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THE ECONOMIC CASE FOR LANDSCAPE RESTORATION IN LATIN AMERICA

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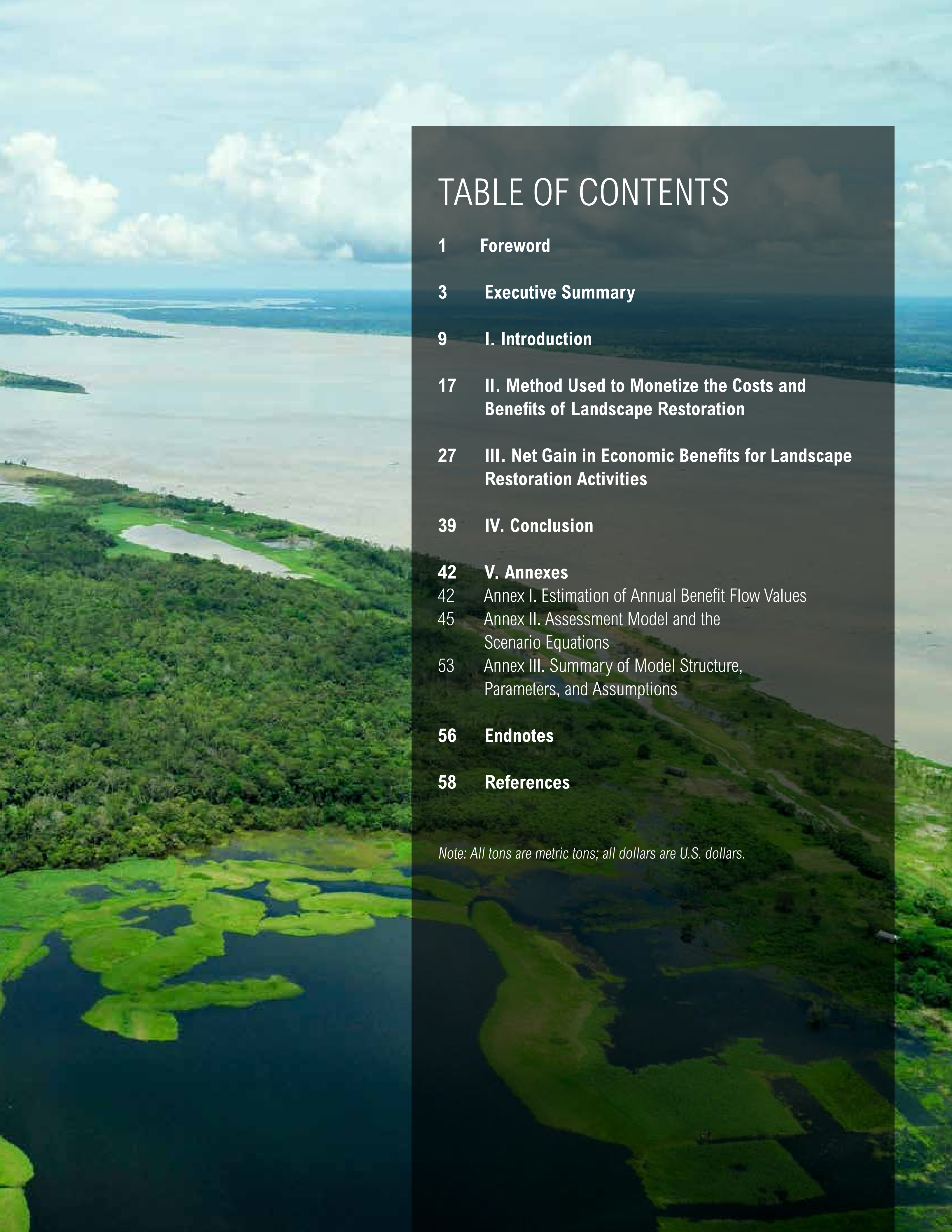

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Note: All tons are metric tons; all dollars are U.S. dollars.

FOREWORD

Land use and land-use change are central to the economic and social fabric of Latin America and the Caribbean, and essential to the region's prospects for sustainable development. Countries are realizing that now, more than ever, is the time for action. Eleven countries, three Brazilian states and several regional programs have already committed to restoring more than 27 million hectares of degraded land in Latin America—but can these ambitions become a reality while supporting good living standards and economic development?

Agriculture and forestry exports from Latin America represent about 13 percent of the global trade of food, feed, and fiber and account for a majority of employment outside large urban areas—numbers only expected to grow as Latin America is called upon to meet an increasing global demand for food. Yet, since the turn of the century, about 37 million hectares of natural forests, savannas and wetlands have been transformed to expand agriculture. Cumulative, unsustainable land-use practices have led to the degradation of about 300 million hectares, resulting in a reduction in yields and quality of production, and in losses in biomass content, soil quality, surface water hydrology, and biodiversity. Deforestation, land-use change, and unsustainable agricultural activities are also currently the largest drivers of climate change in the region, accounting for 56 percent of all greenhouse gas emissions. Today, while some progress has been achieved, the rate of deforestation remains high at an average 3.4 million hectares per year, equivalent to about 70 percent of the land area of Costa Rica. These trends cannot continue.

Landscape restoration, landscape management techniques, and low-carbon sustainable agriculture offer opportunities to reverse some of these losses. Land restoration has the potential to contribute to improved agricultural yields in degraded lands, contain biodiversity losses, contribute to increases in carbon stocks, and secure gains in soil and water quality.

Can these processes yield financial and economic benefits? The report attempts to answer the question at a regional level in the context of Initiative 20x20, a country-led initiative to restore 20 million hectares of degraded land in Latin America and the Caribbean by 2020. The report monetizes the anticipated benefits from improvements in agricultural outputs from sustainable land management practices, the wood and non-wood products from sustainable forestry activities, along with related co-benefits, such as ecotourism, and reductions in food security costs that can be monetized. The results indicate that the answer to this question is a resounding yes—sustainable land use and restoration can lead to outstanding financial and economic benefits.

The analysis and conclusions provided in this report need to be considered as a first but necessary step to motivate and support decision-making and actions on land restoration in the region. We trust that this preliminary analysis will invite subsequent analytical efforts to improve and strengthen its results.

Land restoration in Latin America is an urgent business. This report suggests that it can also be an attractive business.

Andrew Steer
President and CEO
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EXECUTIVE SUMMARY

Degraded lands—lands that have lost some degree of their natural productivity through human activity—account for over 20 percent of forest and agricultural lands in Latin America and the Caribbean. Some 300 million hectares of the region's forests are considered degraded, and about 350 million hectares are now classified as deforested. The agriculture and forestry sectors are growing and exerting great pressure on natural areas. With the region expected to play an increasingly important role in global food security, this pressure will continue to ratchet up. In addition, land degradation is a major driver in greenhouse gas emissions in the region. Forest and landscape restoration can offer a solution to these increasing pressures.

Landscape restoration is a process that improves the functionality of degraded forest and agricultural lands, allowing these areas to deliver a fuller set of benefits. Through Initiative 20x20, countries in the region are aiming to begin restoration of 20 million hectares of degraded land by 2020. A country-led effort launched at the 2014 climate change conference in Lima, the initiative recognizes the varying degrees of land degradation in the region and the range of approaches that may contribute to recover land functionality.

While momentum for restoration is growing, putting a price on the value of a restored landscape is a challenging task. This paper is an attempt to fill this gap by monetizing the benefits that would flow from restoring 20 million hectares of the region's degraded lands.

The study only considers those benefits that can be monetized with relative ease, namely wood forest products, non-wood forest products, agricultural outputs, ecotourism, carbon sequestration, and avoided costs of food security (Table ES–1). Given data and methodological limitations, we do not include other societal and ecosystem benefits from landscape restoration, such as improvements in, or avoided losses of, biodiversity, soil conservation, and surface hydrology. Furthermore, given the lack of reliable estimates on the regional and global implications[1] of alternative land-use practices, we chose not to rely on estimates using the "willingness-to-pay" approach.

Restoration can yield substantial net benefits

A successful effort to restore Latin America and the Caribbean's degraded forests, savannas, and agricultural landscapes—one with the scope and character of Initiative 20x20—would result in substantial net economic benefits. Specifically, such an effort would yield an estimated net present value (a comparison of the amount invested today to the present value of future returns) of about $23 billion over a 50-year period. On a per hectare basis, the average regionwide benefit, measured in net present value, would equal about $1,140.

This estimate is based on a number of assumptions, including a 3 percent discount rate and a carbon market value of $5 per ton of carbon dioxide (CO_2). If discount rates vary between 1 percent and 7 percent, while maintaining the cost of $5 per ton of CO_2, the net present value ranges between $2,500/ha and about $100/ha. Similarly, if the cost of carbon ranges from $0 to $20 per ton of CO_2 and the discount rate remains at 3 percent, the net present value varies from about $900/ha to about $3,300/ha.

Under the assumptions used, the benefits from agricultural outputs account for the largest net gain in net present value, closely followed by carbon revenues and non-wood forest products (Table ES-1).

Table ES–1 | Average net present value of a program to initiate restoration of 20 Mha of degraded land in Latin America and the Caribbean by 2020 ($/ha)[a]

WOOD FOREST PRODUCTS[b] Products that imply a reduction, albeit temporary, in the standing forest biomass; a long rotation cycle of 40 years for wood products is used.	170
NON-WOOD FOREST PRODUCTS Products that do not necessarily affect the standing forest; for example, medicinal and animal products, fruit, nuts, and other tree crops.	245
ECOTOURISM INCOME Income from forest-generated tourism revenues.	161
AGRICULTURAL PRODUCTS Net gains in productivity from key staple crops—using maize, soy, wheat as representative of a mix of agricultural products. This benefit assumes the deployment of sustainable practices and mosaic approaches that integrate trees into mixed-use landscapes, such as agricultural lands and settlements.	274
AVOIDED FOOD SECURITY COSTS Avoided agricultural insurance premiums resulting from enhanced output as a proxy of agricultural losses.	19
CARBON SEQUESTERED The valuation of carbon stocks stored in vegetation of restored landscapes.	270
TOTAL (ROUNDED)	**1,140**

Notes: a. The study assumes that 20 million hectares (Mha) under restoration are distributed across biomes with varying degrees of degradation found across the region (wet biomes are 51 percent of degraded lands in the region; dry biomes are 48 percent; temperate biomes are 1 percent) or are assumed to be distributed across the region's degraded landscapes (lightly degraded landscapes are 34 percent; moderately degraded are 58 percent; and severely degraded are 8 percent). The assessment assumes that Initiative 20x20 will result in reforestation of 13 million hectares, and improved land functionality on 7 million hectares of agricultural landscapes. b. Although wood forest products are considered to be one of the benefits of restoration, in this study we considered their monetization—based on short rotation periods and cutting methods associated with temperate lumber operations—to be less consistent with the long-term goal of land restoration. Instead, the analysis uses a 40-year cycle (similar to the estimates used for monetizing temporary carbon storage credits), thus dampening the expected stream of revenues from wood forest products in the assessment's projections.

Landscape restoration is a process that improves the functionality of degraded forest and agricultural lands, allowing these areas to deliver a fuller set of benefits. Through Initiative 20x20, countries in the region are aiming to begin restoration of 20 million hectares of degraded land by 2020.

The net gain in benefits varies depending on the site of the restoration

The average net present value for restoration depends on the type of biome. In wet biomes, it is about $1,700/ha, and in dry biomes, about $600/ha. Other assumptions considered include the set of benefits from restoration that are being taken into account, the time in which they are accrued, and the magnitude of losses in productivity from degradation.

In general, higher gains are calculated from restoration of wet (or tropical and subtropical moist broadleaf forest), severely degraded lands—implying a comparatively better return from policy actions and investments under these conditions. The lowest gains are anticipated from restoration processes in dry (tropical and subtropical dry broadleaf forest, and tropical and subtropical grasslands, savannas, and shrublands), moderately degraded lands.

Large-scale restoration would reduce emissions from land-use change and agriculture

If the goals of Initiative 20x20 are met, it would result in a net storage of about 1.3 gigatons (GT) of carbon (C) or 4.8 GT of CO_2e over 50 years, as well as an average annual addition to stocks of about 0.063 GT of C per year (or 0.23 GT of CO_2e) during the first 20 years.

Landscape restoration in Latin America and the Caribbean, if conducted at a sufficiently large scale, presents an economically attractive opportunity to slow agricultural expansion, counteract land degradation and deforestation, and maintain the provision of ecosystem services and biodiversity, all while generating income in rural landscapes. Further, landscape restoration is likely to be the central piece of any effort to reduce carbon emissions in the regional economy. The ability of the region to sustain a low-carbon development path hinges on current efforts to reduce carbon emissions from land-use change and other agricultural activities (Vergara et al. 2015). If large-scale land restoration efforts were successful, the region would achieve an important step in this direction.

This report is not intended to provide information at a project scale or even a subnational level; rather, it focuses on regionwide average costs by biome. It is a first-cut attempt to arrive at an estimate of the net present value of large-scale restoration in Latin America and the Caribbean. Feedback that could help refine the analysis is welcome. Improved estimates will be available as part of studies being conducted for specific regions of interest within the countries of Initiative 20x20.

SECTION I

INTRODUCTION

In large areas of Latin America and the Caribbean, unsustainable land practices have resulted in degraded landscapes that fail to deliver the complete set of economic benefits possible under pristine or sustainably managed conditions. Landscape restoration offers an opportunity to reclaim these lost benefits.

BOX 1 | KEY TERMS

Degraded lands are those that have lost through human activities the structure, function, species composition, or productivity normally associated with a natural forest type expected on that site

AGROFORESTRY: A production system integrating crop and forest components through a combination of tree species and agricultural crops.

AGROPASTURE: A production system integrating crop and livestock components in rotation, combination, or succession in the same area and same crop.

SILVOPASTURE: A production system integrating livestock and forest components in combination.

PASSIVE (NATURAL) REGENERATION: The reestablishment of vegetation or increased tree cover through spontaneous successional processes. It occurs in an ecosystem after removing the source of disturbance.

ASSISTED REGENERATION (OR REFORESTATION): Accelerating the process or attempting to change the trajectory of succession via human interventions—for example, tree planting—beyond merely removing a source of disturbance.

Restoration is the process of improving forest and agricultural land functionality, or the ecosystem functions of degraded land. It can be pursued through a range of methods, including passive (or natural) regeneration, assisted reforestation, and landscape management approaches such as agroforestry.[2] Other key terms related to restoration are defined in Box 1.

Initiative 20x20 is a country-led effort to change the dynamics of land use in the Latin America and Caribbean region. Its goal is to bring 20 million hectares (Mha) into the process of restoration by 2020. This target is equivalent to an area the size of Uruguay and covers nearly 15 percent of the Bonn Challenge, a global initiative to restore 150 million hectares by 2020. The initiative supports sustainable climate-resilient agricultural practices (including agroforestry, agro pastures, silvopastoral activities, and improved agriculture); assisted or natural reforestation; and avoided deforestation. It seeks to help countries access the financial and technical resources needed to transition to sustainable land-use practices on degraded land (Box 2).

This report assesses the economic costs and benefits of landscape restoration in Latin America and the Caribbean by monetizing a set of benefits that could flow from 20 million hectares of restored lands. The introduction highlights some of the drivers and impacts of degradation in the Latin America and Caribbean region. The section that follows presents an overview of the method used to monetize the benefits of landscape restoration; detailed descriptions of the methodology and modeling approach are available in the annexes. Next, we present the results—the estimation of net economic benefits from restoration and the different values for biomes and degree of restoration. Finally, we suggest areas where future analysis could provide more location-specific financial estimates.

Agriculture and forestry play an important role in the economy and social fabric of Latin America and the Caribbean

While economic activity in Latin America and the Caribbean has diversified, agriculture and forestry remain central to the region's economy. These sectors contributed 5 percent of the region's gross domestic product (GDP) in 2012, and represent the key economic activity in its rural and small urban communities. The region's aggregate output of agricultural production is estimated to have surpassed $300 billion in 2012 (World Bank 2013), driven largely by increases in the value of agricultural commodities, but also by productivity gains and increases in the area under production.

Globally, the Latin America and Caribbean region is expected to play an increasingly important role in food security as a leading producer and exporter of agricultural commodities. For example, the region is currently the main producer of sugar, soybeans, and coffee in global markets, supplying over 50 percent of worldwide exports of these commodities (FAO 2015). Furthermore, agricultural exports account for 23 percent of the region's total exports and contributed about 11 percent of the global trade in food, feed, and fiber in 2013 (IDB 2014).

BOX 2 | INITIATIVE 20X20

Initiative 20x20 was launched at the 20th Conference of the Parties to the UN Framework Convention on Climate Change in December 2014. It is supported by the restoration programs of Argentina, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Peru, and several Brazilian states. It also includes three regional programs, namely Bosques Modelo, Conservacion Patagonica, as well as the restoration program of the American Bird Conservancy.

In concert with the initiative, more than $1.15 billion has been earmarked for land restoration in Latin America by impact investment funds—Althelia Fund, Andes Amazon Fund, EcoEnterprises Fund, Forestry and Climate Change Sub-Fund, Moringa Partnership, Permian Global, Rare, and Terrabella Global—and other investors—Amazon Reforestry Fund, Carana Corporation, EcoPlanet Bamboo, and SLM Partners.

The initiative's technical partner institutions include World Resources Institute, CIAT, CATIE, IUCN, Bioversity International, CIFOR, CIMA, Conservation International, FAO. Fundacion Agreste, Fundacao Amazonas Sustentavel, ICRAF, Instituto Alexander von Humboldt, Instituto Centro de Vida, International Foundation for Ecological Restoration, Natural Capital Project, Reforestamos Mexico, Oro Verde Foundation, Rain Forest Alliance, and SNV.

