The potential economic values of the multiple benefits from REDD+ in Panama: A synthesis of existing valuation studies

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1. Background

Deforestation and forest degradation is still ongoing in many areas of Panama. This trend is mainly driven by the conversion of forest lands into agriculture with differences in agricultural returns explaining regional differences in forest cover (Wright & Samaniego 2008). An international mechanism to transfer financial incentives to countries for reducing emissions from deforestation and forest degradation and related activities (REDD+) provides a promising opportunity to stabilize and even increase forest cover. Under the UN-REDD Programme, Panama is currently preparing REDD+ implementation to decrease deforestation and forest degradation.

Different REDD+ options of where and how to implement REDD+ activities[1] involve different costs and bring different combinations of carbon stocks, biodiversity benefits and other ecosystem services (Dickson et al. 2012; Narloch et al. 2012). These forest benefits can have high economic values attached to them through their role in underpinning the production of goods and services that are valued by humans and that underpin local livelihoods and national economies (TEEB 2010; Ferraro et al. 2012). But often their values are not visible as these forest benefits do not directly enter markets and thus do not have a financial value (as defined by a market price) attached to them. Valuing forest benefits can help to understand the overall economic importance of REDD+ options and to assess economic trade-offs with other land use options. It is a means to mainstream forest benefits besides carbon into REDD+ strategies and action plans and wider land use planning.

REDD+ related valuation studies are not numerous, but there is already a lot of information on the economic values of forests from a number of case studies, especially in Central America and wider Latin America – found in scientific journals and the grey literature. The aim of this report is to synthesize findings from other studies and show potential monetary values of forest benefits based on estimates from studies undertaken in similar contexts. This can give first insights into the orders of magnitude of the economic values of benefits attainable under REDD+. This report follows best practice, but it needs to be recognized that there are many limitations of using these values for land use planning. That said, this report can help to raise awareness of the potential economic values of REDD+ options in Panama.

The next section explains the requirements of a monetary valuation exercise so as to inform REDD+ planning. Section 3 then explains different forest benefits and illustrates potential values based on existing studies. Summarizing these results, section 4 explains the relevance for REDD+ planning as well as the limitations of the illustrated values. Section 5 provides specific recommendations for a more comprehensive REDD+ valuation study.

[1] These include reducing emissions from deforestation, (2) reducing emissions from forest degradation, (3) conservation of forest carbon stocks, (4) sustainable management of forest, and (5) enhancement of forest carbon stocks (UNFCCC 2010).

2. Monetary valuation for REDD+ planning

The valuation of forest benefits is not only an economic exercise, but also requires understanding of ecological relationships. First of all, REDD+ actions would change land use/cover compared to a baseline scenario without REDD+. This affects carbon stocks, biodiversity and ecosystem services. Generally, ecosystem services as defined by the MEA (2005) play interconnected functions forming input in ecological processes and final outputs that contribute to human well-being (Fischer et al. 2008). For valuation studies there is an increasing focus on final goods (food, fiber, water, etc) or final services (e.g. recreation, ecological knowledge) that directly contribute to human well-being (Ojea et al. 2012; UK NEA 2011).

Monetary valuation of these forest benefits requires a number of steps, as summarized in Figure 1 according to Narloch et al. (2012):

(1) assessing the impacts of REDD+ related land use/cover change (compared to a baseline scenario) on forest benefits (carbon stocks, biodiversity benefits and ecosystem services);

(2) quantifying how these impacts change the flow of goods and services directly valued by humans;

(3) valuing the human welfare effects of these changes in monetary terms.

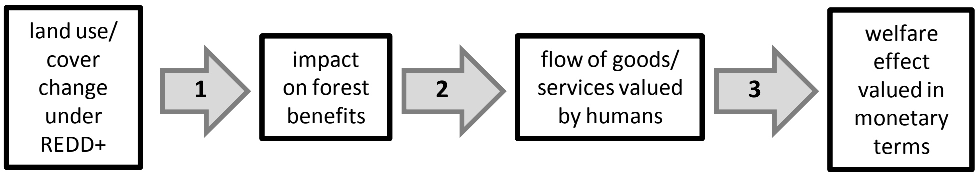

***Fig 1**. The steps of an economic valuation exercise based on Narloch et al. 2012*

It should be pointed out here that forest benefits cannot always be valued in monetary-terms. In fact, in many contexts where monetary valuation is too challenging or politically contested, it may be more practical to value forest benefits in qualitative or bio-physical terms so as to guide REDD+ decisions (see Narloch et al. 2012). However, monetary valuation provides a decision-making metric that allows expressing different forest benefits in a common currency that most policy-makers are very familiar with. Further, it facilitates the comparison of different service types measured in different units and their aggregation so as to inform a comprehensive cost-benefit analysis (Narloch et al. 2012). In what follows, we explain the particular requirements of an economic valuation exercise to inform REDD+ planning (see Narloch 2013).

1. Country relevant REDD+ options: There are many different ways of how to implement REDD+ through one of the five REDD+ activities. Generally, each option brings different combinations of forest benefits (e.g. compared to a protected area a sustainably managed forest may bring lower carbon and biodiversity related benefits, but higher benefits from harvesting timber and NTFP). Most existing ecosystem valuation studies focus on forest conservation (e.g. protecting forest from conversion into agriculture), while the valuation of options that allow for some changes in the forest (e.g. sustainable management of forests) are less frequent. REDD+ valuation studies need to be undertaken for all those REDD+ options that are envisaged and feasible in a specific national REDD+ context.

2. Changes in land use/cover: The impacts of different REDD+ options need to be valued for the change in forest benefits compared to baseline scenarios without REDD+. Most alternative land use/management options still deliver some carbon stocks, biodiversity benefits or other ecosystem services. In fact, a REDD+ valuation study would need to be based on a land use change/cover matrix presenting possible combinations of different REDD+ options and alternative land uses/management options.

Many economic valuation studies have valued the stock of current forests through the total flow of benefits from a forest area without the comparison of benefits flows under alternative scenarios. Without comparison to alternative land use/cover scenarios, the total value of standing forest just indicates the value of preventing the entire ecosystem from disappearing, which is not realistic (unless it were to be concreted over, e.g. as a road).

3. Marginal values: Moreover, absolute values are of less help for land use planning. Land use/management decisions are normally about changing limited numbers of land units into an alternative state (e.g. converting an area of forest into cropping land). Additionally, the quantity of forest benefits and their value can depend on the forest area left. For instance, the contribution of a hectare of natural forest to water filtration services may increase with increasing scarcity of intact forest watersheds). There can also be threshold effects (e.g. a forest natural park is of recreational value only beyond a certain minimum size). In order to guide REDD+ decisions, impacts need to be assessed for incremental changes in land use/cover (Turner et al. 2010). Most studies equate marginal values with average per hectare values, which is only reasonable for benefits that remain constant with the forest area left (e.g. reduced carbon emissions)

4. Spatial variation: The feasibility of different REDD+ options as well as the suitability of alternative land use/management options depend on local factors such as biophysical (e.g. topography, land cover) and socio-economic factors (e.g. property rights, existing land designations). Hence, for each REDD+ location and different land use/change, a matrix could be developed.

