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Valuation of Biodiversity and Ecosystem Services in India

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ABBREVIATIONS AND ACRONYMS

ACS	American Cancer Society	IHD	Ischemic heart disease
ACU	Adult Cattle Units	IQ	Intelligence quotient
ADB	Asian Development Bank	IUC	The International Union for Conservation of Nature
AF	Attributable fraction	Kg	Kilogram
ARI	Acute respiratory illness	LRI	Lower Respiratory Illness
BAU	Business as usual	M	Meter
BLL	Blood Lead Concentration	MMR	Mild Mental Retardation
BP	Blood pressure	NFHS-3	National Family Health Survey-3
C	Carbon	NPV	Net present value
CB	Chronic Bronchitis	NSS	National Sample Survey Organization
CEA	Country Environmental Analyses	OR	Odds ratio
CED	Cost of environmental degradation	ORT	Oral Rehydration Therapy
CI	Confidence Interval	PM	Particulate Matters
CO ₂	Carbon Dioxide	PPP	Purchasing power parity
CO ₂ -eq	Carbon Dioxide Equivalent	RAD	Restricted Activity Days
COI	Cost-Of-Illness	RICE	Regional integrated model of climate and the economy
COPD	Chronic obstructive pulmonary disease	Rs.	Indian Rupee
CPCB	Central Pollution Control Board	SBR	The Sundarbans Biosphere Reserve
CVA	Cardiovascular disease	SD	Standard Deviation
DALY	Disability Adjusted Life Years	MT	Metric Tonne
DPL	Development Policy Lending	TDM	Total Dry Matter
EC	Electrical conductivity	UNEP	The United Nations Environment Programme
G	Gram	USD	US dollars
GBD	Global burden of disease	VSL	Value of Statistical Life
GDP	Gross Domestic Product	WCMC	World Conservation Monitoring Centre
GHG	Greenhouse gases	WDI	World development indicators
Ha	Hectare	WHO	World Health Organization
HCA	Human Capital Approach	WSH	Water supply, sanitation and hygiene
HH	Household	WTP	Willingness to pay

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Disclaimer

The report has been discussed with Government of India, but does not necessarily represent their views or bear their approval for all its contents.

Table of Contents

- EXECUTIVE SUMMARY 1**
- I. BACKGROUND 1**
- II. PROPOSED APPROACH FOR INDIA..... 2**
- III. DIRECT AND INDIRECT SERVICES OF FORESTS..... 4**
 - CARBON SEQUESTRATION IN INDIAN FORESTS 4
 - NON-USE VALUES ASSOCIATED WITH CONSERVATION FORESTS..... 6
- IV. SERVICES FROM GRASSLANDS, WETLANDS, MANGROVES AND CORAL REEFS 8**
 - SERVICES DERIVED FROM GRASSLANDS 9
 - SERVICES DERIVED FROM WETLANDS 11
 - SERVICES DERIVED FROM MANGROVES..... 13
 - SERVICES DERIVED FROM CORAL REEFS..... 15
- V. SUMMARY AND CONCLUSIONS..... 18**
- REFERENCES..... 20**
- ANNEX A: DETAILS OF THE META-ANALYSIS FUNCTIONS 22**

Executive Summary

1. Biodiversity underpins economic development, but it is threatened globally and its ability to continue to provide the goods and services that support economic growth is failing. At a global level, the implications of this have been laid out in a major report – the Millennium Ecosystem Assessment (MEA). The MEA makes notes that humans have made unprecedented changes to the natural world in recent decades to meet growing demands for food, fresh water, fibre and energy and that this demand will only increase as the global population grows and consumption patterns change.

2. Biodiversity loss presents significant economic challenges. While a great deal of economics is required to understand the issues, a simple and important observation is that most species and ecosystems are not traded in markets, so prices are often absent and biodiversity is under-provided. Recent interest in the economics of biodiversity and wider ecosystem services has been given empirical expression through a focus upon economic valuation. Economic valuation techniques are being usefully employed to roughly estimate the value of the benefits provided by biodiversity and ecosystems.

3. This paper reports on a wide range of research that estimates the value of ecosystem services (ESS) in India, including those related to forests, grasslands, wetlands, mangroves, and coral reefs. Estimates for forest services are based on an extensive Indian Green Accounting study, from which the values of timber and non-timber, fodder, forest recreation, water recharge and prevention of soil erosion have been taken. To this we have added non-use value of forests as well as an update of the value for forest sequestration based on the latest estimates of trends in forest management.

4. Estimates of the other ecosystems (grasslands, wetlands, mangroves, and coral reefs) are based on a detailed study in which all patches or sites of each such ecosystem in India were documented and the services valued using the characteristics of the site and a benefit function which linked the value of a site to its characteristics. This function is derived from an international database of valuation studies undertaken as part of the TEEB study and the method is referred to as benefit transfer based on meta-analysis. The valuation of each site also takes account of its Mean Species Abundance, a measure of biodiversity, which has been estimated as part of a global research project carried out by the Netherlands Environment Agency.

5. All figures are for 2009 values (or as close to that year as possible) and are given in rupees with dollar equivalents, using an exchange rate of Rs.47.5 to the dollar.

6. The total value of services from these ecosystems is estimated Rs.1.4 trillion (US\$29 billion) in 2009 as a central estimate. This amounts to about 3.0 percent of the country's GDP in that year. The upper and lower bounds are Rs.746 (US\$16) billion and Rs. 2,577 (US\$57) billion, respectively, or 1.6 to 5.5 percent of GDP.

7. Of the total value, forests account for 22 percent and within the forest service category, fodder is the largest. Of the other services, wetlands are the largest (at 48 percent) and coral reefs next (22 percent). These are followed by grasslands (7 percent) and mangroves (2 percent).

8. The ESS estimates are complementary to the costs of environmental degradation (COED), which calculate the damage done to the economy and losses to the wellbeing of individuals as a result of the damage to the environment. The value of ecosystem services looks at the positive side of what is provided by the environment while the COED looks at the negative side; i.e., at damage caused by different types of pollution and degradation.

9. This study provides some important information, but further work is needed. In particular, a more accurate assessment of who benefits from these ecosystem services is important for policy purposes. While some benefits are clearly global (e.g., those from carbon sequestration), others are for local communities (e.g., those from grasslands, wetlands, non-timber and fodder forest services), and still others are more widely spread, such as those from timber and coral reefs. Many of these data have not yet been captured, so the estimated in this study should be taken as conservative.

10. In addition, some ecosystem services are missing. For example, services from lakes and rivers are important but need more data than was available. We are also missing the value of bio-prospecting and some other services.

11. Finally, the benefit transfer method should be replaced over time with local studies of benefits, although it is impossible to cover the hundreds and thousands of patches with individual studies and some element of benefit transfer is inevitable.

I. Background

12. Much has been written about loss of biodiversity in recent decades, and about the economic and social losses associated with this loss. Yet, while we have a number of pieces of anecdotal evidence, and there are several studies that look at the value of biodiversity in specific contexts, no one has estimated the value of the loss of biodiversity as such¹ at a national or global level. This is because the links between biodiversity and biological systems and the economic and social values that they support are extremely complex. Even the measurement of biodiversity is problematic, with a multi-dimensional metric being regarded as appropriate (Purvis and Hector, 2000; Mace et al., 2003) but with further work being considered necessary to define the appropriate dimensions.

13. For this reason, the focus, initiated by the Millennium Ecosystem Assessment (MEA, 2005), has shifted from biodiversity to measuring ecosystem services, which are related to biodiversity and are derived from the complex biophysical systems. The MEA defines ecosystem services under four headings: provisioning, regulating, cultural, and supporting, each of which has a number of sub-categories.

