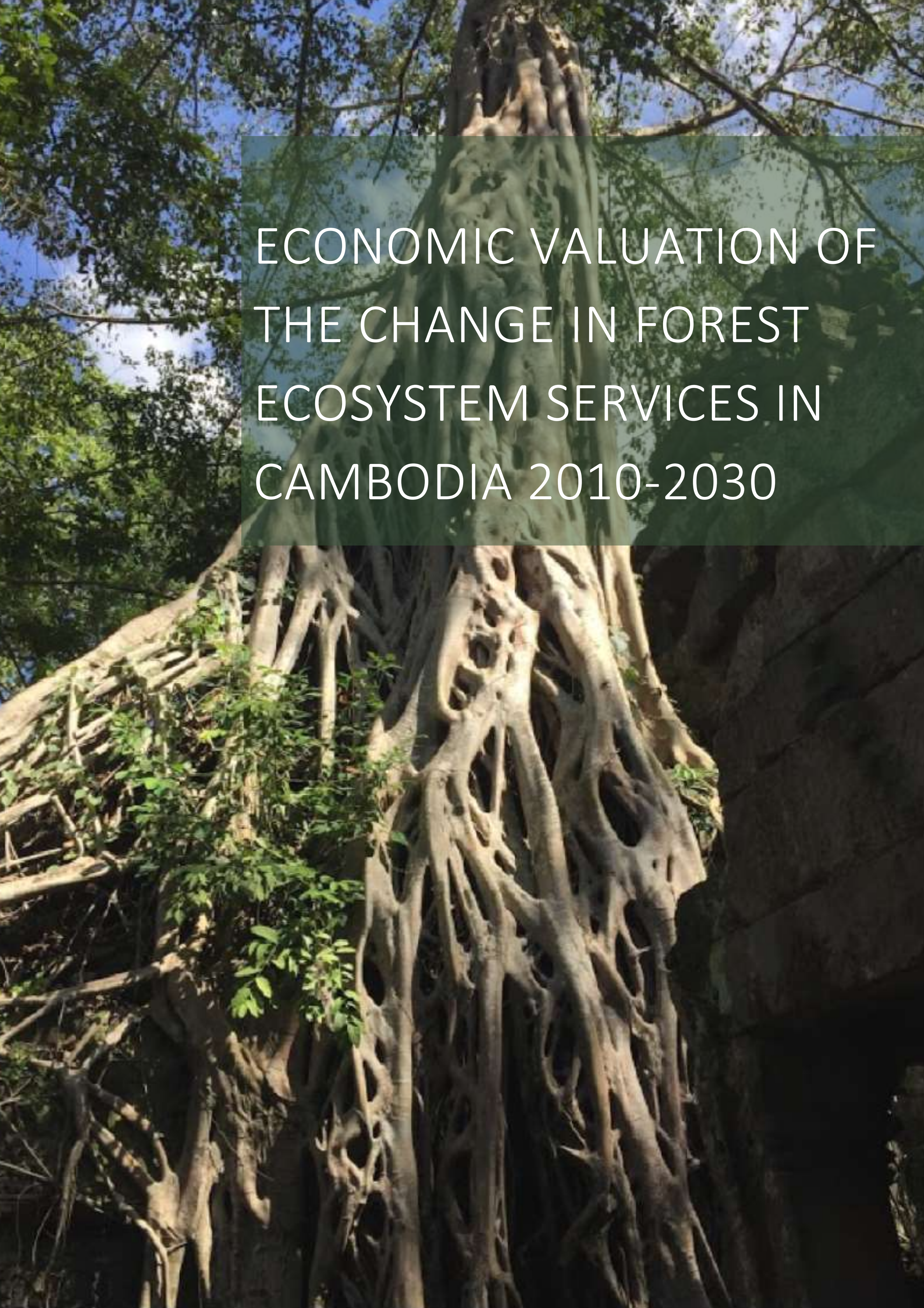
ECONOMIC VALUATION OF THE CHANGE IN FOREST ECOSYSTEM SERVICES IN CAMBODIA 2010-2030



CONTENTS

EXECUTIVE SUMMARY

Forests in Cambodia provide a number valuable ecosystem services that contribute to human wellbeing, including provisioning (e.g., timber, fuel wood and charcoal), regulating (e.g., flood and erosion control; carbon sequestration and storage), habitat (e.g., for wildlife), and cultural services (e.g., tourism, recreation, aesthetic, non-use values).

The purpose of this report is to assess the economic value of the change in the provision of ecosystem services from forests in Cambodia over the period 2010-30 under a continuation of current trends of land use change.

For Cambodia as a whole, the projected loss in forest area during the period 2010-2030 is just over 1.2 million hectares or 11.7% of the area in 2010 (based on continuing trends from 2006-2010 derived from Forestry Administration maps). Some provinces are projected to experience much larger changes in forest area than others. For example, Battambang and Oudor Meanchey are projected to lose 214,000 (67%) and 190,000 (43%) hectares respectively between 2010 and 2030.

The costs of carbon emissions from land use change during the period 2010-2030 is estimated to be approximately US$ -3.2 billion. The benefits of carbon storage, however, are global and do not accrue to land users/owners in Cambodia in the absence of an international climate agreement that enables payments for avoided carbon emissions.