Furthermore, the same land use/cover change can have varying impacts on forest benefits in different locations depending on agro-ecological conditions. Similarly, these impacts vary across space in the goods and services they provide for humans, depending on where beneficiaries are located. For instance, soil sediments travel through a watershed and would only have economic value where drinking water quality, fishing, or hydropower production is affected. Hence economic values of REDD+ options can be distributed very unevenly across space. Yet a spatial analysis is very challenging, as the relationship between land use/cover change in one location and its effects on forests benefits provided in other places is very complex.

5. Dynamic effects: Valuation studies should not only build on a snapshot of conditions at a single point in time, since REDD+ affects the flow of goods and services far into the future. Alternative land use/management options implemented today can trigger the flow of forest benefits that follow a time path. For instance, siltation is a gradual process with larger loads accumulating over time (see Chomitz and Kumari 1995). Moreover future conditions are subject to fluctuations, such as climatic changes and price variability, which can affect the flow of benefits. For these reasons a REDD+ assessment should include a scenario analysis based on future conditions, such as population trends, economic policies, technology development, climate change and a potential REDD+ mechanism.

6. Sensitivity analysis: Economic values depend on different conditioning variables that are subject to variability. Especially when considering value flows far into the future, variations can be significant and often precise future values are hard to estimate, as future conditions and impacts are very difficult to predict. For these reasons a sensitivity analysis should be performed so as to indicate a range of possible values.

7. Total economic values: All forest benefit types that contribute to goods and services valued by humans should be taken into account so as not to estimate only part of the total value of REDD+ options. According to the TEEB framework, benefits from forests or other ecosystems can have direct use values, indirect use values, option values and non-use values (Pascual and Muradian 2010).[2] Yet there are a number of challenges in calculating non-use and option values of forests although these vales can be enormous. And generally, monetary valuation exercises are biased towards valuing economic benefits that somehow can be linked to market activities. Wider social benefits (contribution to shared traditions or social norms and local identities) or health benefits (contribution to physical, mental and social well-being) have found much less attention (UK NEA 2011).

8. High quality ecological and socio-economic data: To undertake the economic evaluation ecological relationships and the socio-economic context determining welfare changes need to be well-understood. In many countries REDD+ relevant information is not readily available, so that new field research is needed to fill data gaps. This data collection can be very expensive and time-consuming, especially if samples are needed that cover wider geographical areas.

In addition, the analysis of data requires technical capacities. It is important to note that due to the context-specific nature of the analyses, standardized tools are often not applicable and those tools and methods available have to be adapted to local and national contexts. Teams with technical knowledge and expertise are needed to undertake detailed analyses. Yet often capacity constraints provide challenges for valuation studies in developing countries (e.g. Christie et al. 2012).

[2] Direct use values relate to human consumptive (e.g. crops, fiber, water, etc) and non-consumptive use of forests (recreation, cultural well-being). Indirect use values arise, for example, from water regulation and purification, pollination, nutrient cycling and soil fertility. Non-use values result from the satisfaction from the mere existence of forests and from knowing that other people or future generations benefit from forests. Option values are linked to future use or non-use values.

3. Valuing forest benefits in Panama

The previous section has highlighted the complexity of undertaking a valuation study so as to inform REDD+ planning. Due to the resources available for this study, this report does not attempt to undertake such a valuation exercise. Instead it illustrates potential forest benefits that can be secured through REDD+ in Panama and their economic values. Estimates are derived from existing studies following a benefit-transfer like approach. To maximize similarity of study context, the focus is on relevant studies from Central America or the wider Latin American region. These studies were identified through a desk based review of literature. Seeking high-quality studies we mainly built on peer-reviewed articles published in scientific journals as identified in van de Ploeg (2010), Ferraro et al. (2012) and Ojea et al. (2012).[3] For reasons of comparability, all values in this study are expressed in 2011 international dollars (see Appendix A).

The numbers estimated indicate the value of a hectare of forest that would otherwise be lost. Most data is available on potential values of forest protection as compared to forest conversion into an alternative land use. Yet as explained, a REDD+ valuation study will need to consider many more than just these two extreme scenarios (e.g. sustainable management of forests versus degrading management of forests). The following elaborations try to be as close to an analysis of marginal values as possible, but in some cases values correspond to average per-hectare values.

The report presents values per year and not net present values for the flow of benefits over a larger time span. If the flow of benefits is constant over time (e.g. protecting one hectare reduces soil erosion by a specific number of tonnes every year), this annual value is indicative of values over any larger time period if multiplied by the number of years and discounted appropriately. Since the benefit flows from alternative land uses can often be constant over time too (e.g. one hectare of land can on average produce a certain amount of agricultural output each year if the same technology and level of inputs are employed), such an analysis will lead to the same policy conclusions as a net present value analysis for a 20 or 30 year time span.

Where data availability allows, a lower and upper bound value is reported. In addition, given the importance of spatial variation, values are differentiated for three different regions: Bocas del Toro region (in the North-West), the Canal region (in Central Panama) and the Darien region (in the South East). These three regions differ to a larger extent in their socio-economic and ecological characteristics, as will be explained in the following section, so that values can vary. The illustrations focus on forest benefits that can be linked to market activities and thus valued in monetary terms: non-timber forest products, genetic resources, recreational benefits, hydrological benefits, erosion prevention, pollination services and climate regulation.

[3] There is a larger grey literature on valuation of forest and ecosystems in Panama or its neighboring countries. Yet due to time constraints it was not possible to critically assess the quality of these studies in terms of scientific soundness of the research design and the robustness of the research results.

3.1 Non-timber forest products (NTFP)

Forests provide non-timber forest products (NTFP), which serve as food, raw materials and medicine in rural communities in Panama (Valle et al. 2000; Ibanez et al. 2002). These goods are either used for self-consumption or sold at local markets and can play an important role for rural well-being, not only as a source of income.

In addition NTFP are used for the production of artisanal products that can have high market prices. In Bocas del Toro the pita plant (*Aechmea magdalenae*) is very prominent. Women collect the fibre (called kiga) in order to make hammocks, fishing nets, ropes and bags (Lincoln and Orr 2011).[4] In the Canal region the acorns and the fibre from the jipijapa palm (Cardulovica palmeta) are used for hats, bags and miniature sculptures, predominantly sold at the artisanal market of Colce (Valle et al. 2000). In Darien, households make artisanal work such as carvings from the seeds of a tagua palm (*Phytelephas seemannii*) which is also considered as "vegetable ivory" as it can be carved like elephant ivory (Velásquez-Runk et al. 2004). The total market value of artisanal goods produced from tagua in 2000 was $860,000 (Valle et al. 2000).[5] Furthermore, local artisans in Darien use the wood of cocobolo tree (*Dalbergia retusa*) for carvings and fibres of the chunga palm (*Astrocaryum standleyanum*) to weave baskets (Velásquez-Runk et al. 2004).

