The Economics of Ecosystems and Biodiversity: The Ecological and Economic Foundations (TEEB D0)

Chapter 1

Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation

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Appendix 3

How the TEEB framework can be applied: The Amazon case

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Introduction

The Greater Amazon includes not only the Amazon River Basin but also adjacent watersheds with similar climates and ecosystems in Colombia, Venezuela, Bolivia, Peru, Ecuador and the coastal states of Guyana, Suriname and French Guiana. Covering approximately 8 million km^2, the region has an enormous diversity of landscapes, habitats, and ecosystems. The Amazon provides numerous and strikingly clear examples of the value of ecosystem services and biodiversity conservation at 4 different scales: global, continental, regional and local. Table 1 provides a summary of some of these services and an estimate of their economic value derived via "back of the envelope" methodologies using information in the public domain. The objective of this exercise is not to provide a detailed valuation of Amazon services, but rather to illustrate the application of the TEEB Framework and underscore the need for a more comprehensive compilation of the economic significance and the impact on the livelihoods of the people living in the Greater Amazon.

Table 1: Characteristics and values of major ecosystems services of the Amazon at varying scale; sources and methodological logic for estimated values are provided in the text.

	Function	Services	Benefit	Estimated Value (US$)
Global Scale				
1	Photosynthesis and maintenance of ecosystem structure	Carbon storage and sequestration	(Global) Climate stability Revenues from carbon markets	$1.5 – 3 trillion (C-stock value) $6 – 12 billion yr^{-1} (REDD)
2	Evolutionary processes (Taxonomic and habitat diversity)	Habitat service (maintenance of life cycles and gene pool protection)	Evolutionary heritage Potential crops and pharmaceuticals	Intangible 73 million/yr (GEF) Unknown
Continental Scale				
3	Convective circulation « water pump »	Climate regulation (esp. mediation of regional precipitation regime)	Agricultural productivity Hydropower generation	$1 – 3 billion yr^{-1} $75 – 750 million yr^{-1}
Regional (Basin) Scale				
4	Soil formation and nutrient cycling	Forest growth (for provision of raw materials)	Sustainable timber harvest	$4 – 7 billion yr^{-1}
5	Ecosystem (vegetation) structure in terrestrial habitats	Erosion prevention	Reduced siltation in hydropower reservoirs	$60 – 600 million yr^{-1}
6	Nutrient cycling in wetlands	Water purification	Clean water	Unknown
7	Ecosystem structure in freshwater habitats	Nursery service for fish populations	Commercially viable fish populations	100 – 500 million yr^{-1}
Local Scale				
8	Viable wildlife (plant and animal) populations	Provide food and other natural resources	Subsistence life styles Forest products	$500 million – 1 billion yr^{-1}
9	Food webs, pollination, mycorrhizae	Biological control	Ecological stability, contribute to crop productivity, and disease prevention	Unknown
10	Landscape Integrity	Aesthetic beauty	Improve quality of life Promote and support tourist industry	$350 million – 1 billion yr^{-1}
11	Habitat for people	Cultural heritage	Maintain cultural identity and ethical principles	Intangible

1 Services and values at the global scale

(1) Carbon storage and sequestration

The Amazon is a vast reservoir of carbon with approximately 76 gigatons (Gt)[1] stored in its above-ground biomass, with perhaps another 30 Gt stored in below ground carbon stocks (Killeen 2007, Saatchi et al. 2007, Aragão et al. 2009). If released into the atmosphere, this carbon would equal approximately 20 years of fossil fuel consumption and in international markets ($5–10 per ton of CO_2), this would have a value between $1.5 and $3 trillion. This not a realistic valuation, however, because carbon markets do not yet recognize the conservation of standing natural forest as a carbon offset, although the UNFCCC treaty process is developing a policy framework that will compensate countries for reducing emissions from deforestation and forest degradation (REDD). Under this scheme, revenues could be calculated by comparing future levels of deforestation with a baseline, which for many countries might be based on historical rates of deforestation. The deforestation rate in the Amazon during the last two decades is estimated to be ~28,000 $km^2 yr^{-1}$, which translates into approximately 1.3 Gt of annual CO_2 emissions (Table 2) and the economic value of these emissions can be calculated by estimating their replacement cost in existing markets. For example, approximately $13 billion would purchase an equivalent amount of industrial based emission reductions; if that payment were repeated annually for 30 years, it would equal $388 billion, which when corrected for inflation and expressed in today's currency, would have a net present value of $134 billion[2].

