only, plus conservation) on biodiversity. The research finds that those countries with the highest numbers of forest endemics opt in to RED, and the corresponding reductions in deforestations and emissions result in almost complete reversals in rates of biodiversity loss in those countries. No countries with high-endemism opt out of RED in our scenario. Some medium-endemism countries experience leakage and thus increased rates of deforestation in our OSIRIS scenario, most likely due to low carbon densities and high agricultural returns.

Voluntary carbon market already include biodiversity as a valued co-benefit of REDD projects, as forest carbon projects with multiple ecosystem services, certified and monitored as such, are viewed as safer investments. The challenge ahead is to ensure compliance markets for REDD+ carry that same commitment to social and ecological co-benefits. Based on research herein, the following policy recommendations and actions to support the biodiversity co-benefits of a REDD+ mechanism include:

1. Preference should be given to those REDD+ projects or programs that include biodiversity conservation as a key objective
2. The carbon carrying capacity of primary forests must be properly accounted for, and methodologies to measure and monitor carbon stocks should be pursued at highest resolution and include biodiversity as an attribute

3. REDD+ strategies at the national and sub-regional level should be integrated with associated climate change adaptation strategies and protected area networks

4. Conserving forests, even if they are currently not threatened, has a strong mitigation benefit

5. Existing forest certification systems, such as the Forest Stewardship Council, can be complimentary to REDD and should be promoted

6. The Climate, Community and Biodiversity (CCB) and Voluntary Carbon Standard (VCS) standards should be promoted in the voluntary market, and their principles and indicators transferred to the compliance market as requirements.

7. REDD+ compliance markets need to incorporate consideration of co-benefits.

The paper concludes with a brief investigation into the barriers and enabling factors for the inclusion of biodiversity co-benefits in both voluntary and compliance forest carbon markets.

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1. Introduction

We stand at a crossroads-- atmospheric greenhouse gas concentrations are increasing beyond levels documented in the fossil record, scientists around the world agree that this is human-induced, largely due to the burning of fossil fuels since the dawn of the industrial age, and we must act decisively and quickly to reverse this trend. Our climate change crisis demands that we systematically alter land use practices to safeguard carbon reservoirs-- especially those in natural and undisturbed forests. Peer-reviewed climate change modeling predicts major changes in global forest cover are likely to occur at temperature increases over 2-3°C, resulting in significant loss of forest towards the end of the century, particularly in boreal, mountain and tropical regions. However, saving those forests is one of the cheapest and easiest solutions at our disposal to reverse that trend. In fact, it is generally agreed that unless tropical deforestation and degradation is contained, it will be impossible to reach the 2°C target even with strong mitigation in other sectors.[1][2]

Reducing carbon emissions from deforestation and forest degradation, conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries is often referred to as "REDD+."

The development of a REDD+ mechanism is premised on the need to limit carbon emissions from deforestation and degradation. However, as demonstrated in this report, an effective REDD+ mechanism can also significantly address tropical biodiversity conservation. Below we explore how to achieve this, and also offer a rationale for why biodiversity conservation should be viewed as an additional benefit of REDD+. Preference should be given to those REDD+ projects or programs that include biodiversity conservation as a key objective; i.e., while the payments for reductions in emissions will be based on the amount of carbon not released into the atmosphere, a side-benefit is that we protect biodiversity in the process.

Furthermore, preserving natural ecosystems as part of REDD+ is cost-effective and guarantees results. A recent column in *Nature* aptly described why: "The maintenance and restoration of natural habitats are among the cheapest, safest and easiest solutions at our disposal in the effort

[1] Stern Nicholas. Policy Update: *Action and ambition for a global deal in Copenhagen*. Centre for Climate Change Economics and Policy, Grantham Research Institute for Climate Change and the Environment, and United Nations Environment Programme, 6 November 2009.

[2] UNEP press release, Reuters story found at: http://www.alertnet.org/thenews/newsdesk/SGE61M0A0.htm

to reduce greenhouse-gas emissions and promote adaptation to unavoidable changes. The basic materials already exist — so there is no need for technological development. Indeed, ecosystem restoration (for example, replanting forest on previously cleared land) may remain for several decades the only realistic large-scale mechanism for removing carbon dioxide already in the atmosphere."[3]

The Eliasch Review[4] aptly summarized the climate change challenge and the role of forests in it:

> "Analysis... estimates that, in the absence of any mitigation efforts, emissions from the forest sector alone will increase atmospheric carbon stock by around 30ppm by 2100. Current atmospheric CO2e levels stand at 433ppm. Consequently, in order to stabilize atmospheric CO2e levels at a 445-490ppm target, forests will need to form a central part of any global climate change deal. In addition to their role in tackling climate change, forests provide many other services. They are home to 350 million people, and over 90 per cent of those living on less than $1 per day depend to some extent on forests for their livelihoods. They provide fuel wood, medicinal plants, forest foods, shelter and many other services for communities. Forests also provide additional ecosystem services, such as regulating regional rainfall and flood defense and supporting high levels of biodiversity. Maintaining resilient forest ecosystems could contribute not only to reduced emissions, but also to adaptation to future climate change."

We know that the rapid destruction of tropical forests produces 12-20% of anthropogenic carbon emissions[5] and poses one of the greatest perils to global biodiversity. Addressing the problem of carbon emissions stemming from tropical deforestation and degradation was never included in the Kyoto protocol. The negotiating bodies under the United Nations Framework Convention on Climate Change (UNFCCC) recognized the importance of including forests as part of an international climate protection effort prior to the year 2000, however the politics associated with forests during and after the negotiation of the Kyoto Protocol resulted in a complex and highly restrictive set of rules regarding how forests and land use would be treated. It took deliberations around the Marrakesh Accords (which prohibited forest protection from crediting under the Clean Development Mechanism), a formal proposal by Papua New Guinea and Costa Rica for a Reducing Emissions from Deforestation in Developing countries mechanism, and future deliberation under the UNFCCC at Bali in the Bali Action Plan in 2006, for the

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[3] Turner, Will, et al, *A force to fight global warming*. Nature, 19 November 2009.

[4] UK Office of Climate Change, report found at: http://www.occ.gov.uk/activities/eliasch.htm

[5] This figure combines recent estimates from van der Werf, G. R., et al, *CO_2 emissions from forest loss, Nature Geoscience*, Vol. 2, November 2009. Found at: www.biology.duke.edu/jackson/ng09.pdf with earlier aggregate estimates from the IPCC (2007).

door to fully open to inclusion of reductions in emissions from deforestation and degradation (REDD) in the UNFCCC negotiation framework. Since then, in the lead-up to the UNFCCC Conference of the Parties at Copenhagen (COP 15), intense focus from the scientific and policy communities have matured the understanding of options for developing a REDD+ mechanism and how effective measurement and monitoring of forest carbon can be achievable.

WWF's Forest Carbon Initiative has developed global benchmark principles for a successful REDD+ mechanism, which it offers as a party to the REDD+ Partnership process and to the UNFCCC, as well as being a signatory to the UN Convention on Biological Diversity and strongly committed to the Millennium Development Goals. Principle 2 of WWF's principles, on biodiversity, seeks to ensure that REDD+ maintains and/or enhances forest biodiversity and ecosystem services.[6]

This report seeks to consolidate best available information on the relationship between REDD+ and biodiversity conservation. The report seeks to provide some answers to the following questions:

- How does deforestation and degradation impact biodiversity?
- What is the overlap between carbon-rich and biologically-rich forests worldwide?
- How does REDD+ offer a unique or different approach to conservation (and how can it potentially safeguard ecological values beyond what current protected area networks provide?)
- How can development of a REDD+ mechanism best respond to the need for biodiversity conservation?

2. The impact of deforestation and forest degradation on biodiversity

2.1 Why is biodiversity important?

Biological diversity is generally defined as the variation of life forms at all levels of biological systems (i.e., molecular, organismic, population, species and ecosystem). Biodiversity is recognized as a key indicator of the health of biological systems. The term refers to both species diversity and species richness. A 2006 update[7] of the World Conservation Union (IUCN) Red List

[6] WWF/CARE 5 principles for REDD+

[7] 2006 IUCN Red List of threatened species. A global species assessment. IUCN Gland, Switzerland. Full resources found at: http://www.iucnredlist.org/

of Threatened Species identified more than 40 percent of species that have been assessed worldwide are threatened with extinction. These include a quarter of the world's coniferous trees, an eighth of its birds, and one-third of its amphibians. The Convention for Biological Diversity reports that population of wild vertebrate species fell by an average of nearly one- third (31%) globally between 1970 and 2006, with the decline especially severe in the tropics (59%).[8]

It is well documented that most species extinctions to date are attributable to human impacts and in particular the destruction and degradation of plant and animal habitats. There are also increasing examples of extinctions linked directly to climate change and species' inability to adapt to changes in temperature.[9] Increased rates of extinction due to human consumptive impacts are particularly apparent in the tropical forests of the world.[10] Concern over the rate of species extinctions in the later Holocene era has caused some scientists to consider this era as the sixth mass extinction in history, with rates of decline in biodiversity matching or exceeding rates of loss in the five previous mess extinction events recorded in the fossil record.[11] Climate change is projected to increase species extinction rates, with approximately 10% of the species assessed so far at an increasingly high risk of extinction for every 1°C rise in global mean surface temperature within the range of future scenarios typically modeled in impact assessments (usually <5°C global temperature rise).[12]

The Millennium Ecosystem Assessment (MEA)[13], released in 2005, assessed the consequences of ecosystem change for human well-being and brought the work of 1,360 experts worldwide together over four years to produce the reports. Some relevant key findings:

- Knowledge of existing biodiversity is uneven, with strong biases toward the species level, large animals, temperate systems, and components of biodiversity used by people. This results in gaps in knowledge, especially regarding the status of tropical systems, marine and freshwater biota, plants, invertebrates, micro-organisms, and subterranean biota.

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[8] Secretariat of the Convention on Biological Diversity (2010) Global Biodiversity Outlook 3. Montréal. Page 24.

[9] *Study documents widespread extinction of lizard populations due to climate change*, May 13, 2010 http://www.physorg.com/news192977666.html

[10] Paul Ehrlich and Anne Ehrlich, *Extinction: the causes and consequences of the disappearance of species*, Random House, New York (1981) ISBN 0-394-51312-6.