Further information can be found at www.Initiative20x20.com.

In addition, millions of people in the region rely to some extent on agriculture and forestry for their livelihood. The agricultural share of total household income reaches over 50 percent among poor rural households in several countries.[3] Across the region, these activities accounted for 19 percent of the male labor force and 9 percent of the female labor force during the 2008–11 period, reaching levels of employment above 50 percent outside large urban centers (World Bank 2013).

The expansion of cultivated land and unsustainable forestry activities has come at the expense of losses in natural grasslands, primary forests, and savannas.

A key factor behind the growth in agricultural and forestry output has been the conversion of natural lands into production. For example, 37 million hectares of the region's natural forests and grasslands (an area nearly the size of Paraguay) were converted into agricultural land between 2001 and 2012 (FAOSTAT 2014). This is another chapter in a long trend: between 1980 and 2000, Latin America relied predominantly on clearing intact forests for new agricultural land (Gibbs et al. 2010).

Furthermore, the 43 percent increase in cultivated land area observed in Argentina, Bolivia, Chile, Paraguay, and Uruguay between the cropping cycles 2000/01 and 2010/11 came mainly at the expense of savanna and forest landscapes (FONTAGRO-BID 2014). An area slightly larger than Costa Rica—5.4 million hectares—has been converted from cerrado or rainforests to soybean cultivation in the agricultural-based states of Goias, Mato Grosso, and Mato Grosso do Sul in Brazil (Chomitz et al. 2007). While a trend toward expansion of production in degraded pastures is emerging, soybean cultivation continues to exert pressure on natural lands in Brazil (MERCOPRESS 2013).

Even though considerable scope remains to expand the land area under production in the region (in terms of availability of potential arable land and freshwater), further agricultural conversion will conflict with, and undermine, land conservation goals and efforts to avoid deforestation. These conflicts can be managed, however, if they are carefully addressed and the expansion of agricultural activity is directed toward already degraded lands.

Land degradation and deforestation are already affecting the region's production capacity.

Degraded lands—lands that have lost some degree of their natural productivity due to human-caused processes—now represent over 20 percent of forest and agricultural lands in Latin America and the Caribbean (Bai et al. 2008). Approximately 300 million hectares of forest lands are classified as degraded forests, woodlands, and savannas (Minnemeyer et al. 2011; Potapov et al. 2011a). In addition, some 350 million hectares are classified as deforested lands (Potapov et al. 2011b). Throughout the region, deforested lands constitute some 21 percent of all original forest lands (Potapov et al. 2011a) and represent an additional target for land restoration opportunities.

Applying the proxy analysis of the Global Assessment of Human-induced Soil Degradation (Oldeman et al. 1991) and soil degradation data (Bai et al. 2008), it can be assumed that 34 percent of the degraded forest and agricultural lands in Latin America and the Caribbean are "lightly degraded" and suffer from an overall ecosystem productivity loss of 10 percent; 58 percent are "moderately degraded" with a corresponding overall productivity loss of 25 percent; and 8 percent are "severely degraded," with an average productivity loss of 50 percent (Daily 1995).[4]

Moreover, land degradation has been estimated to negatively impact the economy at a rate of 3 to 7 percent of annual agricultural GDP, and from 0.4 to 12.5 percent of annual total GDP in a number of countries. Evidence also indicates that the investment needed for restoration is an order of magnitude smaller than the costs that result from degraded land (Berry et al. 2003; Low 2013).

Land degradation contributes to the loss of ecosystem services

Besides the direct financial impact, land degradation affects natural capital—that is, the stock of natural resources that supports the production of goods and ecosystem services. The Latin America and Caribbean region's 1.6 billion hectares of forest and woodland landscapes are found predominantly in subtropical and tropical wet and dry forest biomes. The region has some of the world's most critical reservoirs of tropical forests, cloud forests, and mangroves, which are associated with multiple ecosystem services. It is home to unique ecosystems and habitats that provide key environmental services for economic activities and crucial sustenance for many species. As degradation progresses, soil, hydrology, biomass, biodiversity, and climate in affected lands are all negatively affected.

The Amazonian rainforest, for instance, plays a crucial role as a climate regulating system. Temperature increases and disruption in the energy and water cycles could gradually transform the Amazon rainforest to savanna (Marengo et al. 2011).

Tropical agriculture and forestry may be particularly vulnerable to climate impacts.

Tropical agricultural activities and forests may be particularly vulnerable to soil temperature increases, air temperature increases, and other physical impacts induced by climate change (Vergara et al. 2014). For example, in some plant species, photosynthetic activity becomes less efficient at high temperatures (Hertel et al. 2010; Turnbull et al. 2002). The loss of native vegetation cover, typical of degradation processes and agricultural expansion, contributes to incoming solar energy increasing latent heat and contributing to net increases in soil temperature. Likewise, deforestation-induced change in average temperature and precipitation has been reported to reduce agricultural productivity or shift areas where a particular crop can be grown (Lawrence and Vandecar 2015). Most importantly, decreases in top soil moisture combined with higher soil temperatures are thought to contribute to reductions in the carrying capacity of biomass in humid tropical areas and set up dieback conditions, where the rainforest gradually turns into drier biomes (Marengo et al. 2011; Vergara and Scholz 2011).

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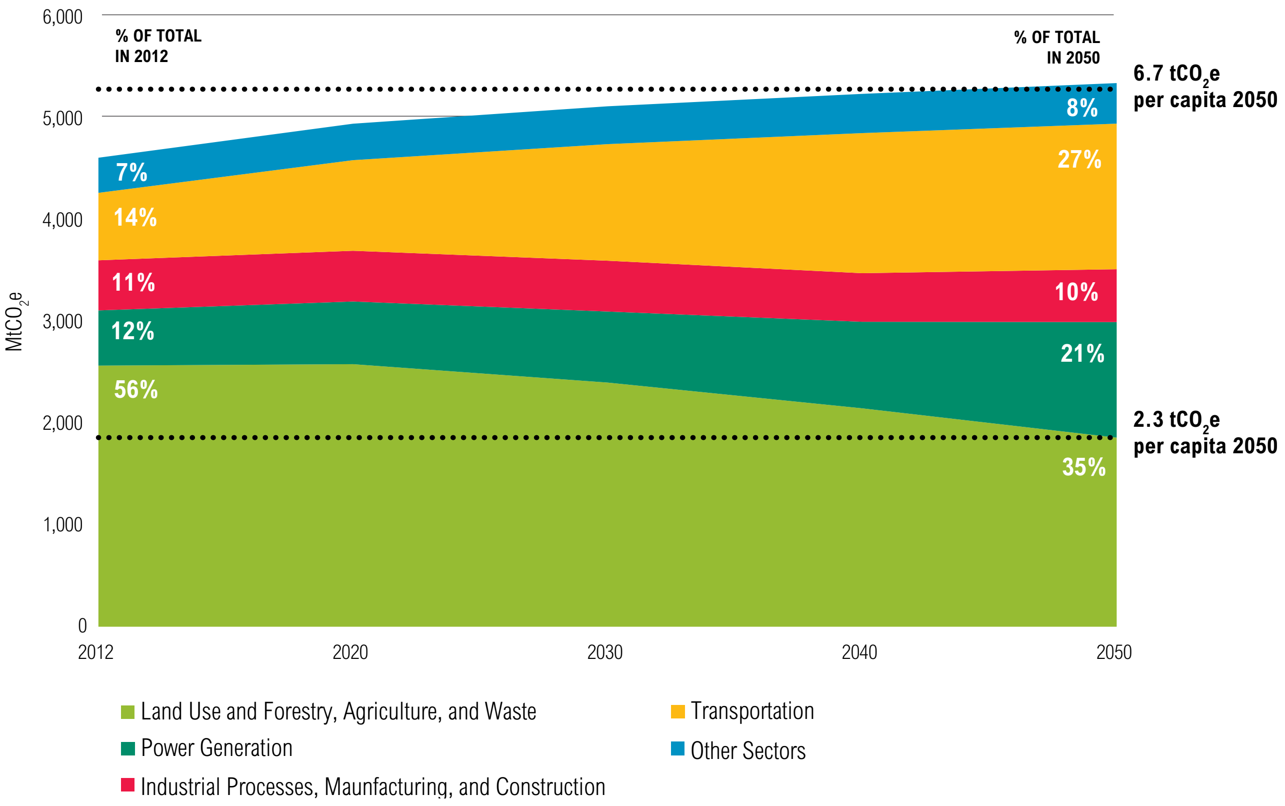
Climate change could lead to changes in total agricultural production as some areas may become unsuitable for crops, leading to agricultural expansion through deforestation; other areas may experience variations in yields (Vergara et al. 2014). Restoration processes may contribute to a delay in the onset of these conditions.[5]

Forestlands in the region are projected to continue to be deforested under business-as-usual conditions.

Although regional deforestation rates have recently fallen (FAO 2015), natural forests continue to be deforested, with some of the affected land adding to the large and growing stock of relatively unproductive landscapes and the associated loss of substantial economic benefits. A total of 3.4 million hectares of tree cover was lost in the region in 2013 (Hansen et al. 2015). Projections under a business-as-usual scenario indicate that between 2000 and 2050, Latin America and the Caribbean would lose an additional 7 percent of its total forest cover (Chiabai et al. 2011).

Figure 1 | **Latin America and the Caribbean business-as-usual emissions trajectory, by sectors 2010–50**



Source: Authors' estimate based on Vergara et al. (2013) and CAIT database as of September 2015.

Land-use-related emissions are the main sources of greenhouse gases in the region.

Of the estimated 4.6 gigatons (GT) of CO_2e emitted in Latin America and the Caribbean in 2012, over half were associated with agriculture, forestry, and other land uses.[6] However, the dominance of land-use-related emissions within the regional profile is changing. Evidence points to significant declines in the regional rate of deforestation, which dropped 67 percent in Brazil's Amazon from 2004 to 2010, and one-third in Central America since the mid-1990s (INPE 2010; Kaimowitz 2008; Hecht 2012). These achievements, if maintained, bode well for a substantial and lasting reduction in land-use-related emissions. Still, under business-as-usual scenarios, even after accounting for a robust reduction in deforestation rates, regional emissions are anticipated to reach almost 5.3 GT of CO_2e per year by 2050 (or 6.7 tons per capita), with agriculture, forestry, and other land uses contributing more than 30 percent of the total (Figure 1).

On the other hand, as part of needed efforts to achieve emission levels consistent with global stabilization goals[7] (1.5 gigatons of CO_2e for the region as a whole by 2050, or 2 tons per capita), regional economies would need to significantly reduce their emissions from land-use change. Specifically, the region would have to reach zero net deforestation by 2020; achieve zero emissions from land-use change by 2030; and accumulate carbon sinks in the soil and biomass at a rate of 750 Mt CO_2e per decade until 2050 (Vergara et al. 2013). Additional efforts, including a large land-restoration drive would be required for the region to become carbon neutral by mid-century (Vergara et al. 2015).

Table 1 | **Restoration opportunities of potential forest lands in Latin America and the Caribbean (million hectares)**

FOREST CONDITION	MHA
Intact	449
Fragmented	559
Degraded	299
Deforested	349
TOTAL	**1,656**

RESTORATION OPPORTUNITY IN DEGRADED AND DEFORESTED FOREST LAND (MHA)		% OF TOTAL
Wide-scale Restoration	91	14
Mosaic Restoration	456	70
Remote Restoration	2	–
Agricultural Lands	99	15
	648	

Source: Potapov et al. 2011a and 2011b.

Land restoration could slow agricultural expansion into forests and other natural ecosystems while reducing the region's carbon footprint.

Under certain conditions (and if properly planned and managed), restoration can decrease the demand for agricultural expansion by enabling improvements in production from degraded lands through agroforestry and agro- or silvopastoral restoration activities.

According to estimates (Potapov et al. 2011b), about 650 million hectares of degraded and deforested landscapes in Latin America and the Caribbean provide opportunities for restoration (Table 1). Over one-third (37 percent) of these hectares are distributed across the region's tropical and subtropical wet and moist forest zone, and over 40 percent are in tropical and subtropical dry and mixed forest biomes, including a significant share in degraded agricultural lands.

Over two-thirds (450 million hectares) of the restoration opportunities are in degraded and deforested landscapes where the vegetation differs from that of the original biome. These lands are used in ways that lend themselves to restoration into a mosaic landscape, with trees coexisting with settlements and agriculture (Potapov et al. 2011b). Such approaches include silvopasture and agroforestry, along with more simple approaches such as assisted regeneration of natural forests.

The remaining third of the identified hectares with restoration opportunities are evenly split between those most suited to wide-scale restoration to a closed forest-dominated landscape (e.g., in areas of low tree planting or natural forest recovery), and those suited to agroforestry and agro- or silvopastoralism in degraded forests, wooded savannas, and other agricultural lands. In addition, open croplands are likely to benefit from additional trees (for example, to reduce erosion from wind and water).

Furthermore, sustainably managed forests, forest management agroforestry, silvopastoral systems, and shifts to well-managed agriculture and forestry—all of which can be included under the umbrella of restoration activities—can contribute to net gains in carbon stocks. Natural regeneration and assisted reforestation has the potential to restore original carbon stocks. Sustainable agroforestry practices have been shown to result in additional carbon storage in vegetation in the range of 6 to 63 tons of C/ha in total compared to degraded lands, depending on the original biome conditions (Montagnini et al. 2004). In summary, restoration efforts could be essential for the achievement of a low-carbon development path in the region, and critical for maintaining and restoring the broad range of regulating ecosystem services that forest and woodland landscapes provide and require.[8]

SECTION II

METHOD USED TO MONETIZE THE COSTS AND BENEFITS OF LANDSCAPE RESTORATION

This section presents the methodology used to estimate the net economic benefits of landscape restoration in Latin America and the Caribbean. It seeks to capture the benefits and costs of restoration compared to a baseline scenario of degraded land.

Only benefits that can be easily monetized have been considered in the analysis, even if they do not return directly to the investor or other stakeholders. Benefits that cannot be easily monetized—such as improvements in biodiversity, species recovery, and improved water supply—are not included, even though it can be argued that the resulting economic returns can be equally tangible and real (Costanza et al. 2014).

The estimates are intended to stimulate national and regional policy discussions. They are not intended to guide actual financial decisions or the operational design of concrete landscape restoration projects in specific localities. Such guidance would require a much finer analysis and consideration of local circumstances.

The analysis covers a 50-year period.[9] It may be argued that policy decisions are usually made by analyzing results within shorter time frames, as results must respond to an immediate political agenda. However, a 50-year period has been selected on the following basis:

a. Restoration is a long-term affair. Many native species and ecosystem processes will not recover over shorter periods of time.

b. Key references and antecedents in the literature have used the 50-year period as the basis for analysis and thus it is important to ensure consistency.

c. The physical realities of restoration are not very different from those of climate change mitigation, and the climate change mitigation literature commonly uses time horizons of 50 or more years.

Estimate calculations

This assessment estimates the net present value (NPV) that would result from restoring 20 million hectares of degraded lands in the region within the scope of Initiative 20x20.[10]

The following equation was used for the estimates:

$$\textbf{(1)} \qquad NPV_{\text{net gain}} = NPV_{\text{20x20}} - NPV_{\text{degraded}}$$

WHERE:

NPV_{degraded} (the baseline scenario) is the NPV of the benefits and services provided throughout a 50-year projection into the future of a representative area of degraded forest or agricultural land in Latin America and the Caribbean.

NPV_{20x20} (the restoration scenario) uses as a basis the restoration target of Initiative 20x20 in terms of coverage and restoration activities to be implemented. It assumes 20 million hectares of degraded Latin American and Caribbean lands are brought into restoration through reforestation, assisted or passive regeneration of natural forests, and agroforestry.

$NPV_{\text{net gain}}$ reflects the net benefits of restoration, representing the net gain in NPV of a landscape future with land restoration compared to the NPV of a future without it. More precisely, $NPV_{\text{net gain}}$ is the difference in the present value of a degraded hectare of forest or agricultural land that has been restored (NPV_{20x20}), compared to the present value of a degraded hectare that has not (NPV_{degraded}).

Both the baseline and restoration scenarios assume that the 20 million hectares targeted for landscape restoration under Initiative 20x20 are distributed across Latin America and the Caribbean in the percentages that are actually found on average across the region in terms of landscape biomes and degrees of degradation. Respectively, these assumed distribution breakdowns are as follows:

- Wet biomes constitute 51 percent of degraded Latin America and Caribbean landscapes; dry biomes, 48 percent; and temperate biomes, 1 percent.[11]

- Lightly degraded landscapes make up 34 percent of all degraded lands in the region; moderately degraded account for 58 percent, and severely degraded, 8 percent.[12]

The assessment assumes that Initiative 20x20 will result in the successful recovery of approximately 13 million hectares of forest landscapes and improved land functionality and close to another 7 million hectares of mixed agricultural landscapes through a combination of agroforestry, silvopasture, or agropasture activities and sustainable agricultural efforts.

The difference between the two scenarios isolates the change in assessed value (benefit or loss) that comes from shifting actions from the baseline scenario to those consistent with the restoration scenario; that is, the application of restoration methods with particular costs and unique rates of recovery. The assessment model and scenario equations are further detailed in Annex II.