The ecosystem services provided by the Amazon are not limited to its capacity to store a fixed quantity of carbon or the potential to reduce emissions from deforestation. Recent studies have shown that tropical forest ecosystems are actually net carbon sinks, because the increase in CO_2 concentrations has altered the physiological pathways in plant cells leading to a shift in carbon fluxes from photosynthesis and respiration (Malhi et al. 2008). The net positive difference in the uptake of CO_2, although small when calculated at the scale of a hectare is a large number when extrapolated over the Amazon and is estimated to be roughly equivalent to the emissions from current deforestation. In summary, the Amazon provides ecosystem services for the global economy by storing carbon, but also by sequestering some of the CO_2 that is being released by human-related activities throughout the globe.[3]

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[1] Gt = 10^9 t, which is equivalent to a Petagram (Pg) = 10^{15} grams (g); in plain English this would be 76 billion ton. The value of 76 Gt is a conservative estimate; if carbon stocks from below-ground biomass and soils were included, this value would be 20–50 percent greater (Killen 2007).

[2] NPV calculated using discount rate of 10%.

[3] This net sequestration will eventually reach a new equilibrium, or flip the other direction if climate change led to a decrease in precipitation in parts of the Amazon, which would cause a shift in ecosystem function from rain forest to a seasonally dry forest. The resulting increase in emissions from forest degradation could offset attempts to reduce emissions from avoided deforestation.

Table 2. Value of carbon stocks in the Amazon forest based on their replacement value in international markets for energy-based carbon credits (from Killeen 2007)

	Forest Cover 1990 (×1,000 ha)	Forest Cover 2000 (×1,000 ha)	Forest Cover 2005 (×1,000 ha)	Annual Rate of Deforestation (×1,000 ha yr^{-1})	Carbon Emissions @ 125 t/ha (×1,000 t)	CO_2 Emissions (×1,000 t)	Value of Emissions @ \$10/t CO_2 (\$ Million)
Bolivia	48,355	46,862	46,070	240	30,001	110,105	1,101
Brazil	364,922	348,129	336,873	2,250	281,250	1,032,188	10,322
Colombia	59,282	57,839	57,117	144	18,044	66,221	662
Ecuador	12,333	11,953	11,764	38	4,748	17,423	174
Peru	72,511	71,727	71,335	78	9,800	35,966	360
Venezuela	43,258	42,529	42,164	73	9,119	33,466	335
Guyana	15,104	15,104	15,104	—	—	—	—
Suriname	14,776	14,776	14,776	—	—	—	—
French Guyana	13,000	13,000	13,000	—	—	—	—
Total	643,540	621,919	608,202				
Annual Rates				2,824	352,961	1,295,369	
						Annual Total	12,954
						30-Year Total	388,611
						NPV[4] for 30-Year Total	134,325

(2) Habitat service (maintenance of life cycles and gene pool protection)

Biodiversity conservation is the most problematic value to estimate, because of the failure of markets to adequately capture or measure its contribution to the global economy — even though biodiversity has been the foundation for the world's economy since the origin of human civilization. The global significance of biodiversity conservation in the Amazon has 2 dimensions: (a) maintenance of genetic diversity on earth (existence value) and (b) maintenance of potential future uses (option value).

(a) Existence value

Individuals across the globe fervently believe conservation of biodiversity to be a moral obligation— to preserve a heritage bequeathed either by a deity or as the end result of millions of years of evolution. In this context, the two most accurate words that describe the value of biodiversity are "priceless" and "irreplaceable." This type of moral valuation is essentially exploited at the global scale by conservation organizations and multilateral organizations and is, in part, the motivation for the Global Environmental Facility (GEF), which since 1991 has invested approximately \$438 million that has leveraged an additional \$874 million on biodiversity projects in one or more of the eight countries of the greater Amazon, an average of only \$72.8 million yr^{-1} (GEF 2009). A recent manifestation of the recognition of the value of biodiversity and the need to leverage its conservation with more marketable services is the REDD+ initiative, which recognizes that value is added to REDD initiatives if they also contribute to maintaining ecosystem services, biodiversity conservation and improve human livelihoods.

