Appendix C:

Estimates of Monetary Values of Ecosystem Services

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Introduction

This Annex presents the monetary values found for ecosystem services provided by the main biomes[1] identified in Chapter 1. As has been explained in earlier TEEB D0-chapters (notably Chapter 1 and 5), economic values have many shortcomings and limitations, not only in relation to ecosystem services but also to man-made goods and services. They are by definition instrumental, anthropocentric, individual based, subjective, context dependent, marginal and state dependent (Goulder and Kennedy, 1997; Baumgartner et al., 2006, Barbier et al., 2009, EPA., 2009). However, despite these fundamental issues in economic theory and practice, information about the monetary importance of ecosystem services is a powerful and essential tool to make better, more balanced decisions regarding trade-offs involved in land use options and resource use.

In this Annex, we present the results of an analysis of 11 main biomes/ecosystem-complexes (i.e. open ocean, coral reefs, coastal systems, coastal wetlands (mangroves & tidal marshes), inland wetlands, rivers & lakes, tropical forests, temperate & boreal forests, woodlands, grasslands and polar & high mountain systems) and collate their monetary values from different socio-economic contexts across the world. For each biome, all 22 ecosystem services identified in Chapter 1 were taken into account in the data collection. With help of the Contributing and Lead authors, hundreds of publications were screened[2] from which approximately 160 were selected for detailed analysis and data-entry into the "TEEB-database" which was especially designed for this study. Thus far, over 1200 original values (data points) are stored and based on a number of criteria slightly over 600 values were used for the analysis presented in this Annex (for details on the data base, the selection procedure and original values will be made available through the TEEB-website (www.teebweb.org) in June 2010.

An important purpose of the TEEB database is the possibility to use the values for scenario-analysis at different scale-levels. To allow for these kind of studies, the database presents the

[1] Throughout this Annex we use 'biome' as shorthand for the 11 main types of ecosystem-complexes for which we analysed the monetary value of the services they provide. Each biome can be split into several ecosystems, each with their own set of ecosystem services, but for the purpose of this chapter, data on monetary values was presented at the biome-level (for details see www.teebweb.org/Database).

[2] In addition to individual publications, the following ecosystem service databases were used: COPI (Ten Brink et al., (2009)), EVRI (1997), ENValue (2004), EcoValue (Wilson et al., 2004), Consvalmap (Conservation International, 2006), CaseBase (FSD, 2007), ValueBaseSwe (Sundberg and Söderqvist, 2004), ESD-ARIES (UVM, 2008) and FEEM (Ojea et al., 2009). See www.es-partnership.org for access to most of these data bases.

data in one value unit (US$) per ha per year and in a contextual explicit way. For each value, the database includes information on, among others, socio-economic variables, biome type, ecosystem type, ecosystem services and sub-services, valuation method, reference details and the location details of the case study. The web-version of the database thus makes it, in principle, possible to analyze the data in relation to the main determining factors of the values, such as influence of income level, population density, and proximity of user to the service

Figures A5.1-A5.3 give an overview of the distribution of the monetary values selected for this Annex by ecosystem (biome), region and service.

Figure A5.1 Number of monetary values used for this Annex per biome

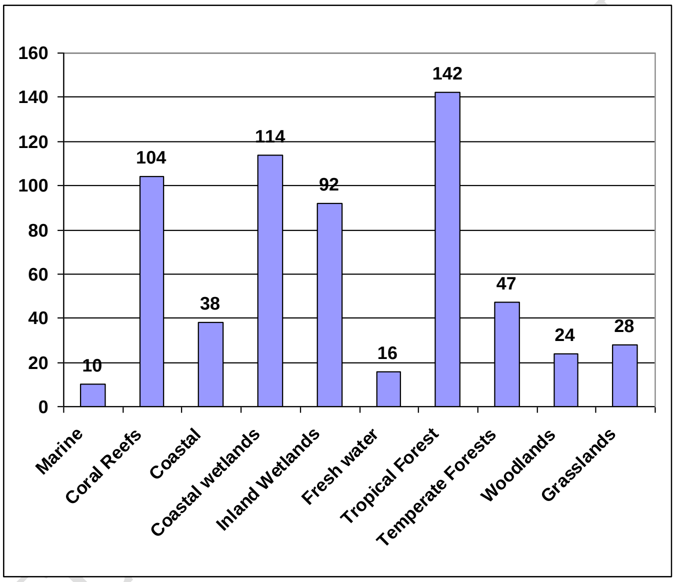


Figure A5.2 Geographic distribution of the monetary values used in this Annex

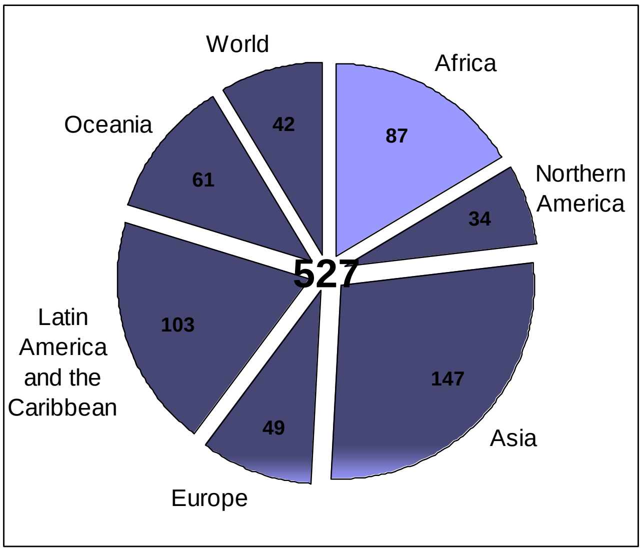
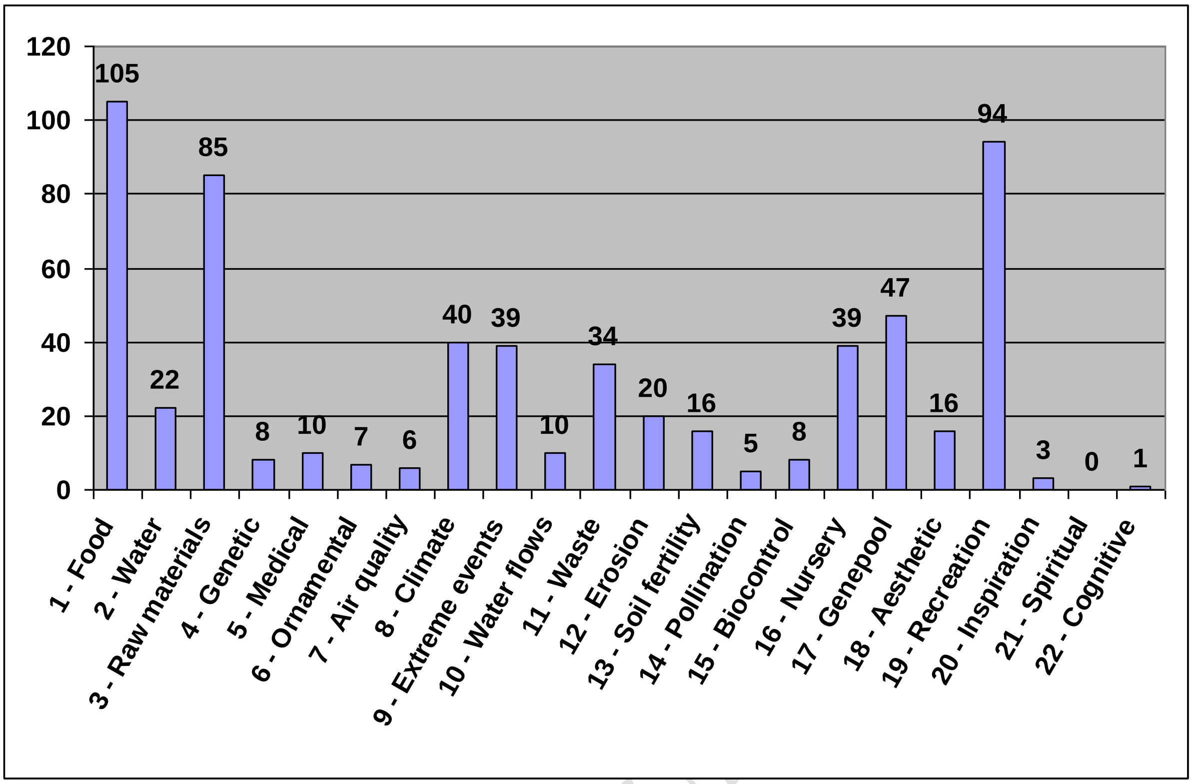


Figure A5.3 Number of monetary values used in this Annex for 22 ecosystem services



For the purpose of this Annex, all values were converted into 2007 Int. Dollar values using the GDP deflators and purchasing power parity converters from the World Bank World Development Indicators 2007 (World Bank, 2007).