The NPV for both the baseline and the restoration scenario is defined as:

$$\text{(2)} \qquad NPV = \sum_{i=1}^{50} \frac{B_i - C_i}{(1+r)^i}$$

WHERE:

B_i is the annual benefit received during year *i* for any given landscape biome or degree of degradation. In the baseline scenario, B_i is constant as it represents the annual benefit degraded by a productivity discount factor to reflect the relative degrees of degradation. In the restoration scenario, B_i rises gradually over the years as the degraded annual benefit flow values are returned to pristine values through restoration according to a simple annual recovery rate model (further detailed in Annex II).

C_i is the cost of landscape restoration during year *i*. Under the baseline scenario, C_i is zero (no restoration). Under the restoration scenario, C_i varies according to restoration method and degree of degradation. Restoration actions are assumed to be implemented gradually over the 50 years of the analysis. For purposes of simplification, costs are equally distributed across benefit categories and are uniformly assigned on an annual basis over the first half of the total required restoration period, after which C_i equals zero (details in Annex II).[13]

r is the discount rate that allows for a comparison of flows that occur in different time periods (the reference analysis uses a 3 percent social discount rate, which properly reflects current opportunity costs for the economic benefits when expressed in US dollars in Latin American countries).[14] The discount rate is a critical element in the evaluation of a project such as the restoration of 20 million hectares of degraded lands. The value of the discount rate varies in the literature according to a wide range of factors, including the time horizon for the benefits to be accrued, activities to be implemented, and the country where the investments will take place. For example, a 0.5 percent to 4.0 percent range has been used in valuation of climate change projects by

BOX 3 | DISCOUNT RATE

On the issue of the discount rate, the arguments presented by Chiabai et al. (2011) and Verdone (2014), reproduced below, are reflected in our analysis:

Chiabai et al. (2011):
The choice of the appropriate discount rate is much debated in the scientific and policy community, especially for valuing losses of natural resources, involving long-time impacts, intergenerational issues, and latent non-marginal impacts. Discount rates between 0 percent and 3 percent are usually used (Hope 2006). According to Weitzman (2001), a declining discount rate should be used for long-term natural resource projects in order to account for intergenerational equity, while allowing for economic efficiency (Portney and Weyant 1999). Evans (2005) refers to a 3 percent discount rate for the near future up to 25 years; 2 percent discount rate for the medium future, 26 to 75 years; and 1 percent discount rate for the distant future, 76 to 100 years. In our study we make the conservative choice of using the 3 percent discount rate as both market and non-market values are included in the assessment, and discounting timber value is less contentious than passive and recreation values.

Verdone (2014):
The highest NPV of achieving the Bonn Challenge ($5.5 trillion) is achieved under a 0 percent rate of discount, which is an appropriate discount rate when equal weight is given to the welfare of future generations who also benefit from the restoration of degraded land (Stern 2006). A 5 percent rate of discount reduces the net benefit to $1.44 trillion, while a 10 percent rate of discount sees the net present value further reduced to $0.46 trillion. World regions with large amounts of severely and extremely degraded land (as a percent of total degraded land) and low stock values, see little benefit from ecosystem service flows that occur 50 or even 200 years in the future regardless of the discount rate value.

A change in the discount rate, then, does little to impact the value of flows that occur far into the future. However, for countries with little severely and extremely degraded areas and high stock values, the benefits of restoration are received over short time periods, and these short time horizons are sensitive to the discount rate.

the Economic Commission for Latin America and the Caribbean. The valuation for forestry projects in Latin America commonly employs a discount rate between 2 percent and 10 percent (Cubbage et al. 2013), whereas ecosystem restoration actions are evaluated using a discount rate of 8 percent (De Groot et al. 2012). Nevertheless, a project that pursues the restoration of 20 million hectares in the region also delivers benefits to society and hence a social discount rate has been used. In any event, the use of a discount rate in the analysis maximizes the impact of upfront costs while deemphasizing resulting future revenues, therefore contributing to a conservative end result.

By maintaining the 3 percent discount rate (see Box 3) and conducting a sensitivity analysis that presents the variation of results when the values of the discount rate deviate from this central assumption, the results are conservative, hopefully avoiding excessive debate over what the various discount rates should be.

The analysis also estimates the internal rate of return of the entire Initiative 20x20. When carbon prices are \$5/tCO_2,[15] the internal rate of return—the discount rate for which the net present value of the future flows of costs and benefits equal zero—is estimated at 8.75 percent, well above the central reference assumption of a discount rate of 3 percent. Therefore, for illustrative purposes we consider a 3 percent discount rate to be a reasonable central reference assumption for this study. A range of discount rates has been considered as part of the sensitivity analysis reported in section III. In this analysis, NPVs represent current "stock values" produced by the sum of all future annual benefits—the inputs of the assessment[16]—under both baseline and restoration scenarios discounted back to net present value over a horizon of 50 years.

Economic benefits considered

Restoration may result in a wide range of benefits. Ideally, the assessment would incorporate all of the financial (provisioning), environmental (regulating), and cultural services provided by undisturbed landscapes. These products and services include water provision, water filtration, pollination, biodiversity conservation and maintenance of a complex array of interactions conducive to the sustenance of life, as well as the enhanced storage of carbon, which assists in the stabilization of climate and prevents damage to ecosystems.

However, substantial data, methodological, and other limitations make it difficult to calculate an estimate that captures and incorporates the full set of benefits created through landscape restoration. For these reasons, some benefits from landscape restoration—such as improvements in, or avoided losses of, biodiversity, soil, and water protection—are not considered in this assessment.

Furthermore, we have chosen not to rely on willingness-to-pay-based estimations, since this methodological approach is difficult to justify when information is imperfect. For example, valuations of biodiversity of global relevance cannot be based only on local groups and their willingness to pay, as these groups may not be aware of all the regional and global implications of biodiversity losses. Instead, such valuations should consider the latest scientific understanding of the worth of genetic resources, biomes, and species. Therefore, such estimates are excluded.

The benefits of landscape restoration, based on indicative categories of economic benefits and any given landscape biome or degree of degradation, are calculated using equation 3.

$$B_i = WFP_i + NWFP_i + ET_i + AP_i + ACFS_i + CS_i \tag{3}$$

Where the representative categories are:

- WFP_i, or wood forest products, refers to gross profits in year i (a constant annual flow value under the baseline scenario and a growing annual value under the restoration scenario) from harvesting wood forest products (timber, firewood, or other products that imply a reduction, albeit temporary, in the standing of forest biomass).

Wood forest products are usually monetized based on current plantation practices that imply short rotation periods and cutting methods associated with commercial forestry operations. However, this assessment assumes a more conservative rotation cycle of 40 years—similar to the estimates used for monetizing temporary carbon storage credits. This assumption reflects the need to allow more time for ecosystem recovery and assumes that no commercialization of wood forest products will take place in the interim, thus dampening the expected stream of revenues from these products in the assessment's projections. A sensitivity analysis to the length of the rotation period is included in section III.[17]

Wood forest products benefits, which are derived from Chiabai et al. (2011), assume that each forest hectare has the same productivity. The values do not account for differences in forest types and species, or for differences in management regimes. Details on the sources of these values can be found in Annex I.

- $NWFP_i$ is the annual gross value of non-wood forest products harvested in a sustainable manner without negatively impacting the biomass of the standing forest (e.g. medicinal and animal products, fruit, nuts).[18]

  Non-wood forest products were derived from Chiabai et al. (2011), which, in turn, were obtained from *FAO's Global Forest Resource Assessment 2005*.

- ET_i refers to the annual gross profits from ecotourism generated by forests, wilderness areas, and related landscapes (including national parks) that could be augmented by landscape restoration efforts. These were assessed using historical revenue data from Costa Rica. These revenues are related to tourism in protected areas instead of degraded land, and were the best available data. The general consideration section below discusses this issue in more detail.

- AP_i takes into account annual gross profits from *agricultural production* that could be enhanced by landscape restoration efforts. In particular, for purposes of this assessment, it captures the expected increased revenues from agricultural production as a result of agroforestry efforts on degraded agricultural lands. For ease of calculations, the assessment assumes that (a) about one-third of the restored area will be dedicated to agroforestry and similar systems that fall under a mosaic approach[19] on agricultural lands; and (b) restoration activities will enhance the production of wheat, maize, and soybeans, selected as proxy staple crops (in temperate, subtropical, and tropical wet and dry biomes respectively). Benefits from agricultural revenue do not account for benefits from silvopasture systems (e.g., an increase in milk or beef production).

- $ACFS_i$ refers to avoided annual food security costs under the restoration scenario. It represents the anticipated real decline in food security premiums as agricultural production increases and becomes more stable within any given and unchanged agricultural frontier in non-degraded landscapes. That is, improved sustainable food production should result in a reduction of food insecurity, which is partially captured by the market value of food security premiums in the region's crop insurance market.
- CS_i represents monetized gains in carbon storage as a result of restoration, when compared to the business-as-usual scenario. Carbon capture and storage could be enhanced as a result of the increase in vegetation cover stemming from reforestation, assisted regeneration, agroforestry, and avoided deforestation.

  A conservative value of $5/ton of CO_2 has been used. This value corresponds to a price level anticipated in the absence of a global or regional fully functioning carbon market (Peters-Stanley and Gonzalez 2014), therefore reflecting the average price under voluntary conditions. But, price projections commonly assumed in carbon market studies under conservative scenarios are much higher, in the order of $20/ton of CO_2 for the period 2020–40 (Luckow et. al. 2014). The estimated financial consequence of CO_2 emissions to the atmosphere as calculated by Stern is $100/ton of CO_2 (Stern 2006).[20] Any increase in the future value of carbon within the period of analysis would only strengthen the case for restoration.

Carbon capture and storage could be enhanced as a result of the increase in vegetation cover stemming from reforestation, assisted regeneration, agroforestry, and avoided deforestation.

In order to produce regionwide estimates of the net economic benefits of landscape restoration, we prepared a simple estimate based on a comparison of alternative future scenarios. The basic outlines of the estimate are presented in the paragraphs that follow. Annexes I, II, and IV have a detailed description of the estimate, its scenario equations, and a list of assumptions used for each benefit considered.

In summary, the baseline projection of benefits for a typical hectare of degraded land is established by applying a productivity discount to the projected annual benefit for non-degraded lands. This discount reflects the degree of degradation on each hectare and the resulting productivity gap (or loss in potential direct instrumental value or PDVI)[21] in relation to pristine (non-degraded) values. The degraded annual benefit flow values are summed 50 years out and discounted to net present value to produce a valuation of the benefits from degraded lands in the business-as-usual scenario.

Under the restoration scenario, the annual projection of benefits for the same typical hectare is established by applying the same productivity discounts to the projected annual flow values, amended by an annual rate of recovery resulting from restoration interventions and upfront and ongoing costs.

The projection of annual flow values under the restoration scenario is summed 50 years out and discounted to NPV to yield the current "stock value" of the economic benefits of restoration. Netting out the NPV of unrestored degraded lands from the NPV of restored lands yields the net NPV—or the net benefits—of landscape restoration.

The NPV output result of the baseline scenario is then subtracted from the NPV output result of the restoration scenario (following equation 1 above) to yield the "net gain" NPV—or net economic benefits—of landscape restoration in Latin America and the Caribbean (details in Annex II).

Costs considered

In general, the cost estimates used here assume that the average cost of each restoration method is the same across Latin America. The model does not account for differences in restoration objectives and strategies. The costs are calculated averages from a sample of projects from the region. In particular, the establishment and maintenance cost for assisted reforestation were derived from costs in Brazil and Colombia (World Bank 2014). Establishment and maintenance cost for agroforestry were estimated from 60 experiences in silvopasture systems in Nicaragua, Colombia, and Costa Rica (CATIE et al. 2005).

The experiences considered in developing the cost estimates do not include the planting costs of agricultural products (wheat, maize, or soybeans). It is assumed that each crop will be planted as a monoculture (no mix of agricultural crops) with trees being planted in the same area.

Benefits and cost estimates

BENEFITS. The input is the annual monetized value of each of the benefits on a hectare of non-degraded forest or agricultural land. These values are estimated based on historic volume, price, and cost data from both the country and regional levels. The

Table 2 | **Annual benefit flow values from non-degraded Latin America and Caribbean land, $/ha/yr**

LAC BIOME	WOOD FOREST PRODUCTS	NON-WOOD FOREST PRODUCTS	INCOME FROM ECOTOURISM	GAINS IN AGRICULTURAL PRODUCTION	AVOIDED FOOD SECURITY COSTS	CARBON STORAGE[a] (TC/HA/YR)
Temperate	21	386	70	372	11	0
Wet	2,424	386	210	360	11	0
Dry + Savanna	702	65	141	575	17	0

Source: Chiabai et al. (2011) for WFPs and NWFPs. For ecotourism, agriculture, food security, and carbon storage: authors' results using data from FAO and WRI. Details in Annex I.

Note: a. For purposes of simplification, it is assumed in the assessment that non-degraded mature forests do not store additional carbon.

Table 3 | **Total restoration cost references, by method and degree, $/ha[a]**

RESTORATION METHOD	DEGRADATION DEGREE		
	Severe	Moderate	Light
Planted forests	2,700	1,350	675
Assisted regeneration	1,500	750	375
Agroforestry	2,700	1,350	675

Source: Authors' results using data from World Bank (2014) and CATIE et al. (2005).
Note: a. The cost figures in the table are the sum of the establishment and maintenance cost averages. These are $900/ha for planted forests, $600/ha for assisted regeneration, and $1,200/ha for agroforestry together with transaction costs (assumed to be $150/ha) and opportunity costs (assumed to be $300/ha for planted forests). Summing each method's E&M average cost reference values together with transaction and opportunity costs yields the total final cost figures per hectare that appear in the table.

pristine annual monetized values for each benefit are presented in Table 2. These figures represent the projected annual net flow of benefits in 2012 US dollars per hectare on non-degraded land. Once these values are introduced as raw inputs into the equations of both scenarios, they are then reduced in proportion to the degree of degradation of the land.

COSTS. Based on a rough averaging of a limited range of landscape restoration cost experiences and estimates in the region (World Bank 2014), the estimates for establishment and maintenance (E&M) costs were set at $900/ha for planted restoration, $600/ha for assisted regeneration of natural forests, and $1,200/ha for agroforestry methods (cost data on agropastures and silvopastures were used as partial proxies). Restoration costs are assumed to include an additional $150/ha in transaction costs. On the basis of this same limited range of restoration experiences, the assisted regeneration of natural forests is assumed to also imply an opportunity cost of $300/ha.[22] Table 3 presents the range of *total restoration costs* (including E&M, transactions and opportunity costs) that were assumed under the assessment.

In order to produce regionwide estimates of the net economic benefits of landscape restoration, the NPV output of the baseline scenario is subtracted from the NPV output of the restoration scenario.

SECTION III

NET GAIN IN ECONOMIC BENEFITS FOR LANDSCAPE RESTORATION ACTIVITIES

This section presents the results of the estimation method introduced in the previous section. Biome, restoration method, and the degree of degradation are influential to the resulting net benefits.

Estimate of net economic benefits from land restoration

Based on the methods and assumptions outlined in section II, the findings indicate that the large effort required to restore the Latin America and Caribbean region's degraded forests, woodland savannas, and other degraded agricultural landscapes (within the scope and character of Initiative 20x20) would result in substantial net benefits. This is true even when carbon storage benefits are very limited (or excluded) and wood forest products are only considered under long-term rotation cycles.

Specifically, such a restoration effort could provide a net present value of easily monetizable benefits equal to about $23 billion, or a regionwide average of about $1,140/ha (Table 4) under the assumptions made for interest rates, carbon prices, and rotation periods. Based on these numbers, land restoration can be a generally attractive economic option in the region.

These results are based on a restoration effort equally implemented through three alternative active restoration approaches: (1) planted restoration with native species; (2) assisted regeneration of natural forests; and (3) agroforestry.

Each of the three restoration approaches is assumed to capture gains from benefit categories most directly impacted by the restoration method in question; for example, planted restoration only yields wood forest product and carbon gains and no benefits from non-wood forest products or agricultural output.

In Table 4, agricultural product gains, stimulated by agroforestry restoration methods, represent the largest NPV gain on a per hectare basis ($274) of all of the estimated economic benefits. The value of the carbon stored is the second largest ($270/ha) NPV gain, even though it is valued under conditions prevalent in a non-functioning market.

Net gains overall from wood forest products are lower ($170/ha) than might be expected if commercial plantations were considered in the calculations. This is a result of the assumption that only long rotation extraction of forests, consistent with the expectation for native species, is considered.

Table 4 | **Economic net benefits of restoration, by benefit type, net gain NPV $/ha**

LATIN AMERICA AND CARIBBEAN AVERAGE ECONOMIC BENEFITS						
Wood forest products	Non-wood forest products	Income from ecotourism	Gains in agricultural production	Avoided food security costs	Carbon storage	Total
170	245	161	274	19	270	1,140[a]

Sources: Results based on annual benefit flow values from Chiabai et al. (2011) (for WFPs and NWFPs); and Inman (1997), Rodriguez (2014), FAO (2010) (for ecotourism, agriculture, food security, and carbon sequestration), and costs from World Bank (2011), World Bank (2014).

Notes. Assumptions: a CBA comparison of business-as-usual and restoration scenarios, a 50-year time horizon, constant US$2012 dollars, 3% discount rate, a carbon price of $5/tCO$_2$, and no commercial exploitation of wood forest products (lumber and firewood) for 40 years.

a. The total has been rounded to the nearest ten.