(b) Option value

All food staples are domesticated varieties of wild plants and animals, and most modern pharmaceuticals have been derived from natural products. Thus, one of the most compelling arguments for conserving biodiversity is the potential for new food sources (Heiser 1990), as well as new medicines and pesticides (Reid et al. 1993, Ortholand and Gane 2004). Unfortunately, it is difficult to harness markets to support biodiversity conservation in the Amazon, because there are three principal constraints to levying fees for biodiversity conservation:

1) Users are incapable of paying for the goods and services because they have no economic resources and/or the goods and services are part of the "public commons" in which traditional use makes it difficult to collect fees (i.e., hunting and fishing).
2) It is difficult to place a value on an undiscovered benefit, because we don't know who owns the resource, how much it might be worth, or who might be interested in acquiring that resource (i.e., a potential new crop or drug).
3) It is not plausible to extract fees for knowledge that was acquired in the past and is now in the public domain (i.e., rubber, cassava, quinine, and atropine).

As a general rule, the difficulty in generating payment for biodiversity and ecosystem services at the local or regional scale does not mean that these services do not have value, even though that value is intangible to local politicians or landholders who will usually act in their own economic interest. Moreover, efforts to assign economic value on the basis of erroneous assumptions or hopeful scenarios (e.g., bioprospecting) may raise expectations that cannot be met and diminish the validity of other, more convincing arguments.

2 Services and values at the continental scale

(3) Mediation the regional precipitation regime (through the "water pump"-mechanism)

The importance of forest cover in maintaining high levels of precipitation in the Amazon has been a basic tenet of ecosystem ecology for decades. The tropical rainforest ecosystem of the Amazon ultimately depends on the humid trade winds that bring water from the Atlantic Ocean – an attribute that provides an enormous element of stability to the Amazon ecosystem. Nonetheless, about 25–50% of the rain that falls on the Amazon is the result of evapotranspiration and precipitation that cycle through the convective systems that form thunderstorms (Salati and Nobre 1991). Partially deforested landscapes actually experience a slight increase in precipitation as this cyclical process is accelerated by increased evaporation over forest that is associated with increased rain over pastures. However, the volume of water cycled through the convection systems decreases once about 50% of the landscape has been deforested (Kabat et al. 2004) and when a landscape is nearly completely deforested, the amount of water cycled through convective systems decreases by about 10–25% (Nobre et al. 1991).

Large-scale land-use change and the subsequent alteration of the regional precipitation regime within the Amazon may impact other distant regions of the Western Hemisphere. The meteorological phenomenon known as the Hadley Circulation describes how warm air rises at the equator, moves toward the poles, descends at higher latitudes, and returns toward the equator along the surface of the earth: rising air promotes precipitation, while descending air suppresses it. This type of long distance phenomenon is referred to as a "teleconnection" by climatologists, because it explains how regional manifestation of global warming in different parts of the world are linked and modulated by energy flows (Feddema et al. 2005). There is concern among climatologists that climate change and deforestation may reduce precipitation and increase temperatures within the Amazon (Malhi et al. 2008); climate models also show that these changes may be linked to reduced precipitation in the lower Midwest of the United States (Avissar and Werth 2005).

A more straightforward example of a teleconnection is the weather system that links the western Amazon with the mid latitudinal region of the South American Continent (Figure 1). In this system, a major gyre originates with the Atlantic trade winds that pass over the Amazon before curving southward as it nears the Andes to form the South American Low Level Jet (SALLJ). The impact of the SALLJ is most noticeable during the austral summer when the region of maximum rainfall is displaced to the South and initiates the onset of the South American monsoon, essentially exporting moisture from the Amazon to the seasonally dry regions of subtropical South America (Marengo *et al*. 2004). A shift in the climate regime of the Amazon would affect this moisture transport system and potentially reduce precipitation in the Paraguay – Paraná River Basin, impacting important agricultural areas in Eastern Bolivia, Southern Brazil, Northern Argentina and Paraguay. The agricultural output of this region is estimated to be greater than $100 billion annually[4] and a reduction in precipitation would either reduce yields or cause farmers to change crops or invest in irrigation; a slight reduction in agricultural productivity would have an enormous economic impact (1–3 billion US$/y). Moreover, Brazil and Paraguay are heavily dependent on hydroelectric energy and a reduction in precipitation would raise the cost of energy for industry and urban centers (Berri et al. 2002).