14. The most important fact about these services is that they have also been facing major losses. During the last century the planet has lost 50 percent of its wetlands, 40 percent of its forests, and 35 percent of its mangroves. Around 60 percent of global ecosystem services have been degraded in just 50 years (ten Brink, 2011).

15. While working at the ecosystem level makes things somewhat easier, it is still important to understand the causes of the loss of these services and the links between losses of biodiversity and the loss of ecosystem services. Indeed, this is a major field of research for ecologists, and one thesis that has been developed over a long period is that more biologically diverse ecosystems are more stable and less subject to malfunction (Haines-Young and Potschin, 2010; McCann, 2000, Tilman and Downing, 1994). The current state of knowledge on the links between biodiversity and ecosystem services is still a topic of research and while some clear lines are emerging, they are not strong enough to allow a formal modeling to be carried out at a level that would produce credible estimates of the global value of biodiversity. This therefore remains an area for research.²

¹ For a review, see ten Brink (2011), Chapter 5.4.

² Theoretical models of the economic values attached to biodiversity have been developed. See, for example, Brock and Xepapadeas (2003). Such models draw simple links among harvesting rates, system biodiversity, and overall system value. The models are, however, not yet supported by applicable empirical estimates.

II. Proposed Approach for India

16. The objective of this study is to obtain estimates of the current values of services from natural systems in India. To do this we have, of necessity, to go for ecosystem function valuation, recognizing that there is a complex link between changes in such values and the changes in the measures of biodiversity (defined appropriately). The proposed methodology takes into account (where possible) the **quality** of an ecosystem and the services it produces, based on the species abundance within it. This is derived from the Mean Species Abundance (MSA) approach, which is explained more fully below. To some extent therefore, the study does build on the linkages between the biodiversity of a biome and its ecosystem functions.

17. The study quantifies and values the following ecosystem services:

- i. Timber services of forests
- ii. Non-timber and fodder services of forests
- iii. Recreation and ecotourism services of forests
- iv. Water recharge services of forests
- v. Contribution of forests to prevention of soil erosion
- vi. Carbon sequestration of forests
- vii. Non-use values associated with dense primary forests
- viii. Services derived from grasslands
- ix. Services derived from wetlands
- x. Services derived from mangroves
- xi. Services derived from coral reefs.

18. The valuation of the services is based on the stock of environmental capital that exists at a point in time (as close as possible to 2010 but not always for one given year), The services are of course a flow from that stock. We do not value the change in ecosystem services as we do have enough data on these changes over time.

19. The analysis draws to the maximum extent on Indian studies.³ This is especially the case for items (i) through (vi). For the services in categories (vii) through (xi), the values are based on international studies but adjusted for the characteristics of the sites in India that are being considered. The procedure for deriving the estimates is to take a set of valuation functions, which calculate the value of an ecosystem per hectare as a function of national, regional and site-specific variables. The functions were estimated as part of the TEEB study. These variables have been estimated for the individual sites in India but the meta-analytical function is estimated from international data, in which only a few Indian studies are included. There is no alternative to taking such a function, which has several limitations but is the best currently available. In each application we indicate these limitations and point out ways in which future estimates can be improved.

³ There is an excellent report prepared by MOEF and GIZ on 'Economics of Ecosystems and Biodiversity in India'. This provides a very good review of the state of knowledge, challenges facing, valuation of ecosystem services and biodiversity. It also suggest as approach and methodology MoEF/GIZ, 2012). The Economics of Ecosystems and Biodiversity – India, Initial Assessment and Scoping Report

20. This report should be seen as complementary to the one on the Costs of Environmental Degradation in India. While the latter looks at the extent to which the decline in environmental services has impacted on the economy and wellbeing, this one looks at the value of the services provided by the environmental resources that are still available to the country.

21. As in the accompanying Cost of Environmental Degradation report, all values are reported in 2009 rupees. To aid comparison, summary values are also reported in US dollars, using the exchange rate of 47.5 rupees to the dollar.

III. Direct and Indirect Services of Forests

22. The direct and indirect services of forests (apart from carbon sequestration, which is better covered by the studies referred to below) are taken from the extended study: “Green Accounting for Indian States and Union Territories Project (GAISP) 2005-2006,” which was designed to build a system of adjusted national accounts for India as part of an estimate of genuine national wealth. Details of sources and the different estimates are provided in the companion to the GAISP report Table 1 takes the figures from that report but excludes carbon sequestration, which has been dealt with separately.⁴

23. Direct use values range from Rs. 184 to 278 billion (US\$3.9 billion to US\$5.9 billion), and indirect use values amount to around Rs. 22 billion (US\$460 million). As noted in Gunimeda et al. (2006), these values exclude services such as bio-prospecting, which have not been covered owing to a lack of data, but which could be significant.

24.

Table 1: Direct and Indirect Use Values of Forests
(Rs. bn. unless otherwise indicated)

	Low	High
Direct		
Timber	17	17
Non timber values	21	21
Fodder	94	189
Ecotourism	51	51
Total direct	184	278
Per hectare, Rs.	6,471	8,871
Indirect		
Soil erosion	16	16
Water recharge	6	6
Total indirect	22	22
Per hectare, Rs.	315	315

Source: Strukova et al. (2011).

Carbon Sequestration in Indian Forests

25. Estimates have been made of the amount of carbon stored in the forests, both in the biomass and in the soil (Kadekodi and Ravindranath, 1997 Kishwan et al., 2009). The data, which go only to 2005, are given in Table 2. The MOEF uses these figures to make projections to 2015 under three scenarios: (a) India follows the same trend as the world

⁴ Table 1 also appears in modified form as Table 8.1 in the Cost of Environmental Degradation Study (Strukova et al., 2011).

average across all forests over the period 2000-2005, resulting in a decline of 0.18 percent per year; (b) India follows a trend similar to the one that prevailed domestically over the same period, resulting in an increase of 0.6 percent per year; and (c) India takes a new path that reflects the forest policy of the Government, in which case forest carbon stocks grow at an annual rate of nearly one percent (MOEF, 2009). Assuming these trends proceed at a constant annual rate over the period 2005-2015, we can estimate the stocks in 2009 (the year for which the estimates of the environmental flows and costs of degradation were made in the parallel study on the costs of environmental degradation in India). The corresponding stock values and annual increments to stock are given in Table 2.

26. The data show a total stock of 6.62 billion metric tons in 2005 and a possible value of between 6.57 and 6.88 billion metric tons in 2009, depending on which trend has prevailed over the period 2005-2009. Annual increments in 2009-2010 then range from -12 million tons to as much as 63 million tons.

Table 2: Stock of Carbon in Indian Forests and Additions to Stock (m. metric tons)

Carbon (MMT)	1995	2005	2015			Stock in 2009			Annual Increment 2009-2010		
			World Trends	Past Indian Trends	Gol Proposed Trends	World Trends	Past Indian Trends	Gol Proposed Trends	World Trends	Past Indian Trends	Gol Proposed Trends
In Biomass	2,692	2,866	2,815	3,039	3,132	2,845	2,933	2,968	- 5	17	26
In Soil	3,552	3,756	3,689	3,959	4,151	3,729	3,835	3,907	- 7	20	38
Total	6,245	6,622	6,504	6,998	7,283	6,574	6,768	6,875	-12	37	63

Source: MOEF (2009); staff calculations.

27. A value of these stocks and additions to the stocks can be made, based on the value of a ton of carbon. We take a range of values, with the lower bound based on the marginal costs of abatement of carbon in 2009, to achieve a target reduction consistent with stabilization of temperature increases globally at 2°C. The upper bound is based on the social costs of carbon, as calculated across a range of studies. A review of the literature, which was conducted as part of The Economics of Ecosystems and Biodiversity (TEEB) study, puts the lower bound at around US\$8/ton of CO₂ equivalent (Rs.380/ton), and the upper bound at around US\$20.5 (Rs. 974/ton) (Hussain et al., 2011). The corresponding values per ton of carbon are US\$29 (Rs. 1,378/ton) and US\$74.4 (Rs. 3,534/ton). They have been applied to the 2009 stock and flow values to give the range of estimates shown in Table 3. The lower bound of the stock value is between Rs.9,072 billion and Rs.9,478 billion (US\$190 and US\$200 billion), and the upper bound is between Rs.23,248 billion and Rs.24,311 billion (US\$490 and US\$510 billion)⁵.