The sum of losses in other forest ecosystem services over the period 2010-2030 is approximately US$ -1.6 billion. Battambang and Oudor Meanchey are expected to suffer annual losses in 2030 of US$ 82 million and US$ 47 million respectively.

This information on the economic value of future land use change provides evidence of the need for careful management of Cambodia's forest resources. Allowing even modest deforestation results in substantial loss of valuable ecosystem services.

1. INTRODUCTION

Forests in Cambodia provide a number valuable ecosystem services that contribute to human wellbeing, including provisioning (e.g., timber, fuel wood, and charcoal), regulating (e.g., flood and erosion control; carbon sequestration and storage), habitat (e.g., for wildlife), and cultural services (e.g., tourism, recreation, aesthetic, non-use values) (TEEB, 2010; Soussan and Sam, 2011). Many of these ecosystem services have the characteristics of 'public goods' such that the people who benefit cannot be excluded from receiving the service provided (e.g., downstream flood mitigation by upstream forests); and that the level of consumption by one beneficiary does not reduce the level of service received by another (e.g., climate regulation). Due to these characteristics, the potential for private incentives to sustainably manage forest ecosystem services is limited and markets for such services do not exist. In other words, there is a 'market failure' and by their inherent nature, forest ecosystem services are under supplied by the market system.[1]

As a result, forests are generally undervalued in both private and public decision-making relating to their use, conservation and restoration. The lack of understanding of (and information on) the values of forest ecosystem services has generally led to their omission in public decision making. Without information on the economic value of forest ecosystem services that can be compared directly against the economic value of alternative public investments (for example in a cost-benefit analysis of land conversion to agriculture), the importance of forests as natural capital tends to be ignored.[2] A number of studies have developed and applied methods to calculate the monetary value of specific forest ecosystems in Cambodia (e.g., Grogan et al., 2009; Sousan and Sam, 2011). Although these studies provide some insight into the range of values that may be assigned to the ecosystem services provided by forests, they are context specific and do not provide a more general overview of the values of forests in Cambodia.

Forest cover was approximately 58% of total land area in Cambodia in 2010 (Forestry Administration, 2011). Cambodian forests comprise a number of different types including evergreen, semi-evergreen and deciduous dipterocarp (a family of tall hardwood tropical tree). Figure 1 presents the area of each forest type and non-forest land cover in

[1] In general, provisioning services such as timber and fuelwood extraction are private goods. In the case that property rights for such resources are defined and enforced, markets and private incentives to sustainably manage them may exist.

[2] It should be noted that the analysis presented in this report employs an economic definition of value in which human preferences for all ecosystem services can be measured in monetary units. This allows the aggregation of values across ecosystem services and the comparison of values for ecosystem services with the values of other goods and services in the economy. It should be noted, however, that some ecosystem services may be very difficult to quantify in monetary terms (e.g. non-use values) and that other conceptualizations of 'value' (e.g. non-anthropocentric concepts of intrinsic values for nature) fall outside of this theoretical framework. Other concepts of value may, in some contexts, be useful for promoting sustainable forest management.

2010.[3] Forests in Cambodia face a number of threats, including logging, fragmentation and conversion to agriculture. The main drivers underlying these threats are increasing populations and economic development. Forests are being converted to other land uses, in particular to agriculture and plantation.

The purpose of this report is to assess the economic value of the change in the provision of ecosystem services from forests in Cambodia over the period 2010-30 under a baseline scenario of land use change. The baseline scenario describes a continuation of current trends of land use change. The analysis attempts to provide a first estimate of the value of forest ecosystem services that is lost (or gained) due to continuing trends of forest loss (gain).[4] In most regions, Cambodia is experiencing a reduction in the area of its forests (see section 4) and so this analysis highlights the cost (forgone benefits) of allowing forests to be converted to other uses. The analysis does not assess the benefits of this land use change (i.e. the value of timber or increase in agricultural land).

The structure of the remainder of this report is as follows. The next section provides an explanation of the methodology used to estimate the change in value of forest ecosystem services. The third section describes the value function for tropical forest ecosystem services. The fourth section provides a description of the change in forest area by province under a baseline scenario for three time horizons: 2015, 2020 and 2030. The fifth section presents the estimated values for forest ecosystem services by province. Finally, the sixth section provides a discussion and draws some conclusions.

[3] Annex 3 provides a detailed description of each forest type.

[4] The analysis attempts to be as comprehensive as possible in terms of the range of forest ecosystem services that are valued but due to data limitations, it is not possible to cover all relevant ecosystem services or report values separately for each service.