Results by Biome, Restoration Method, and Degradation Degree

The results presented above are based on the following (Annex III):

- A biome distribution of the target hectares to be restored that is based on the actual relative shares of each biome across the region's degraded and deforested lands (51 percent wet, 48 percent dry, 1 percent temperate).
- An assignment of hectares that obeys the current distribution of degrees of degradation assumed to hold, on average, across Latin American and Caribbean landscapes (34 percent is assumed to be lightly degraded, 58 percent moderately degraded, and 8 percent severely degraded).
- An even distribution of restoration methods across the 20 million hectares targeted for restoration; that is, 6.67 million hectares to be restored through planted reforestation, 6.67 million hectares through assisted regeneration of natural forests, and another 6.67 million hectares through agroforestry (and related methods).

The average presented in Table 4 is based on a distribution of distinct net gains (or losses) across a matrix of possible characteristics of hectares in the region. However, Table 5 provides more detail on the results for each biome and degree of degradation through varying restoration approaches. For example, if only restoration opportunities in wet forests and their related agricultural lands were under consideration, the net benefits would be nearly 50 percent higher, or $1,671.

Also, average per hectare and aggregate gains would be higher if restoration concentrates on moderately degraded landscapes—where the net gains are consistently higher[23]—as opposed to lightly or severely degraded lands, where NPVs are lower or even negative. For lightly degraded lands, while cheaper and faster to restore in general, the ultimate gain will be lower; meanwhile, in severely degraded lands, the current NPV net gains are mitigated by the length of time and total cost required to fully restore such landscapes (Table 5).

Table 5 | **Net present value gain by biome, method of restoration, and degradation degree in $/ha**

	WOOD FOREST PRODUCTS	NON- WOOD FOREST PRODUCTS	INCOME FROM ECOTOURISM	GAINS IN AGRICULTURAL PRODUCTION	AVOIDED FOOD SECURITY COSTS	CARBON STORAGE	TOTAL
Average (all biomes, degradation degrees, methods)	170	245	161	274	19	270	1,140[a]
Latin America and Caribbean wet forests and agricultural lands							
(Average for all degrees and methods)	332	472	212	135	15	506	1,671
Planted restoration of managed forests in wet biomes							
Lightly degraded forests	352					797	1,148
Moderately degraded forests	1,140					324	1,464
Severely degraded forests	2,699					(172)	2,527
Assisted regeneration of natural wet forests in wet biomes							
Lightly degraded		713	308			1,306	2,327
Moderately degraded		1,825	842			893	3,560
Severely degraded		1,422	534			502	2,458
Agroforestry in wet biomes							
Lightly degraded				199	25	369	593
Moderately degraded				590	53	(29)	615
Severely degraded				(69)	54	(469)	(484)
Latin America and Caribbean dry forests/savanna and agricultural lands							
Average for all degrees and methods	4	(1)	110	425	23	26	587
Planted restoration of managed forests in dry biomes							
Lightly degraded forests	(99)					260	161
Moderately degraded forests	15					(119)	(104)
Severely degraded forests	448					(544)	(96)
Assisted regeneration of natural forests in dry biomes							
Lightly degraded		(24)	149			590	715
Moderately degraded		36	457			302	795
Severely degraded		(193)	187			6	0
Agroforestry in dry biomes							
Lightly degraded				693	40	(27)	706
Moderately degraded				1,651	85	(356)	1,380
Severely degraded				1,013	87	(739)	361

Sources: For WFPs, NWFPs and carbon, our own results using data from WRI (2014), and annual flow values from Chiabai et al. (2011); for agriculture and food security, our own results using data from FAO (2010) and WRI (2014).

Notes: US$2012, $5/tCO$_2$, 50-year horizon, 3% discount rate.

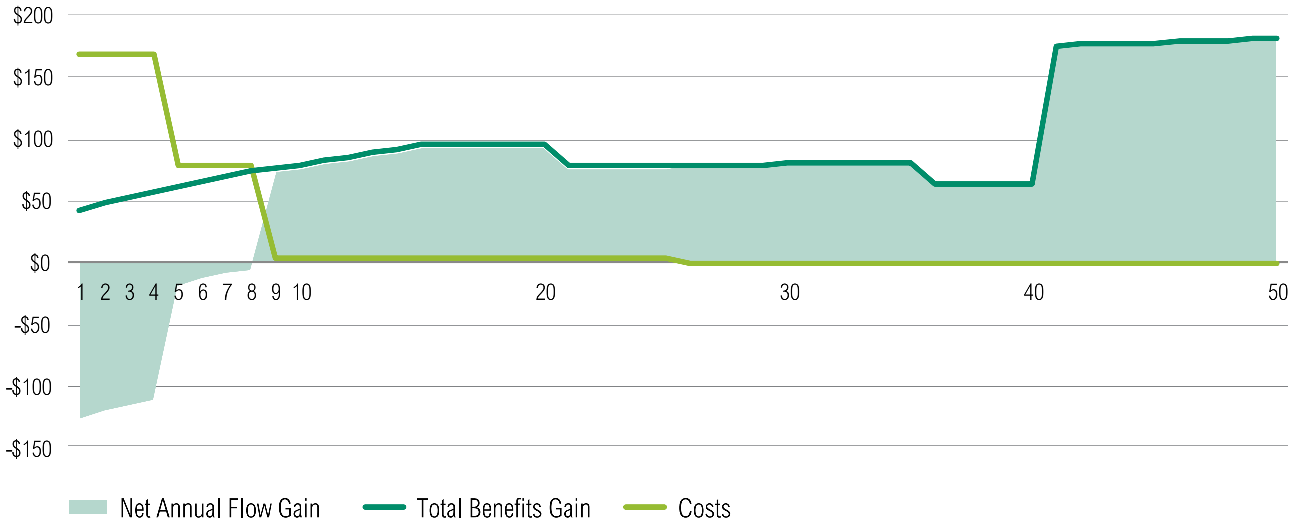
a. The total has been rounded to the nearest ten.

Dynamic aspect of the estimated economic benefits and costs

A year-by-year comparison of the benefits and costs of restoration would shed light on the expected time when net annual flow gains are first accrued. Figure 2 presents the annual net flow gains on a per hectare basis. Under the adopted assumptions, the 20 million hectares restoration effort would first yield net annual flow gains by year 9, when average benefits surpass costs as they continue to rise over the first years of recovery. Benefits from lightly degraded lands will be recovered by year 7, while those from moderately degraded lands will be recovered by year 15. The estimates for restoration costs are adjusted according to the periods of recovery of lightly, moderately, and severely degraded land. As lightly degraded land is recovered, average maintenance costs are reduced. Costs also are reduced as land with moderate and severe degrees of degradation is restored (distributing costs across subsequent periods more evenly would reduce the present value of costs and increase the NPV).

> An effort to restore the Latin America and Caribbean region’s degraded forests, woodland savannas, and other degraded agricultural landscapes—one with the scope and character of Initiative 20x20—would result in substantial net benefits.

Figure 2 | **Net annual flow gain per hectare**



Source: Authors’ calculation. Total benefits follow an irregular recovery structure, which assumes that 34 percent of the degraded lands (light) will be recovered within 7 years, 58 percent (moderate) over 15 years, and 8 percent (severe) only over 50 years. The considered periods for carbon accumulation are 20 years for the 34 percent of lightly degraded lands; 35 years for the 58 percent of moderately degraded lands; and 50 years for the 8 percent of severely degraded lands. The jump in benefits at year 40 is a response to the assumption that wood forest products would only accrue by then.

Note: US\$2012, \$5/tCO_2, 50-year horizon, 3 percent discount rate.

Table 6 | **Net gain in net present value per hectare, and Latin America and Caribbean aggregate benefits, by carbon value**

	$\$0/TCO_2$	$\$5/TCO_2$	$\$20/TCO_2$	$\$100/TCO_2$
Net gain in NPV ($/ha)				
Carbon (Latin America and Caribbean average)	0	270	2,423	13,903
Total Benefits (Latin America and Caribbean average)	869	1,139	3,291	14,772
Total NPV ($ billions)				
20x20 Initiative	17	23	66	295

Source: Author's elaboration, based on annual benefit flow values from Chiabai et al. (2011) (for WFPs and NWFPs), Inman (1997), Rodriguez (2014), FAO (2010), World Bank and WRI (for ecotourism, agriculture, food security and carbon sequestration), and costs from World Bank (2011), World Bank (2014), and CATIE et al. (2005).

The impact of CO_2 prices in the estimation of the economic benefits

The NPV of achieving the scope of 20x20 is sensitive to the price of carbon. If carbon revenues are excluded, the NPV gain is $869/ha. But, if a value of $20/ton is used, the resulting total benefit NPV gain would be $3,291/ha (Table 6).

The effect of restoration on regional carbon stocks as standing biomass

As a result of the restoration process, the carbon stocks of standing biomass would increase.[24] Under the assumptions used, a total of 1.34 gigatons of carbon will be sequestered (Table 7), or about 4.92 gigatons of CO_2e over 50 years. Average annual additional stocks of roughly 13 MT of carbon per year will be attained during the first 20 years of implementation.[25]

If a scaled-up restoration process of about 100 million hectares of landscape restoration—five times the level of effort under 20x20—were achieved by mid-century, the resulting net annual reduction in regional emissions would be of the order of 0.7 Gt CO_2 (Vergara et al. 2015). This level of sequestration would be a substantial contribution toward the global climate stabilization goal of annual emissions at the Latin America and Caribbean region level (Figure 3).

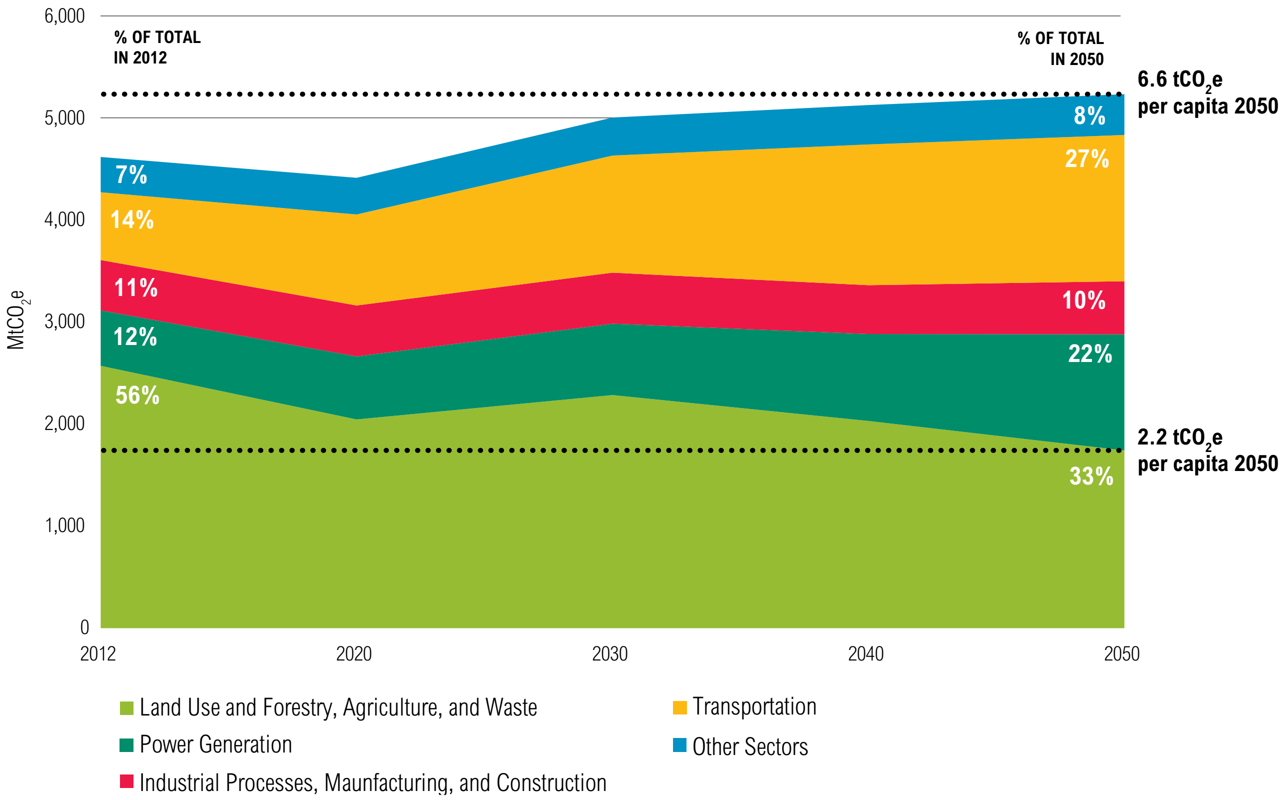
Table 7 | **Estimate of net gains in carbon stock as a result of restoration (megatons or 1 x 10^6 tons)**

DEGRADED LANDS RESTORED UNDER INITIATIVE 20X20	MEGATONS OF CARBON SEQUESTERED
20mn degraded hectares restored	1,340
Degrees of degradation	
Lightly degraded total	446
Moderately degraded total	777
Severely degraded total	107
Per year	
Per year average (over 50 years)	26.8
Per year average (first 20 years)	47.1

Sources: Authors' results using data from Laestadius et al. (2014), Oldeman et al. (1991), and Daily (1995).

The future ability of the region to successfully sustain a low-carbon development path broadly hinges on current efforts to reduce carbon emissions from land-use change and other agricultural activities. Already, some countries have expressed plans to follow a land-use approach for the reduction of emissions. If private, public, and local regional actors can contribute to carbon sequestration and avoidance of carbon emissions through a successful restoration program, it would represent a substantial contribution to reductions in the carbon footprint of the region.

Figure 3 | **Latin America and Caribbean emissions trajectory, with a 100 Mha land restoration program**



Source: Authors' estimate based on Vergara et al. (2013) and adjusting for initial conditions in 2010 derived from an update of CAIT database as of December 2014. Projections are from the business-as-usual scenario in IIASA-GEA as originally reported in Vergara et al. (2013) for all sectors. The AFOLU sector is adjusted following the expected decrease from land restoration programs, which are assumed to be 20 million hectares by 2030, 40 million hectares by 2040, and 100 million hectares by 2050.

Sensitivity of total net gain in NPV to discount rate and carbon valuation

Given the significant impact suggested by the results of the assessment, we devised a sensitivity analysis to discount rates and carbon valuation. The results of the sensitivity analysis show that the results are sensitive to the value of both variables.

Table 8 summarizes the sensitivity of the NPV results, measured in $/ha, both to discount rates and to carbon valuation. Maintaining a $5 per ton price of carbon, NPV ranges from $2,548 per ha to a loss of $131 per ha when the discount rate varies from 1 percent to 10 percent, respectively. A 3 percent discount rate yields an NPV from $869 per ha when carbon has a price of $0, to $3,291 when carbon has a price of $20 per ton. Table 9 shows the impact of these variables on the total NPV of the program.

Table 10 summarizes the sensitivity of return on investments[26] to discount rates and carbon prices. Return-on-investment sensitivity equals zero when carbon is priced at $5/ton and the discount rate is 8.75 percent.

Table 8 | **Sensitivity of net present value ($/ha) to discount rates and carbon price**

CARBON PRICE ($/TCO$_2$)	DISCOUNT RATE (%)				
	1%	**3%**	**5%**	**7%**	**10%**
0	2,098	869	302	28	-151
5	2,548	1,139	460	114	-131
20	5,385	3,291	2,156	1,493	930
50	11,059	7,596	5,549	4,253	3,051
100	20,515	14,772	11,204	8,852	6,587

Note: IRR = 8.75% when $5/t CO$_2$.

Table 9 | **Sensitivity of aggregate benefits (US$ billion) to discount rates and carbon price**

CARBON PRICE ($/TCO$_2$)	DISCOUNT RATE (%)				
	1%	**3%**	**5%**	**7%**	**10%**
0	42	17	6	1	-3
5	51	23	9	2	-3
20	108	66	43	30	19
50	221	152	111	85	61
100	410	295	224	177	132

Note: IRR = 8.75% when $5/t CO$_2$.

Table 10 | **Sensitivity of return on investment to discount rates and carbon price**

CARBON PRICE ($/TCO$_2$)	DISCOUNT RATE (%)				
	1%	3%	5%	7%	10%
0	234	97	34	3	-17
5	285	127	51	13	-15
20	602	368	241	167	104
50	1236	849	620	475	341
100	2,292	1,650	1,252	989	736

Note: Sensitivity to return on investment = 0% when $5/t CO$_2$ and r = 8.75%.

Sensitivity of NPV of wood forest products to rotation cycles in timber operations

The analysis also has used the assumption that timber operations would use a longer maturity time (meaning it would take much longer to reach a point of harvesting when native tropical hardwoods in multispecies plots are used). This assumption is more consistent with the goals of ecosystem restoration, although shorter harvesting periods, if aligned with a sustainable management practice, would also increase NPVs. The results are summarized in Table 11. A value of $170 for wood forest products results as this assessment's main estimate, but it could increase up to $1,862 per hectare when wood forest products are harvested following short rotation cycles and the central assumption of a 3 percent discount rate is considered.

Table 11 | **Sensitivity of gain in net present value of wood forest products ($/ha) to discount rates using short and long rotation cycles**

	DISCOUNT RATE				
	1%	3%	5%	7%	10%
Short Rotation Cycles	3,096	1,862	1,184	789	463
Long Rotation Cycles	588	170	6	-57	-83

Restoration in Latin America and the Caribbean would yield a net present value (NPV) of about $23 billion over a 50-year period, based on an average regionwide NPV of about $1,140/ha under reasonably assumed conditions.

General considerations

The assessment relies on several assumptions in order to deliver a simplified estimate of the NPV of achieving the Initiative 20x20 target of restoring 20 million hectares of degraded forest and agricultural land in Latin America and the Caribbean. These assumptions include discount rates, cost of restoration, harvesting periods for wood forest products, and value of carbon revenues, among others. Nevertheless, the implied simplifications can contribute to uncertainties around the true NPV of restoration.