28. As a percentage of GDP, this stock has a very significant value, ranging from 19.9 to 51.0 percent. The annual increment to the stock could be negative over the period if world trends prevail, in which case there is a loss of between Rs.16 billion and Rs.42 billion (US\$330 million and US\$880 million). But with the other two scenarios, there is a

⁵ An alternative would have been to take a value of carbon based on CDM transactions. These values, however, are dependent on the extent to which CDM credits are allowed in Annex I countries and can vary greatly in value. It was felt better to stay with the valuations of carbon used in international studies.

gain of between Rs.51 billion and Rs.87 billion (US\$1.1 and US\$1.8 billion) using the lower bound of the carbon values, and between Rs.130 billion and Rs.224 billion (US\$2.7 and US\$4.7 billion) using the upper bound. As a percentage of 2009 GDP, the additions to carbon amount to between 0.1 and 0.2 percent. We should also note that preventing the loss of forests, which is part of Government policy, provides a benefit to the extent that any such deforestation would entail a loss of biomass equal to around 42 metric tons of carbon per hectare (Kishwan et al., 2009).

Table 3: Values of Carbon Stocks in Forests and Increments to the Stock (Rs. bn.)

	Stock Values		Flow Values	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
World Trends	9,072	23,248	-42	-16
Past India Trends	9,340	23,935	51	130
GoI Proposed Trends	9,487	24,311	87	224
Average as % of GDP	19.9	51.0	0.1	0.2

Source: MOEF (2009); staff calculations.

29. It may be useful to note here that "National Mission for a Green India" is one of the eight missions under National Action Plan on Climate Change (NAPCC). It aims to increase forest and tree cover on 5 mha. area, improve quality of forest cover on another 5mha. The objective of Mission is to improve eco-system services such as carbon sequestration, bio-diversity conservation, hydrological services, soil conservation, flood control, climate stabilization and overall amelioration of the environment. The Mission will lead to enhanced annual carbon dioxide sequestration by 50 to 60 million tonnes in the year 2020.

Non-use values associated with conservation forests

30. A number of studies show a willingness to pay to conserve forests on the part of people who have never visited them and have no intention of doing so. Nevertheless, they draw some satisfaction from knowing that these resources are not allowed to degrade. For forests in India, both Indian citizens and citizens of other countries may have such values. Most of the studies are for Europe and North America, although there are also a few from other countries, such as Brazil, China, Madagascar, and Israel. Based on a review of this literature, Chiabai et al. (2011) identified⁶ 27 usable estimates of forest passive use values.

⁶ The review covered sources such as EconLit, EVRI database, and IUCN database for forest studies.

A meta-analysis of these studies showed that values per hectare of conserved forest varied with GDP per capita, measured in purchasing power parity (PPP) terms; with the population of the country; and with the area of conserved forest. The underlying relation is given in Annex A and includes the following variables: GDP per capita of the country concerned (measured in purchasing terms), the forest area of the country designated to conservation and the population of the country.

31. The source of data on forest areas as well as on the areas designated to conservation for each region is the Food and Agricultural Organization of the United Nations (FAO) Global Forest Assessment (FAO/FRA, 2010). In the case of India, the area classified as forest under this definition was 29 percent in 2010 (FAO/FRA, 2010). According to the same sources, total forest area in India in that year was 68.4 million hectares, making the area relevant for passive use valuation equal to about 19.8 million hectares.

32. In order to estimate the non-use values of Indian forests, we applied the meta-analysis equation to the Indian data, taking the mean and median values from the literature as the base values being transferred. The application of the above equation gives a mean and median non-use value for Indian forests of between Rs.723,947 and Rs.861,413 (US\$18,135 and US\$15,241) per hectare, respectively. The corresponding total non-values then amount to between Rs.14.25 billion and Rs.17.1 billion (US\$300 and US\$360 million annually).⁷

⁷ All original study values were converted into 2009 dollars and converted to rupees at an exchange rate of 47.5 rupees to the dollar.

IV. Services from Grasslands, Wetlands, Mangroves and Coral Reefs

33. The remaining categories of services are analyzed using a major recent study undertaken by a research group led by Salman Hussain from the Scottish Agricultural College for UNEP, as part of the TEEB exercise (Hussain et al., 2011). The research combined the valuation of ecosystem services from a number of biomes, with detailed GIS data on the biomes themselves. The biomes covered were forests (temperate and tropical), grasslands, wetlands, mangroves, coral reefs, and lakes and rivers. For each biome, a meta-analysis was carried out valuing the services as a function of the characteristics of the site.⁸

34. The estimated function was then applied to each the individual site under that biome. This entailed a major piece of work. To give some indication of the level of disaggregation, the numbers of patches that are individually assessed in the benefits transfer were: grasslands 1,494,581; tropical forest 292,822; temperate forest 672,942; wetlands 191,539; mangroves 6,850; coral reefs 16,149; and lakes and rivers 375,316. For each patch, the team collected the biophysical data relevant to the valuation of that patch. This was done by the group based at the Netherlands Environment Agency (NEA) (PBL, 2010), who kindly made the part of the data related to the patches inside the territory of India available to the author.

35. In separating the Indian data from the rest, some approximations were necessary. The selection of patch records in India was based on a map of the country, including islands belonging to India, as well as mangroves and coral reefs outside the mainland. The India map is produced by selecting the India + region from the Image 24 region map (which was the basic map used in the original study) and clipping out the countries of Afghanistan, Pakistan, Nepal, Bhutan, Bangladesh, and Sri Lanka, and accompanying sliver polygons (using the standard country maps of ESRI, 2008). Coral reefs and mangroves in the original Image 24 region map were allocated a region ID on the basis of a Euclidian allocation.

36. As PBL (2010) did not have accurate information about which specific coral reefs and mangroves belong to the national territory of India and which to the neighboring countries, it assumed that coral reefs or mangroves straight in front of the coast of India belonged to India and otherwise to the surrounding countries. It also assumed that coral reefs / mangroves around islands belonging to India also belong to India. As a consequence, coral reefs / mangroves that cross national borders were split into different parts at the location of the presumed border.

37. This use of benefit transfer in valuing different ecosystem services is a common procedure, although there are well-recognized limitations in terms of accuracy. There exists a sizeable literature that tests the accuracy of value transfer, of which Rosenberger and Stanley (2006) and Rosenberger and Johnston and (2009) provide useful overviews. Although some studies find very high transfer errors (e.g., Downing and Ozuna, 1996;

⁸ In all cases but one (lakes and rivers), values were estimated in US\$/hectare. For lakes and rivers, the meta-analysis was in terms of willingness to pay per household.

Kirchhoff, 1998), most studies find transfer errors in the range of 0-100 percent even in international value transfers (Ready and Navrud, 2006). Hence in the last section, where the results are summarized, a transfer error of +/- 100 percent has been adopted.

38. The final remark on the valuation of ecosystem services relates to the areas to which they are applied. To account for differences in the quality of each patch, an adjustment to the area has been made based on an estimate of the mean species abundance within it. The Global Biodiversity Model used in the TEEB study (IMAGE-GLOBIO3) analyses biodiversity as “the remaining mean species abundance (MSA) of original species, relative to their abundance in pristine or primary vegetation, which are assumed to be not disturbed by human activities for a prolonged period” (Alkemade et al., 2009: 375). First a relationship is estimated among a number of indicators of the pressure that an area is under and the number of species it can support relative to what it could support in natural conditions. Based on this function, an MSA value is calculated for a chosen area, given information on the different pressure indicators.