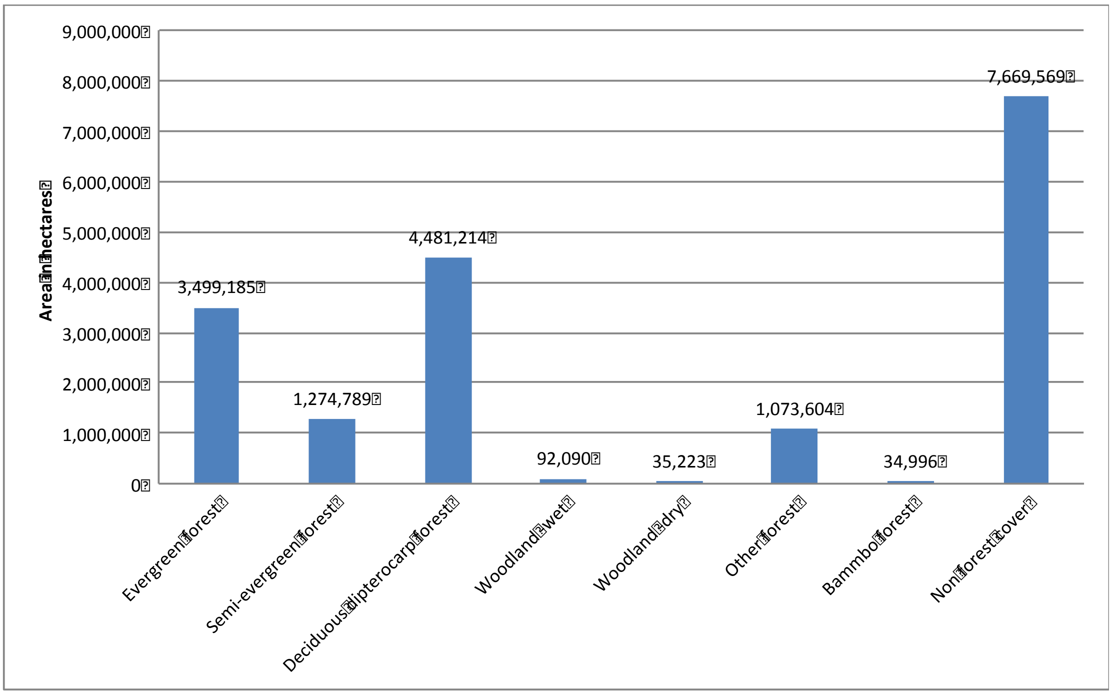


Figure 1. Area of forest types and non-forest land cover in 2010. Source: Forestry Administration (2011)

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2. METHODOLOGY

Separate methods are used for estimating the value of carbon storage and other ecosystem services. The reason for treating carbon storage separately is that as a global pollutant, the economic value of carbon emissions does not vary spatially, whereas the economic value of other ecosystem services is highly spatially variable and requires the use of valuation methods that reflect this.[5]

The methodology used to estimate the change in value of non-carbon ecosystem services due to change in the extent of forests in Cambodia over the period 2010-2030 follows the following steps:

1. Conduct a meta-analysis of monetary estimates of forest ecosystem service values and estimate a value function that relates ecosystem service value to the characteristics of the ecosystem and its surroundings (see section 3).
2. Using GIS, develop a database of forest ecosystems in Cambodia containing information on the variables included in the value function estimated in step 1 (see section 4).
3. Develop a baseline scenario for the change in the spatial extent of forest ecosystems in Cambodia for the period 2010-2030. This baseline scenario is spatially variable to reflect variation in pressures on forest ecosystems (see section 4).

Combine the models and data generated in steps 1-3 to produce estimates of the value of the change in forest ecosystem services under the baseline scenario. This approach allows the estimation of values that are specific to the characteristics and context of each patch of forest ecosystem (see section 5).

Steps 1 and 2 are represented in Figure 2. More detail on the value transfer approach is provided in Appendix 1.

[5] The values of forest ecosystem services are unlikely to be the same for each patch of forest ecosystem in the country and may be expected to vary with the size of the ecosystem, availability of substitute ecosystems nearby, and the number of beneficiaries that live nearby and make use of the ecosystem services. The analysis explicitly attempts to account for such (spatial) variation in the value of ecosystem services produced by each patch of forest.