[11] D. B. Wake and V. T. Vredenburg. (2008). Are we in the midst of the sixth mass extinction? A view from the world of amphibians. Proceedings of the National Academy of Sciences of the United States of America, 105: 11466–11473

[12] UNEP/CBD/AHTEG/BD-CC-2/2/2 30 March 2009. Found at: http://www.cbd.int/doc/?meeting=AHTEG-BDCC-02-02

[13] Found at: http://www.millenniumassessment.org/en/Condition.aspx

- Across a range of measures, tropical forests are outstanding in their levels of biodiversity at and above the species level. Regions of high species richness broadly correspond with centers of evolutionary diversity, and available evidence suggests that across major taxa, tropical moist forests are especially important for both overall variability and unique evolutionary history. Species richness, family richness, and species endemism are all highest for this biome, even after accounting for area and productivity.
- Over the past few hundred years humans may have increased the species extinction rate by as much as three orders of magnitude. However, ...based on recorded extinctions of known species over the past 100 years indicates extinction rates are around 100 times greater than rates characteristic of species in the fossil record. Other less direct estimates, some of which refer to extinctions hundreds of years into the future, estimate extinction rates 1,000 to 10,000 times higher than rates recorded among fossil lineages.
- The majority of biomes have been greatly modified by humans. Between 20% and 50% of 9 of the 14 biomes have been transformed to croplands. Tropical dry forests are the most reduced by cultivation, with almost half of the biome's native habitats replaced with cultivated lands.

The MEA findings above tell us this: We do not know enough about tropical ecosystems, however they contain the richest terrestrial biodiversity on earth. The species extinction rate is increasing exponentially, and there are scant few biomes left that not been modified by humans, including the dwindling tropical dry forest biome. With this in mind, even if stemming carbon emissions to decrease global climate change were of no matter, we would still have a global biodiversity crisis to address, with the tropics being front and centre. The climate change imperative simply offers a different vantage point from which to address the problems of landscape conversion. And it should come as no surprise that recent empirical evidence and predictive modeling studies suggest that climate change will increase population losses and thus dramatically affect biodiversity.

The definition of representative communities for the conservation of biodiversity has been a major focus of research over the last fifteen years, and serves as a benchmark for estimating climate change impacts and other affects on biodiversity, as well as strategies to restore degraded habitats and affected species. WWF completed a Terrestrial Ecoregion of the World assessment in 2001, which is a global benchmark of relatively large units of land containing a distinct assemblage of natural communities and species, with boundaries that approximate the original extent of natural communities prior to major land use change. The biome of greatest focus for REDD+ activities (due to their massive terrestrial carbon storage) is the Tropical and Subtropical Moist Forests (TSMF) ecoregion. These are generally found in large, discontinuous patches centered on the equatorial belt and between the Tropics of Cancer and Capricorn. These forests are characterized by low variability in annual temperature and high levels of rainfall (>200 centimeter annually), and forest composition is dominated by semi-evergreen and evergreen deciduous tree species.

These forests contribute to the highest levels of species diversity in any terrestrial biome. Biodiversity is highest in the forest canopy, where species abundance is higher than in any other terrestrial ecosystem. Half of the world's species may live in these forests, where a square kilometre may be home to more than 1,000 tree species. These forests are found around the world, particularly in the Indo-Malayan Archipelagos, the Amazon Basin, and the African Congo. A perpetually warm, wet climate promotes more explosive plant growth than in any other environment on Earth.[14]

2.2 What is driving tropical deforestation?

Tropical forests are disappearing quickly— 13 million hectares per year—as a result of agricultural, timber and road expansion.[15][16] Assuming current deforestation trends continue, 40% of the Amazon will be gone by 2050.[17] And while rates of Brazilian Amazon deforestation has decreased from its height in the 1990's, rates of degradation have increased. With half the world's population living in cities by last year (the first year in history this is the case), we are increasingly aware of the effects of global consumption patterns and the effects this is having on natural systems.

A February 2010 article, "*Deforestation driven by urban population growth and agricultural trade in the twenty-first century*[18]," in Nature Geoscience points out that that urbanization and export crops are the primary drivers of deforestation. "The main drivers of tropical deforestation have shifted from small-scale landholders to domestic and international markets that are distant from the forests," said lead author Ruth DeFries, a professor at the Earth Institute's Center for Environmental Research and Conservation. "One line of thinking was that concentrating people in

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14 Found at: http://www.panda.org/about_our_earth/ecoregions/about/habitat_types/selecting_terrestrial_ecoregions/habitat01.cfm

15 H.J. Geist and E.F. Lambin. 2002. Proximate causes and underlying driving forces of tropical deforestation. BioScience 52 (2): 143–150.

16 WWF Tropical and Subtropical Moist Broadleaf Forest Ecoregions assessment:

www.panda.org/about_our_earth/ecoregions/about/habitat_types/selecting_terrestrial_ecoregions/habitat01.cfm

17 B.S. Soares-Filho et al. 2006. *Modeling conservation in the Amazon basin*. Nature 440: 520–523

18 DeFries et al. Deforestation driven by urban population growth and agricultural trade in the twenty-first century. Nature Geoscience, 2010; DOI: 10.1038/ngeo756

cities would leave a lot more room for nature. But those people in cities and the rest of the world need to be fed. That creates a demand for industrial-scale clearing." DeFries and her colleagues analyzed remote-sensing images of forest cover across 41 nations in Latin America, Africa and Asia from 2000-2005, and combined these with population and economic trends. They showed that the highest forest losses were correlated with two factors: urban growth within countries; and, mainly in Asia, growth of agricultural exports to other countries.

2.3 The effect of deforestation and degradation on biodiversity and carbon storage

Humans are having long-term cumulative impacts on Earth's ecosystems through a range of consumptive, exploitive, and indirect mechanisms, even to the extent of influencing the global climate. The Millennium Ecosystem Assessment (MEA)[19] investigated all anthropogenic (human-induced) drivers of biodiversity loss and determined habitat change is the most pervasive anthropogenic driver, with habitat fragmentation, introduced alien species, and exploitation being the next most common drivers. Loss of habitat area through clearing or degradation is currently the primary cause of range declines in species and populations. Fragmentation of habitats is having severe effects as well, decreasing habitat ranges and increasing edge effects (which changes microclimates and often enables invasive species). Globally, over half of the temperate broadleaf and mixed forest biome and nearly one quarter of the tropical rain forest biome have been fragmented or removed by humans.

In summary, the major impacts of humans on forest ecosystems include loss of forest area, habitat fragmentation, soil degradation, depletion of biomass and associated carbon stocks, transformation of stand age and species composition, species loss, species introductions, and the ensuing cascading effects, such as increasing risk of fire and decreased resilience in the face of climate change impacts.

[19] Mace, G., Masundire, H., Baillie, J., Millenium Ecosystem Assessment, Chapter 4, Biodiversity; Found at: http://www.millenniumassessment.org/en/Condition.aspx

2.4 How much carbon is stored in forests?

According to FAO's Global Forest Resources Assessment 2005, the world's forests store 283 gigatonnes of carbon in their biomass, while the total carbon stored in forest biomass, deadwood, litter and soil together is roughly 50 percent more than the amount found in the atmosphere - adding up to one trillion tonnes.[20] The IPCC estimates forests sequester the largest fraction of terrestrial ecosystem carbon stocks, recently estimated at 1,640 PgC, equivalent to about 220% of atmospheric carbon[21]. The Amazon alone is believed to sequester more than 10 times the amount of carbon emitted globally each year.[22] Biomass carbon mapping shows that worldwide, living vegetation (trees, grasses, etc.) stores an enormous 500 billion tones of carbon, more than 60 times annual anthropogenic carbon emissions to the atmosphere. The tropics and subtropics combined store 430 billion tones of biomass carbon, while boreal biomass stores 34 billion tones and temperate biomass stores 33 billion tones.[23]

In December 2009, an updated United Nations Environment Program and World Conservation Monitoring Centre (UNEP-WCMC) global carbon map was released, improving upon the rather coarse data on soil carbon in previous maps. It provides a useful tool for visualizing the distribution of carbon stocks, which are dominated by soil stocks in some parts of the world such as boreal peat lands and tropical swamps. That explains why the UNEP-WCMC updated global carbon map includes many areas displayed as having medium- to high-carbon value in temperate and boreal regions that are not included in the Reusch and Gibbs IPCC Tier-1 Global Biomass Carbon Map.

[20] See chapter 2, found at: http://www.fao.org/docrep/008/a0400e/a0400e00.htm

[21] IPCC CLimate Change 2007 Report, Working Group II on Impacts, Adaptation and Vulnerability, found at: http://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch4s4-4-5.html

[22] de Gouvello, Christophe et al. *Brazil Low-carbon Country Case Study*. World Bank, 31 May 2010, page 1.

[23] Ruesch, Aaron; Gibbs, Holly K. 2008. *New IPCC Tier-1 Global Biomass Carbon Map For the Year 2000*. Published by the Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, TN, USA. Found on-line at: http://cdiac.ornl.gov/epubs/ndp/global_carbon/carbon_documentation.html

In 2008, Aaron Reusch and Holly Gibbs created a map of biomass carbon stored in above- and below-ground (root) living vegetation created using the International Panel on Climate Change (IPCC) Good Practice Guidance for reporting national greenhouse gas inventories[24]. This is the first application of the IPCC Good Practice Guidance (at a Tier 1 level) to the whole terrestrial surface. Their analysis synthesized and mapped the IPCC Tier-1 default values using a global land cover map stratified by continent, ecoregion and forest disturbance-level. The map has been used as a base layer for many studies related to terrestrial carbon storage, including the Strassburg et al study (below, on page 30).

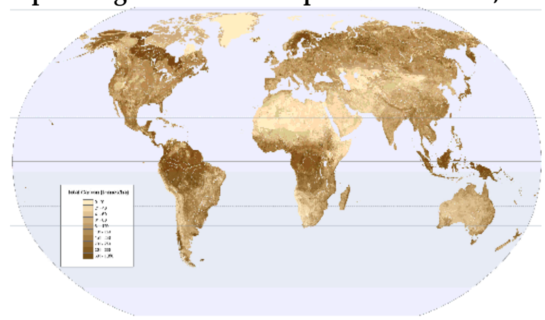
2.5 How does carbon storage differ by forest type?

Forest carbon storage varies dramatically around the world, depending on such variables as climate and temperature, species composition, soils, amount of above-ground biomass, and other factors. IPCC default values are the coarsest and whenever possible should be updated with more site-specific measurements of carbon storage (ideally at an IPCC tier 3 level). Furthermore, the carbon storage capacity of natural, undisturbed forests, are believed to not adequately be captured in global or even national data sets.