To address some of the concerns, we conducted a sensitivity analysis for several of these variables, as described above. However, other elements in the assessment also may signify variation in the results. For instance, a percentage of biomes and degree of degradation is assumed from generalized data at the regional level. If landscape restoration were to occur across a different distribution, results would vary in accordance with the benefits and costs from biomes and levels of degradation that dominate following the results presented in Table 5. Variations in the distribution of land restored and other assumptions would affect the main result presented here. A brief consideration of some of the assumptions sheds light on how these affect the NPV.

Six benefits have been considered in estimating a NPV: wood products, non-wood products, ecotourism, additional agricultural production, avoided costs of food security, and carbon sequestration. In the current assessment, the benefits are the exclusive contributors to the value of restoration and present a synthesis of the general benefits accrued in the process. Each category is synthesized into the assessment through a series of assumptions. However, to ensure a more accurate estimate of the NPV result, the assessment would

have to consider finer assumptions for all biomes and levels of degradation, including other benefits that accrue from restoration and that are specific to a subregion. Such a review would increase the estimate's relevance for policymakers in a specific region, whether the effect is positive or negative. A few considerations that would shift the estimated NPV in this assessment include:

- Wood forest product (per hectare) benefits are considered to be uniform throughout the region (derived from Chiabai et al. 2011). Into this homogeneous scenario, the assessment combines a distribution of forest degradation levels across biomes within the region.[27]

- The value from ecotourism benefits is derived from the Costa Rica case (see Annex I), which is attributed entirely to habitat restoration and may overestimate actual benefits for other countries in the region. Although this assessment assumes that ecotourism accrues only in assisted natural wet and dry forests (as shown in Table 5), these may also be conditional on other complementary investments. The assessment does not observe the need for infrastructure investments in order to capitalize on the intervention's benefits, nor does it observe the ecotourism benefits that arise in landscapes that are subject to other restoration methods.

- Costs were derived from a set of World Bank projects on agropastoralism and used as a proxy for the establishment and maintenance of agroforestry owing to the lack of a better comparable project. Transaction costs are included in this value. In addition, the costs follow a simplified time distribution that results from the expenses being made in response to intervention within multiple degrees of degradation.[28]

SECTION IV

CONCLUSION

Landscape restoration can provide sizable benefits that can be monetized. These include wood forest products, non-wood forest products, income from ecotourism, gains in agricultural production, avoided costs of food security, and carbon sequestration.

The analysis provides strong evidence to support the adoption of policy measures and the removal of barriers for land restoration efforts by national and local governments in the region.

Restoration in Latin America and the Caribbean would yield a net present value (NPV) of about $23 billion over a 50-year period, based on an average regionwide NPV of about $1,140/ha under reasonably assumed conditions, including a discount rate of 3 percent and a market value of $5 per ton of CO_2. This average is only indicative. If the discount rate is changed to 5 percent, the NPV becomes $460/ha. When a $20 value per ton of CO_2 is considered, the average NPV becomes $3,291/ha. In addition, the average NPV for restoration in wet biomes is $1,671/ha and for dry biomes $587/ha under our central assumptions.

In general, the gains would be higher from the restoration of wet, moderately degraded lands, implying a comparatively better return from policy actions and investments under these conditions. The lowest gains, in general, are anticipated from restoration activities in dry, lightly degraded lands. However, the effectiveness of land restoration methods is location-specific and varies depending on the degree of degradation. Further analysis should consider the local social, economic, and ecological characteristics that might influence the magnitude of the benefits. The economic assessment of the benefits of restoration would need to be complemented by regional studies to produce more locally specific estimates with a financial emphasis.

Still, the analysis provides strong evidence to support the adoption of policy measures and the removal of barriers for land restoration efforts by national and local governments in the region. The positive results are expected from most restoration schemes (reforestation, agroforestry) in most biomes (wet, dry, temperate) and for a wide range in the degree of land degradation.

The analysis also supports the assertion that land restoration can be, under the right circumstances, an economically attractive GHG abatement strategy. It not only makes economic sense, but it also has the potential to make a significant difference in the projected emissions of the region when implemented at scale.

Land restoration presents an economic opportunity for the region to simultaneously slow agricultural expansion, counteract land degradation, contribute to climate stabilization, secure provision of ecosystem services and biodiversity, and promote the creation of wealth in rural areas.

ANNEX I. ESTIMATION OF ANNUAL BENEFIT FLOW VALUES

Methods for determining annual benefit values

To estimate the net restoration benefits, a baseline for both non-degraded and degraded benefit flow values (annual per hectare) must be established for each type of benefit considered.

The baseline annual flow of benefits is projected at a constant annual nominal value 50 years into the future. This generates expected annual flow values for land under non-degraded conditions. These values are adjusted by the model's scenario equations (see Annex II). The difference between "pristine" and "degraded" annual flow values represent the potential gain to be garnered through landscape restoration.

Agricultural Output Flows

The agricultural flow values are based on actual regionwide annual revenues from a selection of crops and an assumed distribution of restoration schemes (Tables A1 and A2).

For simplicity, crop prices and pristine yield levels are assumed to be constant into the future under the baseline scenario. As proxies of staple crops, it has been assumed that maize is the principal crop deployed in agroforestry restoration methods in subtropical and tropical wet biomes, and that soybeans and wheat are deployed by such methods in subtropical and tropical dry-mixed and temperate biomes.

Current average regional yields per hectare of maize, soy, and wheat were derived by dividing FAO data on total Latin America and Caribbean production levels for each of these crops in 2012 by the FAO data on hectares under cultivation (FAOSTAT 2014). These represent the total regionwide averages under the current scenario; that is, approximately 20 percent of Latin American and Caribbean forests and agricultural lands are degraded (versus the nearly four-fifths of landscapes in the region that remain more or less in pristine condition). Therefore, these yield averages have been further adjusted to strip out the degraded portion of the "standing average" in order to produce an average yield for each crop under pristine (or non-degraded) conditions (Table A1, column 3).

The adjusted pristine yield averages were multiplied by average prices to produce initial gross per hectare pristine flow values. These values are multiplied, in turn, by the number of degraded hectares (weighted by their distribution across the actual degrees of degradation exhibited in the region) that the restoration model assigns to agroforestry methods relying on maize, soy, and wheat.

The result is an aggregate total gross annual flow value for each crop (see column 5). These values are divided by the total number of target hectares assigned to each crop/biome-focused agroforestry method (Table 3, column 6) to produce gross pristine average annual agricultural output per hectare: $900/ha for maize; $1,438/ha for soy; and $930/for wheat. Finally, it is assumed that costs account for 60 percent of revenues;[29] stripping out costs leaves us with the baseline pristine "net" annual flow value per hectare of agricultural production—$360/ha for maize; $575/ha for soy; and $372/ha for wheat (see Table A1, column 6).

Table A1 | **Buildup of baseline gross annual benefit flows, aggregate and per hectare, 2012**

BIOME	CROP	ADJUSTED PRISTINE YIELD/HA (MT)	PRICE ($/MT)	BASELINE TOTAL GROSS ANNUAL FLOW (US$ BILLION)	BASELINE PRISTINE NET ANNUAL FLOW PER HECTARE ($/HA)
Wet	Maize	4.50	200	3.1	360
Dry/Mixed	Soy	2.60	553	4.6	575
Temperate	Wheat	3.07	303	0.06	372

Sources: FAOSTAT (2014) (yields), Indexmundi.com (prices), and results based on authors' calculations.

Table A2 | Distribution of degraded hectares targeted for agroforestry restoration (thousand ha)

		LIGHTLY	MODERATELY	SEVERELY	TOTAL
Wet	Maize	1,156	1,972	272	3,400
Dry/Mixed	Soy	1,088	1,856	256	3,200
Temperate	Wheat	23	39	5	67
Total Agroforestry		**2,267**	**3,867**	**533**	**6,667**

Source: Authors' calculations using data from Daily (1995), and Oldeman et al. (1991) data on GLASOD.

Annual pristine flow values for each agricultural product are used as inputs into the baseline scenario model equation (see Annex II) to calculate the baseline stock value (i.e., current NPV) for agricultural output per hectare. The model uses three discount factors to account for the crop productivity loss from various degrees of degradation (10 percent lightly degraded, 25 percent moderately, 50 percent severely) to establish baseline scenario flow and stock values in degraded lands. These same baseline flow values are then used as inputs into the restoration scenario model equation to produce their recovered NPV values. Table 2 in the main text presents the basic elements of flow value buildup described above.

Food Security Flows

Restoring degraded agricultural land through agroforestry can improve crop yields and reduce the risk of crop failure, leading to a reduction in food insecurity. The value of reducing food insecurity is partially captured by the market value of food security premiums (crop insurance) in the region—some $780mn in 2009 (World Bank 2010). When the risk of crop failure drops, the premiums for crop insurance also become smaller; this represents a potential "avoided cost" (the equivalent of a "net benefit") under the restoration scenario. The annual flow values (used as inputs in the model scenarios to estimate the food security benefit) represent annual agricultural insurance premiums paid by Latin American and Caribbean agents—or, more precisely, the fraction of these payments that could potentially be offset by agroforestry restoration-induced increases in agricultural output.

The premium levels apply to current crop output levels. However, these premiums only cover 20 percent of regionwide agricultural output, with livestock covered in only residual, and therefore irrelevant, quantities (World Bank 2011). Furthermore, our baseline agricultural output values are produced only from the 6.67 million hectares targeted for agroforestry restoration, which would be the equivalent of only 6 percent of total regionwide output of these three crops.

Therefore, to estimate the pristine annual food security benefit flow value, the gross pristine average annual agricultural flow values per hectare must be scaled downward by a discount factor incorporating the two limiting percentages, or 1.2 percent.

This process yields baseline annual food security benefit flow values of $11/ha/year for maize in subtropical wet landscape biomes; $17/ha/year for soy in subtropical dry biomes; and $11/ha/year for temperate biome wheat.

Ecotourism

The estimate of the stream of revenues associated with ecotourism is based on the historical experience of Costa Rica over the last forty years and uses actual annual visits and revenue growth figures (dating from the beginning of the country's land restoration process in the early 1980s) averaged on a per hectare basis of the reforested or restored areas. For simplicity, we assume that much of Costa Rica's increase in ecotourism revenues over the past thirty years has been associated with the restoration of degraded landscapes. These produce gross standing average annual ecotourism flow values per hectare in the subtropical wet landscape biomes ($303/ha). These are then adjusted to gross pristine average annual ecotourism flow values ($322/ha), and further modified downward ($210/ha) to reflect costs (assumed to be 60 percent of ecotourism revenues), as in agriculture.

Furthermore, it is also assumed that the Costa Rica estimate ($210/ha) can serve as a regionwide proxy for ecotourism in areas with similar social milieus.[30] The analysis uses Costa Rica's experience to estimate annual flow values from ecotourism in subtropical wet landscape biomes, subtropical dry landscape biomes (at 70 percent of this value, or $141/ha), and on temperate biomes (at 30 percent of this value, or $70/ha).

Tourism revenues have been associated with protection of intact landscapes rather than with restoration of degraded landscapes. Also, the revenues tend to be concentrated in specific regions of attraction and may not be uniformly distributed. The effect of the distribution of such benefits in the assessment can then be debated at a deeper level.

Carbon sequestration

Carbon sequestered at the present time in aboveground biomass represents "stocks" (like the forests themselves) and not "flows" (like the monetized flow of the wood forest products, for example, emanating annually from the forest "stock").

At the start of the time horizon, both the unrestored and the targeted restorable hectare have the same "stock" value—both in terms of physical aboveground carbon stocks (54.5 tC/ha in temperate biomes, 48.5 tC/ha in wet biomes, and 23.2 tC/ha in dry-mixed forest and agricultural landscapes, including savanna (Laestadius et al. 2014)), and their monetized NPV values. They also have the same annual flow values. In other words, in the case of estimating the

Table A3 | **Annual flow values versus recoverable gap, carbon sequestration**

BIOME IN LATIN AMERICA AND THE CARIBBEAN	CURRENT STOCKS (TC/HA)	CONSTANT ANNUAL FLOW VALUES ($/HA/YR)	MAXIMUM STOCKS (TC/HA)	RECOVERABLE GAP (TC/HA) DEGRADED FORESTS	RECOVERABLE GAP (TC/HA) DEFORESTED AGRICULTURAL LANDS
Temperate	54.5	0	77	22.1	63
Wet	48.5	0	157	108.5	50
Dry + Savanna	23.2	0	80	56	21

Source: WRI (2014).
Notes: Maximum stocks tC/ha = current intact pristine forest carbon stock levels (except in the case of agroforestry; see Annex II)

monetized carbon benefits from restoration, the annual flow value will be considered to be equal to the change in the carbon stock. In the case of restoration through reforestation, the difference in the total NPV values of both scenarios is accounted for by a recovery of the gap, over the particular time horizon, between average pristine carbon stocks per hectare and the current average carbon stock levels in "degraded" Latin American and Caribbean forests. At the end of the period (which varies according to the degree of degradation), the restored hectare's carbon stock/storage capacity reaches its maximum, fully restored level, assumed to be the same as the current pristine level currently registered in Latin America and the Caribbean for the distinct biomes (Table A3).

Restoration through agroforestry on deforested agricultural lands will result in lower carbon stocks than if the land is reforested. Average annual net carbon stock gains by agroforestry practices globally in the distinct biomes is used to determine the recoverable gap. For example, it has been estimated that agroforestry practices increase carbon storage by 21 tC/ha in subhumid (or dry) biomes, by 50 tC/ha in humid (or wet biomes), and by 63 tC/ha in temperate zones (Schroeder 1994; Montagnini and Nair 2004). For further discussion of the assumed process of carbon recovery, see Annex II.

The potential impact of climate on forests, and more widely in ecosystems is not considered in the analysis.

Wood Forest Products (WFPs) and Non-Wood Forest Products (NWFPs)

In order to estimate the benefits of avoided future deforestation, Chiabai et al. (2011) estimated flow and stock NPV values for a range of forest and related agricultural biomes and world regions, including Latin America and the Caribbean, for a range of benefits (including among them WFPs and NWFPs) and published the stock value NPVs. In order to estimate the net economic benefits of a global forest landscape restoration on the scale of the Bonn Challenge, Chiabai's published stock (NPV) values were converted into annual flow values for the two benefits mentioned here. Similar baseline and restoration scenarios were used, only they did not differentiate for biome or restoration method. Nevertheless, these 2011-based annual flow values can be used as the flow values for our model scenarios as well, given that they rely on similar international, regional, and national data sources.

Chiabai estimated the per hectare present value of WFPs, NWFPs, carbon, recreation, and cultural services provided by forests for eleven world regions using a database of valuation studies and globally available data.[31] Values were expressed in terms of 2005 $/ha on the basis of purchasing power parity (PPP) and contained site, study, and context-specific information from the case studies (these values were later converted into 2012 US dollar values). These economic studies covered a wide range of biomes and areas, differentiated levels of scale, time, and valuation methods. WFP and NWFP values were estimated with data on forest products drawn from the database on forests of the Food and Agriculture Organization (FAO) of the United Nations. Such flow values were estimated by applying adjustments so as to take into account product category or industrial sector, country of origin, forest biome, forest size designated to production, and profitability of the forest sector.

Annual flow values (in 2012$) for WFPs came to $21/ha in temperate biomes; $2,424/ha in wet and moist landscapes; and $702/ha in dry biomes, including savannas. Annual flow values for NWFPs came to $386/ha in temperate biomes; $386/ha in wet and moist landscapes; and $65 in dry biomes, including savannahs.

ANNEX II. ASSESSMENT MODEL AND THE SCENARIO EQUATIONS

Background

This model extends and builds on methodological approaches previously developed by Verdone (2014), using input values from a database developed from Chiabai et al. (2011), and elaborating on independently sourced data. Nevertheless, while relying on these authors for our Latin America and Caribbean input annual benefit flow values for wood forest products and non-wood forest products, this study generates its own method for valuing the other four economic benefits under consideration—agricultural output, food security, ecotourism (none of which were included in these previous lines of work), and carbon sequestration.

In addition, the analysis relies only on benefit flow values that have a physical base. This is in contrast to the aforementioned studies, which include recreational and cultural values as key benefits of landscape restoration, based on “willingness-to-pay” survey methods, which monetize such subjectively held valuations into “societal benefits.” Such estimates are undermined by their subjectivity and reliance on imperfect access to information by key stakeholders. Therefore, not including these values will yield conservative results.

Most importantly, the current study also transforms the general approach followed by Chiabai et al. (2011) and Verdone (2014) to allow for land values to vary between biomes, land-use type, degree of degradation, and restoration method. The previous methods only accounted for either biome (Chiabai et al. 2011) or degree of degradation and land-use type (Verdone 2014).

This 3 by 3 by 3 model (3 biomes, 3 degradation degrees, and 3 restoration methods) produces net gain NPV $/ha values for all combinations of biomes, degrees of degradation, and restoration methods, which represent the net benefits per hectare if all target hectares were concentrated in those particular biome and degradation categories and were restored by that particular method (see Table 6).

The model can provide both global and regionwide estimates. It can also provide a partial foundation and starting point for a more granulated assessment of landscape restoration opportunities and benefits in particular subregions within Latin America and the Caribbean. Finally, the results produced here are also the first regionwide estimates of the net economic benefits of landscape restoration to have been published to date.