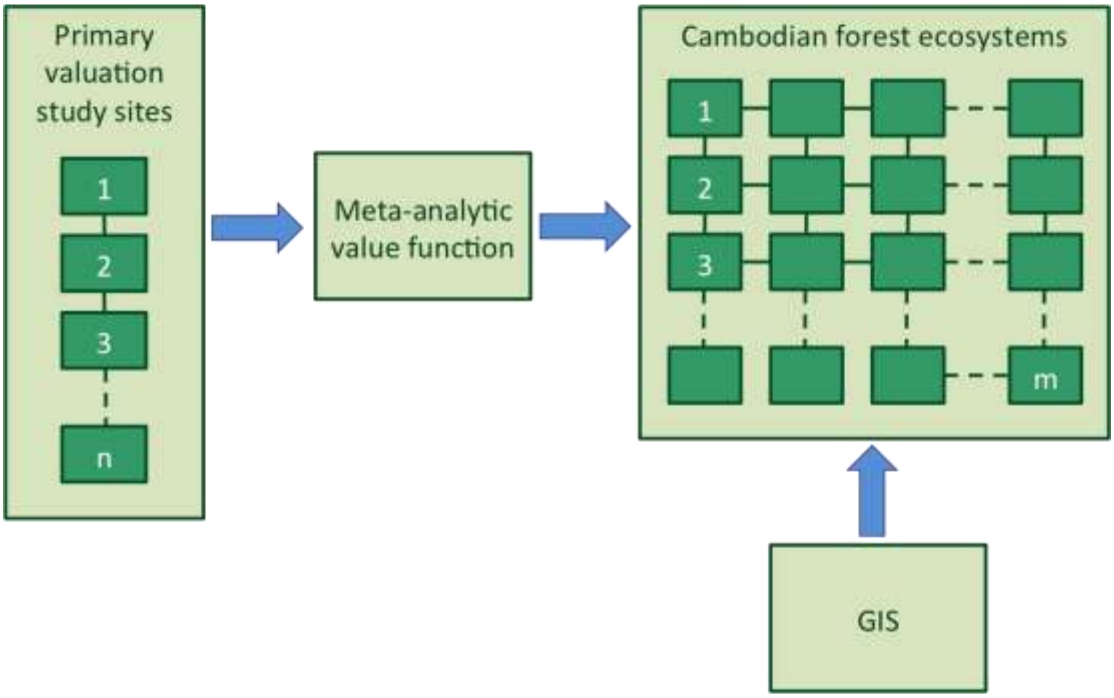

Figure 2. Methodology for transferring ecosystem service values for Cambodian forests

The method used for valuing changes in the quantity of carbon stored in forests follows GEF (2013).[6] This method involves the following steps:

1. Compute the change in quantity of carbon stored due to the change in forest area. The average amount of carbon stored in forest in Cambodia is 250 metric tonnes per hectare (FAO, 2010). The change in quantity of carbon stored following deforestation depends on the replacement land use. Assuming that the replacement land use is plantation forestry, the quantity of stored carbon will decline by 50-90% over a 20 year time horizon (Lasco and Puhlin, 2004). For each year of the analysis we multiply the change in area of forest cover by 70.5 and 130.5 (tC/ha) to obtain lower and upper bound estimates for the change in quantity of stored carbon.
2. Obtain estimates of the value of carbon emissions from available climate change integrated assessment models. Following Hussain et al. (2011), we use estimates of the social cost of carbon estimated by the RICE

[6] Here we value the change in stock of stored carbon or equivalently the flow of emissions. Valuing the entire stock of stored carbon is arguably not policy relevant information since there is no policy scenario under which the entire stock of carbon would be released.

model (Nordhaus and Yang, 1996).[7] Lower and upper bound estimates are 10 and 22 US$/tCO2-e for emissions in 2020. Note that these costs are in tonnes of CO2-e (CO_2 equivalent[8]) so it is necessary to convert quantities of carbon to the same units using the factor 3.67 (i.e. 1 tC = 3.67 x 1 tCO2-e).

3. Multiply the change in the amount of carbon stored by the social cost of carbon. As a sensitivity analysis we compute four possible combinations of parameter values: 1. low carbon emissions; low social cost of carbon; 2. high carbon emissions; low social cost of carbon; 3. low carbon emissions; high social cost of carbon; 4. high carbon emissions; high social cost of carbon. Note that the resulting values are total present values of avoided climate change damage and not annual values (in contrast to the estimated values for non-carbon ecosystem services). In other words, the estimated values represent the cumulative change in carbon storage in each year of the analysis.

[7] The social cost of carbon (SCC) is the monetary value of damages caused by emitting one more tonne of CO_2 in a given year (Pearce, 2003). The SCC therefore also represents the value of damages avoided (i.e. the benefit) for a small reduction in emissions. The SCC is intended to be a comprehensive estimate of climate change damages but due to current limitations in the integrated assessment models and data used to estimate SCC, it does not include all important damages and is likely to under-estimate the full damages from CO_2 emissions.

[8] Expressing quantities of greenhouse gases in terms of CO2 equivalent global warming potential allows them to be directly compared. This is the standard unit used to measure greenhouse gas emission and associated damage costs.

2. 1 VALUE FUNCTION FOR TROPICAL FOREST ECOSYSTEM SERVICES

The TEEB database[9] was used to obtain 103 value estimates for tropical forest ecosystem services. These value estimates represent a variety of different ecosystem services and have been derived using a variety of different primary valuation methods. Table 1 summarises the ecosystem service categories represented by the values. The main provisioning services covered in the data are non-timber forest products (NTFP), particularly food resources, and the provision of raw materials. A number of different regulating services are covered, including climate regulation, moderation of extreme events, regulating water flow, waste treatment, erosion prevention and pollination. Many of the underlying valuation studies for tropical forests attempt to value a wide range of ecosystem services. In two cases, the value reported by a study is for the Total Economic Value of the forest ecosystem.[10] It should be noted that relatively few studies have estimated values for cultural services. In particular, there are very few estimates for non-use values, which in consequence means that the values that are transferred in our analysis also do not reflect non-use values. For this reason, the values produced by our analysis may be considered to be partial or under-estimates of Total Economic Value.

Table 2 summarises the primary valuation methods used to estimate tropical forest ecosystem services. 40% of the value estimates were derived using market values. For example, for NTFP these would reflect either the market values of selling those products or the market cost of substitutes. 23% of tropical forest values reflect production function or net factor income values for regulating services. Site locations are represented in Figure 1 (note that multiple values may have been obtained for individual sites).