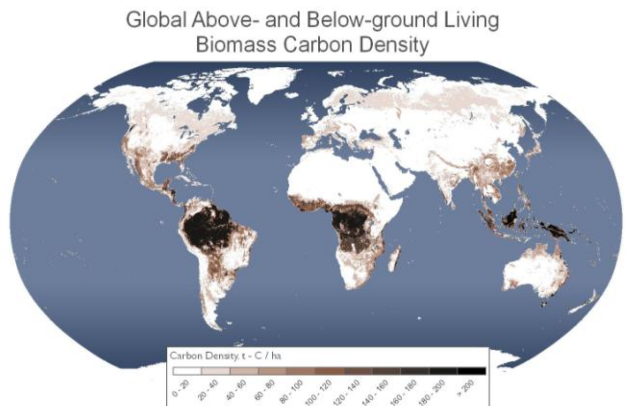
In a recent study, spatially averaged IPCC biome default values (see sidebar) were coupled

[24] Ruesch, Aaron; Gibbs, Holly K. (2008).

Updated global carbon map: UNEP-WCMC, 2009



Reusch and Gibbs New IPCC Tier-1 Global Biomass Carbon Map for the Year 2000



IPCC default values and tiers

Default Values: These refer to the IPCC tables on forestland classifications, emissions factors, above-ground and below-ground ratios, biomass conversion and expansion factors, emission factors related to biomass loss or disturbances.

Guidelines for greenhouse gas inventories: Forest land is stratified into various sub-categories to reduce the variation in growth rate and other forest parameters and to reduce uncertainty. The Guidelines use Food and Agriculture Organization (FAO, 2001) ecological zone and forest cover classifications.

The IPCC's three tiers for carbon accounting: Each tier specifies more data requirements and more complex analyses:

Tier 1: applies default emission factors (indirectly estimates emissions based on the loss of canopy cover) to data on forest activities that are collected nationally or globally,

Tier 2: applies country specific emission factors and activity data,

Tier 3: applies methods, models and inventory measurement systems that are repeated over time, driven by high-with published site biomass data in order to identify those forests with the highest biomass carbon densities[25]. The analysis results in 1) a predictive framework for identifying forests with high biomass carbon stocks, and 2) helps clarify interpretation of average forest biome values such as those published by the IPCC. In the study, Table 1 offers a summary of average site data and biome default values from the IPCC for each global forest type. The Table illustrates that with the combination of carbon values for above-ground living biomass and root/dead biomass, tropical wet and cool temperate moist forests stand out as having the largest biome default values, with 213 and 233 tC ·ha−1 respectively. The importance of this is that cooler temperate forests, and particularly low carbon, high biodiversity forests (such as the Himalayas) are critical for climate change mitigation. Furthermore, the terpenes released in boreal forest also have a major cooling affect, offsetting any albedo issues with that forest type.[26]

Table 1 (Keith, et al): Average published site data for biomass carbon (tC ·ha−1) of each forest biome (mean, standard deviation, and number of sites) and default biomass carbon values (IPCC)

Domain	Climate region	Above-ground living biomass carbon, tC ·ha−1		Root + dead biomass carbon, tC ·ha−1		Total living + dead biomass carbon, tC ·ha−1	
		Average site data	Biome default value*	Average site data	Biome default value†	Average site data	Biome default value
Tropical	Tropical wet	171 (61) n = 18	146	76 (72) n = 7	67	231 (75) n = 7	213
	Tropical moist	179 (96) n = 14	112	55 (66) n = 5	30	248 (100) n = 5	142
	Tropical dry	70 n = 1	73	41 n = 1	32	111 n = 1	105
	Tropical montane	127 (8) n = 3	71	52 (6) n = 3	60	167 (17) n = 3	112
Subtropical	Warm temperate moist	294 (149) n = 26	108	165 (75) n = 20	63	498 (200) n = 20	171
	Warm temperate dry		75		65		140
	Warm temperate montane		69		63		132
Temperate	Cool temperate moist	377 (182) n = 18	155	265 (162) n = 18	78	642 (294) n = 18	233
	Cool temperate dry	176 (102) n = 3	59	102 (77) n = 3	62	278 (173) n = 3	121
	Cool temperate montane	147 n = 1	61		63	153 n = 1	124

[25] The above reprinted from: Heather Keith; Mackey, Brendan G.; and Lindenmayer, David B., *Re-evaluation of forest biomass carbon stocks and lessons from the world's most carbon-dense forests*, Proceedings of the National Academy of Sciences of the United States of America, June 2009, found at: http://www.pnas.org/content/106/28/11635.long)
Tables: http://www.pnas.org/content/suppl/2009/06/25/0901970106.DCSupplemental/0901970106SI.pdf#nameddest=ST1

[26] Spracklen, Dominick V.; Bonn, Boris; Carslaw, Kennth. *Boreal forests, aerosols and the impacts on clouds and climate*. Phil. Trans. R. Soc. A doi:10.1098/rsta.2008.0201

Boreal	Boreal moist	64 (28) n = 28	24	37 (16) n =14	75	97 (34) n =14	99
	Boreal dry	59 (36) n = 24	8	25 (12) n = 9	52	84 (39) n = 9	60
	Boreal montane		21		55		76

In addition to evaluating forest carbon storage by region and biome, research has only recently informed our understanding of the massive carbon carrying capacity of natural, undisturbed forests. Brendan Mackey, et al's 2008 publication, *Green Carbon*,[27] demonstrated that using local data collected from south-eastern Australian eucalypt forests, not disturbed by logging, resulted in calculations of the total stock of carbon stored in their study region, if undisturbed by intensive human land-use activities, is 9.3 Gt; whereas IPCC default values would estimate only 3.1 Gt. Their estimates reflect the carbon carrying capacity of the natural forests. In heavily disturbed forests, the current carbon stocks reflect land-use history. The difference between the two is the 'carbon sequestration potential'—the maximum carbon stock that can be sequestered as a forest re-grows. The greater the carbon sequestration potential of a forest, the more the carbon stock has been degraded by human land-use activities. Mackey, et al argue that most carbon accounting schemes (including Australia's NCAS, which they analyzed) focus simply on the current carbon stocks in a landscape (based on stand-level commercial forestry inventory techniques) which will underestimate a forest's natural carbon carrying capacity (including living and dead biomass and soil), and thus are not suitable for calculating the carbon carrying capacity of natural forests.

2.6 How much forest is cleared every year?

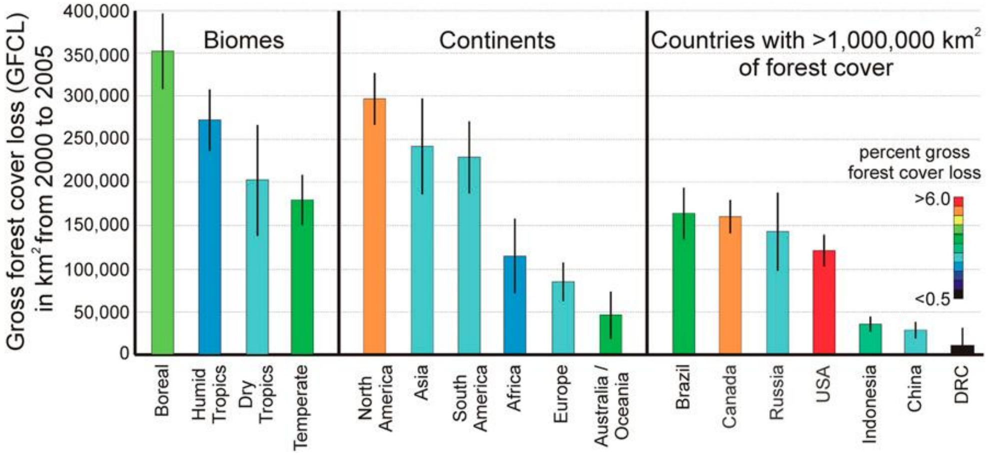
Relying on a globally consistent methodology using satellite imagery to quantify gross forest cover loss from 2000 to 2005—researchers compared results among biomes, continents, and countries, in *Quantification of global gross forest cover loss*[28]. Their findings, summarized in the figure below, reveal that the boreal biome experienced the largest area of gross forest cover loss, followed by the humid tropical, dry tropical, and temperate biomes. Brazil experienced the largest area of gross forest cover loss compared with other countries over the study period, 165,000 km^2, attributed to industrial-scale agricultural clearing, followed by Canada at 160,000

[27] Mackey, Brendan G.; Keith, Heather; Berry, Sandra L. and Lindenmayer, David B. *Green carbon : the role of natural forests in carbon storage. Part 1, A green carbon account of Australia's south-eastern Eucalypt forest, and policy implications.* The Australian National University, Canberra. 2008.

[28] Hansen, Matthew C.; Stehman, Stephen V.; and Potapov, Peter V.: *Quantification of global gross forest cover loss*. PNAS; published online before print April 26, 2010, doi: 10.1073/pnas.0912668107.

km^2. It should be noted that since 2005, Brazil has been successful in reversing that trend, so current rates of deforestation would be lower. The boreal biome's deforestation loss was largely attributed to fires. It is expected that boreal forests will undergo fires, which is a natural part of the ecosystem, however fire is not a natural part of Amazonian forest ecosystems. The second highest amount of gross forest cover loss that occurred in the humid tropics was in western Indonesia and Malaysia, resulting in agro-forestry land uses. The third highest estimated area of gross forest cover loss occurred in the dry tropics biome, made up of largely open-canopied and fire-adapted forests. Primary losses in this biome occurred in Australia and South America (mostly Brazil, Argentina, and Paraguay).

Figure 1 (Hansen et al): Estimated gross forest cover loss (GFCL) by biome, continent, and country (error bars represent 95% confidence intervals for area of gross forest cover loss).