To provide a preliminary overview of the range of monetary values found for each ecosystem service, per biome, only the minimum and maximum values are given in this Annex. Since all values are based on individual case studies this sometimes leads to very big value-ranges. For example, the main economically important service of coral reefs is tourism. Based on 30 studies this service shows a value-range from a little over 0 to more than 1 million US$/ha/y (with an average monetary value of almost 68.500 Int. $/ha/y)[3] This illustrates that using average values in benefit-transfer between locations must be done with great care: there will be many coral reefs that currently have a 0-value for tourism because nobody is going there (yet), or because they are less attractive than the reefs involved in the 30 case studies.

[3] Note that often the minimum and maximum values are outliers. When using the information in this Annex for benefit transfer purposes (which is not recommended since all values are highly context-specific) one should not simply take the average of these minimum and maximum values but consult the original values presented in the Database Matrix on the TEEB Website.

Other issues to be aware of are that values should be based on sustainable use levels (which we tried to verify and when in doubt we chose the lower-bound values) and that the magnitude of the value will vary depending on the socio-economic context (see also Box A5.1 for guidance how to use, or not use, the data presented in this Annex).

Box A5.1 Guidance for use of the data and link with TEEB reports D1-D4

The rationale for developing the database of value estimates was to provide an input to policy appraisal. Specifically, the database was set up so as to provide where possible not only a range of *total* values for a biome on a per hectare basis but also, where data are available, values *disaggregated on the basis of ecosystem services* [ESSs]. This set-up was applied so as to facilitate the application of the Ecosystem Approach. A further benefit of this disaggregation is that it allows policy-makers to determine which of the ESSs are pertinent to their particular policy perspective. We pre-suppose that the objective of the policy-maker using this database is to find a monetary value for the benefits of conserving a particular habitat. However the decision as to whether to choose conservation versus the extractive alternative depends on a number of factors, some of which are linked to the nature of individual ESSs. The database-user may thus decide to *filter* the values outputted.

Filtering for appropriate data points

Some of the filters that might be considered are set out below Once a biome is selected, the total number of available data points/value estimates will be presented. This is important in that filtering only really works if there are sufficient data points for the biome in question.

- *Locally-derived ESSs versus globally derived ESSs*

After the user has determined the biome to be considered, the first choice is between (i) ESSs for which benefits are in the main locally-derived benefits, (ii) ESSs that are in the main globally-derived and finally (iii) ESSs that are local and global in nature, i.e. all ESSs. The reason for allowing this first stage of filtering is that policy-makers might want to focus on ESSs that benefit local people *and local people alone*. This does not imply that these policy-makers do not care about global benefits, only that they might look to global donor agencies to fund the positive global externality.

- *Tourism*

There is enormous variability in the value estimates per hectare and one of the reasons for this is that some sites are valued based in part on tourism revenues. Thus the end-user might decide whether to include values that either (i) include leisure and tourism as an ESS or (ii) exclude it are a better match for the choice the policy-maker is seeking valuation estimates for. It would be appropriate to pick (i) if there is the *potential* for tourism activity.

- *Protected Area designation*

Many of the data points in the valuation database pertain to protected areas (PAs). Although values derived outside PAs might be useful for analysis within PAs, the end-user might choose to select only these PA data points. Again, it would be appropriate to pick PA if a policy-maker is considering the establishment of a PA.

- *High income/low income*

There is evidence from meta-analyses carried out in the environmental economics literature that studies carried out in higher income countries realise a higher value estimate on average.

Appropriate use of the findings

The database of environmental values for biomes and ESSs within these biomes is one of the most extensive (if not *the* most extensive) database of its kind. All values within the database have been screened with respect to the methodological integrity applied in the primary literature sources. Notwithstanding this, caution must be applied in using the values revealed in searches owing to the inherent limitations of benefits transfer. The results are intended to provide an *indicative* value, not *the* value. Even a primary valuation study cannot offer a precise value for a non-traded ESS, and benefits transfer adds an additional layer of abstraction.

Where the outputs may be particularly useful in the policy debate is in considering the relative value of different ESSs. So even if (say) we do not have a reliable, precise value for 'water purification' we can assess broadly how valuable it is as an ESS relative to others.

Below, the main results are briefly presented for the 11 main biomes/ecosystems, we distnguished The Desert and Tundra biomes are not included because there was too little data found on their services and values in this stage of the TEEB study.

Each biome-section starts with a very brief description of the main ecosystem-types included in that biome followed by a table showing the minimum and maximum values found for the services of that biome, follwed by a column with "single values" meaning that for that service only one value was found and thus no minimum or maximum could be given). Services that are not applicable to a given biome were left out of the table. A question-mark means that that service is applicable to that biome but no (reliable) values were found yet.

For each biome the table is followed by an example of a good case study that has applied the Total Economic Value framework, or similar approach, to monetize the total bundle of services provided by that biome/ecosystem, including information on the policy context (purpose) and influence of determining factors (eg. the socio-economic context).

A5.1 Monetary value of ecosystem services provided by Open Oceans

The open ocean is the largest area of the marine ecosystem, including deep sea (water and sea floor below 200 m). Excluded from this biome-section are shelf sea, coral reefs, ocean islands and atolls which are included in other sections (A5.2 – A5.4). As Table A5.1 shows, based on 6 data points, the total monetary value of the potential sustainable use of all services of open ocean combined varies between 13 and 84 Int.$/ha/year. This excludes four services for which only one value was found (which would add 9 Int$/ha/year to the total value*).*

Table A5.1 Monetary value of services provided by Open oceans (Int. $/ha/year-2007)

	Marine	**No. of used Estimates**	**Minimum values (Int$/ha/y)**	**Maximum values (Int.$/ha/y)**	***No. of Single estimates***	***Single values (Int$/ha/y)***
	TOTAL:	**6**	**13**	**84**	***4***	***9***
	PROVISIONING SERVICES	**2**	**8**	**22**	***1***	***0***
1	Food	2	8	22		
3	Raw materials				*1*	*0*
4	Genetic resources	?				
5	Medicinal resources	?				
	REGULATING SERVICES	**4**	**5**	**62**	***1***	***7***
7	Influence on air quality	?				
8	Climate regulation	2	4	55		
11	Waste treatment / water purification	?				
13	Nutrient cycling				*1*	*7*
15	Biological control	2	1	7		
	HABITAT SERVICES	**1**	**0**	**0**	***1***	***2***
16	Lifecycle maintenance (esp. nursery service)					
17	Gene pool protection (conservation)				*1*	*2*
	CULTURAL SERVICES	**1**	**0**	**0**	***1***	***1***
18	Aesthetic information	?				
19	Opportunities for recreation and tourism				*1*	*1*
20	Inspiration for culture, art and design	?				
21	Spiritual experience	?				
22	Cognitive information (education and science)	?				

Box A5.2 **_Example of TEV case study_: benefit-cost assessment of Marine Conservation Zones (MCZs) in UK**

Hussain et al. (2010) analysed the benefits and costs of the UK Marine and Coastal Access Bill (2009)[4] and specifically the establishment of a network of marine protected areas, termed Marine Conservation Zones (MCZs) in UK legislation. The benefit assessment was commissioned in order to provide an evidence base for this legislation and to meet Impact Assessment guidance. Two sets of management regimes (with varying degrees of exclusion/reduced anthropogenic impact) were assessed in the context of three network scenarios describing the proposed location of MCZ sites. The main methodological challenges were (i) the lack of appropriate primary valuation studies for BT and (ii) the way that estimates were framed in these studies, viz. in aggregate terms. Aggregate values for different ESSs pertaining to UK temperate marine ecosystems are presented in Beaumont et al. (2008) which forms a basis for the values used in Hussain et al. (2010).

The methodology developed had to account for the following constraints: (i) the impact of MCZ designation would vary across the different ecosystem services (ESSs); and (ii) within any single ESS, the impacts would vary across different landscape types. The methodology thus scored the impact of designation for each individual ESS/each landscape. This scoring was relative to the benchmark, i.e. how much provisioning of the particular ESS/landscape combination would occur without MCZ designation?