Yet, the extraction or harvest rate of NTFP can be unsustainable. For instance, normally the entire chunga palm is felled to harvest chunga leaves and unsustainable harvest rates are already being observed (Macko 2012). Around 60% of Panamanians use wood for energy supply, which increases the pressure on forest areas (Valle et al. 2000). In this context, it becomes clear that the valuation of timber and NTFP in a REDD+ context needs to be based on sustainable harvest and extraction rates. In addition, wider environmental impacts need to be considered. If REDD+ focuses on strict forest protection, then the collection of NTFP that affect carbon stocks (e.g. firewood by felling trees) should not be valued at all.

Peters et al. (1989) estimate that the potential value of Peruvian rain forest can be as high as $3,430 per hectare per year just through plants that provide fruit and latex products (Peters et al. 1989). Yet often only a small share of these values is captured through the actual collection and use of NTFP. Based on surveys undertaken in Honduras (in 1995 and 1996) and Bolivia (in 1999), Godoy et al. (2001) estimate much lower values for the actual consumption and sale of forest products (see Table 1). They compare values from a remote and a more accessible site to control for the role of market access.

Assuming similar conditions in Panama, these values can indicate the potential values generated if REDD+ protects a hectare of forest that would otherwise be converted. Given its proximity to Panama, the higher estimates for Honduras may be more relevant, but the estimates from Bolivia

[4] Normally the kiga is exchanged for $0.15 – $ 0.38 a leaf and $7.72 a ball (5 in. Diameter) (Lincoln and Orr 2011).

[5] Velásquez-Runk (1998) report that extractors received between $0.31 and $0.45 per kg of tagua in Ecuador ($14.19 and $20.39 for 100 pounds).

could serve as a lower bound reference value. Godoy et al. (2001) report that values include bush meat, fish, edible and medicinal plants, as well as firewood and construction material. Yet there is no reference to NTFP used for artisanal work, so that the values of NTFP in Panama may be higher.

Table 1: The monetary value of NTFP

	remote		accessible		source
	Bolivia	Honduras	Bolivia	Honduras	
self-consumption in $/ha per year	5.68	9.67	14.90	29.02	Godoy et al. (2001)
sales in $/ha per year	1.93	0.58	2.02	12.76	Godoy et al. (2001)
value in $/ha per year	7.61	10.25	16.92	41.78	

As Darien is a rather remote region where people have less access to markets, it is assumed that the calculated values for remote sites in Bolivia and Honduras could indicate the range of potential values of NTFP, $8-10 per hectare per year. Given the proximity to markets of households living in Central Panama, the estimated values for close sites, could indicate potential values of $17-42 per ha per year in the Canal region. For Bocas del Toro it is assumed that potential values are in the middle of these ranges (hence $13-26 per hectare per year).

3.2 Genetic resources

Conserving forests and their diverse resources can facilitate the discovery of new plant or animal species for the development of novel pharmaceutical or other commercial products. Companies can pay for the right to search for genetic resources in a specific area and to use species for pharmaceutical or industrial use through a bioprospecting scheme. There have been at least two schemes implemented in Panama (DOD 1996): One financed by the U.S. National Institutes of Health and carried out in cooperation with the Instituto Nacional de Recursos Naturales Renovables (INRENARE) based on plant samples and one financed by the Sandoz Corporation and INRENARE on assays of fungi. Yet given the laboratory facilities in Panama and its richness in biodiversity, there could be a much higher potential to generate financial resources for forest conservation though bioprospecting schemes. A firm's willingness to pay for such schemes demonstrates the potential value of genetic resources.

There have been a number of studies estimating the marginal values of forests through their contribution to plant-based pharmaceutical products. Adger et al (1995) based on a simple formula presented in Pearce and Puroshothaman (1998) calculate that the pharmaceutical value of a hectare of tropical forest could be between $2.7 and $242 per year. Simpson et al. (1996) estimate the marginal value of a species ($13,100) and derive a marginal willingness to pay $2.2 per hectare in the Colombian Choco, neighbouring the Darien region. Rausser and Small (2000) criticise their assumption of random search and calculate a willingness to pay of $680 per hectare in the

Colombian Choco assuming an informed search, whereby those sites with the highest probability of success are screened first. Costello and Ward (2006) explain that the different value estimates are not due to the informed research assumption, but due to varying parameter values chosen by the authors.

Using an updated range of parameter values as suggested by Costello and Ward (2006), here the formula by Simpson et al. (1996) is applied as shown in Table 2. Based on newer data on endemic species in biodiversity hotspots (Conservation International 2013), the number of endemic plant species per ha is calculated (*e*) for each of the regions. This estimate is then adjusted by a factor of 0.43 (*f*) reflecting the relationship between species and area in order to yield the marginal species contribution per ha (*e*f*). Based on the probability of success per species test (*p*) and the total number of plant species considered (*n*), then the probability of needing to test the last species is calculated as (1-p)^n. Based on the net income upon success for a tested species (*i*) and the costs per species test (c), the expected net income can be estimated (*p*i-c*). Multiplying the net income with the number of searches per year, the probability of needing to test the last species and the marginal species contribution per ha yields the value of genetic resources for pharmaceutical product development per ha and year. Assuming a lower and higher value for the net income upon success and the number of searches as in Costello and Ward (2006) suggest that the annual per ha values can be negligible, but may also be between \$5 and \$16 depending on the region (see Table 2).

Table 2. The monetary value of genetic resources

	Bocas	Canal	Darien	source
no of endemic plant species /ha+	0.00013013	0.000273705	0.00041728	Conservation International (2013)
ecological adjustment factor		0.43		Costello & Ward (2006)
marginal species contribution /ha	5.59561E-05	0.000117693	0.00017943	
probability of success of each species test		0.000012		Rausser & Small (2000)
total no of plant species considered		250,000		Simpson et al. (1996)
probability of testing the last species		0.049786172		
net income upon success for tested species in \$ million		1,500 - 10,400		Costello & Ward (2006)
costs per species test in \$		5,500		Simpson et al. (1996)
expected net income of testing the last species in \$		12,500 - 119,300		
number of searches per year		3 - 15		Costello & Ward (2006)
value in \$ /ha per year	0.10 - 4.99	0.22 - 10.49	0.33 - 15.99	

Notes: + For Bocas information from the Meso-America hotspot is used and for Darien information from the Tumbes-Choco-Magdalena hotspot. For the Canal region a density value in the middle is assumed.