The global forest cover is 3952 million ha, which is about 30 percent of the world's land area. Most relevant for the carbon cycle is that between 2000 and 2005, FAO reports gross deforestation continued at a rate of 12.9 million ha/yr. FAO attributes this to the conversion of forests to agricultural land, as well as the expansion of settlements, infrastructure, and unsustainable logging practices. In the 1990s, gross deforestation was slightly higher, at 13.1 million ha/yr. Due to afforestation, landscape restoration and natural expansion of forests, the most recent estimate of net loss of forest is 7.3 million ha/yr. The loss is still largest in South America, Africa and Southeast Asia[29]. See below for regional specifics:

Table 2: FAO Global Forest Resource Assessment, 2005, Table 9.1: Estimates of forest area, net changes in forest area (negative numbers indicating decrease), carbon stock in living biomass, and growing stock in 1990, 2000, and 2005:

Region	Forest area (mill. ha)	Annual change (mill. ha/yr)		Carbon stock in living biomass (MtCO2)			Growing stock in 2005
	2005	1990-2000	2000-2005	1990	2000	2005	million m3
Africa	63,5412	-4.4	-4.0	241,267	228,067	222,933	64,957
Asia	571,577	-0.8	1.0	150,700	130,533	119,533	47,111
Europe	1001,394	0.9	0.7	154,000	158,033	160,967	107,264
North and Central America	705,849	-0.3	-0.3	150,333	153,633	155,467	78,582
Oceania	206,254	-0.4	-0.4	42,533	41,800	41,800	7,361
South America	831,540	-3.8	-4.3	358,233	345,400	335,500	128,944
World	3,952,026	-8.9	-7.3	1,097,067	1,057,467	1,036,200	434,219

29 FAO 2005 Global Forest Resource Assessment, published 2006. Found at: http://www.fao.org/DOCREP/008/a0400e/a0400e00.htm

2.7 How much carbon is released each year through deforestation and degradation?

The most recent IPCC Assessment Report (Forestry, Chapter 9) estimated emissions from deforestation in the 1990s at 5.8 GtCO2/yr. The proportion of that compared to overall emissions from all carbon sources was originally thought to be in the range of 20%, but that was revised late last year after an analysis titled *CO_2 emissions from forest loss*[30] published in Nature Geoscience, which estimated emissions from degradation of destruction of forests and peat lands amount to around 15 % of CO_2 released by human-caused activities, lower than IPCC estimations. The study looked at revised UN Forest and Agriculture Organization (FAO) estimations of deforestation and degradation and updated satellite-based estimate of deforestation rates, derived from changes in tree cover density in the humid tropics during 2000–2005. Furthermore, the study factored in the substantial increase in carbon emissions from fossil fuel combustion over the same period, making the relative contribution from deforestation and forest degradation smaller than the IPCC estimated. Their estimates thus concluded that deforestation and forest degradation emissions contribute about 12% of total anthropogenic CO_2 emissions, not including peat lands (which are a major source of carbon emissions in Indonesia). In this paper, we combine the IPCC estimates with those derived from the van der Werf, et al research, yielding a range of deforestation and forest degradation contributing between 12 and 20 % of the annual CO_2 emissions.

Due to the volume of Indonesia and Brazil's forest carbon emissions relative to other countries, significantly reversing rates of deforestation via REDD+ would have a profound affect on the amount of carbon emitted globally each year. Indonesia's National Council on Climate Change (NCCC) reports that 80% of Indonesia's 2.3 billion tons of CO^2 emissions per year come from deforestation and degradation, with peat lands contributing 45% of that, and forests contributing the remaining. The NCCC projects Indonesia's emissions will rise 57% to 3.6 billion tons by 2030 without REDD intervention.[31] Brazil follows closely on the heels of Indonesia, with deforestation accounting for 40% of Brazil's gross emissions in 2008. Land use, land-use change, and forestry contributed two-thirds of Brazil's gross CO2e emissions. Avoiding deforestation offers the largest opportunity for greenhouse gas mitigation in Brazil. Under a World Bank-

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[30] van der Werf, G. R., et al, *CO_2 emissions from forest loss, Nature Geoscience,* Vol. 2, November 2009. Found at: www.biology.duke.edu/jackson/ng09.pdf

[31] Indonesia NCCC **Press Release of 27.08.09**.

projected low-carbon scenario for Brazil, avoided emissions from deforestation would amount to about 6.2 Gt CO2e over the 2010–30 period, or more than 295 Mt CO2e per year, significantly decreasing the projected 9,497 Mt CO2e cumulative deforestation emissions over the 20-year period. The Brazilian government aims to reduce deforestation rates by 72% or more by 2017, and has already demonstrated success with its early-action activities.[32]

There are differences of opinion on the magnitude of CO_2 emissions attributed to degradation activities. Forest degradation occurs when carbon emissions from forests are generated without reducing forest cover below 10-30% (the IPCC definition of deforestation is a reduction in crown cover below a minimum threshold varying from 10 to 30%). Degradation emissions are estimated to represent at least 20% of total tropical forest emissions, based on a recent review of regional estimates from all three major tropical forest zones (Amazonia, Congo basin, Southeast Asia), which is double that estimated by the IPCC.[33]

Forest degradation (such as logging, fire, and fuel wood harvest) is often a catalyst leading to deforestation. In many systems degradation such as logging increases the likelihood of additional emissions from degradation (such as fire, as demonstrated in the Amazon) and subsequent deforestation.

2.8 New and existing methods to account for forest carbon, changes to carbon pools, and affects on biodiversity

As demonstrated above, forest carbon accounting is most effective when it moves from a coarse-filter to a fine-filter (i.e. from IPCC Tier 1 to a Tier 3) in specificity and is tailored to local circumstances. Forest carbon accounting methods also need to attune methodologies to best account for particular types of forest-clearing and degradation activity.[34] New methods for detecting major forms of degradation (selective logging and partial canopy fires) using free satellite imagery are beginning to provide credible techniques of measuring and monitoring forest degradation.

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[32] de Gouvello, Christophe et al. *Brazil Low-carbon Country Case Study*. World Bank, 31 May 2010.

[33] Griscom, B., D. Ganz, N. Virgilio, F. Price, J. Hayward, R. Cortez, G. Dodge, J. Hurd, F. L. Lowenstein, B. Stanley. 2009. *The Hidden Frontier of Forest Degradation: A Review of the Science, Policy and Practice of Reducing Degradation Emissions.* The Nature Conservancy, Arlington, VA.

[34] GOFC-GOLD (2009): *A sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals caused by deforestation, gains and losses of carbon stocks in forests remaining forests and forestation.* GOFC-GOLD report version COP-15, Natural Resources Canada, page 2-81.

Techniques and methodologies to differentiate between improved logging practices, as opposed to conventional logging, and more subtle forms of degradation, have not been available until very recently. The accuracy and cost-effectiveness of light detection and ranging (LiDAR) to create a high-resolution carbon map of above ground biomass was recently demonstrated by the Carnegie Institute, World Wildlife Fund, Amazon Conservation Association and Peru's Ministry of the Environment. The project provided estimates of aboveground carbon density at a spatial resolution of 30 meters, making it one of the largest high-resolution biomass mapping studies in the world, and sets a benchmark for future carbon stock assessments globally. This was achieved through use of Carnegie's CLASLite software package that supports regional forest monitoring for REDD, and LiDAR. CLASlite and LiDAR showed that regional carbon stocks are 32.4% lower than the mean Tier I estimate derived from the IPCC Good Practice Guidelines (2006). The new carbon maps show localized areas of higher carbon stocks in some forests than predicted from global mapping approaches, but there are also widespread reductions in biomass attributable to recent deforestation and degradation that was previously undetected without high resolution satellite and airborne LiDAR techniques. While the IPCC Tier I estimates report an uncertainty of 90% or more and do not resolve the natural and human driven variation in carbon density, this demonstration has an uncertainty of 10% and resolves detailed spatial variation in carbon stocks at high spatial resolution.[35]

Once carbon stocks have been adequately measured, REDD+ requires they be monitored, while also maintaining social and ecological co-benefits. Existing forest certification systems, in particular the Forest Stewardship Council (FSC), have already proven their adequacy in delineating high conservation value forest areas, employing effective ground-based auditing of specific logging practices, and offering independent third-party verification of compliance with social and ecological co-benefits. Forest certification in a REDD+ scenario is perhaps most appropriate at a project- and sub-regional level, though growing application of the group-certification process under FSC illustrates the suitability of its application over larger landscapes. FSC certification holds great potential to compliment efforts to measure and verify practices designed to reduce emissions, in combination with forest carbon standards and social and ecological co-benefit standards, and thus can compliment national MRV efforts.[36]

[35] Gregory P. Asner, George V. N. Powell, Joseph Mascaro, David E. Knapp, John K. Clark, James Jacobson, Ty Kennedy-Bowdoin, Aravindh Balaji, Guayana Paez-Acosta, Eloy Victoria, Laura Secada, Michael Valqui, and R. Flint Hughes. *High-resolution forest carbon stocks and emissions in the Amazon*. PNAS 2010 : 1004875107v1-201004875.

[36] This point supported and expanded upon by Griscom, et al (2009).

2.9 The effect of climate change on biodiversity and the role of forests in moderating future climate change impacts

The value of delineated ecoregions[37] in the REDD+ context is that it offers us a sense of the necessary abiotic and biotic features that plant and animal communities require in order to be viable-- in essence, what is needed to maintain biodiversity. While 12% of land globally is in some form of protection, nearly half (44%) of terrestrial eco-regions fall below 10% protection, and many of the most critical sites for biodiversity lie outside protected areas.[38] The value of current protected areas in mitigating and adapting to climate change—via carbon sequestration, disaster relief and supplying human needs—has generally been undervalued, however that is changing.[39] There is a growing body of literature assessing how ecoregions form the basis of assessing future climate change impacts. While natural communities help to buffer the effects of climate change, they are also expected to change in response to climate change. Assessment of minimum distribution and range requirements for important communities and species must form the basis of projections on adaptation and vulnerability to climate change.

It is now well-documented that primary forests are generally more resilient (and stable, resistant, and adaptive) than modified natural forests or plantations, to the effects of climate change. The carbon pool is largest in old primary forests, especially in the wet tropics, which are stable forest systems with high resilience. The regional impacts of climate change, especially interacting with other land use pressures, might be sufficient to overcome the resilience of even some large areas of primary forests, pushing them into a permanently changed state. If forest ecosystems are pushed past an ecological 'tipping point', they could be transformed into a different forest type, and, in extreme cases, a new non-forest ecosystem state (such as from forest to savannah). The Convention on Biological Diversity highlights the example of the Amazon forest as a region particularly at-risk due to the interaction of deforestation, fire and climate change, resulting in widespread dieback and a shift to savanna-like vegetation. The CBD estimates that such dieback becomes much more likely if deforestation exceeds 20 – 30% (it is currently above 17% in the Brazilian Amazon). [40] It would lead to regional rainfall reductions, compromising

[37] For further info and records of all species from each of four taxonomic groups in all terrestrial ecoregions, check out the Wildfinder database at http://gis.wwfus.org/wildfinder/.