A similar model can be used to estimate the impact of reduced rainfall on the *Itaipú* hydropower facility that generates ~94 billon kWh yr^{-1}. The replacement value of this existing energy supply would be worth approximately $7.5 billion based on the current regulated tariff for electrical energy in Southern Brazil of $US 0.08 kWh (IPS 2009). The 2000 drought associated with the 1999 La Niña event decreased power generation at Itaipú by 15%, representing a loss of income of ~$1.2 billion; similarly, a modified precipitation regime that reduced the water carrying capacity of the SALLJ could

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4 This is a conservative estimate extracted from multiple on-line sources for Argentina, Brazil and Paraguay, including: http://www.cideiber.com/infopaises/menupaises1.html
http://www.argentinaahora.com/extranjero/espaniol/bot_ppal/conozca_arg/produccion.asp,
http://www.ibge.gov.br/home/estatistica/economia/pamclo/2005/default.shtm

impact the generating output of Itaipú, where a 1–10% reduction in electrical power generation would force utility companies to generate energy from an alternative source at an additional cost of between 75 to $750 million annually.

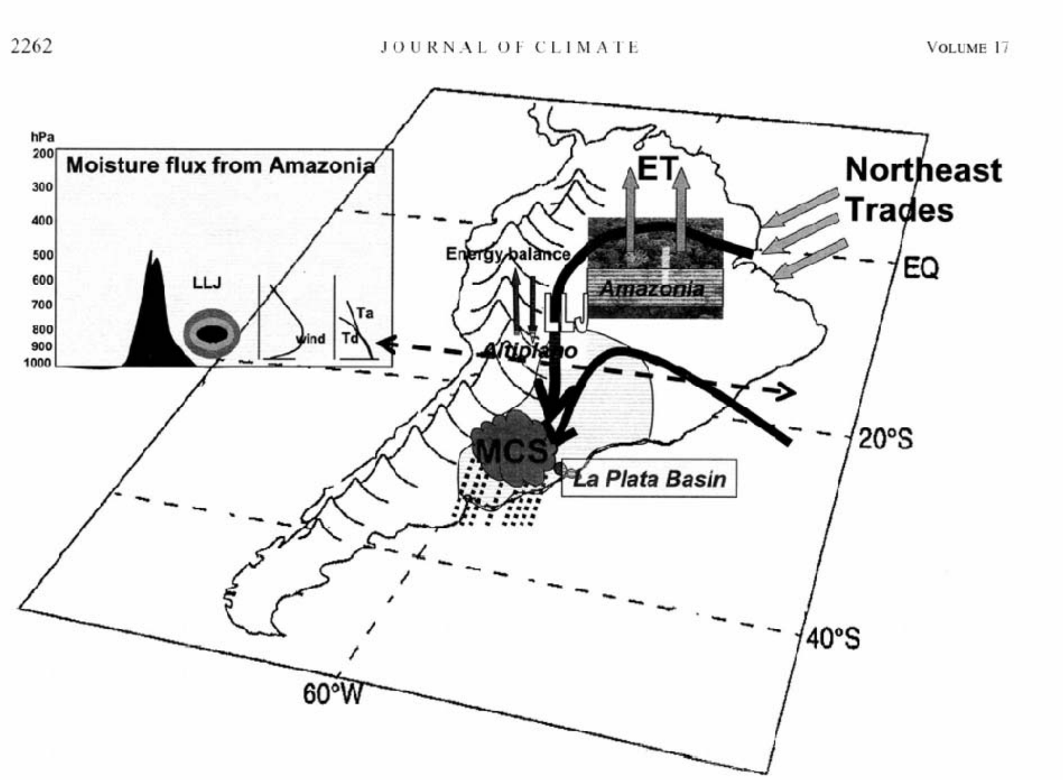

Figure 1. **The South American Low-Level Jet (SALLJ) transports water from the central Amazon to the agricultural regions of the Paraguay - Paraná basin. Deforestation and climate change threaten this important ecosystem service; even a small reduction in precipitation would lead to an annual economic loss in the hundreds of millions to billions of dollars in the Southern Cone and High Andes (Modified from Marengo et al. 2004; © American Meteorological Society).**