3.3 Recreational benefits

Forests provide recreational benefits for local people - but also for national and international tourists that come to visit eco-tourism sites. Tourism is an important source of income for Panama and its share in national GDP can potentially grow from 4% in 2008 to 10% in 2020 (T&L 2008). Many tourists actually come to see and enjoy the natural beauty of the country (ANAM 2010). Generally, it is to be differentiated between multipurpose tourism with a large number of tourists visiting natural parks as part of a longer trip for 1-2 days and specialised ecotourism with longer tours to be undertaken by a smaller number of tourists (Adger et al. 2005). Protected areas reported a total of 179,741 national visitors and 162,105 international visitors between 2005 and 2008 (ANAM 2010). Entrance fees alone made up to revenues of $540,000 in 2008 (ANMA 2010).

Taking these actual revenues can only provide a lower bound value for the recreational benefits from forest and the economic importance of forests. First of all, tourists do not only contribute to national income generation through their payments for entrance fees, but also through their expense for travel, accommodation, food and souvenirs. Their total expense is a better proxy for their willingness to pay for the recreational benefits from Panama's natural heritage. Secondly, the tourism industry in Panama is growing and Panama's Master Plan for Sustainable Tourism envisages that the number of overnight stays grows by a factor of five between 2008 and 2020, to 10 million for international tourists (T&L 2008).

Hence, in order to value recreational benefits, the potential net income from eco-tourism can serve as a better reference point. According to the Master Plan, eco-tourism will generate accumulated revenue of $4,420 million between 2008 and 2020 with a profit margin of 42.4%. This makes an average net income of $144 million per year. When dividing by the total area of protected areas (2.6 million ha as per ANAM 2010), the average net income is $54.5 per hectare per year. Eco-tourism already plays a major role in Bocas del Toro and is expected to further grow till 2020, while in Darien there is potential for significant development from very low current levels, but high investments in infrastructure are needed (T&L 2008). With Soberania Natural Park contributing to a larger share of tourism revenues between 2005 and 2008 (ANAM 2010), the Canal region is also important for eco-tourism given its easy access for visitors from Panama City. To adjust for the regional difference in eco-tourism potential, the average per hectare value is multiplied by a factor of 2 for Bocas del Toro, by 1.2 for the Canal and by 0.5 for Darien.

As summarised in Table 3, this yields an annual per hectare value of $109 in Bocas del Toro, $66 in the Canal region and $27 in Darien. A note of caution: This is only a very crude estimation as the link between ecotourism income and the state of the forest has to be considered. Generally, tourists are willing to pay to experience and see certain attributes, such as unique landscapes or animal species. Hence the true value may be better determined through exercises that reveal the preferences of tourists (see valuation studies for rainforest reserves in Costa Rica from Tobias & Mendelsohn 1991; Menkhaus & Lober 1996). Moreover, the values presented here are average per hectare values. For recreational benefits the calculation of true marginal values is much more difficult. Tourism revenues or willingness to pay WTP are linked to larger areas and the value of an additional hectare of forest can vary. Only below a certain minimum forest size or in critical forest areas, tourist revenues or tourists WTP would be affected by the conversion of one hectare. As these threshold effects are difficult to control for, an average value is the closest estimate of a marginal value in this example.

Table 3: The monetary value of recreational benefits

	Bocas	Canal	Darien	source
total area of protected area in ha		2,644,417.37		ANAM (2010)
ecotourism revenues in $ for 2008 -2012		4,430,000,000		T&L (2008)
profit margin in %		42.4%		T&L (2008)
ecotourism net income in $/ha per year		54.6		
adjustment factor	2	1.2	0.5	
value in $/ha per year	109	66	27	

3.4 Hydrological benefits

Hydrological services from forests are of significant importance in Central America, so that there is a growing body of watershed valuation case studies from the region (Andreassian 2004; Locatelli et al. 2011; Aylward and Hartwell 2010; Ojea et al. 2012). These services contribute to clean drinking water supplies, irrigation for agriculture, hydrological power generation and transport networks. Accordingly, to appreciate that water is a valuable resource, Panama introduced water tariffs, for example $0.0033/m3 for industrial and commercial use, $0.0000318/m3 for hydropower generation, and $0.00033/m3 for domestic use (Republica de Panama 2009).

An interesting case study is the the Panama Canal watershed providing the water supply for the Panama Canal[6], which serves as a route for ships and is Panama's main income source, whilst contributing to electricity generation and supplying drinking water for Panama City and Colon (DOD 1996; Ibanez et al. 2002). It is estimated that 4,400 million m3 of water flow into the Canal yearly[7] and that on average 59% are used for filling the Canal's locks, 27% for generating hydropower and 6% for drinking water (Ibanez et al. 2002). With the recent expansion of the Canal even more water is needed to provide these benefits.

From these numbers it can be seen that these benefits are very sensitive to the overall availability of water. A decline of only 10% would leave insufficient water to provide the above benefits. The 1983 and 1997 droughts resulting from El Nino resulted in a lack of water to fill the locks. Consequently, the number of ships and their maximum load had to be reduced. At the same time reduced stream flow and hydropower production caused electricity blackouts. But not only too little water can be

[6] Water from the river is channelled through Lake Alajuela and Lake Gatun, which provide the necessary draft for transiting ships (FAO 2000).
[7] From the 9,000 million m3 of rainfall from the 3,300 km2 watershed, 4,600 million m3 are lost due to evaporation (Leigh 1999 cited in Ibanez et al. 2002).

harmful for the operation of the canal. If water levels are too high, the Lake can overflow the locks and block their operation as well. In 2010 heavy rains led to a closure of the Canal for the first time since 1995. Additionally, landslides led to soil siltation leaving almost a million of people without clean drinking water for a month.[8]

Yet the relationship between forest cover and water quantity (water yields, water tables, seasonal and peak flows) are widely discussed (Bruijnzeel 2004; Chomitz & Kumari, 2005; FAO 2005; Kaimowitz 2005). The importance of the Canal watershed and the perceived degradation of its ecosystems led to the adoption of Law 21 in 1997 calling for improved watershed management. This also triggered a number of studies in the Canal revisiting the relationships between forest cover and water services. Experiments in the Canal watershed show that forest cover reduces run-off and thus water tables and yields in downstream areas (Aylward 2002; Calder et al. 2001; Ibanez et al. 2002).[9] Furthermore, several studies from the Canal watershed[10] provide no scientific evidence of a positive relationship between forest cover and dry season flows (Aylward 2002).

How far forests increase water tables and yields and stabilize water flows is very location dependent (Kaimowitz & Kumari 2005). In the Canal watershed new research is ongoing to explore these relationships.[11] Generally speaking, it could be that forest conversion has little impact as long as larger areas under forest cover remain in the watershed. Yet as soon as critical thresholds are reached, further conversion could have detrimental impacts on water cycles.