39. As the valuation model adopted in Hussain et al. (2011) uses the area of land as an input, the MSA value of a geographical region is calculated as the area-weighted mean of MSA values for each region. The GLOBIO3 Model is then used to assess the expected impacts of the selected drivers on MSA for a number of world regions and future scenarios, as well as the impacts of specific pre-defined policy measures. The individual valuations are discussed further below.

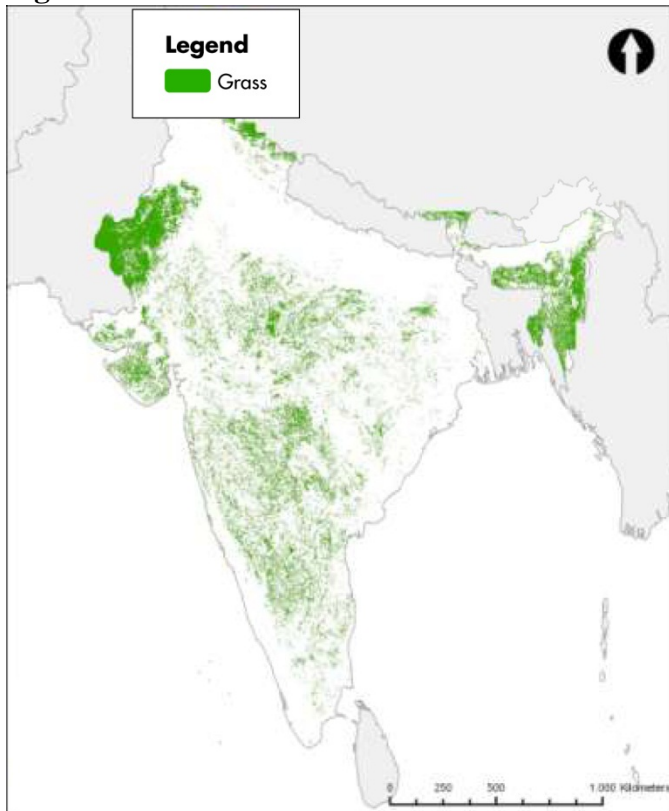
Services derived from grasslands

40. Grasslands provide the following ecosystem services: food provisioning, recreation and amenity, erosion prevention, conservation of biodiversity, and carbon sequestration. An international database consisting of studies from Europe, the United States, Asia, and Africa has estimated values for all these except carbon sequestration.⁹ A meta-analysis was conducted by Hussain et al. (2001) based on 19 observations. The estimated equation (see Annex A for details) gives the value per hectare of grassland as a function of: the grassland area within a 50 km radius of the study site, the length of roads within a 50 km radius of the study site, an accessibility index, and the country GDP per capita measured in PPP terms.

41. As noted earlier, the global database constructed by the Netherlands Environment Agency (PBL) using GIS data identified 1,494,581 patches of grassland. Of these, 66,928 were in India. Figure 1 shows the location of these patches in the country, which make up 53 million hectares.

⁹ Contingent valuation and choice experiments have been used for recreational values of grasslands and wildlife conservation; hedonic pricing has been used for the amenity value; and net factor income and market prices have been used to estimate food provisioning (Hussain et al., 2011).

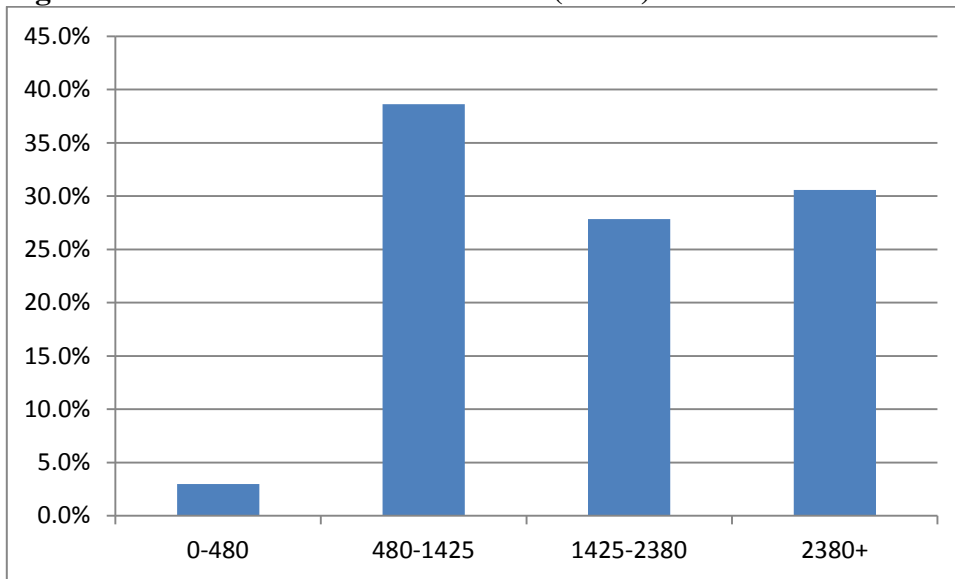
Figure 1: Patches of Grassland in India



Source: Staff extrapolation from NEA's global database

42. A valuation of the services provided across the grassland patches has been made by applying the meta-analysis equation to each of these patches (the PBL database provides data for the explanatory variables for each site). Naturally these vary, depending on the characteristics of the patch. The range of values per hectare across the 66,928 sites is shown in Figure 2. The average is Rs.1,805 (US\$38) per hectare, with 3 percent having a value of less than Rs.480 (US\$10) per hectare and 31 percent having a value of more than Rs.2,380 (US\$50) per hectare. The total value of ecosystem services from grasslands in India is estimated to be Rs.95 (US\$2) billion per annum.

Figure 2: Values of Grasslands in India (Rs/ha)



Source: Staff extrapolation from NEA's global database

Services derived from wetlands

43. A similar approach was taken to valuing the wetlands of India. The global meta-analysis is based on 131 studies, which generated 247 separate value estimates¹⁰. The studies are taken from North America, Western Europe, Southeast Asia, and Australasia. A wide range of ecosystem services are valued in these studies, including flood protection, water supply, water quality, habitat nursery, recreational hunting and fishing, food and material provisioning, fuel wood provisioning, non-consumptive recreation, and biodiversity conservation.

44. The results of the meta-analysis (given in Annex A) found the following variables to be relevant in determining the value per hectare of wetland: the area of lakes and rivers within 50 km of the site being valued, the area of wetlands within a 50 km radius of the site; the population residing within 50 km of the site; the length of roads within a 50 km radius of the site; the human appropriation of net primary production within 50 km of the site; and country GDP per capita measured in PPP^{11,12}.