Since the only estimates (where available) were for 2007-equivalent provisioning, this had to be used as the benchmark. Two elements were scored: (i) the extent to which MCZs would impact on provisioning, measured as a percentage change relative to 2007 provisioning; and (ii) when this change in provisioning would likely occur – the impact trajectory. The latter meets the requirement for a consistent discount rate to be applied (in this case 3.5%, a HM treasury requirement) for both costs and benefits in Impact Assessment. As well as assigning this score for each ESS/landscape, the methodology had to account for how important one hectare of a particular landscape is relative to other landscapes for that ESS. Marine ecologists determined four categories based on combinations of (i) spatial extent, (ii) proximity to coastline, (iii) average per hectare provisioning

Once this methodology had been applied, the aggregate benefit estimates for each of the three propose MCZ networks/two management regimes were calculated. The present value (using the 3.5% discount rate over the 20 year study period) ranged from around £11.0-£23.5 billion. Applying sensitivity analysis reduced this range from around £6.4 to £15.1 billion. 'Gas and climate regulation' accounted for the bulk of this expected benefit (around 70%) with 'nutrient cycling' and 'leisure and recreation' around 10% each.

The assessment of the costs of the MCZ networks was assessed by ABPMer (2007). Secondary data and literature were assessed and interviews carried out with affected industries (fisheries, telecommunications, oil and gas extraction etc.); the cost estimate ranged from £0.4-£1.2 billion, implying a worst-case benefit-cost ratio of five.

The implications of this research are significant: (i) it is possible to apply (to a limited extent) an Ecosystem Approach to the marine biome; (ii) values were found for only seven of the 11 ESSs and yet even these alone derived a significant benefit-cost ratio. The lobbies linked to the exploitation of marine ecosystems are highly organised and well resourced; this kind of research and evidence-based justification for conservation is thus important

[4] This Bill is now an Act, see http://www.defra.gov.uk/environment/marine/legislation/mcaa/index.htm

A5.2 Monetary value of ecosystem services provided by coral reefs

The term "coral reef" generally refers to a marine ecosystem which the main organisms are corals that house algal symbionts within their tissues. These ecosystems require fully marine waters warm temperatures and ample sunlight. They are therefore restricted to shallow waters of tropical and sub=tropical regions. Corals that do not have algal symbionts can also form significant reef communities in deeper, darker, and colder waters, but these communities are distinguished as cold-water coral bioherms. Corals are often included in the "coastal systems-biome" but are dealt with here separately because of their unique and important ecosystem services

As Table A5.2 shows, based on 101 data points, the total monetary value of the potential sustainable use of all services of coral reefs combined varies between 14 and 1,195,478 Int.$/ha/year. This excludes three services for which only one value was found (which would add over 200.000 Int$/ha/year to the total value, mainly from erosion-prevention).

Table A5.2 Monetary value of services provided by Coral reefs
(in Int.$/ha/year-2007 values)

	Coral reefs	No. of used Estimates	Minimum Values (Int$/ha/y)	Maximum Values (Int$/ha/y)	*No. of Single estimates*	*Single values Int$/ha/y)*
	TOTAL:	**101**	**14**	**1,195,478**	***3***	***206,873***
	PROVISIONING SERVICES	**33**	**6**	**20,892**	***1***	***20,078***
1	Food	22	0	3,752		
3	Raw materials	6	0	16,792		
4	Genetic resources				*1*	*20,078*
5	Medicinal resources	?				
6	Ornamental resources	5	6	348		
	REGULATING SERVICES	**17**	**8**	**33,640**	***2***	***186,795***
7	Influence on air quality	?				
8	Climate regulation				*1*	*627*
9	Moderation of extreme events	13	2	33,556		
11	Waste treatment / water purification	2	5	77		
12	Erosion prevention				*1*	*186,168*
13	Nutrient cycling	?				
15	Biological control	2	1	7		
	HABITAT SERVICES	**8**	**0**	**56,137**	***0***	***0***
16	Lifecycle maintenance (esp. nursery service)	?				
17	Gene pool protection (conservation)	8	0	56,137		
	CULTURAL SERVICES	**43**	**0**	**1,084,809**	***0***	***0***
18	Aesthetic information	12	0	27,317		
19	Opportunities for recreation and tourism	31	0	1,057,492		
20	Inspiration for culture, art and design	?				
21	Spiritual experience	?				
22	cognitive information (education and science)	?				

Box A5.3 Example of TEV case study: The total economic value of the coral reefs on Hawaii

Hawaii's coral reef ecosystems provide many goods and services to coastal populations, such as fisheries and tourism. Besides, they form a unique natural ecosystem, with an important biodiversity value as well as scientific and educational value. Also, coral reefs form a natural protection against wave erosion. Without even attempting to measure their intrinsic value, this paper shows that coral reefs, if properly managed, contribute enormously to the welfare of Hawaii through a variety of quantifiable benefits. Net benefits of the State's 166,000 hectares of reef area of the Main Hawaiian Islands are estimated at US$360 million a year for Hawaii's economy (Cesar and van Beukering 2004).

Table 1: Annual benefits of the Hawaiian coral reefs

Types of value	units	Value
Recreational value	Million$/year	304
Amenity (real estate) value	Million$/year	40
Research value	Million$/year	17
Fishery value	Million$/year	2.5
Total annual benefits	Million$/year	363.5

Source: Cesar and van Beukering 2004, p.240.

To assess the spatial variation of economic values of the Hawaiian reefs, the overall values are also expressed on a 'per area' basis (Cesar et al., 2002). Three case study sites were considered in particular. The most valuable site in Hawaii, and perhaps even in the world, is Hanauma Bay (Oahu) which was an extremely high intensity of recreational use. Reefs at Hanauma are ecologically average for Hawaiian standards, yet are more than 125 times more valuable (US$92 per m^2) than the more ecologically diverse reefs at the Kona Coast (US$0.73 per m^2). This demonstrates that economic values can differ dramatically from ecological values or researchers' preferences.

A5.3 Monetary value of ecosystem services provided by coastal systems

The coastal biome includes several distinct ecosystems such as sea-grass fields, shallow seas of continental shelves, rocky shores and beaches, which are found in the terrestrial near-shore as well as the intertidal zones – i.e. until the 200m bathymetric line with open oceans. Usually, coral reefs and coastal wetlands (mangroves and tidal marshes) are also included in the “coastal systems-biome” but are dealt with here separately (in A5.2 and A5.4 respectively) because of their unique and important ecosystem services.

As Table A5.3 shows, based on 32 data points, the total monetary value of the potential sustainable use of all services of coastal systems combined varies between 248 and 79,580 Int.$/ha/year. This excludes six services for which only one value was found (which would add over almost 78,000 Int$/ha/year to the total value, mainly from moderation of extreme events).

Table A5.3 Monetary value of services provided by Coastal Systems
(in Int.$/ha/year-2007 values)

	Coastal systems	No. of used Estimates	Minimum Value (int$/ha/y)	Maximum Value (Int$/ha/y)	*No. of Single estimates*	*Single values (Int$/ha/y)*
	TOTAL:	**32**	**248**	**79,580**	***6***	***77,907***
	PROVISIONING SERVICES	**19**	**1**	**7,549**	***1***	***1,453***
1	Food	14	1	7,517		
2	(Fresh) water supply				*1*	*1,453*
3	Raw materials	5	0	32		
4	Genetic resources	?				
5	Medicinal resources	?				
6	Ornamental resources	?				
	REGULATING SERVICES	**4**	**170**	**30,451**	***2***	***76,144***
7	Influence on air quality	?				
8	Climate regulation	?				
9	Moderation of extreme events				*1*	*76,088*
10	Regulation of water flows	?				
11	Waste treatment / water purification	?				
12	Erosion prevention	?				
13	Nutrient cycling / maintenance of soil fertility	4	170	30,451		
14	Pollination	?				
15	Biological control				*1*	*56*
	HABITAT SERVICES	**2**	**77**	**164**	***1***	***164***
16	Lifecycle maintenance (esp. nursery service)	2	77	164		
17	Gene pool protection (conservation)				*1*	*164*
	CULTURAL SERVICES	**7**	**0**	**41,416**	***2***	***146***
18	Aesthetic information				*1*	*110*
19	Opportunities for recreation and tourism	7	0	41,416		
20	Inspiration for culture, art and design	?				
21	Spiritual experience	?				
22	cognitive information (education and science)				*1*	*37*

Box A5.4 Example of TEV case study: Valuing the services provided by the Peconic Estuary System, USA (Johnston et al., 2002)

This study looks at the wide range of ecosystem services provided by the Peconic estuary system, NY, USA, with twofold objectives. On the one hand, it aims at informing local coastal policies by assessing the economic impacts of ecological management strategies for the reservation or restoration of the estuary. On the other hand, it discusses various non-market valuation methodologies to identify the most appropriate approaches for different types of services, and the highlights the issues arising in the integration of the findings of different methods in a total economic value.