The relationship between forest cover and water quality is more clearly established, as forest cover supports filtration services and reduces soil siltation from soil erosion on upstream lands (Bruijnzeel 2004; FAO 2005; Aylward and Hartwell 2010). Total drinking water supply in Panama equals 294hm3, 2.3% of total water demand (Castillo 2011). Plants to generate drinking water are distributed all over the country serving more than 1.5 million people in the Canal region, 58,390 people in Bocas del Toro and about 4,500 people in Darien (Castillo 2011 based on data from ANAM). Accordingly, the forest values associated with water quality may vary across the country.

So far water quality in most streams of Panama is considered to be good, but in the region of the Canal around Panama city high levels of contamination are observed (ANAM 2010; Castillo et al. 2011). Yet with increasing land conversion, water quality may deteriorate and make the application of expensive treatments indispensable. Bernard et al. (2011) report that in Costa Rica water from a forest watershed are treated with an average dose of aluminium sulphate of only 16,400 mg/m3, while for water from a deforested watershed 26,600 mg/m3 are needed due to five time higher

[8] http://www.stri.si.edu/english/about_stri/stri_science/Landslides_How_Rainfall_Dried_up_Panamas_Drinking_Water.php).

[9] In experiments undertaken in the Canal watershed Calder et al. (2001) show that forest lands (as compared to pasture lands) reduce run-off by between 29% in drier zones (Trinidad catchment with 2222 mm annual rainfall) and 18% in wetter zones (Chagres catchment with 3420 mm annual rainfall). Ibanez et al. (2002) estimate from different experiment in the Canal watershed that in a forested catchment run-off is reduced by 12% of annual rainfall (compared to a deforested catchment).

[10] These studies are undertaken as part of the Plan Regional by Nathan and Associates (1996) and the Panama Canal Watershed Monitoring Project (1999) and a MIDA/World Bank project (see report by Calder et al. 2001).

[11] This is coordinated by the Smithsonian Tropical Research Institute in Panama with funding from the HSBC Climate Partnership (see http://www.ctfs.si.edu/group/Panama+Canal+Watershed+Experiment).

siltation loads. At a price of $0.42 per kg of aluminium sulphate, this makes water treatment costs of $4 per 1,000m3 of contaminated water (Bernard et al. 2011). This is much lower than the value calculated in a World Bank study for the Canal watershed of $100 per 1000m3 (Porras and Aylward 2001). Yet this review could not identify relevant studies that help to quantify by how much lost forest cover reduces water quality, which impedes a valuation of these forest benefits.

From these considerations it appears that better understanding of the relationships between forest cover and water quantity or quality is needed for the valuation of hydrological benefits in Panama. Yet there are a number of relevant studies that have shown the willingness of consumers and firms to pay for the protection of forests for hydrological benefits, as summarized in Table 4. Koellner et al (2010) find that firms in Costa Rica are willing invest $130 per year in a hectare of forest that secure watershed protection.[12] Similarly, under the *Programa de servicios ambientales* (PSA) in Costa Rica a water bottling company and a municipal water supplier pay land users $105 per year for forest conservation. Under the same programme hydropower producing companies pay between $19 and $63 per hectare per year for forest protection (Pagiola 2008). Given the value of electricity foregone by having to spill excess water, a hydropower company from Costa Rica pays $48 to upstream land users to reforest their land, engage in sustainable forestry and/or conserve their forested land (Perrot-Maître and Davis 2001). Johnson and Baltodano (2004) estimate that on average a household residing in micro watershed in Nicaragua are willing to pay $28 for improved water supply.[13] From these estimates, the annual values of hydrological benefits from forests could range between $19 and $130 per hectare.

Table 4: The monetary value of hydrological benefits

	country	$/ha per year	source
firms' willingness to invest in forests to provide watershed protection	Costa Rica	130	Koellner et al. (2010)
payments from a water bottling company/ municipal water supplier for upstream forest protection	Costa Rica	105	Pagiola (2008)
payments from a hydropower company for upstream reforestation/forest protection	Costa Rica	75	Perrot-Maître &Davis (2001)
payments from hydropower companies for up-stream forest protection	Costa Rica	19 - 63	Pagiola (2008)
households' willingness to pay for improved access to water of better quality	Nicaragua	28	Johnson & Baltodano (2004)

[12] In the exercise watershed services are explained as follows: "Watershed protection: tropical forests filter water, regulate its flow, and prevent erosion. This ecosystem service plays an important role in water quality for rural, urban, industrial, and agricultural use"(Koellner et al. 2010).
[13] In their contingent valuation exercise they define improved water supply as "improved access to a source that provides more water of better quality " (Johnson and Baltodano 2004).

3.5 Erosion prevention

Deforestation can also cause soil erosion and the loss of soil fertility, as well as soil sedimentation in downstream rivers and water reservoirs. Chomitz and Kumari (1995) summarizing earlier work show that forest land cover relates to soil erosion rates that are between 0.37 t/ha and 63.8 t/ha (median 2.5 t/ha) lower than on cropping lands under shifting cultivation. In Mexico forest conversion is estimated to lead to soil loss of between 0.169 t/ha and 7.43 t/ha (Adger et al. 1995). Soil erosion depends on the topography of the watershed. In the Birris watershed in Costa Rica with steep slopes, soil erosion rates increased by 30 t/ha when the share of agricultural land in the watershed increased from 15% to only 30% (Vignola et al. 2012).

Soil erosion can be associated with high economic costs through the effects on agricultural production, transport and hydropower generation capacity. First of all, the movement of topsoil can result in the loss of nutrients and soil fertility. This loss can be compensated by the higher fertilizer use on agricultural lands. Torras (2000) estimated the on-site value of nutrient loss through increased fertilizer requirement to be $190 per hectare per year. They further extrapolated a ratio of 2:5 to calculate the value from off-site losses of $480. As here the scenario is one in which a forest plot is fully protected, there are no on-site benefits to agricultural production. Hence an overall value of soil erosion control through maintaining soil fertility of $480 is used (see Table 5).

Furthermore, eroded soils can be washed away and cause soil sedimentation in rivers and water reservoirs. With historical data on sediment loads and spatial land cover (see Miguel 2010) Nunez & Shirota (2011) estimate that sedimentation increases by 0.1476 t/ha for a 1% loss of forest cover in the Canal Watershed. Under 100% forest cover loss resulting from converting forest land into other land uses and with all other control variables being the same, forests contribute to reduced sedimentation of 14.76 t/ha. This number needs to be adjusted by density of sediments (1.113 t/m3) and by additional ground sedimentation (8%) so as to derive the volume of sediments affecting river basins or water reservoirs, which is 14.33 m3/ha.[14] Maintaining forest cover can have high economic values through avoided soil sedimentation that affects the functioning of the Panama Canal as a transport network and hydropower generation.