[38] Secretariat of the Convention on Biological Diversity (2010) *Global Biodiversity Outlook 3*. Montréal, page 35.

[39] Dudley, N., S. Stolton, A. Belokurov, L. Krueger, N. Lopoukhine, K. MacKinnon, T. Sandwith and N. Sekhran [editors] (2010); Natural Solutions: Protected areas helping people cope with climate change, IUCNWCPA, TNC, UNDP, WCS, The World Bank and WWF, Gland, Switzerland, Washington DC and New York, USA.

[40] Secretariat of the Convention on Biological Diversity (2010) *Global Biodiversity Outlook 3*. Montréal.

agricultural production. There would also be global impacts through increased carbon emissions, and massive loss of biodiversity. It is generally expected that the new 'post-tipping point' ecosystem states would be poorer in terms of both biological diversity and delivering ecosystem goods and services.[41] Please refer to an amalgamation of relevant studies from the tropical regions of the world that quantified the affect of human disturbance on biodiversity by forest type and land use type, on page 23.

Forests can also influence regional climates, depending on their extent and this is particularly true of the Amazon forest. As such, there is an iterative relationship between climate and forests that changes in response to changes in precipitation, temperature and other climate change effects.

Climate change will have impacts on ecosystems and biodiversity. Ecosystem distribution changes are expected to be large and more complex in the tropics, where the effects of rising temperatures and reduced precipitation are exacerbated by the effects of land-use change.[42] Peer-reviewed modeling approaches predict that major changes in global forest cover may occur at temperature rises over 2-3°C, resulting in significant loss of forest towards the end of the century, particularly in boreal, mountain and tropical regions.[43]

[41] CBD Technical Series No. 43: Forest resilience, Biodiversity, and climate change: A Synthesis of the Biodiversity/Resilience/Stability Relationship in Forest Ecosystems, 2009. Found at: http://www.cbd.int/ts/

[42] CBD Technical Series No. 42: Review of the Literature on the Links between Biodiversity and Climate Change – Impacts, Adaptation and Mitigation, found at: http://www.cbd.int/ts/

[43] CBD Technical Series No. 42, p. 15-16.

3. Ranges of human disturbance on forest biomes and the effect on biodiversity

3.1 The effects of human disturbance on forest biodiversity

Biodiversity generally decreases the more forest habitats are disturbed by humans and this is well demonstrated in the literature. The purpose of this section is to consolidate relevant information from across the world's tropical regions, in order to estimate the impacts of human disturbance (spanning the full range between deforestation and degradation activities) on forest ecosystems and the resultant impacts on biodiversity.

Uneven-aged forests stands and mixed tree species within forests have long been identified in the forest management literature as key indicators of biodiversity. Of the 21 peer-reviewed studies considered in the Convention on Biological Diversity Technical Series Report No. 43 published in 2009[44], 76% suggested a positive effect of mixed species (i.e., number of species) on ecosystem production. The CBD report excluded studies using herbicides, thinning, fertilization, and nitrogen-fixing facilitation to eliminate confounding effects. Furthermore, the report references a study in Costa Rica that demonstrated that the multi-species plots developed much higher soil fertility over time than did monocultures, indicating superior production and nutrient retention in complex systems.

The consolidation of findings from these studies provides evidence that more diverse forests are more productive than forests with low species diversity. Further, many studies indicated that carbon sequestration, a frequently measured variable among the studies, is enhanced by the presence of multiple complex levels of functional groups in forests. This again reinforces the premise that biodiversity and carbon storage have a correlation. This notion is further supported by several recent studies showing that complex old-growth forests provide high-value carbon sinks and may continue to do so for centuries in all forest biomes, unless disturbed (For further information, refer to O.L. Phillips *Changes in the Carbon Balance of Tropical Forests: Evidence from Long-Term Plots*, 1998, as it is the most often cited study). Please also refer to the Strassburg et al study (below, on page 30), which offers a spatial comparison of the correlation between biodiversity and carbon values.

[44] CBD Technical Series No. 43: Forest resilience, Biodiversity, and climate change: A Synthesis of the Biodiversity/Resilience/Stability Relationship in Forest Ecosystems, 2009.

A 2002 study in the Brazilian Amazon, *Degradation of forests through logging and fire in the eastern Brazilian Amazon*,[45] evaluated the impacts of forest degradation based on field inventories and plots. The results are striking:

- Logging impacts: moderate intensity logging decreased aboveground biomass by 20%, whereas high intensity logging caused a 48% reduction.
- Impacts of fire: Light burning of moderately logged forest resulted in a total biomass reduction equal to that of high intensity logging. Whereas moderately logged and heavily burned forest had 83% less live biomass than intact forest.
- Increased amounts of coarse woody debris and greatly reduced canopy cover in both heavily logged and heavily burned forests increased the risk of future fires that could further degraded these forests. As more and more logging frontiers in the eastern Brazilian Amazon mature it is likely that repeated logging of previously logged stands will increase, and this combined with the increased flammability of previously burned stands is projected to further increase forest degradation.

Deforestation also makes forests more susceptible to the effects of climate change, such as increasing canopy openings making forests susceptible to other factors such as wind-throw. With respect to mitigating CO_2 emissions from deforestation and degradation, maintaining long-term stable forest ecosystems will be critical, as opposed to for example, rapidly growing simple low diversity forests that have limited longevity, resistance, resilience or adaptive capacity.

3.2 Field-based evidence of ranges of human disturbance on biodiversity in tropical forests

Human disturbance in tropical forests primarily occurs due to land clearing for agriculture, to convert primary forests to plantations, and logging. Biodiversity's response to human disturbance is extremely complex as many factors influence this interaction, such as a species' adaptation potential, the threat of invasives, competition, changes in moisture regimes and a many other factors. Conservation science offers us a very small basis of literature, largely based on peer-reviewed field studies, to evaluate changes in taxonomically diverse groups along gradients of land use within tropical landscapes. The most important aspect of this is quantifying the impacts of *degradation*, which is not as well-studied in the literature as deforestation. The tropical regions of the world are probably the least-studied, and very few pan-tropical studies exist. Our purpose in assembling these study outcomes is to demonstrate the limitations of the species-area relationship applied in modeling the potential impacts of a REDD mechanism on

[45] Gerwing, J., *Degradation of forests through logging and fire in the eastern Brazilian Amazon*, Forest Ecology and Management, Vol 157, 1 March 2002.

biodiversity, and to offer a sense of the complexity involved in estimating the affect of deforestation on biodiversity loss and the probability of REDD reversing those trends.

The results of these studies follow a clear gradient: the Barlow et al (2007) and Schultze et al (2004) studies demonstrate that primary tropical forests are roughly 50% more biodiverse than secondary forests in both tropical wet and tropical montane climate regions, and as human impacts increase, biodiversity dramatically decreases. The most extreme example is the conversion of tropical moist forests in Indonesia for oil palm plantations, where only 15% of primary forest species remain. The land use gradients within each study differed greatly; for instance, Schulze et al. studied a range from natural forests to annual crop fields devoid of trees, while Barlow et al. ranged from natural forests to Eucalyptus plantations. The range of degradation activities has a correspondingly varied impact on biodiversity, none of which can replace the value of primary forests. These studies suggest that different species groups exhibit significantly different responses to logging impacts depending on their life-history strategies and resource requirements. The forest dependent and specialist species decline first, while generalist and omnivorous species are unaffected or even increase in abundance and diversity.

Table 3: Summary of field-based evidence of ranges of human disturbance on biodiversity in tropical forests

Climate region	Total living + dead biomass tC ha-1 (biome default value)[1]	Land use type	Biodiversity values based on study findings	Study and relevant notes
Tropical wet	213	Primary forest	25% species unique to forest Held <100% of primary forest species	Barlow et al (2007)[2] Study area: Jari, north-eastern Brazilian Amazon. Methods: 15 different taxa, patters of biodiversity based on comparison of observed species richness, % of species unique to each habitat type, community turnover between habitats. As old growth surrounded the study area, represents a best case scenario.
		Secondary forest	8% species unique to forest Held 46% of primary forest species	
		Plantation forest	11% species unique to forest Held 39% of primary forest species	
		Agricultural	n/a	
Tropical moist	142	Primary forest	100% primary forest species	Study: Fitzherbert et al (2008)[3]: Compared the biodiversity value of Indonesian oil palm plantations with that of forest and alternative land uses to assess whether biodiversity loss can best be reduced by making plantations more wildlife friendly or by linking yield increases with habitat protection.
		Secondary forest	n/a	
		Oil palm plantation	15% primary forest species	
Tropical dry	105	Primary forest	n/a	
Tropical montane	112	Primary forest	Average: 278	Schultze et al (2004)[4]: Study area: Central Sulawesi, Indonesia, at eastern margin of Lore Lindu National Park.
		Secondary forest	Average: 169	
		Agroforestry	Average: 74	

[1] Source: Keith et al (2009). See table on page 13.

[2] Barlow (2007): Quantifying the biodiversity value of tropical primary, secondary and plantation forests. PNAS, vol. 104 no. 47 and the subsequent Barlow et al (2010): Measuring the Conservation Value of Tropical Primary Forests: The Effect of Occasional Species on Estimates of Biodiversity Uniqueness. PLoS ONE 5(3): e9609. doi:10.1371/journal.pone.0009609

[3] Fitzherbert, E. B., Struebig, M. J., Morel, A., et al. (2008). How will oil palm expansion affect biodiversity? Trends in Ecology and Evolution, 23, 538–545.

[4] Schulze, Christian H. Matthias Waltert, Paul J. A. Kessler, Ramadhanil Pitopang, Dorthe Veddeler, Michael Mühlenberg, S. Robbert Gradstein, Christoph Leuschner, Ingolf Steffan-Dewenter, Teja Tscharntke (2004): Biodiversity indicator groups of tropical land-use systems: Comparing plants, birds and insects. Ecological Applications: Vol. 14, No. 5, pp. 1321-1333.

Notes on methodologies in footnote, below.[46]

4. Quantifying biodiversity loss as a consequence of deforestation and forest degradation and estimating the effect of REDD+

Section 2 of this report summarized the affect of deforestation and degradation on carbon storage and biodiversity, while Section 3 highlighted how human disturbance affects forests, affects their ability to maintain biodiversity, and offered examples of how complex the responses of natural systems are to disturbance. This section seeks to inform our understanding of the affect of REDD+ on biodiversity, first by engaging an economic model to estimate the affect of RED (the model is limited to deforestation only, plus conservation) and complimenting those findings with a recent spatial analysis. It is hoped the combination of the modeling results with field-based patterns described in Sections 2 and 3 will round out an understanding of the relationship between biodiversity and land use and the potential for REDD to safeguard biodiversity values while protecting carbon stocks.