[9] See De Groot et al. (2012) for a description of the TEEB database.

[10] The *Total Economic Value* (TEV) of an ecosystem encompasses all of the benefits humans receive from an ecosystem. The components of TEV are direct use values (e.g. recreation, aesthetic enjoyment, timber, fuelwood), indirect use values (e.g. climate regulation, flood control), and non-use values (the values associated with knowing that an ecosystem exists or will be available for future generations).

Table 1 Ecosystem services covered in the value data

Ecosystem service category	Number of value estimates
Provisioning services	43
Regulating services	32
Cultural services	22
Supporting services	4
Total economic value	2

Table 2 Valuation methods

Valuation method	Number of value estimates
Contingent valuation	10
Contingent ranking	0
Choice experiment	2
Group valuation	1
Hedonic pricing	0
Travel cost	8
Replacement cost	1
Factor income / Production function	24
Market price	41
Opportunity cost	0
Avoided cost	15
Other/unknown	1
Total	103

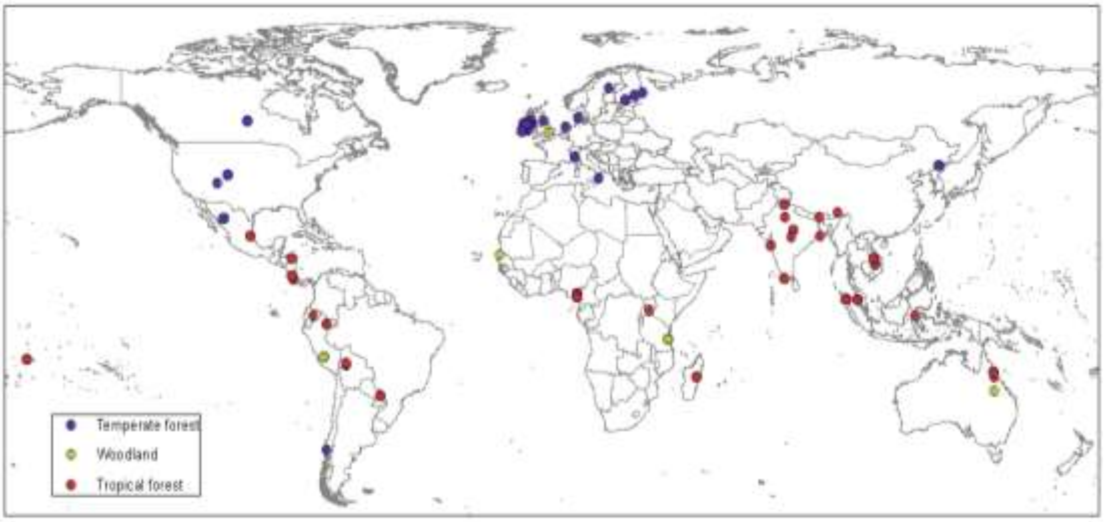

Figure 1. Forest study site locations

These data on the value of forest ecosystem services is then used in a statistical meta-analysis to estimate a value function that relates the value of the ecosystem service to the characteristics of the ecosystem and other context variables. Table 3 summarises the dependent and explanatory variables used in the meta-analysis. Table 4 presents the estimated meta-analytic value function. The value function includes variables for the area of forest within 50km of the study site and the length of roads within 50km; both of these have negative signs. For the former variable we suggest that this can be interpreted as the effect of having substitute sites in the same area that can provide a similar range of ecosystem services. The negative sign on the variable measuring the length of roads within 50km of each study site suggests that this might reflect the degree of forest fragmentation. The positive estimated coefficients on the variables representing income (gross cell product[11] within 50km) and population (urban area within 50km) suggest that the value of forest ecosystem services increases with this variables.

The adjusted R^2 figure indicates that 39.2% of observed variation in ecosystem service value is explained by the model. With the exception of the variables for human appropriation of net primary production and length of road, all the explanatory variables are significant at either the 5% or 10% level.

[11] Gross cell product is a spatially disaggregated measure of economic activity. The sum of gross cell product over the territory of a country would be equivalent to national gross domestic product (GDP).

Table 3 Dependent and explanatory variables for tropical forests.

Variable name	Variable definition	Mean	Median	Std. Deviation	Minimum	Maximum
VALUE_07	Site value 2007 US$/ha/annum	444.98	14.86	1612.03	0.01	11706.50
LN_VAL	Natural log of site value US$/ha/annum	3.28	2.76	2.22	0.01	9.37
LN_AREA	Natural log of the study site area	11.68	12.06	2.82	1.10	16.59
LN_GCP50	Natural log of Gross Cell Product within 50km radius	5.51	5.11	1.93	0.00	8.90
LN_URB50	Natural log of urban area within 50km radius of study site	2.07	1.10	1.79	0.00	6.42
LN_HAN50	Natural log of human appropriation of NPP within 50km radius of study site	14.06	13.97	0.84	12.28	15.72
LN_FOR50	Natural log of area of forest within 50km radius of study site	7.96	8.47	1.84	0.00	8.95
LN_RDS50	Natural log of length of roads within 50km radius of study site	8.52	9.10	2.18	0.00	10.02

Table 4: Tropical forest value function.