Sedimentation clogs the channel directly and causes problems for shipping. Hence regular and expensive dredging is needed to ensure that the Canal is deep enough for large vessels (Ibanez et al. 2002). With a dredging expense of $20 per m3, the costs of forest conversion due to increased soil sedimentation are $286 per ha per year. Approximately 14,000 ships go though the Canal per year and there are about 37 locks to be passed each requiring ca. 191,000m3 of water, so that 13m3 of water are needed to transport one ton of cargo (Stallard et al. 2010; Castillos 2011). The weighted average of net revenues from the transport of cargo on the Canal is $0.32 per m3 of water per day and $115.2 per m3 per year[15] (Porras & Aylward 2001). If we assume that each m3 of soil sediment

[14] This value is derived from the following formula: 14.76 t/ha * 1.08 / 1.113 t/m3
[15] This is not the highest potential value, as extra costs of shipping goods by alternative routes may conservatively be put at around $1.88/m3 per day and $676.8 per m3 per year (Porras & Aylward 2001).

(as calculated per above values) reduces water flow for the canal operation by the same volume, this yields a value of $1,650 per ha in the Canal watershed.

70% of total water demand comes from the hydropower sector generating about 54% of all electricity in Panama (Castillas et al. 2011). Sedimentation can cause costs to hydropower operators due to (i) lost generation capacity in hydropower reservoirs and/or increased dredging and maintenance costs (Aylward and Hartwell 2010; Arias et al. 2011). In Costa Rica one energy company spends up to $4.3 million annually for production losses and silt removal (Vignola et al. 2012). Sediment removal can represents up to 70% of operational costs of dams for hydropower projects in the tropics (Bernard et al. 2009). Although it has been shown that at current rates, siltation poses no real threat to hydropower plants in Panama (Kaimowitz 2005), this may change once larger areas of forest are converted.

For the Canal watershed Porras and Aylward (2001) estimate a gross income between $0.006/m3 per day or $2.33/m3 per year (at the Gatun Plant) and $0.014m3 per day or $5.82m3 per year (at the Alajuela Plant). Assuming that operating costs of hydropower are generally very low and are not variable in volume of water used (Aylward 2002), this value is close to the net income gain per m3. Assuming that each m3 of soil sedimentation due to forest conversion relates to the equivalent loss of water for hydropower generation, the annual soil erosion control value is between $33 and $83 per hectare (compared to $73 and $157 per hectare at Lake Arenal in Costa Rica, see Aylward 1998). As the watersheds with the greatest potential for hydropower generation are found in the North-Western or Central Panama (FAO 2000), these values are likely to only be relevant in Bocas del Toro and the Canal.

Table 5: The monetary value of erosion prevention

	estimates	source
<u>soil fertility</u> off site cost of nutrient loss in $/ha per year	480	Torras (2000)
<u>soil sedimentation control</u>		
volume of soil sedimentation caused by forest conversion in m3/ha	14.33	Nunez & Shirota (2011)
gain in cargo revenues in $/m3 per year	115 - 677	Porras & Aylward (2001)
Dredging cost or value of transport capacity in $/ha per year	286 - 1,651	
gross income from hydropower production in $/m3 per year	2.33 - 5.82	Porras & Aylward (2001)
value of hydropower production capacity in $/ha per year	33.4 - 83.4	

3.6 Pollination services

Forests provide habitat for wild bees and other insects that contribute to pollination services, thereby enhancing agricultural production on nearby fields (Ricketts et al. 2005; Olschewski et al. 2006). Experiments in Costa Rica show that coffee plants close to the forest received more visits by more bee species and experienced higher pollen-deposition rates than plants at greater distances (Ricketts 2004). Accordingly, Olschewski et al. (2006) estimate that coffee yields decrease by 45% over a distance of 1500m from the forest frontier in Ecuador. Rickets et al. (2005) conclude from their data that it is difficult to establish a clear relationship between forest distance and coffee yields, but that it seems that forest have productivity increasing impacts on plots within 1000m. They estimate that within this boundary forest pollinators increased coffee yield by 20%.[16] Converting a hectare of forest at the forest frontier means that one hectare of agricultural land that previously was at the pollination boundary, will no longer benefit from these pollination services (as per Olschewski et al. 2006).[17]

Coffee is an important export product for Panama and yields have been increasing sharply over the last fifty years (MIDA, et al 2007). The harvest area in 2011 was almost 30,000 ha (see data from FAOSTAT). The leading coffee producing province is Chriqui neighbouring Bocas del Toro province, where coffee production is much smaller (MIDA, et al 2007). The central provinces also include larger coffee growing areas, while coffee farms are nearly absent in the South-Eastern regions (MIDA, et al 2007). Therefore, we assume that pollination services play a role in Bocas del Toro and in the Canal sites but not in Darien.

Based on the latest production and price data, coffee yields are about 427kg/ha, while producer farm gate prices greatly varied within a year, with price lows of $ 1,186 per tonne and peaks of $2,710 per tonne (FAOSTAT). Cost elements aside[18], these number suggest a value of between $101 and $231 per ha per year (see Table 6). These values only apply for forest protection in the proximity to agricultural lands with pollinator crops, such as coffee farms in Bocas del Toro and by the Canal.

Table 6: The monetary value of pollination services

	estimates	source
increase in agricultural yields with pollination service per ha of forest	0.20	Ricketts et al. (2005)
coffee yields in kg/ha per year	427	FAOSTAT
farm gate coffee price in $/kg	1.19 – 2.70	FAOSTAT
value in $/ha per year	101 - 231	

[16] They also found that pollination improved coffee quality near forest by reducing the frequency of peaberries (small misshapen seeds) by 27%.

[17] This would be based on the assumption that forest land is not converted for coffee production. In this case the overall coffee area receiving pollination services does not change.

[18] Only some cost elements are output dependent (such as cleaning and transport to the market) and would thus increase with production.

3.7 Climate regulation

Forest cover plays an important function in regulating climate patterns through its role in determining rainfall patterns (Sheil & Murdiyarso, 2009; Makarieva et al. 2013).[19] This can stabilize the climate at different scales and have high economic values (Verweij et al. 2009). Yet there are likely threshold effects, so that it is difficult to quantify the role of one hectare of forest to such patterns.

In addition, forests contribute to climate change mitigation storing large amounts of carbon stocks in biomass, both above ground and in the soil. The economic importance of this function has found wide recognition, including through an international REDD+ mechanisms under discussion within the UNFCCC. A REDD+ mechanisms would in fact convert these benefits into financial flows through carbon credits traded at carbon markets or carbon payments from a public fund (CIRAD 2012).