The coastal region valued is at the East End of Long Island and comprises a system of bays, islands, watershed lands, and coastal communities. It includes a wide range of coastal resources, including fisheries, beaches, parks, open space, and wildlife habitat, which are under threat from localized water pollution and loss of coastal habitats due to land conversion by development activities.

The study integrates the results of four economic studies:

A hedonic pricing study examines the value of environmental amenities such as *open space and attractive views* on the market price of property in the coastal town of Southold. In the 374 investigated parcels of land, the preservation of nearby open space is found to increase property values on average by 12.8%, while dense development and proximity to highways and agricultural land have negative impacts ranging from 13.3 to 16.7%.

A travel-cost study investigates the value of recreational activities such as *swimming, boating, fishing, and bird and wildlife viewing* taking place in the estuary. Based on 1,354 completed surveys, the study estimated the consumer surplus that recreationists received, i.e., the value above the cost of their recreational trip. Aggregating individual consumer surplus estimates over the whole population or recreationists reveals values equal to 12.1 M$/year for swimming, 18.0 M$/year for boating, 23.7 M$/year for recreational fishing, and 27.3 M$/year for bird and wildlife watching.

A productivity function study assesses the value of eelgrass, sand/mud bottoms, and inter-tidal salt marshes as a *nursery habitat for fish, shellfish and birds.* The study simulates the biological functions of the ecosystems to assess the marginal per acre value of productivity in terms of gains in commercial value for fish and shellfish, bird-watching, and waterfowl hunting. Estimated yearly values per acre are $67 for inter-tidal mud flats, $338 for saltmarsh, and $1,065 for eelgrass.

Finally, a contingent choice study investigates the willingness-to-pay of local residents for the preservation and restoration of key ecosystems in the Peconic estuary. Although the value estimates elicited partly overlap with the results of the other three methods, this study adds the additional dimension of *non-use and existence values* to the picture of the total economic value of the estuary. The highest values are found for the preservation of farmland ($6,398-9,979 acre/year), eelgrasses ($6,003-8,186 acre/year), and wetlands ($4,863-6,560 acre/year). Lower values are for undeveloped land ($1,203-2,080 acre/year) and shellfish areas ($2,724-4,555 acre/year).

Some useful general lessons for the valuation of the total economic value of coastal ecosystems can be drawn. First, a single valuation method can hardly capture the complexity of the interactions between different types of land uses and services in coastal areas. Consider the case of farmland in the discussed study. Although hedonic pricing indicates negative *use values* of farmland, the contingent choice experiment shows that the willingness-to-pay of residents for farmland is high, suggesting that *non-use values* may play an important role in determining the total value of such land use.

Second, even when budget and time limitations allow for the implementation of different valuation methodologies, one must consider that integration of their findings is not straightforward. In the present study, simply summing up the values determined with hedonic pricing and the travel cost methods would lead to double-counting benefits, since property values will likely also reflect the opportunities for recreation available in the neighborhood. Similarly, the values elicited by the production function will partly reflect the opportunities for bird-watching and waterfowl hunting that high productivity entails.

A5.4 Monetary value of ecosystem services provided by Coastal Wetlands

The coastal wetlands biome includes two main types of ecosystem, tidal marshes and mangroves (for other coastal systems, see A5.3). The coverage of this section is weighted towards mangrove ecosystems although the available valuation literature on tidal marshes is also presented.

As Table A5.4 shows, based on 112 data points, the total monetary value of the potential sustainable use of all services of coastal wetlands combined varies between 1.995 and 215.349 Int.$/ha/year. This excludes two services for which only one value was found (which would add 960 Int$/ha/year to the total value).

Table A5.4 Monetary value of services provided by Coastal wetlands
(in Int S$/ha/year-2007 values)

	Coastal wetlands	No. of used Estimates	Minimum value (Int$/ha/y)	Maximum value (Int$/ha/y)	*No. of Single estimates*	*Single values (Int$/ha/y)*
	TOTAL:	**112**	**1,995**	**215,349**	***2***	***960***
	PROVISIONING SERVICES	**35**	**44**	**8,289**	***0***	***0***
1	Food	12	0	2,600		
2	(Fresh) water supply	3	41	4,240		
3	Raw materials	18	1	1,414		
4	Genetic resources	?				
5	Medicinal resources	2	2	35		
6	Ornamental resources	?				
	REGULATING SERVICES	**26**	**1,914**	**135,361**	***2***	***960***
7	Influence on air quality				*1*	*492*
8	Climate regulation	6	2	4,677		
9	Moderation of extreme events	13	4	9,729		
10	Regulation of water flows	?				
11	Waste treatment / water purification	4	1,811	120,200		
12	Erosion prevention	3	97	755		
13	Nutrient cycling and maintenance of soil fertility				*1*	*468*
14	Pollination	?				
15	Biological control	?				
	HABITAT SERVICES	**38**	**27**	**68,795**	***0***	***0***
16	Lifecycle maintenance (esp. nursery service)	33	2	59,645		
17	Gene pool protection (conservation)	5	25	9,150		
	CULTURAL SERVICES	**13**	**10**	**2,904**	***0***	***0***
18	Aesthetic information	?				
19	Opportunities for recreation and tourism	13	10	2,904		
20	Inspiration for culture, art and design	?				
21	Spiritual experience	?				
22	cognitive information (education and science)	?				

Box A5.5 Example of TEV case study: The Total Economic Value of the Muthurajawela Wetland, Sri Lanka (*Emerton and Kekulandala, 2003)*

The Muthurajawela Marsh covers an area of 3,068 hectares, and is located near Colombo, the capital of Sri Lanka. It forms a coastal wetland together with the Negombo Lagoon. It is rich in biodiversity and in 1996 part of the wetland was declared a Wetland Sanctuary.
The pressures facing the Muthurajawela wetland are growing. Major threats are urban, residential, recreational, agricultural and industrial developments; over-harvesting of wetland species; and pollution from industrial and domestic wastes. As a result, the wetland has been seriously degraded.
The economic values of ecosystem services and total economic value of the Muthurajawela wetland are presented in Table 3. This study used direct market prices to estimate direct use values such as fishing, firewood, agricultural production, recreation and also the support service to downstream fisheries. The replacement cost method was used to value indirect use values including wastewater treatment, freshwater supplies and flood attenuation.

Table 3: Economic Value of the Muthurajawela Wetland, Sri Lanka

Economic Benefit	**Economic Value per year (converted to 2003 US$)**
Flood attenuation	5,033,800
Industrial wastewater treatment	1,682,841
Agricultural production	314,049
Support to downstream fisheries	207,361
Firewood	82,530
Fishing	64,904
Leisure and recreation	54,743
Domestic sewage treatment	44,790
Freshwater supplies for local populations	39,191
Carbon sequestration	8,087
TOTAL ECONOMIC VALUE	7,532,297

A5.5 Monetary value of ecosystem services provided by Inland Wetlands

This biome-type includes (freshwater) floodplains, swamps/marshes and peat lands. It explicitly does not include coastal wetlands and rivers & lakes, which are addressed in sections A5.4 and A5.6 respectively.

As Table A5.5 shows, based on 86 data points, the total monetary value of the potential sustainable use of all services of inland wetlands combined varies between 981 and 44.597 Int.$/ha/year. This excludes six services for which only one value was found (which would add 282 Int$/ha/year to the total value).