Description of the model

The assessment estimates the additional net present value ($NPV_{\text{net gain}}$) that would result from restoring 20 million hectares of degraded lands in the region with the scope of Initiative 20x20. This net present value results from the difference in the present value of a degraded hectare of forest or agricultural land that has been restored (NPV_{20x20} or restoration scenario), and the present value of a degraded hectare that has not been restored (NPV_{degraded} or baseline scenario).

(1) $$NPV_{\text{net gain}} = NPV_{20x20} - NPV_{\text{degraded}}$$

The model can be synthesized into the following equation from the extended forms of NPV_{20x20} from the restoration scenario and NPVdegraded from the baseline scenario.[32]

(4) $$NPV_{\text{net gain}} = \sum_{t=0}^{50} \left(\frac{1}{1+r}\right)^{t} [(PDVI_{dt} - PDVI_{d}) \times (B_{bl}) + (t \times R_{tbldm} - Cost_{dm})]$$

where

(3) $$B_{bl} = WFP_{bl} + NWFP_{bl} + ET_{bl} + AP_{bl} + ACFS_{bl} + CS_{bl}$$

(5) $$R_{tblmd} = \frac{(PDVI_{dt} - PDVI_{d}) \times (B_{bl})}{T},$$ where T is the time for recovery.

The inputs to the model are the average annual values of benefits and costs generated in each landscape biome as a result of the restoration processes (see Annex I). The outputs are net present values (or current stock values, presented in both aggregate and per hectare terms).

The variables include:

- **LANDSCAPE BIOME:** Degraded lands in Latin America and the Caribbean are concentrated in subtropical and tropical wet forests and related agricultural landscapes (51 percent) and in subtropical and tropical dry-mixed forests and other agricultural lands (48 percent). Temperate forests (1 percent) and related landscapes are marginal but have been included for comparative purposes. Annual benefit flow values vary across biomes. The region’s wet biomes are generally more productive, in both non-degraded (pristine) and degraded states, than either the dry-mixed or temperate biomes.
- **LAND-USE TYPE:** The land to be restored includes (1) managed forests, (2) natural forests, and (3) wooded savannas and other related degraded agricultural lands. To allow for both the calculation of an average regional estimate of the economic benefits of restoration and estimates according to biome and method, the following assumptions have been made:

  - ☐ Each restoration method is assigned to particular land-use types (planted restoration to managed forests, assisted regeneration to natural forests, and agroforestry to wooded savannas and other related degraded agricultural lands).
  - ☐ Each benefit is assigned to a single restoration method—WFPs to planted restoration, NWFPs and ecotourism to assisted regeneration of natural forests, and agricultural output and food security gains to agroforestry in degraded savannas and other agricultural lands. (The only exception is the carbon benefit, which is produced by all methods in each land-use category. It is associated with all the other benefits, which are each limited to one land-use type and method.)
- **DEGRADATION DEGREE:** Degrees of degradation include light, moderate, or severe degradation (more in the section below on the restoration scenario).
- **RESTORATION METHOD:** Restoration methods include planted restoration, assisted regeneration, or agroforestry (more in the section below on the restoration scenario).
- **RESTORATION COSTS:** Costs are calculated by method, but distributed equally across all benefits in each land-use/restoration method category, and scaled for and distributed annually according to the degree of degradation (see section on restoration costs below).

Biome, land-use type, and relative degree of landscape degradation are at play in both the baseline and the restoration scenarios. However, the last two variables—restoration method and restoration costs—apply only to the restoration scenario, and constitute the key variables of change between the two scenarios. For more on degradation degree, restoration method, and restoration costs, see the section below on the restoration scenario.

The Baseline Scenario

The baseline scenario is based on a "business-as-usual" (BAU) trajectory over the next fifty years. Under this scenario, the 20 million hectares of degraded Latin America and Caribbean forest, savanna, and agricultural landscapes targeted by Initiative 20x20 for restoration remain degraded and unrestored. As such, the annual monetized flow values of the economic benefits produced by the provisioning, regulating, and other ecosystem services of degraded forests and agricultural lands in the region remain far below their optimal or potential levels. This is due to the productivity losses associated with degradation.

These degraded levels of ecosystem services productivity are captured in the model equations by discount factors (based on "PDVI" or potential direct instrumental value) that are applied to all of the annual benefit flow values of the region's pristine forests and agricultural landscapes: 10 percent for lightly degraded land, 25 percent for moderately degraded land, and 50 percent for severely degraded.[32] The only exception is the carbon benefit, which is calculated according to a different buildup of annual flow values, a modified recovery model (still partially based on Daily 1995), and actual carbon stocks on currently degraded Latin American and Caribbean lands (WRI forest carbon data). See below for a separate explanation of the carbon benefit.

Discounting the "pristine" annual flow values allows a baseline level of flow values from currently degraded landscapes to be established. The baseline of annual benefit flow values is then converted to a stock by being summed to current NPV. Although there would be costs associated with any restoration option, this business-as-usual productivity gap between currently degraded forests and agricultural lands represents the source of potential net benefits to be garnered by landscape restoration.

The Restoration Scenario

In the restoration scenario, a representative set of 20 degraded hectares in Latin America and the Caribbean—51 percent from subtropical wet and moist landscapes and 48 percent from dry-mixed forest and savanna biomes—is assumed to be brought under restoration and fully restored (WRI 2014; Potapov et al. 2011).

The 20 million hectares are pulled from each of these biomes according to the actual distribution of the degrees of degradation—34 percent lightly degraded, 58 percent moderately degraded, and 8 percent extremely degraded (Oldeman et al. 1991).[33] The restoration scenario then assumes that a balanced menu of three broad restoration methods—(1) wide-scale planted restoration, (2) assisted regeneration of secondary and naturally existing forests, and (3) agroforestry—will split equally between, and applied to, these target hectares.

The effect of restoration on the annual benefit flow values of degraded forests and agricultural lands will depend on (1) the annual "benefit recovery rate" in ecosystem productivity that each method generates, and (2) the total costs of restoration. Such costs reduce the net annual benefit flow values, diminishing to some degree the total potential net benefits against the baseline (see below).

Annual Recovery Rate

This rate is determined by the interaction of the following variables:

- **DEGRADATION DEGREE:** A landscape's degree of degradation affects the length of recovery and the size of the productive gap between the current "degraded" annual flows and restored benefit flows. Lightly degraded landscapes are assumed to take 3 to 10 years to be fully restored (or, on average, 7 years). Moderately degraded forests require 10 to 20 years to recover, while severely degraded lands take up to 50 years or more (Daily 1995). Therefore, while more highly degraded land faces a larger overall potential productivity gain than more lightly degraded lands, it also takes longer to restore to full potential. Likewise, restoring a more lightly degraded hectare produces a smaller increase in productivity, but it is achieved much more rapidly.
- **RESTORATION METHOD:** For clarity and simplicity, it has been assumed that:
  1. *planted restoration* captures WFPs and carbon sequestration benefits (although only 75 percent as much carbon as assisted regeneration)
  2. *assisted regeneration of natural forests* captures NWFP and ecotourism benefits, along with those of carbon sequestration (registering the highest gains from the carbon benefit among the three considered methods)

3. *agroforestry* captures agriculture, food security, and carbon benefits (45 percent of the carbon sequestered by assisted regeneration of natural forests).

Carbon Sequestration

The carbon benefit estimate is based on Laestadius et al. (2014) for carbon stocks (t/ha) in currently degraded forests and agricultural lands—rather than relying on the GLASOD data in Oldeman et al. (1991) and proxy averages of degrees of degradation and an average productivity discount (as in the application of the PDVI) in Daily (1995).

What can be recovered through different restoration methods in terms of tC/ha is obtained by subtracting the current carbon stocks from the Latin American and Caribbean degraded lands in the three biomes (Annex I) from the maximum recoverable stock levels. This gap is then divided by the number of years of a time horizon to constitute the annual amount recovered. This is the constant annual rate of recovery for carbon stocks.

It is assumed that carbon stocks are fully restored—over a 20-year horizon on the targeted hectares considered to be lightly degraded; over a 35-year horizon on the landscapes assumed to be moderately degraded; and over a 50-year horizon on the hectares assumed to be severely degraded—in tandem with the time periods expected for restoration of the corresponding biomes. It has also been assumed that assisted regeneration of natural forests achieves 100 percent recovery of pristine forest carbon stocks; that planted restoration is assumed to recover 75 percent;[34] and that agroforestry methods restore about 45 percent.[35] As a result, the annual recovery rate for carbon stocks is constant with respect to time.

Finally, for agroforestry the analysis uses the same WRI data for current aboveground carbon stocks in degraded forests and deforested landscapes (including agricultural lands) to establish the initial levels of carbon stocks. But because carbon storage levels in pristine Latin American and Caribbean forests cannot be used as an upper limit for the recoverable gap in the case of agroforestry on degraded or deforested agricultural lands, we therefore use data on the average net gain in carbon storage for agroforestry restoration methods to establish a specific recoverable gap in the case of agroforestry. This "notional gap" (based on average net carbon stock gains for agroforestry) is on average (weighted) only 45 percent of the gap recovered by assisted regeneration of natural forests.

Restoration Costs

Costs arise from (1) the establishment and maintenance (E&M) of activities required to restore landscapes and (2) transaction costs. The model's total per hectare cost estimates are presented in Table A4, and have been generated by a process described below and presented in Table A5.

Restoration experiences in Latin America and the Caribbean (World Bank 2014; CATIE et al. 2005) suggest that such E&M costs can range widely—from as little as $300/ha to over $3,000/ha, depending on a range of factors, including location, method, and degree of degradation.

Table A4 | Final restoration cost references, by method and degree, $/ha

RESTORATION METHOD	DEGRADATION DEGREE		
	SEVERE	MODERATE	LIGHT
Planted restoration	2700	1350	675
Assisted regeneration	1500	750	375
Agroforestry	2700	1350	675

Sources: Authors' estimates and Verdone (2014); CATIE et al. (2005).

This broad range of estimates was divided into three subranges, one for each of the model's restoration methods. An average for each method was calculated from the data points of experience and previous estimates (see Table 8, column two). The resulting historical E&M averages reflect the varying impact of different restoration methods on upfront, ongoing, and total costs. Assisted regeneration was found to cost less on average ($600/ha) than planted restoration ($900/ha) or agroforestry ($1,200/ha).

We assumed an additional $150/ha for transaction costs and another $300/ha, in the case of planted restoration, to account for assorted opportunity costs (see Table A5, columns 3 and 4). This raises the total adjusted historical cost estimates to: assisted regeneration ($750/ha); planted restoration ($1,350/ha), and agroforestry ($1,350/ha) (see column 5).

Finally, it is assumed that costs rise and fall with the degree of degradation, given that it affects not only the amount of productivity loss that must be regained, but also the length of the restoration period required for full recovery of ES potential.

Because moderately degraded landscapes account for the majority of regional degraded lands, the total adjusted historical averages for each method (found in column 5) have been assigned to represent the baseline costs of restoring moderately degraded lands (column 7).

Severely degraded lands are those with less than half of the primary productivity of non-degraded land—twice the size of the gap of moderately degraded lands. Therefore, estimated restoration costs of severely degraded lands are higher than the moderately degraded baseline by 100 percent.

On the other hand, costs for restoring lightly degraded lands are half of the restoration costs for the moderately degraded baseline. The final adjusted average cost of restoration for Latin America and the Caribbean is around $1,150/ha.

Table A5 | **Restoration cost references, by method and degree, $/ha**

RESTORATION METHOD	E&M COSTS	TRANSACTION COSTS	OPPORTUNITY COSTS	TOTAL COSTS	COST OF LIGHTLY DEGRADED LANDS	COST OF MODERATELY DEGRADED LANDS	COST OF SEVERELY DEGRADED LANDS
Wide-scale planted	900	150	300	1,350	675	1,350	2,700
Assisted naturally regenerating	600	150	0	750	375	750	1,500
Agroforestry	1,200	150	0	1,350	675	1,350	2,700
Average	900	150	100	1,150	575	1,150	2,300

Source: Authors' results using data from World Bank (2010). and CATIE et al. (2005).

Adjusted restoration costs were integrated into the restoration model by subtracting them from the annual benefit flow values associated with each restoration method. However, rather than dividing and assigning that cost equally to each year along the required restoration time horizon, a final adjustment was made to allow costs to be assigned to particular annual benefit flows that more accurately reflect the dynamics of restoration, which require upfront costs in relation to a more extended period of recovery.

Nevertheless, because E&M activities will always require more than a single year to be fully implemented, the full per hectare cost should not be assigned to the first year of restoration alone, but rather to a number of initial years along the restoration time horizon. In the case of lightly degraded landscapes, the total cost/ha (from Tables 7 and 8) has been divided and assigned equally to the first four years (or roughly the first half) of the restoration time horizon. In the case of moderately degraded lands, the total cost has been subtracted from annual benefit flow values in equal annual tranches over the first 8 years (again, roughly the first half of the restoration time horizon). Finally, total costs for severely degraded lands are subtracted in equal annual amounts over the first 25 years of the restoration time horizon. Allocating costs over a 25-year time horizon has the effect of discounting costs relative to the benefits.

However, while costs are only distributed along the first 4, 8, or 25 years of the time horizon, the cost burden is split between the annual flow values of each benefit captured by each method. This distribution of estimated costs across time and annual benefit flow value streams is captured in the restoration scenario's model equation (explained more fully below).

The net annual benefit values are inserted as "inputs" into the model scenario equations, which sums them to net present value (NPV) and converts them into stock values (the "outputs" of the model).

Baseline Scenario Estimate

The basic estimate of the baseline scenario is the net present value (the "stock value") of degraded Latin America and Caribbean forests and related agricultural landscapes. This is calculated for each biome, forest land use, and degradation degree according to:

$NPV_{degraded}$ represents the net present value of degraded Latin America and Caribbean forests and related agricultural landscapes. The indices b, l, and d in the equation represent, respectively: (1) forest biome in the region; (2) land-use category; and (3) degradation degree. The discount rate (r) is assumed to be 3 percent and the time horizon is 50 years.

Relevant forest biomes (b) include tropical and subtropical wet, tropical and subtropical dry, and mixed temperate forests, wooded savannas, and related agricultural landscapes.

The forest land-use types (l) considered in the model include: (1) managed forests, (2) natural and multi-use forests, and (3) agricultural lands. Each land-use type (l) is assigned with a particular combination of forest and agricultural product and service flows from our range of economic benefits.

$$\textbf{(5)} \quad NPV_{degraded} = \sum_{t=0}^{50} \left(\frac{1}{1+r}\right)^{t} [PDVI_{d} \times (WFP_{bl} + NWFP_{bl} + ET_{bl} + AP_{bl} + ACFS_{bl} + CS_{bl})]$$

The NPV calculations for each distinct land use include only the principal benefit(s) from our set, which are generally associated by the literature with each land-use type. The exception is the carbon benefit (C), which is included in the total benefit flows of all land-use types. As a result, the calculation of NPV stock values includes:

- WFP + CS, when (l) represents managed forests
- NWFP + ET + CS, when (l) represents natural forests
- AP + ACFS + CS, when (l) represents savannas and related agricultural lands.

The matrix of values presented in Table 5 allows for a set of distinctions concerning land-use and restoration potential in Latin America and the Caribbean.

It is certainly plausible that certain WFP flows might (or could) be produced in some natural forests and some agricultural woodlands and savannas; or that some NWFP flows could occur in certain managed forests; or that certain agriculture flows could be generated in both managed and natural forests. However, given the data available from the literature, these additional flow benefits are not considered.

DEGRADATION DEGREE (D) is defined as either lightly degraded, moderately degraded, or severely degraded—measured against a non-degraded (or pristine) baseline (following GLASOD). For simplification purposes, extremely degraded land has been excluded from the analysis, given that this category applies to only a minimal area of Latin America and Caribbean forests.

PDVI—or "potential direct instrumental value" (see Daily 1995)—serves as a productivity variable that, when subtracted from maximum potential (or pristine levels), results in the productivity loss associated with each degradation degree (d). In this sense, it is assumed that lightly degraded forests suffer an average productivity loss of 10 percent and register a corresponding PDVI of 90 percent. Moderately and severely degraded forests register PDVIs of 75 percent and 50 percent, respectively, and suffer from corresponding productivity gaps of 25 percent and 50 percent (following Daily 1995 and Oldeman et al. 1991 data on GLASOD).

Finally, **WFP**, **NWFP**, **ET**, **AP**, **ACFS**, and **CS** are equation (1)'s inputs and represented by the annual flow values of wood forest products, non-wood forest products, agroforestry products, food security benefits (avoided insurance costs), and carbon sequestration. (See Annex I for a description of the modified buildup method used for carbon annual flow values).

The Restoration Scenario Estimate

The basic estimate of the restoration scenario is the net present value (the stock value) of restored Latin American and Caribbean forests and related agricultural landscapes. This is calculated for each biome, land use type, and degradation degree following equation (2):

(6)

$$NPV_{20X20} = \sum_{t=0}^{50} \left(\frac{1}{1+r}\right)^{t} [(PDVI_{dt} \times (WFP_{bl} + NWFP_{bl} + ET_{bl} + AP_{bl} + ACFS_{bl} + CS_{bl})) + (t \times R_{tbldm} - Cost_{dm})]$$

$\mathbf{NPV_{20x20}}$ represents the net present value of restored Latin American and Caribbean forest and related agricultural landscapes. NPV_{20x20} is a function not only of landscape biome (b), land-use type (l), and degradation degree (d)—as in the case of $\boldsymbol{NPV_{degraded}}$ in the baseline scenario— but also of the employed restoration method (m), which in turn affects both the rate of recovery (R_{tbldm}) and the costs ($Cost_{dm}$) of restoration.