As the inclusion of soil carbon in a REDD+ mechanism is a matter of ongoing discussion here we draw our estimates only on above ground biomass carbon. Based on data from Bacccini et al. (2012) the average carbon stock under forest cover and agricultural land use are estimated for the three regions in Panama. The difference in carbon stocks between forests and agriculture is converted into avoided CO2 emission units using the standard conversion factor of 1tC=3.67tCo2e. Carbon credits generated from REDD projects have ranged between $4 and $11.5 per tCo2e at carbon markets in 2011 (Peters-Stanley et al. 2012). As these prices are paid once for the whole life span of a REDD+ project, they have to be divided by the years of the project so as to yield per year values. Here we assume a 30 year horizon, with most analyses undertaken being based on 20-50 year cycles. Under these assumptions the value of reduced emissions from forest can range between $41 and $156 per ha and per year in Panama. It is to be noted that these estimates are based on the potential financial revenues from carbon markets. When valuing these benefits at the avoided damages from climate change, which come as a cost to wider society, the value can be much higher (see e.g. Verweij et al. 2009).

Table 7: The monetary value of climate regulation

	Bocas	Canal	Darien	source
forest carbon stocks in tC/ha+	180	162	163	Baccini et al. (2012)
carbon stocks of agricultural land in tC/ha++	69	74	80	Baccini et al. (2012)
avoided CO2 emissions per tCo2e/ha	407	323	305	
REDD carbon market price in $ per tCO2e		4 - 11.5		Peters-Stanley et al. (2012)
value in $/ha per year	54 - 156	43 - 124	41 - 117	

Notes: + average biomass carbon content in mature primary and secondary forests in Bocas del Toro, Colon and Darien respectively, ++ average biomass carbon content of lands under agricultural (non-subsistence) use in the same regions.

[19] See also http://blog.cifor.org/13658/forests-as-rainmakers-cifor-scientist-gains-support-for-a-controversial-hypothesis/.

4. Potential values of multiple benefits from REDD+

A final adjustment to some of the previous estimates is made for multipliers. When economic activity takes place which has relied upon the benefits delivered by the forest ecosystem, it not only generates direct income, but also generates demand from other industries in the domestic economy as well as supplying inputs to other industries further down the marketing chain. In addition, the income generated by the initial activity will be spent by the producer's household, increasing the income of other suppliers of goods and services. These positive impacts are known as multiplier effects. In some instances they can be very high for certain economic activities and can have a very positive impact on the incomes of the poorest households. For Panama the multipliers for eco-tourism and exported agricultural crops are relatively high, 2.2 and 2.9 respectively (Klytchnikova & Dorosh 2012). These are applied to the values derived for recreation and pollination forest benefits.

The estimates illustrating the potential monetary values of forest benefits in the three regions of Panama are summarized in Table 8. The different forest benefits are listed according to the types of values attached to them (as per TEEB 2010). These only include direct and indirect use values, as this has been the focus of valuation studies. Nevertheless, non-use and option values can be very important as will be discussed below. The overview in Table 8 demonstrates the economic values that could be secured through REDD+ options that focus on forest protection on lands that would otherwise be converted.

Table 8: Overview of potential monetary values in $ per hectare per year of forest benefits

forest benefit	valued good/service	Bocas	Canal	Darien
direct use values				
NTFP	food, raw materials, medicine, artisanal products	13-26	17-47	8-10
genetic resources	pharmaceutical product development			
recreation	eco-tourism	316	191	78
indirect use values				
hydrological benefits	water quantity / quality	19-130	19-130	19-130
	soil fertility	480	480	480
erosion prevention	transport capacity	-	286-1,659	-
	hydropower production	33-83	33-83	-
pollination services	increased agricultural output	222-508	222-508	-
climate regulation	reduced carbon emissions	56-156	43-124	41-117
non-use values				
cultural benefits	spiritual experience, social traditions/norms, existence values	unknown	unknown	unknown
option values				
biodiversity	ecological functioning and resilience	unknown	unknown	unknown
Total (indicative)		1139-1699	1291-3122	626-815

4.1 Main findings

It can be seen that in addition to the financial revenues from reduced emissions, REDD+ implementation can trigger much higher economic benefits. Table 8 highlights three findings from this synthesis: (i) as forest benefits are not worthless, REDD+ can contribute to the annual flow of goods and services that can play an important economic role; (ii) economic values depend on the type of forest benefit and the goods and services they provide (e.g. erosion prevention so as to maintain transport capacity), (iii) even in a small country like Panama there can be extreme spatial variation between different regions.

The economic values of forests depend on which benefits would be secured where. For instance, forests play hardly any role for transport networks, hydropower generation or agricultural productivity in Darien. Generally, in this remote, less populated and developed region, the economic values secured through REDD+ may be lowest compared to other regions where forests more directly support livelihoods and economic activities for a larger number of beneficiaries.

The case of the Canal watershed is certainly an exceptional case due to its crucial role in supporting shipping transport across the world. The crucial importance of forests around the Canal is already recognized. Reforestation activities are envisaged by law in order to restore forest benefits (Stallard et al. 2010). Interestingly, a resolution from 2003 (Resolución No. AG-0235-2003) set compensation payments for each hectare of primary forest or mature secondary forest lost at $6,800 per ha per year (URS 2007).

4.2 Total economic values

This overview can give a first idea of the economic benefits from REDD+, which are to be compared to the opportunity costs of REDD+ expressed by the financial benefits from alternative land use options (e.g. net incomes from cash crops, pasture, mining, etc) and other REDD+ costs elements. Under the UN-REDD Programme in Panama work is ongoing to assess the cost of REDD+. It is to be pointed out that the potential values in Table 8 do not provide decision support that allows directly comparing forest benefits with REDD+ costs. This is for two main reasons: (i) the aggregated values are indicative only, and (ii) the total economic values of forests will be much higher, as several use values are not included and non-use and option values are not considered at all.

First of all, aggregation of these values is inaccurate because not each hectare of forest provides all benefits discussed. The values generated depend very much on the use of land in nearby areas. It is unlikely that the same hectare of forest that provides pollination benefits to agricultural land nearby also contributes to erosion prevention in the downstream watershed. And it is unlikely that converting a hectare of forests affects transport routes, hydropower generation and drinking water at the same time.

More importantly, the above illustrations cannot help to understand the total economic value of forests benefits. Due to a lack of studies, values for several benefits cannot be established with the current knowledge base. Forests benefits include cognitive information, which can have use values though its contribution to education and research activities. For example, the Panama canal area is attracting researchers from all over the world due to the availability of long-term datasets for this areas and the ecological variability within the zones (DOD 1996). The inflow of revenues from international research projects is an indication of this. In addition, tropical forests in Latin America have indirect use values through disease prevention and fire protection (Andersen et al. 1997).

Important health benefits aside, this report does not explore socio-cultural benefits either, such as spiritual experience and social traditions and norms linked to forests. These can have enormous non-use values. Some people even value the existence of forests as home for diverse plant and animal species and an important livelihood element for other people or generations (e.g. Naidoo & Adamowicz 2005).