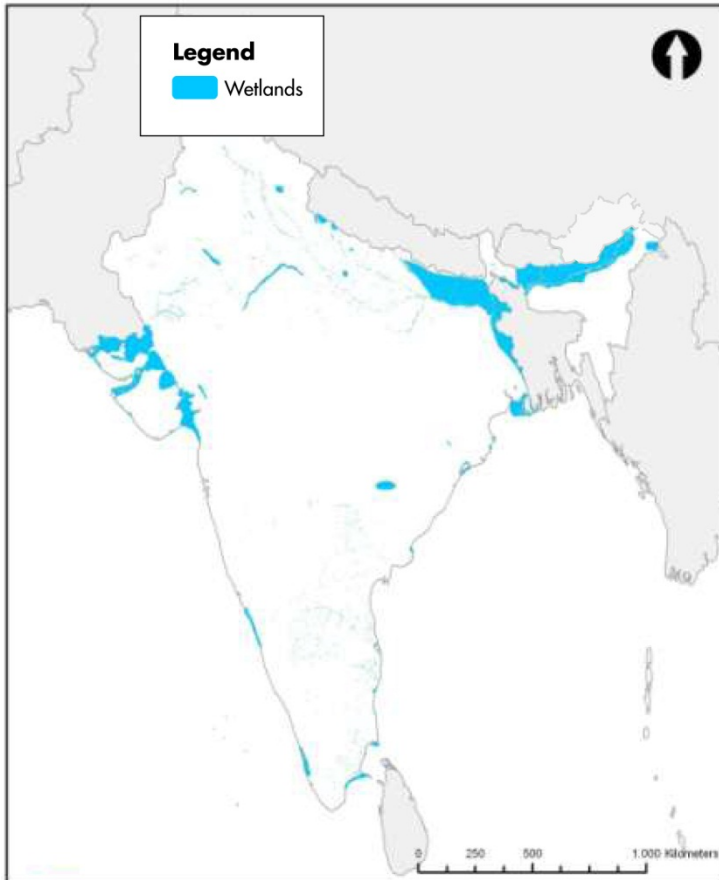
¹⁰ The collection of wetlands in the database used includes coastal wetlands but not mangroves, which are treated separately. The data was provided by PBL and a reviewer from the Ministry of Environment and Forests has noted there are differences between this set and the wetlands identified in the The National Wetland Atlas prepared by Space Application Center in 2011. The latter for example has only 15.25 million hectares whereas our database has 17.5 million hectares. We have stayed with our database because we did not have the individual patches in the Wetland Atlas, nor the defining variables for the meta analysis.

¹¹ Note that the database does not include lakes and rivers as part of the wetland ecosystem, although these bodies affect the unit value of a given wetland.

¹² The choice of regressors indicates that the valuation model is more focused on *in situ* conditions, and does not address the scale dimension of ecosystem functioning. This is a limitation of the analysis and something to be addressed in future work.

45. The database identified 191,539 wetlands globally, of which 3,768 are in India. Figure 3 shows the location of these patches in the country, which constitute 17.5 million hectares.

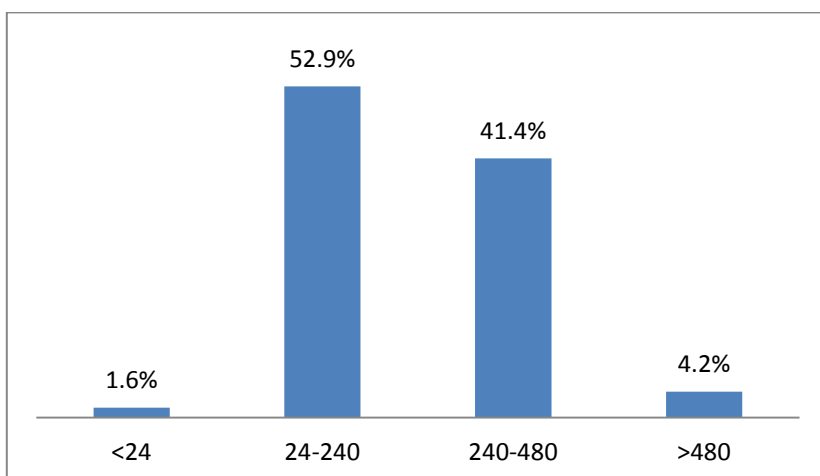
Figure 3: Wetlands in India



Source: Staff extrapolation from NEA's global database

46. By applying the meta-analysis equation to each of these patches, a valuation of the services provided across the wetlands in the country has been obtained. The range of values per hectare across the 3,768 sites is shown in Figure 4. The average is Rs.38,000 (US\$800) per hectare. Although many of the sites have a greater value per hectare, the largest sites have much lower values, so the average comes out as indicated. The total value of ecosystem services from grasslands in India is estimated to be Rs.665 billion (US\$14 billion) annually.

Figure 4: Values of Wetlands in India (Rs.000/ha)



Source: Staff extrapolation from NEA's global database

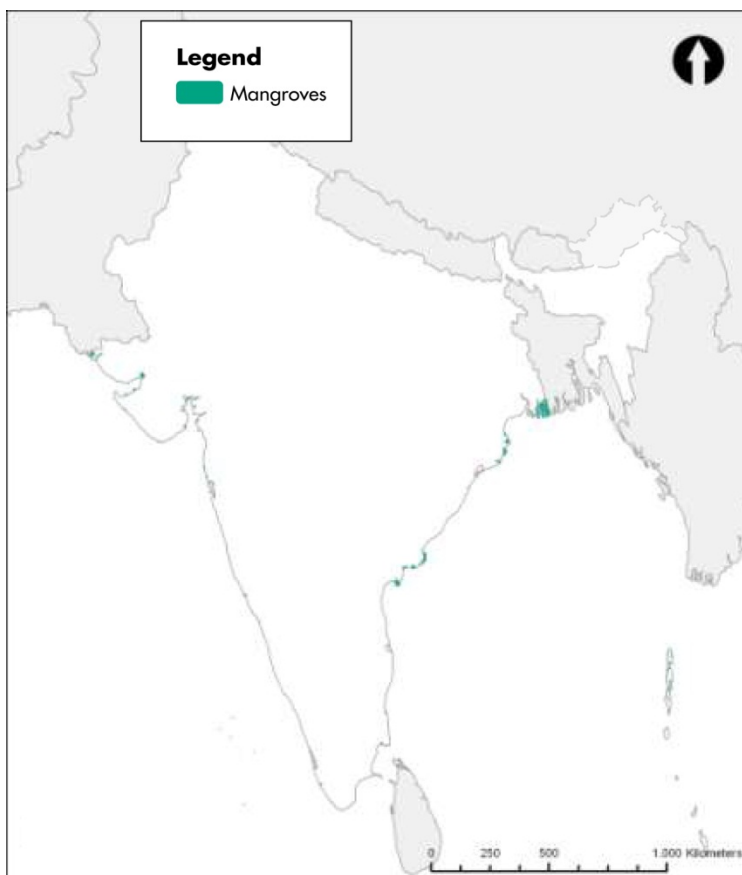
Services derived from mangroves

47. The global database for mangroves consists of 48 original studies, from which 111 separate value estimates were obtained. These studies were conducted in Southeast Asia, Central America, the United States Gulf Coast, and East Africa. The ecosystem services included were coastal protection, water supply, water quality, habitat nursery, recreational hunting and fishing, food and material provisioning, fuel wood provisioning, non-consumptive recreation, and biodiversity conservation.

48. The meta-analysis (results given in Annex A) found the following variables to be relevant in determining the value per hectare of mangroves: the size of the mangrove, the area of other mangroves within 50 km of the site, the population resident within 50 km of the site, length of roads within 50 km of the site, the urban area within 50 km of the site, the area of wetlands within 50 km of the site, and country GDP per capita measured in PPP.

49. The database identified 6,850 mangroves globally, of which 89 are in India. Figure 5 shows the location of these patches in the country. In total they amount to 674,000 hectares. By applying the meta-analysis equation to each of these patches a valuation of the services provided across the mangroves in the country has been obtained.