In the restoration scenario, PDVI becomes a function not only of degradation degree (d), but also of time (t), reflecting the varying capacity of restoration to recover ecosystem functioning, depending on the severity of the initial degradation degree. This implies that in the restoration equation,

$\boldsymbol{PDVI_{dt}}$ takes on its normal, assigned value (as in the baseline) for each degree of degradation over the course of the restoration recovery time-horizon in question (7, 15, or 50 years), in accordance with the required recovery period for lightly, moderately, and severely degraded forests. When the restoration time-horizon ends, and the landscape is considered to be restored, $PDVI_{dt}$ becomes equal to one.

The $PDVI_{dt}$ for lightly degraded land, as an example, is equal to 0.9 and can be restored to 1 over a period of 7 years—over which time the ES productivity of the landscape is fully recovered. The $PDVI_{dt}$ for t = 1,2, 3,...,7 would therefore be equal to 0.9, but for t=8,9,10,…,50, PDVI would equal to 1. The $PDVI_{dt}$ for t = 15 years, in turn, is equal to 0.75, and will be restored to 1 after 15 years, while $PDVI_{dt}$ for t = 50 years (i.e., on severely degraded lands) is equal to 0.5 over all 50 years.

$\boldsymbol{R_{tblmd}}$ denotes the annual rate of recovery, or the annual change in flow values that can be achieved through restoration over the designated recovery time horizon. The length of time required to restore the productivity of degraded forests was estimated by Daily (1995) to be 3–10, 10–20, 50–100, and more than 200 years, depending on whether land is lightly, moderately, severely, or extremely degraded (extremely degraded lands have been excluded from the current analysis). At the end of the required recovery period (i.e. which we have set, following Daily, at 7, 15, or 50 years), the annual flow of values from the restored landscapes become equivalent to the annual flow from non-degraded forests and agricultural lands.

Figure A1 | PDVI value throughout restoration process

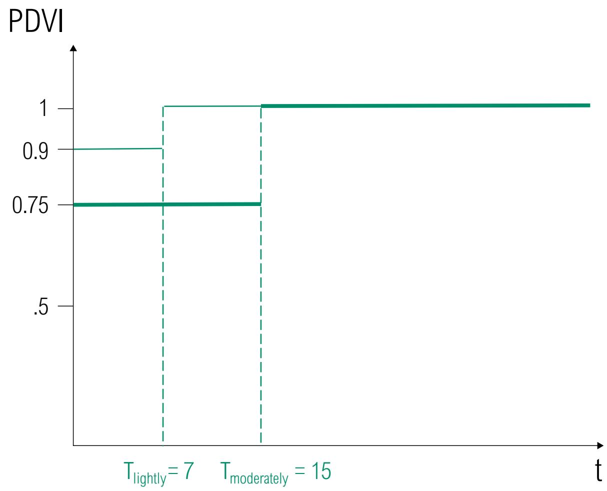
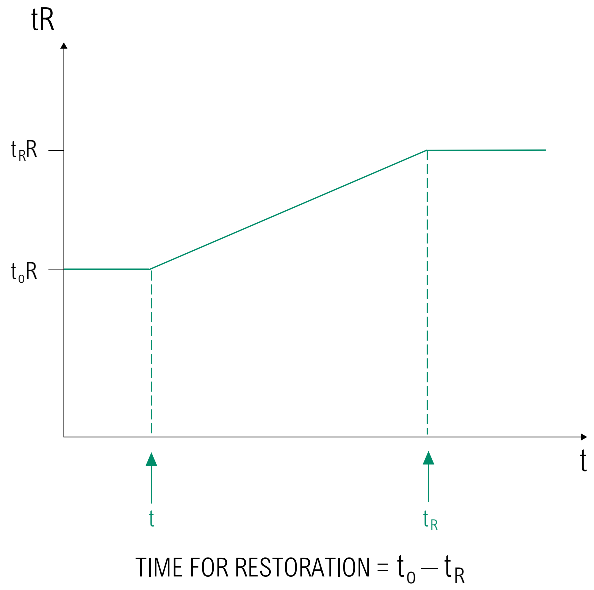


Figure A2 | Annual recovery in flow from restoration



The annual rate at which restoration can recoup the annual value of ES services can be estimated for each biome in the region, land-use type, and degradation degree by calculating the difference between (1) the annual flow value of non-degraded lands (or pristine forest and related agricultural lands) and (2) the annual flow value of the degradation degree, biome and land-use type, and then dividing this difference by the number of years required for full restoration. The annual rate of recovery for a specific type of degradation is assumed to be linear, but the amount of time required to fully restore productivity is nonlinear in relation to degradation degree.

The term $[t \times R_{tbldm}]$ reflects the ongoing annual increase in the total value of recovered flows over the recovery time horizon. At the end of the recovery period, the annual recovery rate, $t \times R_{tbldm,}$ becomes equal to zero, reflecting the complete restoration of full value of annual flows from non-degraded or pristine forest landscapes.

This recovery rate, however, is also a function of the restoration method employed (m). First, carbon is assumed to be sequestered the most intensively by assisted regeneration in natural forests, followed by planted restoration in managed forests, and agroforestry, the method that sequesters the least carbon per ha in relative terms. Therefore, in order to capture this difference in the capacity to sequester carbon across methods, a scaling parameter of 75 percent has been applied to the carbon gains from planted forests. Furthermore, the modified recovery model for carbon produces a benefit level only 45 percent of that generated from assisted regeneration of natural forests.

However, because the carbon gain represents augmented stock value, as opposed to a flow value gain, this annual recovery rate remains constant every year (minus restoration costs), rather than growing by a constant amount every year. In other words, in the case of carbon storage, the term $[t \times R_{tbldm}]$ in the restoration equation presented above (which for the other benefits reflects the ongoing annual increase in the total value of flows) is modified simply to $[R_{tbldm}]$. At the end of the restoration recovery period, the annual recovery rate, R_{tbldm}, becomes equal to zero, reflecting the complete restoration of full maximum pristine values for aboveground carbon stocks (or their equivalent in the agricultural lands targeted with agroforestry) and the elimination of the recoverable carbon stock gap.

Secondly, because the restoration methods considered in this study (see below) are structurally better suited to particular forest land-use types, they also each tend to produce a particular range of benefits characteristically linked to their associated forest land-use type. This particular range of benefits will differ from those generated by the other methods. For example, planted restoration in managed forests generates benefits in the flows of wood forest products and carbon sequestration, but none from non-wood forest products, ecotourism, agricultural output, or food security.

On the other hand, assisted regeneration in natural forests captures the flows of non-wood forest products, ecotourism, and carbon sequestration (but no wood or agricultural benefits), while agroforestry produces benefit flows primarily from enhanced agricultural output and food security. Although all three restoration methods allow for the accrual of carbon gains, their distinctive capacities for sequestration are embedded in the scaling parameters mentioned above that are applied to the annual recovery rates of carbon sequestration flows, and in the modified recovery rate model used for the carbon benefit.

As a result, each restoration method will have a different impact on the overall potential annual rate of recovery of benefit flows of standing forests in Latin America and the Caribbean.

This method difference in the annual recovery rate is a function of (1) the selected benefit range to be estimated (each restricted to the restoration of particular land-use types), (2) current land-use patterns, and (3) relative differences in carbon sequestration efficiency and potential. It also represents the relative cost-benefit tradeoff faced by any restoration opportunity as its stewards contemplate the available options of transforming a particular set of degraded lands into either protected or managed forests, enhanced natural and assisted regenerating forests, or improved agricultural lands.

Restoration costs ($cost_{dm}$) are a function of both the restoration method (m) and the existing degree of degradation (d). Such costs have been estimated and distributed among benefits for their appropriate deduction from the annual benefit flow values—as described at the beginning of Annex II.

Table A6 | Annual benefit flow values from pristine/non-degraded forests and agricultural lands in Latin America and the Caribbean, $/year/ha

LAC BIOME	WFP	NWFP	ECOTOURISM	AGRICULTURE	FOOD SECURITY	CARBON (TC/HA/YR)
Temperate	21	386	70	372	11	0
Wet	2,424	386	210	360	11	0
Dry + Savanna	702	65	141	575	17	0

Source: Results using Chiabai et al. (2011) for WFPs and NWFPs; and FAO (2010), WRI (2014), and World Bank (2010) for ecotourism, agriculture, food security, and carbon.

Distinction between Baseline and Restoration Equations

The baseline equation and the restoration equation differ in the following: (1) the additional term of the restoration equation, which contains the recovery model (i.e., ($t \times R_{tbldm}$ – cost) and represents the effects of restoration; and (2) the PDVI discounts applied in the first half of the restoration equation (i.e., ($PDVI_{dt} \times (wfp_{bl} + nwfp_{bl} + et_{bl} + ap_{bl} + acfs_{bl} + cs_{bl})$), which are also delimited by subscript t, which in effect limits the accounted-for benefits only to the years of each method's recovery horizon (i.e., 7, 15 or 50 years, depending on degree of degradation).

This implies an underestimation of benefits given that, in this form, the restoration scenario equation does not account for the remaining annual difference in net flow values between the degraded hectare that is restored and the same hectare left degraded for the years between full restoration and the end of the study's overall assumed 50-year time horizon. The NPVs of all target hectares would have to be calculated for all 50 years, particularly in the cases of lightly and moderately degraded lands which have recovery periods under restoration (delimited in this equation by t, which are only 7 and 15 years, respectively).

For example, restoration of lightly degraded lands restores the full productivity by year 8; however, the benefits are only accounted for during the first 7 years. The difference between the net flow values between the fully restored land and the baseline values between year 8 and year 50 are not captured. The same is true for restoration of moderately degraded lands after year 15. On the other hand, restoration of severely degraded lands does not imply such an undercounting given that the recovery period for severely degraded lands is assumed to be 50 years, equal to the overall 50-year time horizon of the aggregate estimate.

In short, the current model underestimates the net benefits of restoration for two reasons. First, as mentioned earlier, we have made the simplifying assumption that currently degraded hectares remain at a constant level of degradation for all 50 years under the baseline scenario. This implies that no further degradation takes place in Latin America and the Caribbean, making this a conservative assumption with respect to the results. Second, because of the delimitation of the benefits summations of only the years of the recovery period, the results are also conservatively underestimated because the net gains in the remaining years after full recovery and until the end of the overall 50-year reference horizon of the study are not accounted for in the restoration of lightly and moderately degraded lands. On the other hand, the fact that in the baseline equation, PDVI is not delimited by subscript 't'—and therefore is always summed back to NPV for all 50 years in the case of each degradation degree (including lightly and moderately degraded hectares)—introduces a slight overcalculation (compared to the alternative in which the baseline equation delimits the summations to the particular anticipated recovery period for each degree of degradation).

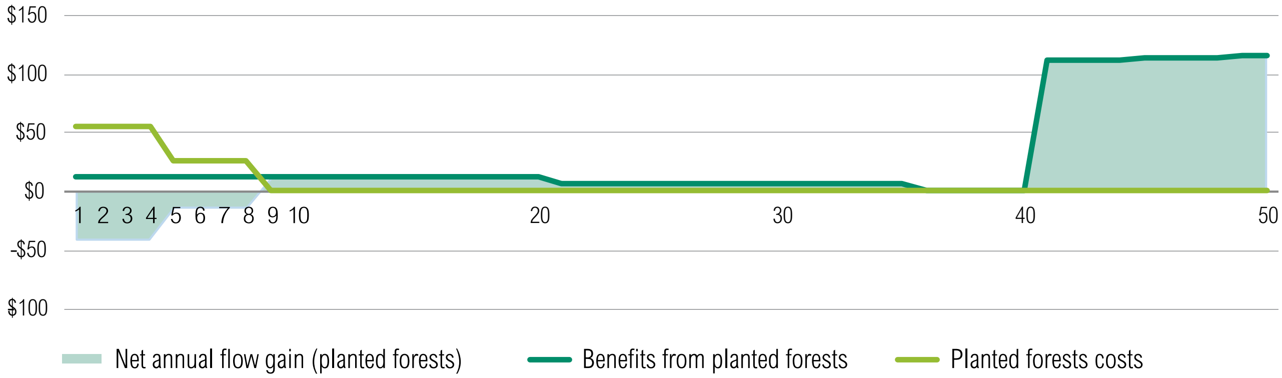
A superior model could be developed in the future that could capture these unaccounted for gains for the entire 50-year time horizon, which serves as the study's overall time frame reference. This could be done by removing the "t" subscript from PDVI in the restoration equation and from the second half of the equation where it modifies R; and then by redefining R so that it reflects both the gains accounted for over each recovery period and the gains that would continue to accrue annually from the end of the recovery period to the end of the 50-year time horizon.

Summary of annual benefit flow values

The annual benefit flow values generated by the methods and processes described above are summarized in Table A6.

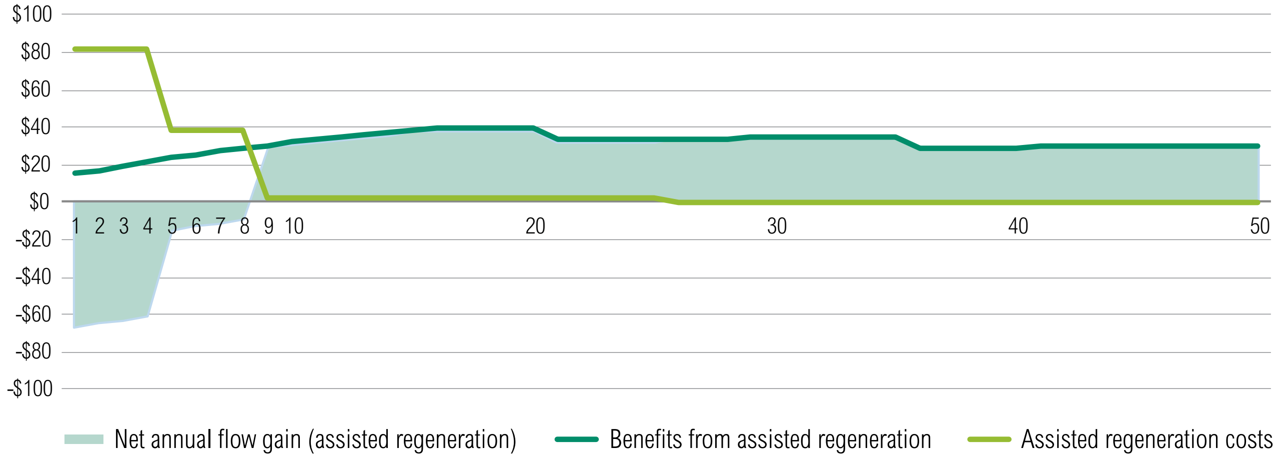
Annual benefits by restoration method can also be visualized in Figures A3, A4, and A5. Each figure provides flow detail for all three restoration methods: planted restoration, assisted regeneration, and agroforestry.

Figure A3 | Net annual flow gain per hectare for planted restoration (WFP restricted until year 40)



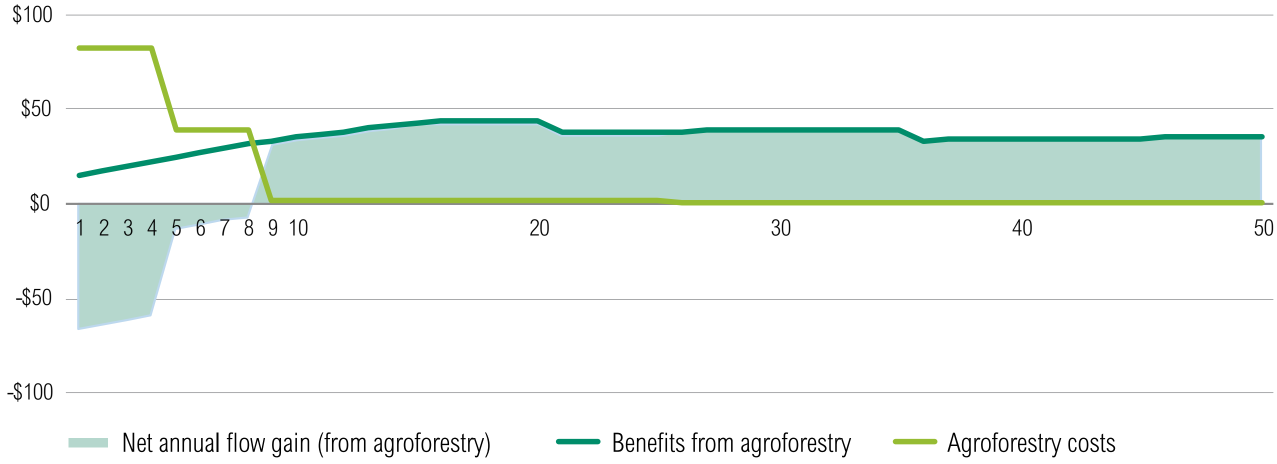
Source: Authors' elaboration. WFP benefits are considered restricted until year 40.

Figure A4 | Net annual flow gain per hectare for assisted regeneration



Source: Authors' elaboration.

Figure A5 | Net annual flow gain per hectare for agroforestry



Source: Authors' elaboration.