Variable name	Variable definition	Beta	Std. Error	Sig.
Constant		12.960	4.071	0.002
LN_AREA	Natural log of the study site area	-0.230	0.070	0.001
LN_GCP50	Natural log of Gross Cell Product per capita within 50km radius	0.402	0.173	0.022
LN_URB50	Natural log of urban area within 50km radius of study site	0.424	0.121	0.001
LN_HAN50	Natural log of human appropriation of NPP within 50km radius of study site	-0.394	0.292	0.181
LN_FOR50	Natural log of area of forest within 50km radius of study site	-0.336	0.202	0.100
LN_RDS50	Natural log of length of roads within 50km radius of study site	-0.204	0.131	0.124
N		102		
Adjusted R^2		0.392		

2. 2 CHANGE IN FOREST AREA

To define a baseline scenario for forest change for the period 2010-2030, we use a continuation of past trends of change in forest area at the provincial level. Province level annual rates of change in forest area are computed using data on the extent of forest cover in 2006 and 2010.[12] Using these change factors and patch level data on forest area (Forestry Administration, 2011), we calculate the change in area of each patch of forest for the period 2010-2030. The aggregated area of forest in each province in 2010, 2015, 2020 and 2030 is presented in Table 5 and Figure 2.

For the country as a whole, the projected loss in forest area is just over 1.2 million hectares or 11.7% of the area in 2010. Some provinces are projected to experience much larger changes in forest area than others due to a combination of high forest cover and high rates of deforestation. For example, Battambang and Oudor Meanchey are projected to lose 214,000 (67%) and 190,000 (43%) hectares respectively between 2010 and 2030.

For each of the 21,311 forest patches in Cambodia that are included in the database, spatial data is used to obtain information on the site characteristics (forest size), bio-physical context (forest abundance and road density within 50 km) and socio-economic characteristics of beneficiaries (GCP within 50km). The GIS processing to obtain these variables is described in Appendix 2.

[12] Annual rates of change in forest cover (r) for each province (i) are computed as: $r_i = ((F_{i2006} - F_{i2010}) / F_{i2006}) / (2010\text{-}2006)$; where F_i is the total area of forest cover in each province. In applying these annual rates of change in forest cover to project future changes in forest cover (in 2015, 2020 and 2030) we compute change factors that reflect compounded annual changes. These change factors (c) for each province (i) are computed as: $c_i = (1 + r_i)$^(t - 2010); where t is the year of analysis (i.e., 2015, 2020 or 2030).

Table 5 Total area of forest by province (hectares)

Province	2010	2015	2020	2030
Banteay Meanchey	108,959	77,359	54,923	27,685
Battambang	319,921	242,556	183,900	105,711
Kep	174,449	169,293	164,288	154,719
Kampong Cham	162,384	154,528	147,053	133,169
Kampong Chhnang	349,942	353,946	357,997	366,237
Kampong Speu	615,016	604,237	593,647	573,019
Kampong Thom	156,744	155,465	154,195	151,687
Kampot	17,946	17,209	16,501	15,172
Kandal	3,142	2,901	2,678	2,282
Koh Kong	881,755	877,190	872,647	863,634
Kratie	866,244	828,349	792,111	724,322
Mondul Kiri	1,097,919	1,090,852	1,083,831	1,069,924
Oudor Meanchey	444,358	385,526	334,483	251,776
Pailin	24,418	20,231	16,761	11,506
Preah Sihanouk	218,099	229,864	242,263	269,103
Preah Vihear	1,236,032	1,202,324	1,169,535	1,106,616
Prey Veng	6,545	4,653	3,309	1,673
Pursat	1,079,819	1,065,641	1,051,649	1,024,214
Rotanak Kiri	931,358	915,985	900,866	871,373
Siem Reap	508,604	463,097	421,661	349,581
Stung Treng	1,191,480	1,163,568	1,136,310	1,083,695
Svay Rieng	14,811	19,400	25,410	43,595
Takeo	46,086	43,392	40,855	36,218
Total	10,456,032	10,087,563	9,766,874	9,236,913