Table A5.5 Monetary value of services provided by Inland wetlands
(in Int $/ha/year-2007 values)

	Inland wetlands	No. of used Estimates	Minimum value (US$/ha/y)	Maximum Value (US$/ha/y)	*No. of Single estimates*	*Single values (US$/ha/y)*
	TOTAL:	**86**	**981**	**44,597**	***6***	***282***
	PROVISIONING SERVICES	**34**	**2**	**9,709**	***3***	***167***
1	Food	16	0	2,090		
2	(Fresh) water supply	6	1	5,189		
3	Raw materials	12	1	2,430		
4	Genetic resources				*1*	*11*
5	Medicinal resources				*1*	*88*
6	Ornamental resources				*1*	*68*
	REGULATING SERVICES	**30**	**321**	**23,018**	***3***	***115***
7	Influence on air quality	?				
8	Climate regulation	5	4	351		
9	Moderation of extreme events	7	237	4,430		
10	Regulation of water flows	4	14	9,369		
11	Waste treatment / water purification	9	40	4,280		
12	Erosion prevention				*1*	*84*
13	Nutrient cycling and maintenance of soil fertility	5	26	4,588		
14	Pollination				*1*	*16*
15	Biological control				*1*	*15*
	HABITAT SERVICES	**9**	**10**	**3,471**	***0***	***0***
16	Lifecycle maintenance (esp. nursery service)	2	10	917		
17	Gene pool protection (conservation)	7	0	2,554		
	CULTURAL SERVICES	**13**	**648**	**8,399**	***0***	***0***
18	Aesthetic information	2	83	3,906		
19	Opportunities for recreation and tourism	9	1	3,700		
20	Inspiration for culture, art and design	2	564	793		
21	Spiritual experience	?				
22	Cognitive information (education and science)	?				

Box A5.6 Two examples of TEV case studies on island wetlands

a) Economic value of Whangamarino wetland, North Island, New Zealand (Kirkland, 1988)
Whangamarino wetland is the second largest peat bog and swamp complex on North Island, New Zealand. It is the most important breeding area in New Zealand for Botaurus poiciloptilus and a habitat for wintering birds and a diverse invertebrate fauna. The wetland covers and area of 10,320 hectares and supports a commercial fishery, cattle grazing, recreational activities. Estimated use and non-use values for Whangamarino are presented in Table X. These value estimates are estimated using the contingent valuation method.

Table X Economic Value of Whangamarino wetland, New Zealand

Economic Benefit	**Economic Value per year (converted to 2003 US$)**
Non-use preservation	7,247,117
Recreation	2,022,720
Commercial fishing	10,518
Flood control	601,037
TOTAL	**9,881,392**

b) Economic value of the Charles River Basin wetlands, Massachusetts, US (Thibodeau and Ostro, 1981)
The Charles River Basin wetlands in Massachusetts consist of 3,455 hectares of freshwater marsh and wooded swamp. This is 75% of all the wetlands in Boston's major watershed. The benefits derived from these wetlands include flood control, amenity values, pollution reduction, water supply and recreational opportunities. Estimates of economic values derived from these wetlands are presented in Table X. Value estimates are obtained using a variety of valuation methods including hedonic pricing, replacement costs, and market prices.

Table X Economic Value of Charles River Basin wetlands, Massachusetts, US

Economic Benefit	**Economic Value per year (converted to 2003 US$)**
Flood damage prevention	39,986,788
Amenity value of living close to the wetland	216,463
Pollution reduction	24,634,150
Recreational value: Small game hunting, waterfowl hunting	23,771,954
Recreational value: Trout fishing, Warm water fishing	6,877,696
TOTAL	**95,487,051**

A5.6 Monetary value of ecosystem services provided by lakes and rivers

This biome-type includes freshwater rivers and lakes. Saline lakes, and wetlands and floodplains are not included in this biome (see coastal and inland wetlands).

As Table A5.6 shows, based on 12 data points, the total monetary value of the potential sustainable use of all services of rivers and lakes combined varies between 1.779 and 13.488 Int.$/ha/year. This excludes four services for which only one value was found (which would add 812 Int$/ha/year to the total value).

Table A5.6 Monetary value of services provided by Rivers & Lakes
(in Int. $/ha/year-2007 values)

	Rivers and Lakes	No. of used Estimates	Minimum Value (Int$/ha/y)	Maximum Value (Int$/ha/y)	*No. of Single estimates*	*Single values (Int$/ha/y)*
	TOTAL:	**12**	**1,779**	**13,488**	***4***	***812***
	PROVISIONING SERVICES	**5**	**1,169**	**5,776**	***1***	***3***
1	Food	3	27	196		
2	(Fresh) water supply	2	1,141	5,580		
3	Raw materials				*1*	*3*
4	Genetic resources	?				
5	Medicinal resources	?				
6	Ornamental resources	?				
	REGULATING SERVICES	**2**	**305**	**4,978**	***2***	***129***
7	Influence on air quality	?				
8	Climate regulation				*1*	*126*
9	Moderation of extreme events	?				
10	Regulation of water flows	?				
11	Waste treatment / water purification	2	305	4,978		
13	Nutrient cycling and maintenance of soil fertility				*1*	*3*
15	Biological control	?				
	HABITAT SERVICES	**0**	**0**	**0**	***1***	***681***
16	Lifecycle maintenance (esp. nursery service)					
17	Gene pool protection (conservation)				*1*	*681*
	CULTURAL SERVICES	**5**	**305**	**2,733**	***0***	***0***
18	Aesthetic information	?				
19	Opportunities for recreation and tourism	5	305	2,733		
20	Inspiration for culture, art and design	?				
21	Spiritual experience	?				
22	cognitive information (education and science)	?				

Box A5.7 Example of TEV case study: TEV of the River Murray, Australia

The 2,700 km River Murray is Australia's longest freshwater river system and has been heavily modified and developed. Water from the River Murray is used for human consumption, and industrial and agricultural production. The River Murray channel and interconnected wetlands are important habitat for a large diversity of species and many locations along the river are recognised as internationally significant under the Ramsar Convention. The major ecosystem services provided by the river include freshwater for human consumption, recreation and tourism, aesthetics, agricultural production, and fishing. Over development and extraction of water for consumption and production purposes, exacerbated by recent drought, has compromised the ecological health or the river system. In 2007-08, the lack of inflows resulted in near-zero allocations to many irrigators who extract water from the River Murray and its upstream tributaries.

The annual economic values of major ecosystem services provided by the River Murray is listed in Table X. Values are drawn from several sources. Food produced from irrigation water diverted from the River Murray and the tourism and recreation services along the river account for the bulk of economic value. Other smaller but important values are the avoided damages provided by a freshwater system with low salt content, and the maintenance of sufficient environmental flows to maintain riverine species habitat.

Total economic value of ecosystem services provided by the River Murray, Australia
(2007 $AUD/Year)

Ecosystem Service	Valuation Method	Source	Total Value ($m)
Recreation and tourism	Market Prices	Howard, 2008	2,970
Food production	Market Prices	Australian Bureau of Statistics, 2008	1,600*
Water Quantity (environmental flows)	Contingent Valuation	Bennett, 2008	80
Water Quality (no salinity)	Avoided Cost	Connor, 2008	18
Total Economic Value			**4,668**

**An estimate for the River Murray water only. Total value of irrigated agriculture in Murray-Darling River Basin is $4,600m. Water drawn from the River Murray for irrigation is approximately a third of the total water drawn from the Basin, suggesting the river's water accounts for a third of irrigated agriculture value.*

For other examples of good TEV-studies, see Thomas et al., (1991)

A5.7 Monetary value of ecosystem services provided by Tropical Forests

The Tropical Forests biome includes various types of forests, eg. moist- or rainforests, deciduous/semi-deciduous broadleaf forest and tropical mountain forests.

As Table A5.7 shows, based on 140 data points, the total monetary value of the potential sustainable use of all services of tropical forests combined varies between 91 and 23.222 Int.$/ha/year. This excludes two services for which only one value was found (which would add 29 Int$/ha/year to the total value).

Table A5.7 Monetary value of services provided by Tropical Forests
(in Int. $/ha/year-2007 values)

	Tropical Forests	No. of used Estimates	Minimum Value (US$/ha/y)	Maximum Value (US$/ha/y)	*No. of Single estimates*	*Single values (US$/ha/y)*
	TOTAL:	**140**	**91**	**23,222**	***2***	***29***
	PROVISIONING SERVICES	**63**	**26**	**9,384**	***0***	***0***
1	Food	24	0	1,204		
2	(Fresh) water supply	3	8	875		
3	Raw materials	27	2	3,723		
4	Genetic resources	4	14	1,799		
5	Medicinal resources	5	1	1,782		
6	Ornamental resources	?				
	REGULATING SERVICES	**43**	**57**	**7,135**	***1***	***12***
7	Influence on air quality	2	13	957		
8	Climate regulation	10	13	761		
9	Moderation of extreme events	4	8	340		
10	Regulation of water flows	4	2	36		
11	Waste treatment / water purification	6	0	665		
12	Erosion prevention	11	11	3,211		
13	Nutrient cycling and maintenance of soil fertility	3	2	1,067		
14	Pollination	3	7	99		
15	Biological control				*1*	*12*
	HABITAT SERVICES	**13**	**6**	**5,277**	***1***	***17***
16	Lifecycle maintenance (esp. nursery service)				*1*	*17*
17	Gene pool protection (conservation)	13	6	5,277		
	CULTURAL SERVICES	**21**	**2**	**1,426**	***0***	***0***
18	Aesthetic information	?				
19	Opportunities for recreation and tourism	21	2	1,426		
20	Inspiration for culture, art and design	?				
21	Spiritual experience	?				
22	Cognitive information (education and science)	?				