3 Services and values at the regional (basin) scale

(4) Forest growth (for provision of raw materials)

The productivity of the Amazon forest is a function of radiant energy, water and soil resources, of which the later plays a key role in determining the growth rate of trees in different parts of the Amazon. Net primary productivity (NPP) in the Amazon varies between 9.3–16.0 t C ha^{-1} $yr^{-1}$and about 15–30% is allocated to stem biomass (Aragão et al. 2009). One definition of sustainable forestry is that the amount of timber harvested is less than the quantity of wood produced; consequently, a model that assumes 5% of NPP could be harvested annually provides a conservative estimate of the Amazon ecosystem potential as a sustainable source of timber. With an average wood density of 750 kg/m^3, this would translate into 425–740 million m^3 of timber and, assuming that only 25% of this timber had a market value, this would yield between $US 4–72 billion annually when based on current prices for round wood of \$10–100 kg/m^3. This simple calculation provides an estimate of the opportunity cost for "sustainable" logging between \$5 and \$89 ha^{-1}. There are other estimates of the value of timber extracted from the Amazon. For example, the *Instituto Brasileiro de Geografia e Estatística* (IBGE 2007) reports timber commerce of approximately \$900 million dollars in 2007; but most of that wood is extracted from a small fraction of the Brazilian Amazon forests via salvage logging operations on the agricultural frontier. A recent report on the opportunity costs of timber in Brazil estimated the value at between \$US 419–615 ha^{-1} (Verweij et al. 2009), but as those authors observed these higher values are not likely to be representative of a forest management model that is truly sustainable.

(5) Erosion prevention

The value of this ecosystem service can be estimated by evaluating how increased sedimentation decreases the economic utilities of hydropower facilities caused by increased sediment loads from deforestation and intensive land-use. As a reservoir fills with sediment, capacity to store water is reduced and electricity generation is curtailed during low water periods. Eventually, the facility will be shut down when the reservoir can no longer store enough water to power the turbines, cover its operating costs, and return a profit (Palmieri et al. 2001). The annual rate of sedimentation can be expressed as the percent of the storage capacity lost each year due to sedimentation, which varies depending on climate and geology, as well as land-use and watershed management. The lowest reported sedimentation rates are for the United Kingdom with only 0.1% yr^{-1}, which implies the average reservoir in the British Isles will last a millennium; however, the world average is about 1% and that translates into an expected lifetime of less than 100 years (Jiahua and Morris 1992).

The value of forest conservation can be estimated by comparing the lost revenues of a rather small 50 MW hydro facility producing 300 million kW-h yr^{-1}, which experiences a sedimentation rate of 0.5% on a forest landscape versus 1% on a deforested landscape (Lawrence et al. 2008). Increased sedimentation would cause the facility to be decommissioned after 65 years with the total lost revenues of ~\$ 300 million dollars from mean lost revenues of ~\$6 million yr^{-1}. This amount would be greater for very large facilities such as Itaipú, although in that specific example it will take almost three centuries for the siltation process to culminate to the point of decommission.[5] Brazil is expanding investment in the dams and reservoirs within its own country, as well as in neighboring across the region,[6] while funding agencies like the World Bank are increasing their commitments to hydropower as part of their climate change investment strategy (World Bank 2009). If the lost revenues from the hypothetical 50 MW facility described by Lawrence et al. (2008) were extrapolated across the region to the 10 existing and 89 planned facilities in Brazil (Killeen 2007), then the annual impact on

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5 The current predicted life-span of the Itaipú dam is estimated at about 300 years (pers. comm. T.A. Cochrane, July 2009).

6 Two hydroelectric facilities are under construction on the Madeira River are under construction, while the Presidents of Peru and Brazil made commitments to jointly invest in 6 additional hydropower facilities that would 7,000 MW of electricity at an estimated cost of \$16 billion. Source: Bank Information Center, see http// www.bicusa.org/es/Articles.11184;

generating facilities when averaged over their collective lifespan would approximate \$600 million yr^{-1}, a sum would be even greater if the similarly untapped potential of the Andean countries was included in the estimation.