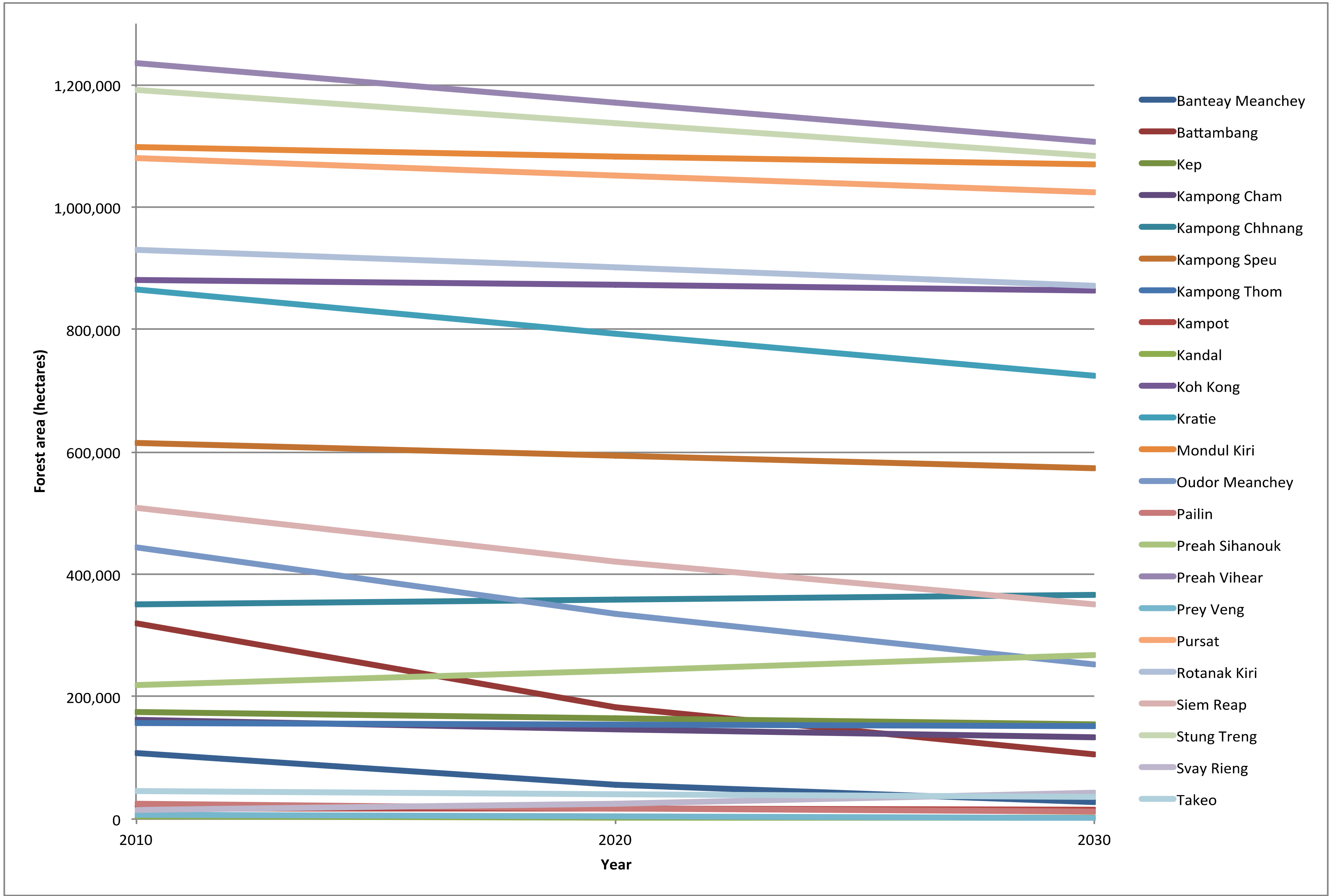

Figure 2. Total area of forest by province, 2010-2030

2.3 VALUE OF CHANGE IN THE PROVISION OF FOREST ECOSYSTEM SERVICES

At the level of individual patches of forest, patch specific parameter values are substituted into the meta-analytic value function to estimate values of ecosystem services per unit area (US$/ha/annum) for each patch. These estimates are then used to calculate the value of the projected change in area of each patch. For the country as a whole, the mean annual value of ecosystem services provided by a hectare of forest is estimated to be US$/ha/annum 511 in 2010, rising to US$/ha/annum 929 in 2030.[13] The increase in the annual unit value (value per hectare) of forest ecosystem services over time is driven by increasing scarcity of forests and increasing incomes. To put these estimated values in perspective, we can compare them to the value of agricultural land in Cambodia. Based on a sample of current agricultural land prices, the annualised value of agricultural land per hectare is computed to be approximately US$/ha/annum 450[14], which suggests that on average Cambodian forests are at least as economically productive as agricultural land. To put our estimated values for Cambodian forest ecosystem services in perspective with estimates published in the economic literature, De Groot et al. (2012) report average values for individual forest ecosystem services ranging from US$/ha/annum 3–2,044 and compute a total value of a bundle of all ecosystem services to be US$/ha/annum 5,264. This figure is substantially higher than the estimates produced in our analysis. It should be noted, however, that the De Groot et al. (2012) calculation implicitly assumes that each hectare of forest provides all ecosystem services, which is unlikely to be the case. Our analysis, on the other hand, makes the more conservative assumption that each hectare of forest provides ecosystem services in proportion to how well represented those services are in the underlying primary valuation literature (see Table 1).[15] Moreover, our analysis accounts for spatial variation in the value of ecosystem services reflecting the fact that not all forests provide ecosystem services to the same extent.

Changes in the value of non-carbon forest ecosystem services, aggregated to the provincial level, are presented in Table 6 and Figure 3. An uncertainty analysis of the estimated values is provided in Annex 4. Comparing the 2010 stock of forest to the projected 2030 stock, the change in annual value of ecosystem services from forests in Cambodia is estimated to be approximately

[13] These national levels mean annual values are computed as the average of the patch level annual values estimated using the meta-analytic value function.