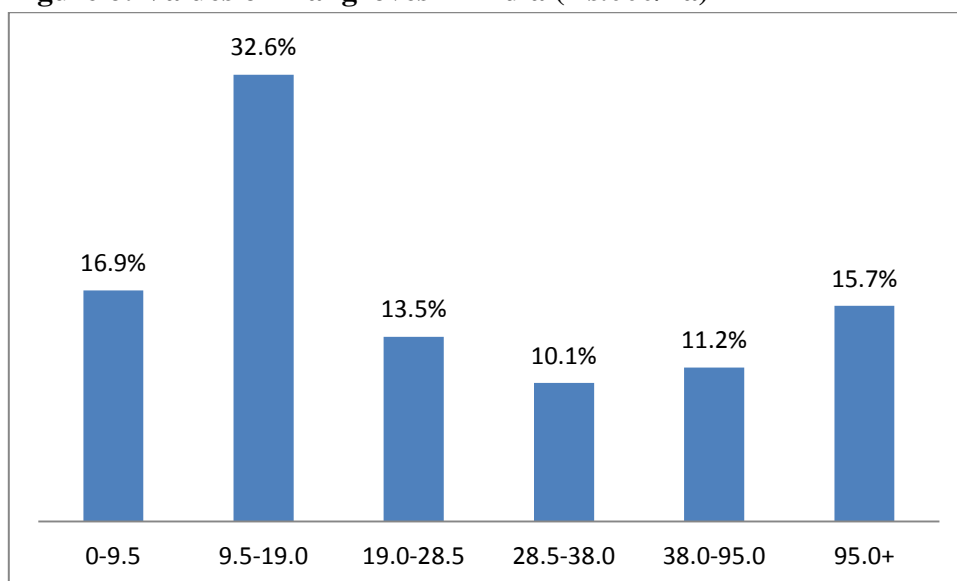
Figure 5: Mangroves in India



Source: Staff extrapolation from NEA's global database

50. The range of values per hectare across the 89 sites is shown in Figure 6. The average is Rs.37,860 (US\$797) per hectare. The most common group is Rs.9,500-19,000 (US\$200-400) per hectare, but around 10-12 percent of sites have values in each of the categories: Rs.19,000-28,500 (US\$400-600), Rs.28,500-38,000 (US\$600-800), and Rs.38,000-95,000 (US\$800-2000) per hectare. The total value of ecosystem services from grasslands in India is estimated to be Rs.25.5 billion (US\$537 million).

Figure 6: Values of Mangroves in India (Rs.000/ha)



Source: Staff extrapolation from NEA's global database

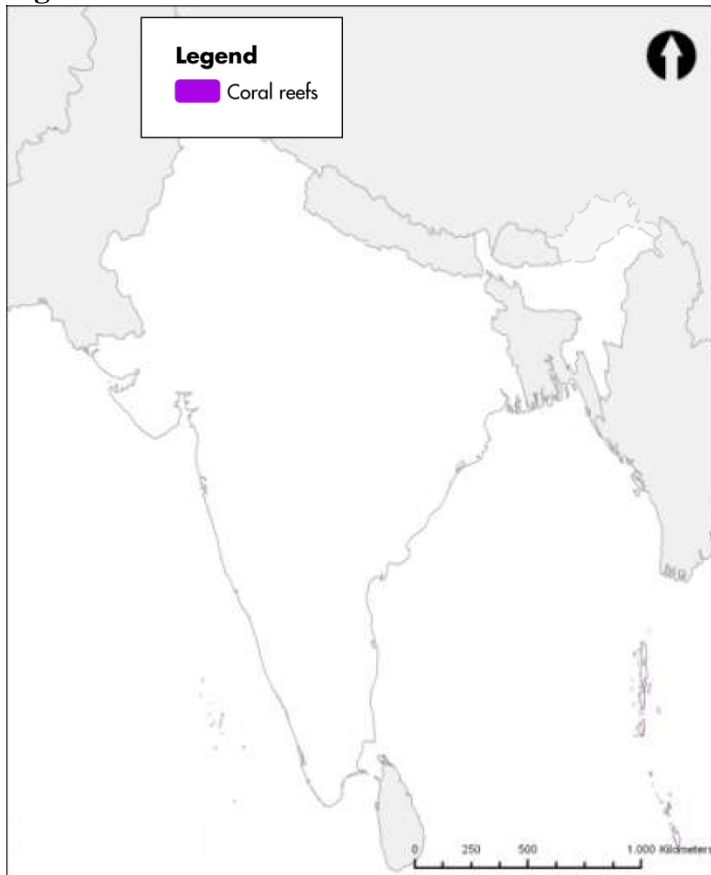
Services derived from coral reefs

51. The global database for coral reefs consists of 72 original studies, from which 163 separate value estimates were obtained. These studies cover the areas with known coral reefs quite well: the Caribbean, Indian Ocean, Southeast Asia, and Pacific. The ecosystem services included were recreational diving and snorkeling, other tourism activities, recreational and commercial fishing, coastal protection, coral mining, biodiversity (including biodiversity prospecting), and non-use values.

52. The meta-analysis (results given in Annex A) found the following variables to be relevant in determining the value per hectare of coral reefs: the size of the reef, the value of income produced within 50 km of the reef, the population resident within 50 km of the site, length of roads within 50 km of the site, the human appropriation of net primary production within 50 km of the site, and the area of other coral reefs within 50 km of the site.

53. The database identified 16,149 coral reefs globally, of which 281 were within the territory of India. Figure 7 shows the location of these patches in the country. They amount to 421,800 hectares. By applying the meta-analysis equation to each of these sites, a valuation of the services provided across the coral reefs in the country has been obtained.

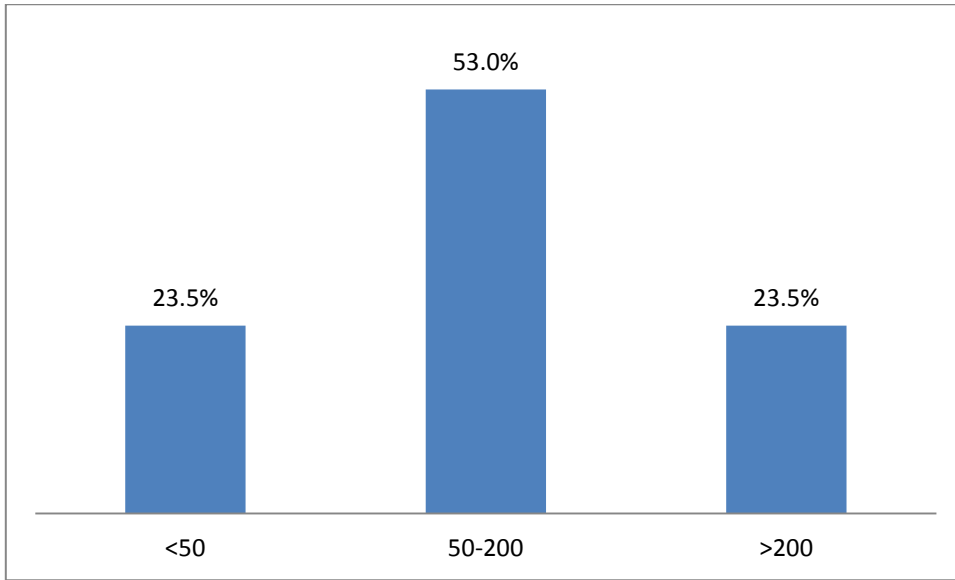
Figure 7: Coral Reefs off the Coast of India



Source: Staff extrapolation from NEA's global database

54. The range of values per hectare across the 333 sites is shown in Figure 8, the most common range being between Rs.50,000 and Rs.200,000 (US\$10,000 and US\$40,000) per hectare. Values can be as low as Rs.50,000 (US\$5000) per hectare and as high as Rs.5.7 million (US\$120,000). The average is Rs.711,455 (US\$14,978) per hectare. The total value of ecosystem services from grasslands in India is estimated to be Rs.299 billion (US\$6.3 billion).

Figure 8: Values of Coral Reefs in India (Rs.000/ha)



Source: Staff extrapolation from NEA's global database

V. Summary and Conclusions

55. This assessment has brought together the values of ecosystem services from the major biomes in India. Table 4 summarizes the findings, and includes a range of values to allow for uncertainty in the estimates, especially those derived from the benefit transfer method. The total value amounts to Rs.1.4 trillion (US\$29 billion) in 2009 as a central estimate, or about 3.0 percent of the country's GDP that year. The upper and lower bounds are Rs.746 (US\$16) billion and Rs.2,577 billion (US\$57), respectively, or 1.6 and 5.5 percent of GDP.