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[46] Notes on methodologies of key studies:

The Schultze et al (2004) study: Took their findings on species richness (true number of recorded species) for each species (understory plants, insectivorous birds, trees, butterflies, birds, endemic butterflies, endemic birds, fruit-feeding butterflies, frugivorous and nectar-feeding birds and dung beetles) and by each habitat type (near-primary forest, old secondary and young secondary forest (were combined), agroforestry, agriculture). For purposes of this report, totals for each species were grouped according to habitat type.

The Barlow et al (2007) study deployed a large international team of researchers to evaluate species richness for 15 taxa in primary forests, 4–5 year old Eucalyptus plantations and 14–19 year old native second- growth, in Jari, northeastern Brazilian Amazonia.

The Fitzhubert et al study (2008) is particularly insightful as global palm oil production increased by 55% between 2001 and 2006, and is expected to increase as demand for edible vegetable oils and biofuels increase. The biodiversity value portion of the study consisted of an extensive literature survey: they found no published studies of plants, but did find 13 of animal species. Oil palm consistently held fewer than half as many vertebrate species as primary forests, however invertebrate taxa showed greater variation.

4.1 Projections of biodiversity loss under a business as usual and historical-adjusted reference level REDD scenario using OSIRIS

The Open Source Impacts of REDD Incentives Spreadsheet (OSIRIS),[47] developed by Conservation International, Environmental Defense Fund, the Woods Hole Research Centre, the Terrestrial Carbon Group, and the University of East Anglia, was used to evaluate how different rates of deforestation affect biodiversity. The absolute estimates OSIRIS generates are subject to caveats [48] and the model does not predict the nuances of how specific taxa respond to land use change, which is a highly complex adaptation and adjustment process, as framed in Sections 2 and 3 of this report. The great value of OSIRIS it its ability to discern the potential impacts different REDD scenarios can have on biodiversity on a global scale, and to evaluate options to optimize biodiversity. Presented below are findings on this analysis, and recommendations on policy options that can optimize biodiversity conservation under REDD.

First, a few notes on model design:

- OSIRIS estimates extinction rates using the species-area relationship ($E_i = S_i \ [1-(1-d_i)^z]$, where E_i represents the rate at which species in country $_i$ become committed to extinction, S_i represents the current number of forest species in country $_i$, d_i represents the deforestation rate (%/year) in country $_i$, and parameter z equals 0.25, from the archipelagic species-area relationship. More accurate estimates of extinctions due to forest loss could be generated based on the spatial pattern of forest loss and distribution of species within countries (see next section on spatial approaches), or taxa-specific response to habitat loss with a species' sensitivity to surrounding matrices of land use types to determine the likelihood of extinction (e.g. the recently published article, "*A Matrix-Calibrated Species-Area Model for Predicting Biodiversity Losses Due to Land-Use Change*," by Koh and Gahzoul, 2010). For purposes of this assessment, we prefer application of the species-area relationship, and encourage evaluation the site-specific research and data presented in Section 3 to offer a robust picture of how biodiversity responds to various types of land use change.
- At Copenhagen in December 2009, the UNFCCC Subsidiary Body on Science and Technical Advice (SBSTA) reached a decision setting national reference levels based on historical data, adjusted for national circumstances. Thus, this OSIRIS exercise used the Combined In-

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[47] Busch, J., B. Strassburg, A. Cattaneo, R. Lubowski, F. Boltz, R. Ashton, A. Bruner, R. Rice, Anna Creed (2009). Open Source Impacts of REDD Incentives Spreadsheet (OSIRIS v3.1). Collaborative Modeling Initiative on REDD Economics. October 2009.

[48] Absolute estimates generated by the OSIRIS model of impacts should be considered uncertain, for several reasons: the model relies on global data sources of varying quality, aggregates certain spatially explicit data to the national scale, has no prior implementation of a global REDD mechanism against which to test model performance, and is sensitive to parameters such as elasticity of demand for frontier agriculture whose values are uncertain. The OSIRIS model includes values to estimate the reduction in extinction rates of endemic, forest-obligate mammal and amphibian species, based on IUCN data. In essence, it uses a focal-taxa approach to demonstrate biodiversity values, and does not reflect the full diversity of biological systems, which would of course include plants, lianas, birds, insects and other species.

> centives design option (developed by Strassburg et al), which adjusts reference levels for countries with historically low deforestation rates upward from historical rates and adjusts reference levels for countries with historically high deforestation rates downwards, in order to incentivize the conservation of carbon stocks in those countries. Model parameters were based on default values with the exception of the design option just mentioned, the commitment period was set for 2000-2005 (FAO), and forest cover based on the Options Assessment Report 2000-2005.[49]

Based on these OSIRIS model design options, the annual finance for REDD of $27 billion (in 2008 US$)[50] would have reduced deforestation by over 66%, reduced emissions from deforestation by almost 72%, and reduced extinctions from deforestation by a maximum of 86%. Deforestation would be reduced in Latin America and Asia by 77%, and African deforestation would decrease by 43%. Decreases in carbon emissions generally correspond, especially in Africa where carbon emissions are reduced 44%. Latin America's emission rates drop 78%. However, Asia's emission rate drops 88% and this drop in emissions exceeding the drop in deforestation is likely due to REDD incentives targeting higher-carbon forests for avoided deforestation.

The extinction rates of forest obligate mammals and amphibians generally correspond with deforestation rates, with extinctions in Latin America dropping by 84% and extinctions in Africa dropping by 49%. However in Asia, extinctions drop by 94%. Generally, the reduction in the extinction rate exceeds the deforestation rate due to the species-area relationship, such that as forest habitat is diminished, each unit of habitat lost becomes more valuable in preventing further extinctions.

Table 4: Estimates of the effect of REDD on deforestation and related extinctions based on OSIRIS modeling

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[49] Parameter values: Market price of carbon (2008 US$/ton CO2), default = $5; permanence scaling factor applied to market price of carbon, default = 1.00 assumes no permanence reduction; fraction of soil carbon eligible for credits, default = 0.10; coefficient on slope of supply curve extensions, default = 0.10; social preference for agricultural surplus relative to REDD surplus, default = 1.00; management and transaction cost, per hectare per year (2008$/Ha/yr), default = $4.20; fraction of national average timber rent included in opportunity cost, default = 1.0; deflator from 2008 US$ to 2000 US$, default = 0.8106, deflator from 2004 US$ to 2000 US$, default = 0.9116; multiplier from annual payments to NPV, default = 9.576; demand= exponential; forest carbon density data source: Reusch and Gibbs (2008); all developing countries included; reference period: FAO 2011-2015; no dynamic updating of forest cover and carbon debt over time; reference level: Weighted average of national and global, with .85 weight on national historical rate and .0058 as global average deforestation rate; forest cover/deforestation rate bins based on Options Assessment Report 2000-2005; biodiversity: z parameter in species-area curve s=cA^z, default = 0.25

[50] The Eliasch Review estimated the finance required to halve emissions to be $17-33 billion per year, so this cost estimate is within that range.

Scenario	Deforestation rate (ha/yr)			Emission rate (ton CO2e/yr)			Extinction rate		
	Africa	Asia	Latin America	Africa	Asia	Latin America	Africa	Asia	Latin America
Business as Usual (without REDD)	4,039,800	3,555,000	4,877,800	2,096,657,314	2,367,578,170	3,146,355,908	0.36	1.87	1.17
With REDD	2,313,312	801,963	1,144,022	1,173,624,249	294,650,226	696,802,006	0.18	0.11	0.19
% reduction due to REDD	-43%	-77%	-77%	-44%	-88%	-78%	-49%	-94%	-84%

Using the OSIRIS model to estimate the effect of REDD on biodiversity, we see that those countries with the highest numbers of forest endemics opt in to REDD, and the corresponding reductions in deforestations and emissions result in almost complete reversals in rates of biodiversity loss. This explains the pattern we see in Table 5 related to high-endemism countries, and the correlation between deforestation and emission rates, and the affect on endemics, in our REDD modeling scenario. The modeling results in a very distinct pattern: countries with the highest rates of endemism (and highest rates of carbon storage) are most likely to participate in REDD and see dramatic reductions in deforestation and rates of biodiversity loss. These countries include Indonesia, Brazil, Madagascar, Mexico, Papua New Guinea, Columbia, Peru and the Philippines. This illustrates a very strong correlation between REDD and biodiversity, especially as we consider that those reversals occur in some of the most at-risk landscapes, such as in Indonesia and Brazil.

Table 5: Correlation between countries with high endemism, deforestation and emission rates as a result of REDD, and the resulting affect on endemics

Countries with high endemism + decreased deforest/emissions	# forest endemics	% reduction deforestation/emissions	% change in biodiversity loss
Indonesia	199	-100%	100%
Brazil	189	-92%	93%
Mexico	168	-96%	96%
Madagascar	156	-94%	94%
Papua New Guinea	122	-100%	100%
Colombia	114	-99%	99%
Peru	97	-100%	100%
Philippines	82	-100%	100%

While REDD decreases deforestation and emissions, each country responds differently based on whether they chose to opt in to REDD and the opportunity costs of land use decisions. As deforestation is decreased in some countries, the amount of land for frontier agriculture decreases, the price of frontier agriculture increases, and the pressure to deforest elsewhere increases. This drives leakage such that a reduction in deforestation in particularly carbon-rich forests could drive some portion of deforestation to low-carbon forests. Thus, Table 6 illustrates those medium-endemism countries in our analysis that either experience increases in deforestation, or for which we have insufficient data but believe leakage could occur. Most notable are the impacts on Tanzania and Bolivia, which experience leakage in our OSIRIS runs, most likely due to low carbon densities and high agricultural returns, resulting in deforestation rates increasing 38% and 139% respectively. It is predicted this would have a corresponding impact on biodiversity, though it should be noted that while many of Tanzania's remaining endemics are concentrated in the forest areas, they are also found in drier bush land and grassland habitats,[51] so may be more adaptable than species only found in forests. Overall, it is noted that, with the exception of Guyana, all countries in Table 6 have smaller fragments of primary forest nested in matrices of low carbon and low biodiversity forest, plantations, and agricultural areas. Bolivia and Tanzania stand out as hotspots-- places with medium-endemism more at risk in a REDD scenario. Further analysis is required, drawing upon the nuances identifiable at a finer-scale of assessment, in order to safeguard the resilience of their remaining forests.