Box A5.7 Example of TEV case study: Economic valuation of the Leuser National Park on Sumatra, Indonesia.

One of the best examples of an evaluation of the total economic value of tropical forests is the research undertaken by Van Beukering et al. (2003) which aimed to evaluate the TEV of the ecosystem services associated with the 25,000 km^2 Leuser rainforest and buffer zone, and evaluate the consequences of deforestation on the delivery of these services.

Despite its protected status, about 20% of Leuser National Park has been lost or degraded due to logging, exploitation of non-timber forest products (NTFP), illegal poaching, unsustainable tourism, and conversion to crop plantations. The consequence of this is that there has been a reduction in the forest area (ultimately leading to the development of wastelands), increased soil erosion (reducing agricultural productivity), reduced water retention (leading to increased frequency and intensity of floods and droughts), and reduced pollination and pest control (reducing agricultural productivity). To address these issues, the study examines three possible future scenarios for Leuser: a *deforestation* scenario (i.e. the current trend in logging and exploitation of NTFP continues); a *conservation* scenario (i.e. logging of primary and secondary forest cease, and eco-tourism is developed); and a *selective use* scenario (i.e. logging of primary forest is substantially reduced and logged forests are replanted + some eco-tourism development).

Eleven services were identified as being important for the appraisal of the three scenarios: water supply, fishery, flood and drought prevention, agriculture and plantations, hydro-electricity, tourism, biodiversity, carbon sequestration, fire prevention, NTFP, and Timber. The economic value of the impacts were assessed using a wide range of economic techniques, including production functions, market prices and contingent valuation. The important message here is the fact that no single valuation method is capable of evaluation all the benefits streams; different valuation methods are suited to evaluate different impacts.

Following the approach described above, the authors estimate that the total economic value of Leuser National Park (for the period 2000 – 2030) is 9,538m US$ for the *Conservation* scenario, 9,100m US$ for the *Selective use* scenario and 6,958m US$ for the *Deforestation* scenario.

Finally, it is worth highlighting some key factors that made this an exemplar case study of the value of tropical forests. First, the authors utilized the knowledge and experience of local, regional and national stakeholders at all stages of the research. This is important as it helps to better define the impacts. Second, the use of the 'impact pathway' is important to help identify what they key impacts are. Finally, the research utilized a wide range of valuation methods to assess the impacts.

A5.8 Monetary value of ecosystem services provided by Temperate and Boreal Forests

This biome-type includes Temperate and Boreal forest, or taiga. Temperate forests can be sub-divided in temperate deciduous forest, temperate broadleaf and mixed forest, temperate coniferous forest, temperate rainforest.

As Table A5.8 shows, based on 40 data points, the total monetary value of the potential sustainable use of all services of temperate and boreal forests combined varies between 30 and 4,863 Int.$/ha/year. This excludes seven services for which only one value was found (which would add 1,281 Int$/ha/year to the total value).

Table A5.8 Monetary value of services provided by Temperate forests
(in Int $/ha/year-2007 values)

	Temperate Forests	No. of used Estimates	Minimum Value (Int$/ha/y)	Maximum Value (Int$/ha/y)	*No. of Single estimates*	*Single values (Int$/ha/y)*
	TOTAL:	**40**	**30**	**4,863**	***7***	***1,281***
	PROVISIONING SERVICES	**15**	**25**	**1,736**	***1***	***3***
1	Food	5	0	1,204		
2	(Fresh) water supply	3	0	455		
3	Raw materials	5	2	54		
4	Genetic resources				*1*	*3*
5	Medicinal resources	2	23	23		
6	Ornamental resources	?				
	REGULATING SERVICES	**14**	**3**	**456**	***5***	***1,277***
7	Influence on air quality				*1*	*805*
8	Climate regulation	8	3	376		
9	Moderation of extreme events				*1*	*0*
10	Regulation of water flows	2	0	3		
11	Waste treatment / water purification	4	0	77		
12	Erosion prevention				*1*	*1*
13	Nutrient cycling and maintenance of soil fertility	?				
14	Pollination				*1*	*452*
15	Biological control				*1*	*20*
	HABITAT SERVICES	**7**	**0**	**2,575**	***0***	***0***
16	Lifecycle maintenance (esp. nursery service)	?				
17	Gene pool protection (conservation)	7	0	2,575		
	CULTURAL SERVICES	**4**	**1**	**96**	***1***	***0***
18	Aesthetic information	?				
19	Opportunities for recreation and tourism	4	1	96		
20	Inspiration for culture, art and design				*1*	*0*
21	Spiritual experience	?				
22	Cognitive information (education and science)	?				

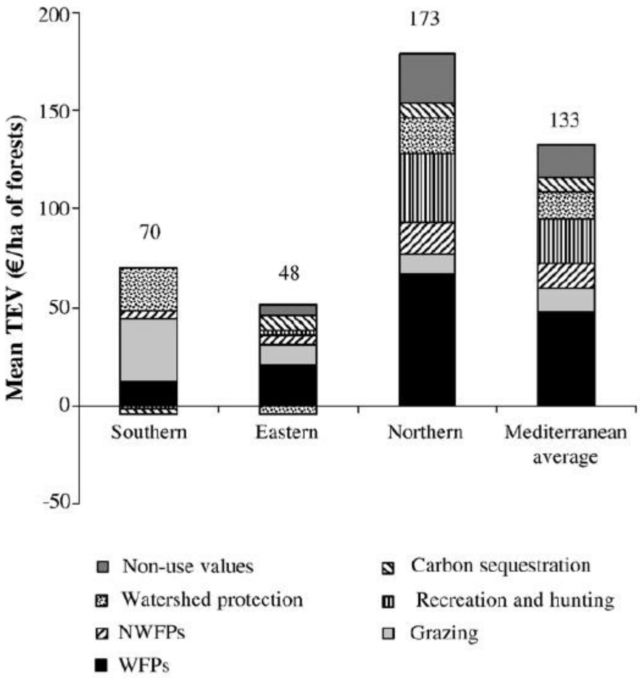
Box A5.9 Example of TEV case study: Economic valuation of Mediterranean forests (Croitoru, 2007)

Mediterranean forests provide a wide array of benefits; however, most of them are poorly recognized. This study attempted to value comprehensively all forest benefits in Mediterranean countries. Its objective is to arrive at a rough order of magnitude of total forest value in each country and in the Mediterranean region as a whole, and of the composition of this value, using available data. Forest benefits are identified based on a common framework and valued using a range of methods. The novelty of this study arises from undertaking it on a large scale, within a structured framework that allows for estimates to be aggregated within countries and compared across countries.

The study covered 18 countries, divided into: Southern countries: Morocco, Algeria, Tunisia and Egypt; Eastern countries: Palestine, Israel, Lebanon, Syria, Turkey and Cyprus; Northern countries: Greece, Albania, Croatia, Slovenia, Italy, France, Spain and Portugal.

The average TEV of Mediterranean forests is about €133/ha. The average TEV in northern countries (about €173/ha) is higher than that in the southern (about €70/ha) and eastern countries (about €48/ha). In per capita terms, forests provide annual benefits of over €50 to the Mediterranean people. Average benefits are higher in northern countries (over €70 per capita) and lower in southern (under €7 per capita) and eastern countries (under €11 per capita). The large difference between the estimates for northern and those for southern and eastern countries is due in part to the much larger extension of forest area relative to population in the north, as well as to their relatively higher quality, thanks to more favourable climatic conditions and lower levels of degradation. To some extent, it is also due to the greater degree of underestimation of benefits in southern and eastern countries.

The figure below shows the average estimates of forest benefits at Mediterranean and sub-Mediterranean levels.