56. Of the total value, wetlands are the largest at 48 percent. Of the other services, coral reefs and forests each account for 22 percent (fodder alone accounts for 10 percent). These are followed by grasslands at 7 percent, and mangroves at 2 percent.

Table 4: Values of Ecosystem Services in India (Rs.m)

Biome/Service	Central Value	Lower Bound	Upper Bound	Central as % of Total
Forest carbon sequestration	40,565	-16,340	87,400	2.9%
Timber services	17,200	17,200	17,200	1.2%
Non-timber forest services	21,000	21,000	21,000	1.5%
Fodder	141,600	94,400	188,800	10.1%
Forest recreation services	51,200	51,200	51,200	3.7%
Water recharge services of forests	15,485	15,485	15,485	1.1%
Prevention of soil erosion by forests	6,413	6,413	6,413	0.5%
Non-use services of forests	15,675	14,250	17,100	1.1%
<i>Total services from forests</i>	309,138	203,608	404,598	22.2%
Grasslands	94,430	47,215	188,860	6.8%
Wetlands	665,950	332,975	1,331,900	47.7%
Mangroves	25,508	12,754	51,015	1.8%
Coral reefs	300,105	150,053	600,210	21.5%
Lakes and rivers	n.a.	n.a.	n.a.	n.a.
<i>Total</i>	1,395,130	746,604	2,576,583	100.0%

Source: Staff calculations

Some qualifications are in order to help interpret these figures.

- (i) The total value as a percentage of GDP (central estimate of 3 percent may seem small, but this can be misleading. Another way of looking at the role of environmental resources is in terms of the "GDP of the poor."¹³ The services

¹³ Gundimeda and Sukhdev (2008) introduced the concept "GDP of the poor." It includes GDP only from agriculture, forestry and fishery, since these sectors reflect the most growth potential for the rural poor in India, who comprise 72 percent of the total poor. Of course, not all income in these sectors goes to the poor, but possibly a higher percentage does than in most other sectors. A reviewer from MOEF has noted that while GDP of the poor is a useful theoretic construct, a meaningful analysis would have been to spatially explore the correlations between incidence of poverty and

become more significant when compared with the income of the poor. The growth potential for the poor is in the share of GDP generated in agriculture, forestry, and fishery, and this share constituted about 17 percent of GDP in 2010. Although not all services from these ecosystems are for the poor, a significant percentage of them are. If we exclude the values of carbon sequestration, coral reefs, and non-use values of forests, the remaining services amount to about 13 percent of GDP.

- (ii) A more accurate assessment of who benefits from ecosystem services is warranted. While some services clearly have global benefits (e.g., those from carbon sequestration) and others are clearly for local communities (e.g., those from grasslands, wetlands, non-timber, and fodder forest services), there are some that have different benefits for different stakeholders (e.g., those from timber and coral reefs). An attribution of how these benefits are distributed would be useful to policymakers.
- (iii) The magnitude of the benefits of the ecosystem services is less than the costs of environmental degradation, **which are estimated at around 6.6 percent of GDP (Strukova et al., 2011). One reason for the difference is the major role played by damage to environmental health from air and water pollution in the latter. Arguably the atmosphere provides provisioning ecosystem services in the form of clean air and water, but these have not been valued in the present exercise, or indeed in most estimates of the value of ecosystems.** Further work is needed to improve these estimates.
- (iv) The inclusion of services from lakes and rivers is also important, but more data are needed on household beneficiaries from lakes. We are also missing the value of bio-prospecting and some other services. The benefit transfer method should be replaced over time with local studies of benefits, although it is impossible to cover the hundreds of thousands of patches with individual studies, and some use of the benefit transfer method is inevitable. Finally, the forest estimates here are based on less of a bottom-up approach than that used for the grasslands, wetlands, mangroves and coral reefs. The forest values, however, are based on more local data, which is clearly an advantage. Eventually one would want to combine local data with the bottom-up approach.

ecosystem service values. This can then provide better insights into conservation targeting and prioritization. This is something to plan in future work.

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Annex A: Details of the Meta-Analysis Functions

Passive Use of Forests

Based on a review of this literature, Chiabai et al. (2011) identified¹⁴ 27 usable estimates of forest passive use values. The studies were conducted mainly in Europe and North America, although there were also studies from Brazil, China, Madagascar, and Israel. The estimated benefit transfer function is:

$$V_{WR} = V_{Eu}^* \left(\frac{N_{WR}}{N_{Eu}} \right)^\delta \left(\frac{S_{Eu}}{S_{WR}} \right)^\sigma \left(\frac{PPPGDP_{WR}}{PPPGDP_{Eu}} \right)^\gamma$$

The notations *WR* and *Eu* denote figures referring to, respectively, the *WR_{-th}* world region and the *study site* Europe region. V_{WR} is the estimated WTP stock value per hectare in the *WR_{-th}* world region. V_{Eu}^* is the WTP stock value per hectare for passive use in the *study site* world region. S denotes the forest area designated to conservation in the relevant region. N denotes the population of each region, and $PPPGDP$ indicates the GDP adjusted using PPP taken from the *World Development Indicators*.

The estimated values for the coefficients δ , σ and γ were 0.64, -0.39 and 0.74 respectively. All three were statistically significant.

Grasslands¹⁵

The mean of grasslands value in the original studies is US\$216/ha/yr and the median is US\$37/ha/yr. These values are low in comparison to those of the other biomes examined in the original study.

Given the very limited sample size of grassland ecosystem service values, the number of explanatory variables that can be included in the value function is also low. The explanatory variables included in the value function are GDP per capita; the area of grassland within a 50 km radius of the study site; the length of road within 50 km of the study site; and the accessibility index.

The estimated equation is given in Table A1. The estimated coefficients on the explanatory variables all have the expected signs but are only marginally statistically significant. The positive coefficient on the income variable (GDP per capita) indicates that grassland ecosystem services have higher values in countries with higher incomes; i.e., grassland ecosystem services are a normal good for which demand increases with income. The negative effect of grassland abundance (area of grassland within 50 km radius) on value indicates that the availability of substitute grassland areas affects the value of ecosystem

¹⁴ The review covered sources such as EconLit, EVRI database, and IUCN database for forest studies.

¹⁵ The discussion of the valuation functions for grasslands, wetlands, mangroves and coral reefs is taken directly from Hussain et al. (2011).

services from a specific patch of grassland. The negative effect of roads on grassland values captures the effect of fragmentation on the provision of ecosystem services from grassland. Grasslands that are more fragmented by roads tend to have lower values. The positive coefficient on the accessibility index indicates that grassland areas that are more accessible tend to have higher values. In this case, direct use values derived from grasslands (e.g., recreation and food provisioning) appear to dominate values that do not require access (e.g., wildlife conservation).

Table A1: Grassland Valuation Function

Variable name	Variable definition	Beta	Std. Error	Sig.
Constant		-2.366	5.094	0.444
GDPPC_LN	Natural log of country level GDP per capita (PPP US\$ 2007)	0.856	0.514	0.120
GRA50_LN	Natural log of area of grassland within 50km radius of study site	-0.029	0.142	0.839
RDS50_LN	Natural log of length of roads within 50km radius of study site	-0.225	0.213	0.309
SITES_AI	Accessibility index	2.590	1.322	0.072
N		17		
Adjusted R ²		0.27		

Source: Hussain et al. (2011).