Table 6: Medium-endemism countries, registering an increase in deforestation and emission rates as a result of REDD*

Countries with medium endemism + increased or unknown deforestation/emissions	# forest endemics	% increase deforestation/emissions
Tanzania	38	38%
China	37	n/a
India	35	n/a
Cuba	35	n/a
Dominican Republic	28	n/a
Bolivia	25	139%
Guyana	13	n/a
Vietnam	9	n/a

[51] For more information on the endemic species found in Tanzania's forests, visit: http://www.worldwildlife.org/wildworld/profiles/terrestrial_at.html#moistbroad

* Note: those countries for which we have insufficient data (indicated by n/a in last column) may be at increased risk under REDD due to leakage effects.

It should be noted that the OSIRIS model does not allow for an assessment of the affect of REDD scenarios on countries experiencing afforestation or no change in deforestation rates, as reported in the FAO Global Forest Resource Assessment, 2005. This is due to the model evaluating changes to deforestation rates. The following medium-endemism countries that fall out of the analysis include China, Cuba, the Dominican Republic, Guyana, India and Vietnam. In the FAO Global Forest Resource Assessment 2005, China, Cuba, India and Vietnam reported experiencing afforestation, while the Dominican Republic and Guyana reported no change in deforestation rates. These medium-endemism countries may be at increased risk in a REDD scenario.

In summary, the emphasis of this analysis was placed on tracking the effect of REDD on countries with high endemism, tracking if any high-endemic countries did not participate in REDD (all did participate), and finding the effects of leakage in other countries, which shifted deforestation pressures to some countries with medium forest endemism. Countries with medium endemics with decreased deforestation and carbon emissions under the modeled REDD scenario were not included.

Perhaps of most importance in this analysis is that no high-biodiversity countries opt out of REDD and thus experience high rates of deforestation and biodiversity loss. And while deforestation increases in some places, those are consistently areas with less biodiversity.

4.2 A spatial approach to estimating the impacts of REDD on biodiversity

Only at the end of 2009, with the run-up to the global climate negotiations in Copenhagen (COP 15), were spatial approaches published to assess the crossover between REDD+ and biodiversity conservation. The value of a spatial approach in this context is that all taxa for which global data is assembled can be included in the analysis. A study by Bernardo Strassburg et al titled, *Global congruence of carbon storage and biodiversity in terrestrial ecosystems*[52], published in December 2009 by Conservation Letters, claims to be the first map-based analysis using high-resolution data of the distribution of carbon and biodiversity. The research mapped and investigated potential synergies between carbon in biomass and biodiversity-oriented conservation. This report identifies areas of convergence and divergence between their spatial approach and the OSIRIS model estimates described in the last section.

[52] Strassburg, Bernardo, et al, *Global congruence of carbon storage and biodiversity in terrestrial ecosystems.* Conservation Letters, November 2009. Found at: http://www3.interscience.wiley.com/cgi-bin/fulltext/123216302/PDFSTART

The methods applied in the research apply the new global carbon data set (see Ruesch & Gibbs Carbon Map, 2008). Strassburg et al investigated the congruence between carbon and each of three biodiversity indices: richness (number of species per cell), threat (number of threatened species per cell), and range-size rarity (number of species per cell whose ranges are in the lowest quartile for their class). Congruence between carbon and biodiversity was investigated visually (through maps) and analytically (through correlations). The analysis is at a coarse-scale, using IPCC Tier-1 level data, and while vigorous, it deserves mention that higher-resolution carbon and biodiversity assessments completed at smaller scales should yield more refined results.

The study findings indicate a strong association between carbon stocks and species richness. However, while synergies between carbon stocks and species richness would be high, they would be unevenly distributed. Many areas of high value for biodiversity could be protected by carbon-focused conservation, while others could benefit from complementary funding arising from their carbon content. Some high-biodiversity regions, however, would not benefit from carbon-focused conservation, and could become under increased pressure if REDD+ is implemented. Key concepts in Figure 1 (below) summarized:

- Areas of high congruence between carbon and biodiversity: a) areas of high congruence between carbon and overall species (e.g., the Amazon; Figure 1A), b) threatened species (e.g., Indonesia; Figure 1B), and c) endemic species (e.g., New Guinea; Figure 1C).
- Some areas that did not rank high in carbon and biodiversity values may have already experienced extensive deforestation, and thus remaining natural habitats are concentrated in sparse forest fragments, and each remaining forest fragment may be carbon-rich on a per-forest area basis. Habitat loss means many of these forests' species will be threatened, particularly if their ranges are small. Hence, further analysis at a finer-scale is necessary to move these areas that qualify into the category of small fragments of high value for both carbon and biodiversity, surrounded by a matrix of low carbon and low biodiversity. The research team postulates this is probably true for parts of the Atlantic Forest of South America, the Tropical Andes, and Southeast Asia (those areas in orange/red in Figure 1.b., below)
- REDD+ activities might displace and intensify activities such as agriculture in lower carbon but equally biodiversity-rich locales. Such areas include parts of East Africa and Brazil. This is consistent with our OSIRIS findings, particularly with regards to Tanzania. However, in our OSIRIS modeling, Brazil opts in to REDD+, and thus in-country leakage is not modeled.
- The authors highlight the need to factor in the carbon sequestration potential of primary tropical and temperate forests at a finer-scale of analysis, in order to adequately value different ecosystems for carbon sequestration. As mentioned previously in this report, the congruence between primary forests and biodiversity is high, with the

noted exception of the Congo Basin where bushmeat extraction has diminished the animal biodiversity of primary forests. Further, it should be noted that recent research in Amazonia and tropical Africa[53] demonstrates that old growth forests are increasing their carbon storage (in the African example, the increase was documented over a time period from 1968 to the present), providing evidence that increasing carbon storage in old-growth forests is a pan-tropical phenomenon.

- The research team postulates that biodiversity-rich and relatively carbon-poor regions could suffer from a "double conservation jeopardy," with conservation investment diverted away from them, and human pressure redirected toward them, as carbon- rich areas become the focus of conservation efforts. Areas potentially at risk include some that are widely recognized as global biodiversity conservation priorities such as the Brazilian Cerrado, the Cape Floristic province, and the Succulent Karoo.

Strassburg et al, Figure 1: Global congruence between biomass carbon and overall species richness (A), threatened species richness (B), and restricted-range species richness (C). The two-dimensional color scale used displays both the concentration of biomass carbon and biodiversity and the congruence

[53] Lewis, S.L., Lopez-Gonzalez G., Sonke B. et al. (2009), Increasing carbon storage in intact African tropical forests. Nature 457, 1003–1006. Found at: http://www.nature.com/nature/journal/v457/n7232/abs/nature07771.html

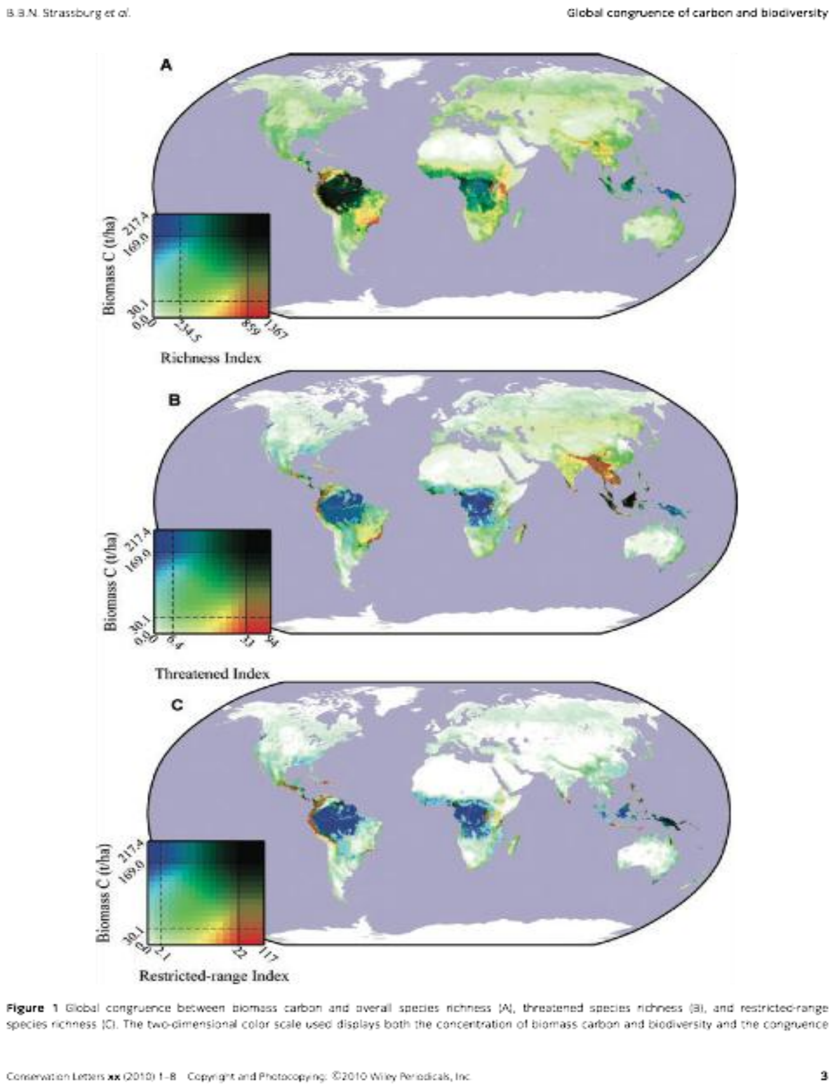
B.B.N. Strassburg *et al.* Global congruence of carbon and biodiversity

Figure 1 Global congruence between biomass carbon and overall species richness (A), threatened species richness (B), and restricted-range species richness (C). The two-dimensional color scale used displays both the concentration of biomass carbon and biodiversity and the congruence

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Policy recommendations stemming from this analysis include:

- Apply a biodiversity premium for emissions from more biodiversity-rich areas directly into the REDD+ mechanism, by setting aside a fraction of REDD+ financing for targeting biodiversity-rich areas that would not be conserved for their carbon content alone (Strassburg et al. 2009),
- Promote cooperation between programs for REDD+ and conservation at a national to international scale, redirecting conservation funding to these areas (a concept attributed to Grainger et al. 2009).