(6) Water purification

Wetlands and other Amazon forest ecosystems have multiple ecosystem functions, such as mediating water flows and acting as sinks for sediments and urban effluents ensuring that downstream populations enjoy steady clean water supplies. The Amazon has 12.5% of the world's fresh water, while it is on of the most pristine of all the major river basins in the world. The purity of the water in the Amazon and its tributaries is the consequence of the vast natural filter provided by its natural ecosystems for the sediments, nutrients and pollutants that are washed into the rivers by innumerable farms, mines, villages, and cities. The relatively pristine state of the waters of the Amazon was recently validated by a systematic effort to study water quality in the rivers of Brazil (Figure 2); while these studies demonstrate that most of the watershed remains pristine, there are localized areas that have been impacted by human effluents (Moss and Moss 2009). The cost of these services are difficult to know due to the "veracity" of the civil engineer's antiquated paradigm for dealing with pollution (e.g., the solution to pollution is dilution); the vast quantity of the water in the Amazon as yet masks the economic impact of its degradation.

Figure 2. Water quality of Brazilin rivers; from pristine (light blue) to heavily impacted (red); tributaries in the Southern Amazon shows a slight degradation, that this is generally not observable a downstream is due to the ecosystem services provided by riparian habitats (adapted from Moss and Moss 2009).

(7) Nursery service for fish populations

One of its most economically important services of wetlands is providing habitat and a food web that support the basin's strategically important fisheries. Floodplain forests on "white water" rivers are particularly productive because the sediments washed down from the Andes bring essential chemical nutrients that support a strategically important aquatic ecosystem.[7] Fish migrate locally into the floodplain wetlands during periods of high water to spawn and feed, then return to the river channels during low-water periods. Long distance migration is a behavioral trait characteristic of many Amazonian fish, including the economically important commercial species, such as the *piramutaba* and *dourada*; as well as other species that move within subsectors of the basin, such as the *tambaqui, pacú, jaraqui, and curimatã* (Barthem and Goulding 1997).

Fishing is arguably the most important component of the Amazonian economy, providing employment and sustenance to an overwhelming majority of its residents, either directly by subsistence fishing or indirectly by commercial and sport fishing. Large migratory catfish are charismatic species that are the mainstay of the commercial fishing industry and, for that reason, are particularly useful as representatives of the value of ecosystem services at a regional scale. The commercial fishing industry in the Brazilian Amazon generates about $100, million annually and more than 200,000 direct jobs, statistics that do not include related sectors such as boat building, tourism, mechanical shops, and other services (Almeida et al. 2001, Ruffino 2001). The total economic value of fisheries in the Greater Amazon is many times greater than the reported commercial value on the lower Amazon (see service next section). Our upper estimate of five times the amount documented for the lower Amazon takes into account the upper Amazon and its numerous tributaries, as well as the contribution of sport fishing. In spite of its resiliency, there is concern about the sustainability of current fishing practices, particularly on the main trunk of the Amazon River (Jesús and Kohler 2004).

4 Services and values at the local scale

(8) Provide food and other natural resources

Most fishermen in the Amazon are subsistence fisherman and their activities are largely focused at the local scale and fish are the most important source of protein for the approximately 500,000 indigenous and traditional people living in the Amazon, as well as the millions of migrants that have made the region home over the last several decades. Meat from mammal and birds represents an important protein source on all forest landscapes in the Greater Amazon. Restaurants specializing in bush meat are a common, particularly along major transportation corridors that transect wilderness areas. Large mammals are subject to overharvesting in areas with moderately dense human populations and are usually the first species to be exterminated in settlement zones. Nonetheless, small mammals and game birds persist in degraded forests and are an important source of protein for many rural families. Because of its informal nature and tendency to be practiced in remote places where no data is collected

[7] Amazonian rivers are stratified into 3 broad categories (white, black, clear) based on their chemistry and physical properties; white water flood plain forests, known as *varzea*, are perhaps the most productive freshwater fishery in the world (Barthem and Goulding 1997).

by government agencies, there are no reliable estimates for the economic value of subsistence fishing and hunting.