The study shows that Wood Forest Products (WFPs) such as timber account for only a small portion of total forest benefits. Watershed protection benefits are often much more important. In the southern and eastern Mediterranean, grazing dominates. Recreation is already very important in the northern Mediterranean and its importance is likely to grow throughout the region. This multifunctionality needs to be explicitly recognized and incorporated into forest policy

Another good TEV-study was done on Chilean Temperate rainforests by Nahuelhual et al., 2007.

A5.9 Monetary value of ecosystem services provided by Woodlands

The “woodland-biome” includes a large range of vegetation types including savannas, shrublands, scrublands and chaparral interleaved with one another in mosaic landscape patterns distributed along the western coasts of North and South America, areas around the Mediterranean Sea, South Africa, and Australia, jointly representing about 5% of the planets surface.

As Table A5.9 shows, based on 18 data points, the total monetary value of the potential sustainable use of all services of woodlands varies between 16 and 1.950 Int.$/ha/year. This excludes six services for which only one value was found (which would add 5,066 Int$/ha/year to the total value).

Table A5.9 Monetary value of services provided by Woodlands
(in Int. $/ha/year-2007 values)

	Woodlands	No. of used Estimates	Minimum Value (US$/ha/y)	Maximum Value (US$/ha/y)	*No. of Single estimates*	*Single values (US$/ha/y)*
	TOTAL:	**18**	**16**	**1,950**	***6***	***5,066***
	PROVISIONING SERVICES	**12**	**7**	**862**	***1***	***25***
1	Food	4	0	203		
2	(Fresh) water supply					
3	Raw materials	8	7	659		
4	Genetic resources	?				
5	Medicinal resources	?				
6	Ornamental resources				*1*	*25*
	REGULATING SERVICES	**6**	**9**	**1,088**	***2***	***130***
7	Influence on air quality				*1*	*80*
8	Climate regulation	2	9	387		
9	Moderation of extreme events	?				
10	Regulation of water flows	?				
11	Waste treatment / water purification	4	0	701		
12	Erosion prevention				*1*	*49*
13	Nutrient cycling and maintenance of soil fertility	?				
14	Pollination	?				
15	Biological control	?				
	HABITAT SERVICES	**0**	**0**	**0**	***2***	***1,005***
16	Lifecycle maintenance (esp. nursery service)				*1*	*1,003*
17	Gene pool protection (conservation)				*1*	*1*
	CULTURAL SERVICES	**0**	**0**	**0**	***1***	***3,907***
18	Aesthetic information				*1*	*3,907*
19	Opportunities for recreation and tourism	?				
20	Inspiration for culture, art and design	?				
21	Spiritual experience	?				
22	Cognitive information (education and science)	?				

Box A5.10 Example of TEV case study: Goods and services from Opuntia Scrublands in Ayacucho, Peru *(Rodriguez et al., 2006)*

Opuntia scrublands, one of the most important Andean socio-ecosystems in terms of the social and ecological functions that they provide. They perform a major role protecting slopes against erosion, improving the soil properties and providing a variety of products employed in the human diet, and in animal feeding, as well as cochineal insects, a highly valued source of dyes.
The ecosystem goods and services provided by Opuntia scrublands are very diverse with regard to the structures and functions involved in their supply, in their level of integration to diverse markets, and with regard to their contribution to human wellbeing**.**

Rodriguez et al. 2006 contributed to the estimation of the use value of Opuntia scrublands to local communities in Ayacucho by initially exploring the 'cultural domain' of Opuntia in order to identify the ecosystem goods and services recognized by the Andean communities. Then, the local perception of the internal relationships among the goods and services provided by the scrubland was estimated, as well as the relationships between the Opuntia scrubland and-other environmental and socio-economic systems existent in the region. The authors presented empirical estimates of the values of the goods and services provided by the Opuntia scrubland and their contribution to household income (see Table below)

Goods and services from Opuntia Scrublands in Ayacucho, Peru)
Source: Rodriguez et al., 2006

	Average value PEN/US$/year
Provisioning services	**461**
Cochineal production	215.69
Fruit production	100.64
Fodder production	73.62
Fuel production	59.05
Ornamental production	12.41
Total Production Function	
Habitat service	**497**
Cochineal infestation for dye production	496.83
Regulating services	**5**
Erosion control	5
Information Function / cultural services	
Not quantified in monetary terms. Many lyrics of Pumpin music, a traditional genre in Ayacucho are inspired by the Opuntia. Lyrics represent advices, rules and norms for the sustainable use of the goods and services provided by Opuntia scrublands	NA

Note: see section A5.10 for examples of TEV-calculations for fynbos & thicket ecosystems in S.Africa

A5.10 Monetary value of ecosystem services provided by grasslands

Grasslands occur in a wide variety of environments. They include tropical grasslands (savannas), temperate grasslands (including the European and Central Asian steppe and North American prairie), boreal grasslands (tundra's) and mountainous grasslands (such as the Latin American Paramo highlands). The largest continuous stretch of tropical grassland is the North African Sahel, that stretches from Senegal to the Horn of Africa.

As Table A5.10 shows, based on 25 data points, the total monetary value of the potential sustainable use of all services of grasslands varies between 297 and 3.091 Int.$/ha/year. This excludes three services for which only one value was found (which would add 752 Int$/ha/year to the total value).

Table A5.10 **Monetary value of services provided by Grasslands** (in Int. $/ha/year-2007 values)

	Grasslands	No. of used Estimates	Minimum Value (Int$/ha/y)	Maximum Value (Int$/ha/y)	*No. of Single estimates*	*Single values (Int$/ha/y)*
	TOTAL:	**25**	**297**	**3,091**	***3***	***752***
	PROVISIONING SERVICES	**9**	**237**	**715**	***1***	***0***
1	Food	3	4	82		
2	(Fresh) water supply	4	219	602		
3	Raw materials	2	14	31		
4	Genetic resources				*1*	*0*
5	Medicinal resources	?				
6	Ornamental resources	?				
	REGULATING SERVICES	**10**	**60**	**2,067**	***2***	***752***
7	Influence on air quality				*1*	*219*
8	Climate regulation	5	9	1,661		
9	Moderation of extreme events	?				
10	Regulation of water flows	?				
11	Waste treatment / water purification	3	13	358		
12	Erosion prevention	2	38	47		
13	Nutrient cycling and maintenance of soil fertility				*1*	*533*
14	Pollination	?				
15	Biological control	?				
	HABITAT SERVICES	**3**	**0**	**298**	***0***	***0***
16	Lifecycle maintenance (esp. nursery service)	?				
17	Gene pool protection (conservation)	3	0	298		
	CULTURAL SERVICES	**3**	**0**	**11**	***0***	***0***
18	Aesthetic information	?				
19	Opportunities for recreation and tourism	3	0	11		
20	Inspiration for culture, art and design	?				
21	Spiritual experience	?				
22	Cognitive information (education and science)	?				

Box A5.11 Example of TEV case study: The difference in ecosystem services supply before and after restoration in five catchments in dryland-areas in South Africa

An example of a best-practice study is an elaborate hydrological-ecological-economic study undertaken to analyse ecosystem rehabilitation options in the Maloti–Drakensberg and Tsitsikamma-Baviaanskloof mountain ranges in South Africa (Blignaut et al., 2010, Mander et al., 2010). These studies targeted a fire-prone grassland ecosystem (the Maloti-Drakensberg sites), and compared it with Fynbos and Subtropical-thicket sites (the Tsitsikamma-Baviaanskloof), which together form some of South Africa's most strategic sources of fresh water. For example, the Maloti-Drakensberg range occupies less than 5% of South Africa's surface area, yet it produces 25% of the country's runoff through rivers, major dams, and national and international inter-basin transfers.

The specific objective of the studies was to analyse the financial and economic viability of restoration of these catchments, considering the costs of restoration and the benefits of enhanced watershed regulation, carbon sequestration and sediment retention services. Restoration includes the removal of invasive alien woody plant species, the introduction and re-vegetation of areas that are denuded of any vegetation due to overgrazing with indigenous vegetation, erosion control measures and improved fire management regimes. The results are listed in the table below.