Last but not least, the importance of biodiversity is not captured in above illustrations. Biodiversity provides supporting services without which the provision of above discussed goods and services would not be possible (MEA 2005; Verweij et al 2009). Furthermore, maintaining diverse landscapes, species and gene pools increases resilience to disturbances and adaptability to changes (Tilman et al. 1996; Loreau et al. 2011, Folke et al. 2004). Under increasing exposure to shocks and accelerating changes (such as climate change), forest protection can relate to enormous option values, which are difficult to estimate.

4.3 Further limitations

In light of the requirements of REDD+ planning, the above illustrations suffer from a few more limitations relating to marginal values, spatial variation and dynamic effects. These limitations are difficult to account for in economic analyses, so that most existing valuation studies face the same caveats.

(1) Marginal values: Some values actually indicate true marginal values for the conversion of one additional hectare of forest (e.g. the pollination benefits), while others are based on average per hectare values ignoring that the forest benefits and their values raise with scarcity of forests. Yet generally it is difficult to control for threshold effects, whereby a small change in forest cover would bring an enormous change in the flow of forest benefits. Generally, close to such tipping points, valuation would be an inappropriate assessment tool (see Farley 2012).

(2) Spatial variation: In an attempt to control for spatial differences, values are illustrated for three different regions. Yet there can be enormous variation within these regions: The value of erosion prevention may only be extremely high on lands close to the Canal, where erosion would immediately increase sedimentation. Similarly, forest values due to hydropower generation are only relevant in areas close to river basins or water reservoirs with hydropower facilities. In addition, scale plays an important role in determining economic values. For instance, the amount of sediment deposited varies inversely with the size of the watershed, so that the forest area needs to be controlled for (Chomitz & Kumari 1995).

(3) Dynamic effects: The above illustrations are based on a static analysis that may only provide crude estimates under changing conditions in the future. Annual values may change considerably under changing production or demand patterns. Feedback relationships can also to a large extent determine future values. For example, expanding the use of forest resources, such as NTFP and water, may on the one hand reduce its price due to an oversupply, while undermining the resource stock, where extraction rates are unsustainable.

5. Recommendations

Based on a comprehensive review of existing literature from Latin America, this report demonstrates the range of potential values of forest benefits that could be delivered through REDD+. Yet the illustrated economic values cannot directly be integrated in decision-support systems that can inform REDD+ related land use planning. However, this exercise can help with raising awareness and recognizing the economic importance of forests beyond carbon. Such understanding supports policymakers in integrating wider forest benefits in their REDD+ action plans and strategies even without exact monetary information on their values.

In order to undertake a more comprehensive valuation exercise that can inform REDD+ planning, this report brings forward the following recommendations:

1. *Consider different combinations of REDD+ and alternative land use/management options:* A valuation exercise needs to compare forest benefits under a REDD+ scenario and a baseline scenario. As explained, REDD+ can be implemented in many different ways and similarly there may be different land use/management alternatives in a given location. A valuation exercise cannot only compare benefits in the two extreme cases of protecting well-preserved forest and converting it all into agriculture.

2. *Derive marginal values:* In order to support land use planning, valuation studies have to move away from presenting average per hectare values. The values of small incremental changes need to be assessed by controlling for the remaining forest areas and making scarcity adjustments (as in Torras et al. 2000). Whenever critical levels are approached, forests should be safeguarded to minimize the risks of irreversible impacts.

3. *Evaluate spatial variations:* Valuation studies do not only need to account for regional differences within countries but also for spatial variation within regions. This requires local level studies (e.g. at the watershed level) which can then be up-scaled to a whole region. Modeling software, such as InVest can help to quantify and value forest benefits under alternative scenarios and to map these values. Where such data intense models cannot be applied, critical areas for the provision of certain goods and services within different regions can be identified on maps based on layers of topography and other ecological variables (e.g. rainfall) and socio-economic information (e.g. location of water treatment plant or hydropower station and number of beneficiaries).

4. *Assess dynamic affects:* A comprehensive REDD+ valuation study needs be based on a scenario analysis that elaborates different scenarios. This can be done through expert consultation and collaborative working sessions. In addition, feedback relationships need to be accounted. This may require economic models that simulate interactions between supply and demand-side factors in different sectors (such as GLOBIOM).

5. *Perform a sensitivity analysis*: As part of above scenario analysis, the possible future development of different factors (e.g. commodity prices) could be delineated. This would allow establishing a lower and upper bound of values for different forest benefits.

6. *Estimate the total economic value*: Valuation studies need to go beyond the direct and indirect use values of forest benefits that can be linked to market activities. More attention should be paid to health and socio-cultural benefits, including through non-monetary valuation exercises. Given their potential large values, an increased focus should be on the non-use and option values of forests.

7. *Ensure high quality ecological and socio-economic data:* The transfer of values from existing studies as done in this report can only to a very limited extent provide more than very crude estimates for the true values of forests benefits. Given the ongoing discourse about the contribution of forests to water cycles and the functioning of the canal watershed, a rich body of ecological data is actually available in Panama. This existing primary data should be analyzed in the light of specific REDD+ planning questions. Such analyses can be complemented with existing socio-economic data at local level about non-timber forest products, forest related eco-tourism and research projects, hydropower production, agroforestry and below and above ground carbon stock.

These recommendations make it clear that comprehensive valuation exercise that can inform REDD+ planning requires a larger-scale, collaborative study involving a range of different actors that collect and analyze different information. Provided sufficient time and budget, such a study can help to overcome the existing knowledge gap and to provide value estimates that can directly inform REDD+ planning.

Appendix A: Standardization of values

The values found in a number of studies from different countries and undertaken at different points in time need to be standardized to a common metric. Firstly, inflation means that one currency unit in the past could purchase more goods than today. Secondly, the cost of living varies between countries (e.g. for US$1 one can buy more goods in Panama than in the US). The 2011 international dollar (henceforth $) is indicative of the purchasing power of one US$ in the United States in 2011.

Here the standardization approach is followed as described in van der Ploeg et al. (2010) based on data from the World Bank's World Development Indictors (WDI) database. Most country-specific values (*V*) found in the literature are actually expressed in US$ for a specific year, *t.* If the specific year of data collection is not known, the publication year of the study is taken.

Firstly, these values are converted into the local currency units (LCU) using the official exchange rate *E* (LCU per USD, period average in WDI) at time *t*. Secondly, these values are transferred into 2011 values using the GDP deflators (*D*) for the respective years. Finally, these 2011 local currency value are converted into international dollars by dividing by the purchasing power parity conversion factor ('local currency per international $' series of WDI), *F*. The formula to calculate values in 2011 international dollars is:

$V_{\$\ 2011} = V_{US\$\ t} * E_{LCU/US\$\ t} * D_{2011}/D_t * 1 / F_{LCU/\$}$.

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