Wetlands

The average wetland value is US\$4,774/ha/yr and the median is US\$250/ha/yr. The explanatory variables included in the value function are as follows: the area of the wetland study site; the GDP per capita of the country in which the study site is located; the area of lakes and rivers within a 50 km radius of the study site; the area of wetlands within 50 km of the study site; the population within 50 km; and the human appropriation of net primary product (HANPP) within 50 km.

The value function is presented in Table A2. The estimated coefficients on the explanatory variables all have the expected signs and are all statistically significant at the 5 percent level, except for HANPP, which is significant at the 10 percent level. The negative effect of the area of the wetlands indicates diminishing returns to scale for wetland values. In other words, the value of an additional hectare to a large wetland is of lower value than an additional hectare to a small wetland. The positive effect of the income variable (GDP per capita) indicates that wetland ecosystem services have higher values in countries with higher incomes; i.e., wetland ecosystem services are normal goods for which demand increases with income.

The positive effect of the area of lakes and rivers in the vicinity of a wetland indicates that lakes and rivers are complements to wetland ecosystem services; i.e., that the combination of surface water bodies results in higher-value ecosystem services. The negative effect of the size of other wetland areas in the vicinity of a wetland indicates substitution effects between wetlands. The ecosystem services from a specific wetland will be of higher value if there are fewer other wetlands in the vicinity.

The positive effect of population on the value of wetland ecosystem services relates to market size or demand for those services. A larger population in the vicinity of a wetland means that more people benefit from the services it provides. The negative effect of HANPP indicates the effect of ecosystem degradation on the value of services provided by wetlands. More intensive use and appropriation of environmental resources has a negative effect on the value of wetland services.

Table A2: Wetland Valuation Function

Variable name	Variable definition	Beta	Std. Error	Sig.
Constant		1.708	1.978	0.725
AREA_LN	Natural log of the study site area (ha)	-0.209	0.049	0.000
GDPPC_LN	Natural log of country level GDP per capita (PPP US\$ 2007)	0.610	0.106	0.000
LAK50_LN	Natural log of area of lakes and rivers within 50km radius of study site	0.159	0.081	0.050
WET50_LN	Natural log of area of wetlands within 50km radius of study site	-0.175	0.048	0.000
POP50_LN	Natural log of population within 50km radius of study site	0.426	0.106	0.000
HAN50_LN	Natural log of human appropriation of NPP within 50km radius of study site	-0.201	0.118	0.091
N		247		
Adjusted R ²		0.32		

Source: Hussain et al. (2011).

Mangroves

The average value of mangroves in the original studies is US\$803/ha/yr and the median is US\$220/ha/yr. The explanatory variables included in the value function are as follows: the area of the mangrove study site; the GDP per capita of the country in which the study site is located; the population within a 50 km radius of the site; the length of roads within 50 km; the area of mangroves within 50 km; the area of urban land use within 50 km; and the area of wetland within 50 km of the study site.

The value function is presented in Table A3. The estimated coefficients on the explanatory variables mostly have the expected signs and are all statistically significant at the 5 percent level, except for the length of roads variable, which is significant at the 10 percent level. The negative coefficient on the area of the mangrove indicates diminishing returns to scale. The positive effect of the income variable (GDP per capita) indicates that mangrove ecosystem services have higher values in countries with higher incomes. The positive effect of population on the value of mangrove services relates to market size or demand. A larger population in the vicinity of a mangrove means that more people benefit from the ecosystem services it provides.

The positive effect of the area of other mangroves on the value of a mangrove study site indicates that mangrove patches within a region are complementary. This suggests that isolated patches of mangrove are of lower value than more intact contiguous mangrove systems. The negative effect of the area of urban land uses in the vicinity of a mangrove reflects the associated effect of degradation on the value of ecosystem services. Similarly, the negative effect of roads on mangrove ecosystem services reflects the detrimental effects

of fragmentation. The negative coefficient on wetland area in the vicinity of a mangrove indicates substitution effects between wetlands and mangroves. The estimated value function is a relatively good fit with the data, with an adjusted R^2 of 0.41 showing that 41 percent of variation in mangrove values is explained by the model. This still means that 59 percent of variation in values is not explained by the variables included in the regression model.

Table A3: Valuation Function for Mangroves

Variable name	Variable definition	Beta	Std. Error	Sig.
Constant		-8.239	3.157	0.010
AREA_LN	Natural log of the study site area	-0.311	0.069	0.000
GDPPC_LN	Natural log of country level GDP per capita (PPP US\$ 2007)	1.499	0.218	0.000
POP50_LN	Natural log of population within 50km radius of study site	0.572	0.194	0.004
MAN50_LN	Natural log of area of mangrove within 50km radius of study site	0.208	0.083	0.014
URB50_LN	Natural log of urban area within 50km radius of study site	-0.382	0.173	0.029
RDS50_LN	Natural log of length of roads within 50km radius of study site	-0.317	0.182	0.084
WET50_LN	Natural log of area of inland wetland within 50km radius of study site	-0.158	0.064	0.016
N		111		
Adjusted R^2		0.41		

Source: Hussain et al. (2011).

Coral Reefs

The average coral reef value is US\$4,422/ha/yr and the median is US\$772/ha/yr. The explanatory variables included in the value function are as follows: the area of coral cover study site; the GDP per capita of the country in which the study site is located; the population within a 50 km radius of the site; the length of roads within 50 km; the human appropriation of net primary product within 50 km; the net primary product within 50 km; and the area of coral cover within 50 km of the study site.

The value function is presented in Table A4. The estimated coefficients on the explanatory variables all have the expected signs, but only the area of coral cover at the study site is statistically significant. The negative coefficient on the area of coral cover indicates diminishing returns to scale. The positive effect of the income variable (GDP per capita) indicates that coral reef ecosystem services have higher values in countries with higher incomes; i.e. coral reef ecosystem services are normal goods for which demand increases with income. This variable, however, is difficult to define and interpret clearly, since the beneficiaries of coral reef ecosystem services are often not from the country in which the reef is located. This is the case for most tourism and recreational services. The positive effect of population on the value of coral reef ecosystem services relates to market size or demand for ecosystem services. A larger population in the vicinity of a coral reef means

that more people benefit from the ecosystem services that it provides. The negative effect of the length of roads in the vicinity of a coral reef reflects the associated effect of fragmentation and degradation on shore. Similarly, the negative effect of HANPP indicates the extent of human exploitation of natural resources in the region. The conversion of natural land uses or cultivation of crops often results in increased sedimentation in coastal waters, which can negatively affect reefs. The negative coefficient on the area of coral reefs in the vicinity of a specific reef indicates substitution effects between patches of coral reef. In areas where coral reefs are abundant, the value of a specific patch of reef will be lower.

The adjusted R^2 is relatively low (0.18), indicating that the estimated model explains only 18 per cent of variation in coral reef values. There are clearly a number of important factors influencing the value of coral reefs that are not captured by this set of explanatory variables. The direction and magnitude of estimated effects of our set of explanatory variables do, nevertheless, follow theoretical expectations.

Table A4: Valuation of Coral Reefs

Variable name	Variable definition	Beta	Std. Error	Sig.
Constant		16.093	3.707	0.000
AREA_LN	Natural log of the study site area	-0.293	0.066	0.000
GCP50_LN	Natural log of Gross Cell Product within 50km radius	0.039	0.099	0.695
POP50_LN	Natural log of population within 50km radius of study site	0.238	0.154	0.125
RDS50_LN	Natural log of length of roads within 50km radius of study site	-0.035	0.107	0.743
HAN50_LN	Natural log of human appropriation of NPP within 50km radius of study site	-0.076	0.054	0.161
NPP50_LN	Natural log of NPP within 50km radius of study site	-0.379	0.287	0.189
COR50_LN	Natural log of area of coral reef within 50km radius of study site	-0.207	0.231	0.372
N		163		
Adjusted R^2		0.18		

Source: Hussain et al. (2011).