***The difference in ecosystem services supply before and after restoration in five catchments in dryland-areas in South Africa** [1]*

	Unit	**Upper-Thukela**	**Upper-Mzimvubu**	**Krom**	**Kouga**	**Baviaans**
		Grasslands biome	Grasslands biome	Fynbos biome	Fynbos biome	Sub-tropical thicket biome
Size of catchment	ha	187,619	397,771	101,798	242,689	160,209
Changes in watershed services						
Change in base-flow	m^3/ha/yr	68.6	9.9	196.7	65.4	35.3
Sediment reduction	m^3/ha/yr	6.7	12.4	0.9	0.5	0.3
Carbon dioxide sequestration	t//ha/yr	0.7	0.9	1.5	1.2	2.2
Financial and economic analysis of changes in watershed services following restoration						
PV of base flow	$./ha/yr	2.8[2]	1.1[2]	7.2	2.4	1.3
PV of carbon	$./ha/yr	10.5	12.6	9.5	7.4	14.0
PV of sediment reduction	$./ha/yr	4.4	8.5	0.3	0.2	0.1
PV of all other services[3]	$./ha/yr	8.7	8.7	1.7	5.5	8.6
PV of total services	$./ha/yr	26.5	31.0	18.7	15.5	24.0
PV of cost of intervention[4]	$./ha/yr	5.1	12.5	7.1	2.9	6.4
NPV of intervention[5]	$./ha/yr	21.5	18.5	11.6	12.6	17.6
Benefit-Cost Ratio	ratio	5.2	2.5	2.6	5.6	3.7
Average net return per ha: unsust. land use[6]	$/ha/y	11.3 (+/- 3)	11.3 (+/- 3)	6.7 (+/- 4)	6.7 (+/- 4)	6.7 (+/- 4)

*) sources: Blignaut et al., 2010; Mander et al., 2010

Notes:
1. Taken over 30 years at a social discount rate of 4%.
2. Taken only for the dry winter months.

3. Value of all other quantifiable services for which a market exist, such as tourism, sustainable agriculture, etc.
4. Intervention implies the cost of restoration and the ensuing annual management action(s) after restoration.
5. Difference between the benefits and the costs.
6. These are the returns before the introduction of restoration and the conversion of the land use practice to sustainable land management practices. These are therefore the current net financial returns to the landowner/user as a result of current land use practices that result in increased degradation as a result of, among others, overgrazing and the application of wrong fire management practices. These values are lower than the NPV of restoration, indicating a positive societal benefit and net benefit for the landowner/user if they can be lured into a PES scheme and change their land use practices.

The study shows that the PV of the benefits of the examined watershed services ranges from $15.5 to $31/ha/yr over the project period. The PV of the cost (both restoration and management) ranges from $3 to $12.5/ha/yr resulting in an NPV of $11.6 to $21.5/ha/yr. The study concluded that the benefits of introducing improved management practices exceeds cost in low to medium degraded areas, but not in heavily degraded ones. The economic return on the water (baseflow) produced by such a system of improved land use management, however, far exceeds that of conventional (construction-based) water development programmes and offers meaningful economic and market development opportunities in the study area.

Another interesting study was done by Fernandez-Nunez, et al. (2007) on an economic evaluation of land use alternatives between forest, grassland and silvopastoral systems.

A5.11 Monetary value of ecosystem services provided by polar & high mountain systems

The definition of polar and high mountain biomes used here deviates slightly from that used in the Millennium Ecosystem Assessment (2005). In particular, we define this biome in terms of its cryosphere (Kotlyakov, 2009). Based on this definition, Polar regions include all the Arctic seas and much of the Southern Ocean, the tundra/permafrost zone to the tree line, areas where there is long term snow cover (especially in the Arctic), and sub/marine zones in the Southern/Arctic oceans. This definition corresponds well with the WWF Arctic ecoregions (www.panda.org), the Udvardy (1975) and Clark and Dingwall (1985) biogeographical provinces for Antarctica.
Similar criteria could be applied to high mountains extrapolating from the altitudinal maps produced by Messerli and Ives at the UNU. So, for example, high mountain regions could be defined as those areas higher than the 1000masl mean line.
The MA gives the share of terrestrial space of polar and high mountains as 31% (MA, 2005 Synthesis volume p31 Table 1.1). Our revised definition would put the cryosphere proportion nearer 50% of terrestrial space (at maximum seasonal extension).

As Christie et al. (2005) note, there is currently very little quantification of the monetary value of services provided by polar and high mountain systems. The lack of monetary valuation research, however, should not be interpreted to infer the polar and high mountain areas to do deliver important services. Indeed, it is clear that these cryospheres are of paramount importance in terms of global ecosystem services.
The most important services are briefly discussed below.

1) Fishing
It is estimated that the Southern Oceans contribute around one sixth of the global fish take (Kock, 1992) and that this resource may become increasingly important as other areas are fished out. However, legal protection of these marine resources are fragile (Constable et al., 2000). For example, the Commission for the Conservation of Antarctic Marine Living Resources suggests that 80 – 90% of the take of the rare Patagonian toothfish was illegal (MA, 2005 p 487).

2) Freshwater Storage
Approximately 80% of the planet's freshwater (ID 2) is locked up in the ice caps (Pitt, 1995; Gabler, 2008). A significant proportion of the world's population depends on the meltwater of high mountain glaciers. Climate change threatens the existence of these glaciers, which in turn could have significant local and global consequences. For example, the glaciers in the Himalayas and on the Tibetan plateau sustain the major rivers of India and China which are used for irrigation of wheat and rice fields. Given that India and China are the world leading wheat are rice producers, projected melting of the glaciers presents a significant threat to local and global food security (Brown, 2009).

3) Raw Materials
Raw materials (ID 3) are very valuable too in the cryosphere (e.g. Howard, 2010; Emmerson, 2010; Orrego-Vicuña (Edited), 2009) and becoming a major area for international conflict. The Arctic is said to contain more than a quarter of the world's hydrocarbons (Mikkelsen and Langhelle (Edited), 2008) and is widely presumed to be a future flashpoint as nations compete. The Antarctic Treaty System (ATS) currently prohibits exploitation of raw materials and creates the world's largest protected and demilitarized area reserved “for peace

and science": however, the ATS expires in 2041 and its replacement is uncertain. Even now there is conflict over resources. The Australians and New Zealanders are currently taking the Japanese to court over abuses of the whaling moratorium. The British and Argentineans are involving warships as oil drilling is explored in the Falkalnds/Malvinas, whilst even old friends like Canada and the USA are at daggers drawn over the NW passage"

4) Climate Regulation

Both the Southern Ocean and the Arctic Permafrost / tundra are major greenhouse carbon sinks. However, global warming is likely to convert the Arctic permafrost/tundra into a net source of GHG (including methane) (McGuire et al., 2000). The polar regions also have a significant role in reducing climate change through the albedo effect, i.e. they reflect the sun's light back into space (MA, 2005 v1 p859). Prizborski (2010) also suggest that the recent calving of the 2,545 km^2 Mertz glacier tongue iceberg may disrupt ocean currents worldwide by blocking the flow of bottom water.

The Pew Report on Arctic melting (Goodstein et al., 2010) estimates that the loss of Arctic snow, ice and permafrost currently costs the world US$61 billion to US$371 billion annually.

5) Habitat service

The apparently dead and frozen waste of the cryosphere has been called species poor but evidence is accumulating not only of life in the extreme cold (including suspended animation), but also of vibrant hot spots e.g. in the polynyas, sea leads , extensive sub glacial lakes or on the seamounts, around the volcanic vents etc. The IPY archive will contain faunal census material though we have some estimates for some species (e.g. Shirihai (2007) for Antarctica, CAFF (2001) and Ervin (2010) in the Arctic) whilst the international circum Antarctic census of marine life will be a benchmark in the Southern Ocean (Stoddard, 2009). In biomass terms the primary productivity of the Southern Ocean is enormous: van der Zwaag (1986) estimates that it is more than fifty times that of the North Sea in terms of grams of carbon per m^2 per annum. The NPP figures in the MA Synthesis Table (op cit) are very low for the polar biome especially and may need revisiting after IPY.

6) Cultural services and Tourism

Current there is little information on the aesthetic, recreational, inspirational, spiritual, cognitive etc values (ID 18-22) of the cryosphere, and innovative methods such as those highlighted by Christie (2005) will be needed to calculate these types of values. For example, Samson and Pitt (Edited) (2000) explore the passive use values of the cryosphere including the role it plays in what has been called the noosphere: the realm of ideas which embraces all cultural activities. Pitt (2010) have explored how iconic cryosphere species score in terms of internet hits: penguins top the poll. High mountains contain the most sacred and holy sites of humanity.

The cryosphere is also an important tourism resource. Snyder and Stonehouse (Edited) (2007) project that in 2010 there will be 1.5 million visitors to the Arctic, 80, 000 Antarctic, 10 million to the Alps and many more in other high mountains.

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