5. How can biodiversity values be reflected in a REDD+ mechanism?

REDD+ has great potential to safeguard the most biologically-rich forests of the world. Our OSIRIS analysis demonstrates that that those countries with the highest biodiversity (measured by forest endemics) opt in to REDD, and thus the corresponding reductions in deforestation and emissions result in almost complete reversals in rates of biodiversity loss in those countries. Within forests of identical carbon stock, prioritization of REDD implementation should occur in forests of greatest biodiversity value, and which contribute most to landscape connectivity. Voluntary carbon markets already include biodiversity as a valued co-benefit of REDD projects, as forest carbon projects with multiple ecosystem services, certified and monitored as such, are viewed as safer investments. The challenge ahead is to ensure compliance markets for REDD+ carry that same commitment to social and ecological co-benefits. Below is a summary of key policy recommendations and actions that will support the biodiversity co-benefits of a REDD+ mechanism, followed by a brief investigation into the inclusion of biodiversity co-benefits in both voluntary and compliance forest carbon markets.

5.1 Policy recommendations and actions that will support the biodiversity co-benefits of a REDD+ mechanism

An effective REDD+ mechanism holds great potential to limit carbon emissions from destructive land uses and reverse the effects of climate change. REDD+ can also significantly address tropical biodiversity conservation, by:

1. **Preference should be given to those REDD+ projects or programs that include biodiversity conservation as a key objective**: While the payments for reductions in emissions will be based on the amount of carbon not released into the atmosphere, a side-benefit is that we protect biodiversity in the process.

2. **The carbon carrying capacity of primary forests must be properly accounted for, and methodologies to measure and monitor carbon stocks should be pursued at highest resolution and include biodiversity as an attribute**: Carbon accounting schemes must be robust, strive for IPCC Tier-3 resolution at a fine-scale, and adequately account for a forest's natural carbon carrying capacity (including living and dead biomass and soil). The accuracy and cost-effectiveness of light detection and ranging (LiDAR) to create high-resolution carbon maps of above ground biomass is a proven means to achieve that, and holds great potential to include measurements and monitoring of biodiversity.

3. **REDD+ strategies at the national and sub-regional level should be integrated with associated climate change adaptation strategies and protected area networks**: Assessment of minimum distribution and range requirements for important communities and species must form the basis of projections on adaptation and vulnerability to climate change, and this should be incorporated into national-level REDD monitoring, reporting and evaluation activities.

4. **Conserving forests, even if they are currently not threatened, has a strong mitigation benefit**: Including forest conservation as a mitigation option within REDD+ is very important for biodiversity conservation, particularly for high forest cover, low deforestation countries, as it will create incentives for countries to conserve large areas of forests even if current drivers of deforestation do not threaten these areas. Countries that have smaller fragments of primary forest nested in matrices of low carbon and medium- to low-biodiversity forests, plantations, and agricultural areas will need to pursue a mix of incentives, including REDD, to keep primary forests intact.

5. **Existing forest certification systems, such as the Forest Stewardship Council, can be complimentary to REDD and should be promoted:** In particular, FSC employs ground-based auditing of specific logging practices, and offers independent, third-party verification of compliance with social and biodiversity co-benefits. It is potentially very compatible with REDD+ in its' ability to assist measurement and monitoring practices designed to reduce emissions, and thus could compliment national MRV efforts. Explicit links should be developed between existing forest management standards (such as FSC) and forest carbon standards (such as the Voluntary Carbon Standard) and social and ecological co-benefit standards (such as Climate, Community and Biodiversity Alliance standards).

6. **The Climate, Community and Biodiversity (CCB) and Voluntary Carbon Standard (VCS) standards should be promoted** in the voluntary market, and their principles and indicators transferred to the compliance market as requirements.

7. **REDD+ compliance markets need to incorporate consideration of co-benefits:** This is achievable via the point above, and in addition: 1) preferential demand, similar to supply agreements, where a credit buyer or government expresses interest in credits with multiple co-benefits, and 2) the supply of multiple co-benefit projects be promoted at regional and national levels, with the help of the engagement of civil society and added capacity and technical support to bring projects and deals to maturation, in order to ensure transaction costs are lowered but standards remain high.

5.2 Should REDD+ include biodiversity premiums?

Should the design of a REDD mechanism include provision of payments for co-benefits of REDD forest carbon projects, such as biodiversity conservation? Some have referred to this as a biodiversity premium, defined as a payment over and above the payment for avoided deforestation. Externalities such as watershed protection, biodiversity protection, economic development and community- or aboriginal-benefit-sharing are not currently included in market transactions that are limited to payments for not releasing forest carbon (though they are viewed as important indicators of being lower-risk investments; more on that below). Payments for ecosystem services, including biodiversity, watershed protection, and carbon, offer an important method of compensating parties to avoid destructive land uses that affect our global climate. However, stacking ecosystem service payments would have the effect of overpaying to safeguard the resource. The payment to leave a forest standing should be enough to protect most other ecosystem services in the forest. Forest carbon projects are not considered viable unless additionality can be proved-- meaning it must demonstrate it is 'additional to' the business-as-usual scenario in order to represent a net environmental benefit. As viable forest carbon projects should protect the carbon storage and therefore the integrity of the forest, the accompanying biodiversity protections could not be argued to be additional (unless, for instance, a forest carbon project area was increased in order to capture a biodiversity-rich and low-carbon forest area). Careful consideration should be given to cases of carbon offset values not being great enough to compete with alternative high-value land uses (such as oil palm or mining).

The voluntary marketplace for forest carbon does place greater value on multiple ecosystem services, which we'll explore more in a moment. The reason for this is not that multiple buyers are willing to buy discrete ecosystem services generated by a forest carbon project, but rather that forest carbon projects with multiple ecosystem services, certified and monitored as such, are safer investments. This is similar to the price and risk correlation in the bond market, where 'AAA' bonds carry a higher price than risky 'C' rated bonds. Below we'll explore why voluntary markets are willing to recognize greater value in multiple ecosystem service forest carbon projects, why compliance forest carbon markets will likely not display a willingness to pay more, and how biodiversity can best be served in this voluntary and compliance forest carbon market context.

5.3 Why do voluntary carbon markets recognize biodiversity values?

The voluntary carbon market already includes biodiversity as a valued co-benefit of some REDD projects, and that value is conveyed via the quality of the project. The quality of the project is largely determined by whether it has met independent, third-party standards. Projects that have sought out voluntary certification are seen as less risky for investment and thus voluntary certification is a major determinant of the prices of voluntary carbon credits. In essence, investors are willing to pay a price premium for a high quality carbon offset. Quality assurance has been of critical concern in the emerging forest carbon market, especially as investors recently experienced a collapse in confidence in the monetary and banking system as a result of the US sub prime mortgage market.

The Ecosystem Marketplaces' *State of the Voluntary Carbon Markets 2009*[54] report stresses that standards are increasingly utilized for establishing quality benchmarks and consistency, with the Over the Counter (OTC) forest carbon offsets market exhibiting an intensifying use of standards, particularly those that emphasize the co-benefits of forest carbon projects and third-party verification. Together, the top three standards (VCS, Climate Action Reserve and Gold Standard) verified 69% of credits on the market in 2009.

The verification standard used has a large effect on forest carbon credit prices. Generally, the Climate, Community and Biodiversity, the Gold Standard, and California's Climate Action Reserve are commanding the highest prices, reflecting their wider consideration of project benefits and impacts than other standards. Presumably, any post-Kyoto compliance market for REDD credits would base its standards on those already accepted and in use in the voluntary carbon market.

The most appropriate examples for forest carbon projects are the Climate, Community and Biodiversity (CCB) and Voluntary Carbon Standard (VCS) standards. The VCS verifies and issues credits, and includes consideration of biodiversity values but it is limited to demonstration of the greenhouse gas mitigation project not impacting native ecosystems and does not include the robust project design criteria present in the CCB.[55] The CCB standard offers a set of

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[54] Found at: http://www.ecosystemmarketplace.com/

[55] "The VCS does not wish to provide potential perverse incentives for the clearing of native ecosystems in order to generate carbon credits from AFOLU activities. Therefore, in order to be eligible for crediting under the VCS, ARR and ALM project proponents must demonstrate that the project area was not cleared of native ecosystems, such as forests, grasslands, scrublands or wetlands, to create VCUs. Such proof is not required if such clearing or conversion

project- design criteria for evaluating land- based carbon mitigation projects and their community and biodiversity co- benefits.[56]

5.4 Steps to ensure compliance forest carbon markets recognize biodiversity values

Regulatory or compliance carbon markets are expected to behave differently from voluntary markets for forest carbon. Current compliance markets (i.e. Kyoto markets and regional regulatory markets) contain very few forestry credits due to restrictive regulations regarding the CDM. What existing compliance carbon markets demonstrate, however, is that buyers are primarily motivated by complying with regulations and minimizing their cost to do so. Thus, these buyers are not expected to be willing to pay more for high-quality credits, as presumably the regulated credits are less risky and purchase of them will not generate good press or other benefits enjoyed by companies paying more for high-quality credits in the voluntary market.

So, how can compliance markets be expected to incorporate consideration of co-benefits such as watershed protection, biodiversity protection, economic development and community- or aboriginal-benefit-sharing? There are three likely methods, and the most likely future scenario involves all three: 1) market standards, which incorporate principles already in practice in the voluntary market such as certification standards and eligibility requirements, 2) preferential demand, similar to supply agreements, where a credit buyer or government expresses interest in credits with multiple co-benefits, and 3) the supply of multiple co-benefit projects be promoted at regional and national levels, with the help of the engagement of civil society and added capacity and technical support to bring projects and deals to maturation, in order to ensure transaction costs are lowered but standards remain high.

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took place at least ten years prior to the proposed VCS project start. The burden of proof rests with the project proponent (page 7 of Guidance for AFOLU projects)".

56 "The project must generate net positive impacts on biodiversity within the project zone and within the project lifetime, measured against the baseline conditions. The project should maintain or enhance any High Conservation Values (identified in the original condition of the project area) present in the project zone that are of importance in conserving globally, regionally or nationally significant biodiversity. Invasive species populations must not increase as a result of the project, either through direct use or indirectly as a result of project activities. Projects may not use genetically modified organisms (GMOs) to generate GHG emissions reductions or removals (pages 28-31 of CCB Standards, Second Edition , December 2008)."