ANNEX III. SUMMARY OF MODEL STRUCTURE, PARAMETERS, AND ASSUMPTIONS

Table A7 | **Summary information**

CATEGORY/ PARAMETER	PARAMETERS/ ASSUMPTIONS	PARAMETERS/ ASSUMPTIONS	PARAMETERS/ ASSUMPTIONS	SOURCES	NOTES
BIOME	% OF DEGRADED LAC LANDSCAPES				
Subtropical wet/ moist	51%			WRI (2014); Potapov et al. (2011a)	
Subtropical dry/ mixed	48%			WRI (2014); Potapov et al. (2011a)	
Temperate	1%			WRI (2014); Potapov et al. (2011a)	
DEGREE OF DEGRADATION	ASSUMED % OF DEGRADED LANDS	ASSUMED PDVI	RECOVERY PERIOD		
Lightly degraded	34%	90%	7 years (20 years for carbon)	Oldeman et al. (1991); Daily (1995)	Annual recovery rates remain constant and linear
Moderately degraded	58%	75%	14 years (35 years for carbon)	Oldeman et al. (1991); Daily (1995)	Same as in lightly degraded
Severely degraded	8%	50%	50 years	Oldeman et al. (1991); Daily (1995)	Same as in lightly degraded
LAND-USE TYPE/ RESTORATION METHOD	% OF TARGETED (20 MHA) DEGRADED AND DEFORESTED HA	TARGET ASSUMPTIONS AND PARAMETERS	BENEFIT CATEGORIES CAPTURED		
Managed forests/planted restoration	33% 6.67 Mha	Less than 2% of LAC forests are managed; most of the targeted ha will imply new wide-scale planted reforestation	WFPs, CS		
Natural forests/ assisted and passive regeneration	33% 6.67 Mha	All targeted ha assigned to natural forests (98% of LAC total)	NWFPs, ET, CS		
Agricultural savannas, woodlands, etc./ Agroforestry	33% 6.67 Mha	Agroforestry is assigned to WRI-designated deforested lands (nearly 30% of which are also WRI-identified as restoration opportunities classified as agricultural lands (some 100 Mha LAC-wide))	AP, ACFS, CS		

Table A7 | **Summary information (continued)**

CATEGORY/ PARAMETER	PARAMETERS/ ASSUMPTIONS	PARAMETERS/ ASSUMPTIONS	PARAMETERS/ ASSUMPTIONS	SOURCES	NOTES
BENEFIT FLOW VALUES	QUANTITIES	PRICES	ASSUMPTIONS	SOURCES	NOTES
WFPs	LAC regional averages based on national data buildups from Chiabai et al. 2011 (via Verdone)	LAC regional averages based on national data buildups from Chiabai et al. 2011 (via Verdone)	Constant 2012 wood prices into the future (Chiabai et al. 2011 assumption based on historical price data from WB; adjusted by Verdone to 2012)	Chiabai et al. (2011)	Constant real prices into the future supported by constant historical prices over long-run, on average (conservative bias on results)
NWFPs	Same as in WFPs	Same as in WFPs	Same as in WFPs	Same as in WFPs	Same as in WFPs
Ecotourism	Historical tourism revenue data (adjusted to model parameters)	Historical tourism revenue data (adjusted to model parameters)	Data from Costa Rica serves as proxy for LAC; Scaled link assumed between historical forest protection/ restoration efforts and ecotourism	Inman et al. (1997); Rodriguez (2014)	
Agricultural output	Quantities, harvested ha, yields from FAO Adjusted Pristine Yield/ha Maize: 4.5 metric tons/ha Soybean: 2.6 mt/ha Wheat: 3.1 mt/ha	Prices based on simplified average historical prices from multiple sources for corn/maize (1995–2014), soybeans (2013–14) and wheat (2014)	Constant prices assumed into the future maize: $200/metric ton soybean: $553/mt wheat: $303/mt	FAOSTAT (2014) (for Q, HA, Y); indexmundi.com and World Bank data (for crop prices)	Assumed assignment of corn/maize to wet biomes; soybeans to dry/mixed biomes; wheat to temperate biomes Constant real prices into the future (support: as in WFPs)
Avoided food security costs	Agricultural insurance premiums: $780mn annually in LAC in 2009	Same as in Quantity	Agricultural output gains from agroforestry displace 1.2% of current annual LAC premiums (20% insurance coverage of crops in LAC x 6% of LAC crop production affected)	World Bank (2010); FAOSTAT (2014)	Analysis only covers three crops: maize, soybean, wheat
Carbon storage	Current LAC aboveground carbon stocks (average tC/ha for average of degraded forests and deforested lands) Wet biomes: 48.5 tC/ha Dry/Mixed: 23.2 tC/ha Temperate: 54.5 tC/ha	Recoverable carbon stock gap (average tC/ha) Wet biomes: Forests: 108.5 tC/ha Agricultural lands: 50 tC/ha Dry/Mixed: Forests: 56 tC/ha Agricultural lands: 21 tC/ha Temperate: Forests: 22 tC/ha Agricultural lands: 63 tC/ha	Constant average recovery rate = recoverable gap divided by: 20 years (recovery cycle in lightly degraded landscapes) 35 years (recovery cycle in moderately degraded landscapes) 50 years (recovery cycle in severely degraded landscapes)	WRI (2014), Potapov et al. (2011a) for the average of degraded forests and deforested lands; Schroeder (1994), and Montagnini and Nair (2004) for recoverable carbon gap in agricultural lands	

Table A7 | **Summary information (continued)**

CATEGORY/ PARAMETER	PARAMETERS/ ASSUMPTIONS	PARAMETERS/ ASSUMPTIONS	PARAMETERS/ ASSUMPTIONS	SOURCES	NOTES
RESTORATION COST VALUES	BY RESTORATION METHOD	BY DEGREE OF DEGRADATION	ASSUMPTIONS	SOURCES	NOTES
Establishment and Maintenance Costs	Planted: $900/ha Assisted: $600/ha Agroforestry: $1,200/ha		Based on simple averages of some 60 LAC experiences and estimates	World Bank (2014); CATIE et al. (2005)	
Transaction costs	$150/ha each		Assumed to be 10% to 25% of E&M costs		
Opportunity costs	$300/ha for planted only		In line with degraded annual flow value of agricultural production; Reasonably assumed to apply to planted or protected forests		
Total restoration costs	Planted: $1,350/ha	Light: $675/ha Moderate: $1,350/ha Severe: $2,700/ha			
	Assisted: $750/ha	Light: $375/ha Moderate: $750/ha Severe: $1,500/ha			
	Agroforestry: $1,350/ha	Light: $675/ha Moderate: $1,350/ha Severe: $2,700/ha			

COST-BENEFIT ANALYSIS	DISCOUNT RATE	TIME HORIZON	CARBON PRICE		NOTES
Baseline scenario	3%	50 years (with varying recovery cycles, see above)	$\$5/tCO_2$		
Restoration scenario	3%	50 years (with varying recovery cycles, see above)	$\$5/tCO_2$		
Net gain NPV	3%	50 years (with varying recovery cycles, see above)	$\$5/tCO_2$		Sensitivity analysis in Section III of discount rate (1%–10%) and carbon dioxide price ($\$0/tCO_2$–$\$100/tCO_2$)

ENDNOTES

1. For example, in biodiversity, willingness-to-pay estimates to prevent its loss should ideally include the scientific and academic community, as well as regional populations that may value biodiversity loss under a different lens. Circumscribing willingness-to-pay estimates to local populations does not necessarily capture the true value of the global service it provides.

2. Other landscape management alternatives such as silvopastures are important but were not included in the analysis because of insufficiency of data.

3. Including—among others—Nicaragua (IFAD 2010), Brazil (World Bank 2003) and El Salvador (World Bank 1998).

4. Productivity loss is measured as the loss of potential direct instrumental value, or loss in PDVI. Daily (1995) defines PDVI as the potential to yield direct benefits in agriculture, forestry, and other industries.

5. The long-term, systemic impact of climate change on agriculture will not be easy to reverse. Unless a drastic change in direction is achieved in the rate of emission of greenhouse gases, these impacts will continue to be felt by agricultural and forestry activities. For a more detailed review of these impacts, see Vergara et al. (2014).

6. Authors' estimates based on data from CAIT and IIASA-GEA, as of December 2014.

7. Climate stabilization goals set at a temperature rise of no more than 2°C by the end of the century require a global per capita emission of no more than 2 tons per capita (tpc) by 2050 and 1 tpc by 2100.

8. Land restoration efforts including those targeting agroecosystems have been positively correlated with the recovery of environmental services, including those that result from improvements in biodiversity (Barral et al. 2015).

9. In theory, a 20-year horizon could be applied to the large-scale regional estimates. However, using a 20-year time horizon would necessitate breaking the simplified ecological recovery model used in the analysis, which considers that several degraded lands are assumed to recover lost productivity over a longer period of time and that the costs of restoring severely degraded land is assumed to be distributed over the first 25 years. An adjustment would have to be made for these time flows, which already exceed a 20-year time horizon, and this would require that the model take on even more generalized assumptions.

10. Initiative 20x20 aggregates national, regional, and subregional commitments for the restoration of 20 Mha of degraded Latin American and Caribbean landscapes by 2020. This assessment, however, is based on the assumption that the restoration process occurs in a distribution of degraded lands that differs from the commitments made under Initiative 20x20.

11. Wet biomes include tropical and subtropical moist broadleaf forests; dry biomes include tropical and subtropical dry broadleaf forests and tropical and subtropical grasslands, savannas, and shrublands; and temperate biomes include temperate broadleaf and mixed forests.

12. The baseline and restoration scenarios assume that the 20 Mha targeted for landscape restoration are distributed across the region's degraded lands in the actual shares of the region's principal biomes and degrees of degradation that have been documented (as in the case of the biomes) or assumed (as in the case of degradation degrees which have been based on GLASOD soil degradation data).

13. Restoration periods are based on Daily (1995).

14. A sensitivity analysis of the impact of discount rates has been included in Section III.

15. A conservative market value of \$5/tCO$_2$ is used. This value corresponds to a price level anticipated in the absence of a fully functioning global or regional carbon market (Peters-Stanley & Gonzalez, 2014), therefore reflecting the average price under voluntary conditions.

16. These inputs—the projected annual flow values—have been estimated through a buildup of data capturing the productivity, volumes, and prices of the recent historical annual flows of the relevant forest and agricultural products and services; annual flows are then projected into the future. These buildup processes are described in detail in Annex 1.

17. For example, tropical native tree species, on average, have been shown to require much longer maturity periods. In addition, fuller realization of the environmental benefits of restoration might require planting diverse species, not necessarily compatible with planting procedures normally associated with commercial lumber operations. Finally, it has been shown (Lamb et al. 2005) that even the partial recovery of species associated with natural forests requires the maintenance of a diverse and stable forest (or savanna) biome. Instead, this assessment uses a 40-year cycle (similar to the estimates used for monetizing temporary carbon storage credits, dampening the expected stream of revenues from WFPs in the assessment's projections).

18. Tree crops are considered but would be expected to be in dispersed planting patterns requiring more manual labor. The marketing and collection routes also are assumed to be more expensive.

19. Mosaic restoration integrates trees into mixed-use landscapes, such as agricultural lands and settlements, where trees can support people through improved water quality, increased soil fertility, and other ecosystem services.

20. As in Stern (2006), a fuller value of carbon would ideally be derived from the avoided economic consequences or damages of the physical impacts of climate change under commonly used scenarios applied to the period under analysis. However, this estimate is not readily available. Also, the current market valuation of carbon is not an appropriate measure to capture the damages. It reflects a global market failure, where demand has been distorted by the inability to recognize the full extent of the implications of climate damage.

21. PDVI—or "potential direct instrumental value" (Daily 1995)—serves as a productivity variable that, when subtracted from maximum potential, represents the productivity loss associated with a degree of land degradation. In this sense, it is assumed

that lightly degraded forests suffer an average productivity loss of 10% and register a corresponding PDVI of 90%. Moderately and severely degraded forests register PDVIs of 75% and 50%, respectively, and suffer from corresponding productivity gaps of 25% and 50% (following Daily 1995 and GLASOD data).

22. For restoration of lightly degraded lands, which take (on average) seven years to recover fully (Daily 1995), the costs are assigned to the first four years (or roughly half of the recovery period) in equal tranches. For restoration on moderately degraded lands, which take (on average) 15 years to fully recover, costs are assigned to the first eight years (or roughly half of the recovery period) in equal tranches. For restoration of severely degraded lands, which take (on average) 50 years to fully recover, costs are assigned to the first 25 years (half of the recovery period) in equal tranches.

23. The only exception to this tendency is found in wood forest products. This is due to our assumption that hectares restored through planted restoration will not commercialize wood forest products for the first 40 years from the outset. This eliminates the net gain accruing to wood forest products in our estimates for the entire 25-year time frame required for moderately degraded lands to be fully restored. Therefore, the benefits for both lightly and moderately degraded lands that are restored through planted forests are truncated, while those accruing to restoration on severely degraded lands are far less affected.

24. Carbon stocks in soil have not been considered as part of the benefit.

25. The assessment uses the assumption that, as a result of the restoration process, land will recover a level of carbon stocks associated with pristine forests (or, in the case of agroforestry or silvopastures, it will reach nearly half of those levels). Furthermore, lightly degraded lands are assumed to take 20 years on average for full carbon recovery; moderately degraded lands require on average 35 years for full restoration; and severely degraded lands required 50 years on average.

26. Return on investment measures the amount of return on an investment relative to the investment's cost.

27. To provide a more accurate estimate of wood forest product benefits, however, the assessment would require distinct wood forest product revenues per degree of degradation and across different countries and forest biomes.

28. Costs are distributed evenly over approximately the first half of the years that it takes land to be restored: lightly degraded land is restored by year 7 (and costs are registered in equal parts for each restoration method over the first four years), moderately degraded land is restored by year 15 (with costs distributed equally across the first eight years), and severely degraded land is restored by year 50 (with costs distributed evenly over the first 25 years). Nevertheless, in a more realistic scenario, additional costs might arise from future expenditures to maintain the restored area and allow it to continue to accrue the benefits from restored landscapes, thereby reducing the profitability of the restoration process. In brief, multiple restoration strategies would imply different evolutions in time of the cost and benefit analysis with potentially lower resulting values of restored land.

Annex I

29. The cost of production of agricultural commodities varies significantly depending on the commodity, location, and costs of land, fertilizers and other inputs. In the United States, for example, the cost of production for soybeans was estimated at about 86% of revenues for the crops years 2013 and 2014 (USDA statistics 2014). The comparable costs of production in Brazil are expected to be generally lower given the lower opportunity costs of land. An analysis by Iowa State University (2001) indicated that production costs in 2001 were about 60% of costs in the US. For purposes of this analysis, we have used a ratio of costs to revenues of 60% for agricultural commodities in Latin America.

30. Costa Rica has made substantial investments on infrastructure to promote ecotourism. The study assumes that the revenue would be similar under specific conditions. However, in some countries it is difficult to materialize these revenues in the short term, and so only a fraction of the benefits has been used to account for ET revenues (see assumptions).

31. This approach assumes that forest productivity is independent of forest area and implies a linear relationship between the restoration of forest area and forest benefits.

Annex II

32. Daily (1995) estimated the productivity loss associated with the various GLASOD degradation degree classifications. Expressed as the potential direct instrumental value (or PDVI), this loss is estimated to be 10% for lightly degraded forests, 25% for moderately degraded, 50% for severely degraded, and 100% for extremely degraded forests.

33. This distribution of degrees of degradation across forests and savannas in the region is also used as the proxy for the distribution of degrees of degradation across the relevant agricultural lands to be restored.

34. This 25% discount applied to the carbon stock recovery gain of planted forest restoration—compared to the carbon stock gained by assisted regeneration of degraded natural forests to their pristine levels—is based on the assumption that higher tree densities (more typical of planted restoration) ultimately sequester less carbon than forests with lower tree densities (characteristic of assisted regeneration of natural forests). See IPCC (2000).

35. It has been estimated that agroforestry practices increase carbon storage by 21 tC/ha in subhumid (or dry) biomes, by 50 tC/ha in humid (or wet biomes) and by 63 tC/ha in temperate zones (Schroeder 1994; Montagnini and Nair 2004). Using this carbon gain data as a proxy for the recoverable gap in the case of deforested agricultural lands produces a net carbon storage gain on average—when weighted by the assumed, GLASOD-based distribution of degrees of degradation across all degraded hectares—of approximately 45% of the carbon stock gained by assisted regeneration of degraded natural forests to their pristine levels.

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ACKNOWLEDGMENTS

The authors wish to acknowledge the support—notably comments on an earlier draft—provided by Craig Hanson, Nigel Sizer, Sean de Witt, Lars Laestadius, Katie Reytar, Juan Carlos Altamirano, Emily Schabacker, and Christopher Delgado (WRI), Ruben Echeverria and Andy Jarvitz (CIAT), Jose Joaquin Campos and Pablo Imbach (CATIE), Kelly Witkowski (IICA), Adrian Fernández (LACI), and Michael Verdone (IUCN).

The authors also wish to acknowledge all of those who granted their profound support in graphic design, editing, and layout as well as communications and outreach for its release: Julie Moretti, Hyacinth Billings, Emily Schabacker, Carni Klirs, James Anderson and Lauren (Cole) Zelin.

For this publication, WRI is indebted to the generous financial support of the German Federal Ministry of the Environment; Nature Conservation and Nuclear Safety's International Climate Initiative; and the Royal Norwegian Ministry of Climate and Environment.

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Cover photo, table of contents, pg. 2, CIFOR; pg. iv, pg. 4 (left), pg. 5 (right), pg. 7, pg. 37 (right), CIAT; pg. 5 (left) Horticulture Group; pg. 8, pg. 12, pg. 16, pg. 19, pg. 21, pg. 22 (left), (right), pg. 24, pg. 26, pg. 29, pg. 33, pg. 36 (left), pg. 37 (left), pg. 38, pg. 41, Luciana Gallardo Lomeli/WRI.

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Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

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ISBN 978-1-56973-899-3