Somewhat better information is available for the economic value from plant products due to the Brazilian government's efforts to document commerce in a broad category of what are now referred to non timber forest products (NTFP) that are traded via some sort of formal market (Table 3). The products with the largest trade are all palms, including the açaí (both fruits and hearts), babaçu (oil extracted from seeds) and piaçaba (fibers used for handicraft), followed by Brazil nuts, which in Brazil is known as *Castanho do Pará*. The total commerce in these products is a surprising \$246 million yr^{-1}, but this value excludes other Amazonian countries, such as Bolivia that exports between \$50 and 60 million yr^{-1} in Brazil nuts and another \$4 million in açaí palm hearts annually (CBF 2005). Many more plant products are not reported, but represent important sources of cash income to supplement subsistence livelihoods; for example, restaurants in all Amazonian cities offer a wide assortment of native fruits drinks and ice cream flavors, while urban residents take pride in having a home barbeque protected by a thatched roof.

Table 3. Trade in non timber forest products from the Brazilian (IBGE 2007)

Commodity	Volume (t)	Value ($US)
Latex and Rubber	3,958	42,000,000
Gums	38	69,000
Waxes	22,463	43,707,000
Fibers	84,141	55,502,000
Tannins	208	53,000
Oils	128,124	71,748,000
Food Products	390,192	74,292,000
Cosmetics, dyes, etc	1,733	1,163
Total	435,76	246,465,000

(9) Biological interactions

Many of the other ecosystem services described above are also dependent on this functional attribute of all ecosystems. Food webs are essential for maintaining all wildlife and fish populations, while the productivity of the forest itself is dependent on the ability of invertebrates and fungi to decompose the billions of tons of biomass produced each year. Mycorrhizae and *Rhizobium* symbionts are known to exist for thousands of plants, many of which are economically important timber species or non timber species. Bees produce honey and play an indispensable role in pollinating coffee and citrus fruits worth hundreds of millions of dollars to the economies of the Amazonian countries.

However, one of the most important economic contributions that forest conservation provides to human economies may be from the avoidance of disease and the costs needed to manage the impacts of disease. Parasitic pathogens such as malaria and leischmaniasis cost governments tens of millions of dollars in health care and lost productivity. New migrants are not adapted either culturally or biologically to a forest ecosystem and thus are more susceptible to these diseases. In the habitats of the agricultural frontier, the traditional host – parasite relationship is often disturbed and the pathogens may find different ways to reproduce or choose alternate hosts, as evidenced by the periodic outbreak of Hanta virus or hemorrhagic fever in the Bolivian Amazon.[8] The cost of an avoided disease is difficult to calculate, because the severity of that disease is unknown, but HIV was once restricted to primates in Central Africa, but since it passed to humans it has had a massive impact on the global economy.

(10) Aesthetic beauty

The scenic landscapes of the Amazon add value to the life of the average citizen, as well as forming a fundamental linchpin to its strategically important tourist industry. Operators in all Amazonian countries offer a diversified assortment of products that include ecotourism, adventure tourism, cultural tourism for overseas visitors, but also recreational tourism for local and regional inhabitants. It is not just the specialized ecotourism niches that benefit from the natural beauty of the region, however, because all tourists expect to visit areas that are aesthetically pleasing. The revenues from Amazonian tourism are difficult to estimate because most countries have multiple tourist options and do not separate out the portion related to the Amazon. For example, Peru has an approximately $1 billion annual tourist industry, which is dominated by visitors to Cuzco and Machu Picchu, a unique archeological site set in a majestic natural setting (Macchu Picchu is part of the Amazon drainage basin on the lower Urubamba). Venezuela's approximately $200 million industry is largely based on the Caribbean, but the Grand Savanna (not Amazonia) is a major domestic tourist destination. Ecuador's $435 million tourist industry is dominated by the Galapagos Island, but also has important tourist destinations in the Andes that are located within the Amazon watershed. Brazil has a globally important tourist industry that generates about $80 billion revenues per year with between 1 and 2 % of that total originating in the Amazon (IBGE 2007).

Tourism is particularly beneficial because it generates direct benefits at the local level, creating business opportunities for small and medium-sized enterprises, and provides employment for semi-skilled and unskilled labor. When poorly regulated, tourism can cause environmental degradation and cultural homogenization, thus damaging the natural asset that is at the core of its business model. Many of the geographic centers of the tourist industry in the Amazon are situated near or within protected areas. The most important contribution that tourism can make to conservation is job creation at the local level, which generates a vested interest to conserve the forest ecosystem.

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[8] The author is a survivor of a virulent viral pathogen that was diagnosed as either an unknown strain of hanta virus or Bolivian hemorrhagic fever.

(11) Cultural heritage

The native peoples of the Amazon are proud of their cultural heritage and consider the natural landscape as an essential and irreplaceable component of that cultural heritage. Over the past two decades, the indigenous peoples of the Amazon have demanded and largely obtained control over the natural resources of their traditional landscapes. The legal framework varies from country to country, but in each country some type of formal recognition of these rights is now enshrined in law and followed in practice. The importance of formalizing these rights can not be quantified by an objective methodology. Similarly, respecting nature is an inherent part of most of the world's great religions, while the major philosophical and scientific frameworks abhor the wasteful depredation of Nature.

5 Limitations and Caveats

The valuations we provide here loosely follow the proposed TEEB framework for ecosystem services assessment and valuation. It is, however, a preliminary effort and should be interpreted as such. First and foremost, there are problems with the estimate of values from ecosystem services in general and their comparison with estimates made for well-established, traditional economic activities. Although this is not so problematic for provisioning services, such as timber and other marketable goods, they become increasingly difficult as one moves to incipient markets, such as the carbon market, and even more so for markets that are not yet established. This is particularly the case for ecosystem services that are quasi-public goods, such as the mediation of regional precipitation regimes that carry no "hard" monetary value that might benefit individuals. The current non-market—and hence non-priced—nature of many of these ecosystem services is an impediment to the creation of incentives that would lead land holders in the Amazon to perceive the loss of an ecosystem service as a significant opportunity cost.

Second, valuation relies on many assumptions that are a simplification of extremely complex situations that often depend upon context. For example, the use of estimated monetary value per unit of land (i.e. \$US $ha^{-1}yr^{-1}$) and extrapolating those value over the entire region disregards the extremely heterogeneous nature of the region (Verweij et al. 2009). This is true in our own use of NPP ranges and average biomass values that we use to estimate the potential economic value of a sustainable timber harvest and climate regulation. Perhaps one the most challenging aspect of a valuation effort is to account for the fine-scale estimate of value of forest ecosystem services and the opportunity costs of forest conversion. This is mainly the case of values estimated for goods and services in informal markets at the local scale for which there are no available statistics, but which have important implications for assessing the true opportunity costs of avoided deforestation. These values may represent, at aggregate levels, the most compelling argument to protect the forest and services it provides for the communities, many of them poor, who actually live within the Amazon. For example, in the Brazilian Amazon, there are currently at least 10 million rural inhabitants in the region, most of whom are poor settlers in unfamiliar terrain; they lack knowledge of how to best protect and make productive use of these goods and services, and there are still no mechanisms to transmit the global and regionally recognized benefits to stimulate their conservation and wise use.

Despite these and other limitations, it is worthwhile to assess the value of ecosystem services, because this demonstrates their dimension at different scales and the economic impact that would occur due to their loss or, more probably, from a reduction in the quantity and quality of those services. It also underscores the need for a more a detailed assessment and for careful consideration of the costs and benefits of un-priced goods and services; for which the TEEB framework can provide important guidance and a better perspective for integrated assessment.

Finally, this exercise is important for supporting new policies and improving governance at all political levels in the Amazon. By acknowledging the tangible value of these services and their contribution to local and national economies, even a back-of-the-envelope method is sufficiently illuminating to influence most decisions makers. This is particularly relevant for the Amazon, which provides a variety of market and not market goods and services that are extremely important to the individuals who actually live in the Amazon, but also for societies on other continents that indirectly benefit from the existence of the Amazon. The closing of the enormous gap between values and revenues is probably impossible, but a reduction in that gap can be attained by the creation of innovative market mechanisms, while recognizing that non market measures are essential in order to conserve the goods and services provided by the Amazon ecosystem.

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