[14] This estimate is based on a mean price of agricultural land of US$/ha 3,462; and computing an annualised value assuming a 10 year time horizon and a discount rate of 5%.

[15] This assumption may therefore reflect any bias in the primary valuation literature regarding the selection of ecosystem services that are valued but in the absence of information on the actual mix of ecosystem services provided by each forest patch, we prefer to make this conservative assumption.

US$ -300 million in 2030 (2007 prices). Note that this is the lost value of ecosystem services in a single year. The present value[16] of changes in forest ecosystem service provision over the period 2010-2030 using a discount rate of 5% is approximately US$ -1.6 billion (2007 prices).

At a provincial level, the annual value of foregone forest ecosystem services follows the pattern of loss of area, with Battambang and Oudor Meanchey expected to suffer the highest losses. Two provinces, Preah Sihanouk and Svay Rieng, are projected to experience small increases in the value of forest ecosystem services due to expansion of forest area.

The value of changes in carbon storage in Cambodian forests, aggregated to the provincial level, are presented in Table 7 and Figure 4. These estimates are based on assumed low net change in carbon storage (i.e. -50%) and low social cost of carbon (i.e. US$ 10/CO_2-e). In other words, we use conservative assumptions. A sensitivity analysis of the estimated values using alternative parameter values is provided in Annex 5. Comparing the 2010 stock of forest to the projected 2030 stock, the cost of carbon emissions from land use change is estimated to be approximately US$ -3.2 billion (2007 prices). It is important to note that the values reported in Table 7 are total present values of avoided climate change damage and not annual values (such as those presented in Table 6). Comparing like-with-like (i.e. present values of changes in the provision of non-carbon ecosystem services with those for changes in carbon storage) reveals that carbon storage is approximately twice as valuable as all other ecosystem services combined. The combined present value of the change in carbon and non-carbon ecosystem services for the period 2010-2030 is approximately US$ 4.8 billion (2007 prices).

[16] The calculation of the present value of a stream of values that are incurred in the future involves discounting. The practice of accounting for time preference is called discounting and involves putting a higher weight on current values. There are two motivations for this higher weighting of current values. The first is that people are impatient and simply prefer to have things now rather than wait to have them in the future. The second reason is that, since capital is productive, a dollar's worth of resources now will generate more than a dollar's worth of goods and services in the future.

Table 6 Annual value of change in forest ecosystem service provision in Cambodia for selected years: 2015, 2020, 2030 (US$/year; 000's; 2007 prices)

Province	2015	2020	2030
Banteay Meanchey	-9,370	-19,243	-44,579
Battambang	-17,404	-35,813	-81,514
Kep	-1,253	-2,643	-5,986
Kampong Cham	-1,356	-2,852	-6,436
Kampong Chhnang	412	875	2,000
Kampong Speu	-1,589	-3,359	-7,626
Kampong Thom	-210	-444	-1,011
Kampot	-283	-595	-1,345
Kandal	-113	-236	-530
Koh Kong	-520	-1,101	-2,506
Kratie	-4,968	-10,456	-23,614
Mondul Kiri	-858	-1,818	-4,138
Oudor Meanchey	-10,195	-21,191	-47,483
Pailin	-1,182	-2,445	-5,487
Preah Sihanouk	2,139	4,580	10,609
Preah Vihear	-3,650	-7,704	-17,453
Prey Veng	-1,541	-3,164	-7,328
Pursat	-1,459	-3,086	-7,013
Rotanak Kiri	-3,048	-6,446	-14,641
Siem Reap	-7,395	-15,458	-34,697
Stung Treng	-3,668	-7,745	-17,561
Svay Rieng	2,226	5,033	13,169
Takeo	-536	-1,125	-2,534
Total	-65,819	-136,436	-307,705

Table 7 Present value of change in forest carbon storage in Cambodia (US$; 000's; 2007 prices)

Province	2010 – 2015	2010 – 2020	2010 – 2030
Banteay Meanchey	-84,080	-143,776	-216,249
Battambang	-205,849	-361,918	-569,959
Kep	-13,721	-27,036	-52,498
Kampong Cham	-20,902	-40,792	-77,733
Kampong Chhnang	10,655	21,432	43,358
Kampong Speu	-28,681	-56,860	-111,744
Kampong Thom	-3,405	-6,783	-13,455
Kampot	-1,963	-3,846	-7,382
Kandal	-643	-1,236	-2,289
Koh Kong	-12,148	-24,234	-48,217
Kratie	-100,831	-197,250	-377,619
Mondul Kiri	-18,802	-37,483	-74,486
Oudor Meanchey	-156,538	-292,350	-512,412
Pailin	-11,142	-20,373	-34,358
Preah Sihanouk	31,302	64,293	135,708
Preah Vihear	-89,688	-176,931	-344,343
Prey Veng	-5,032	-8,610	-12,963
Pursat	-37,724	-74,953	-147,950
Rotanak Kiri	-40,903	-81,131	-159,605
Siem Reap	-121,083	-231,332	-423,119
Stung Treng	-74,266	-146,793	-286,789
Svay Rieng	12,210	28,202	76,586
Takeo	-7,168	-13,917	-26,255
Total	-980,402	-1,833,676	-3,243,772

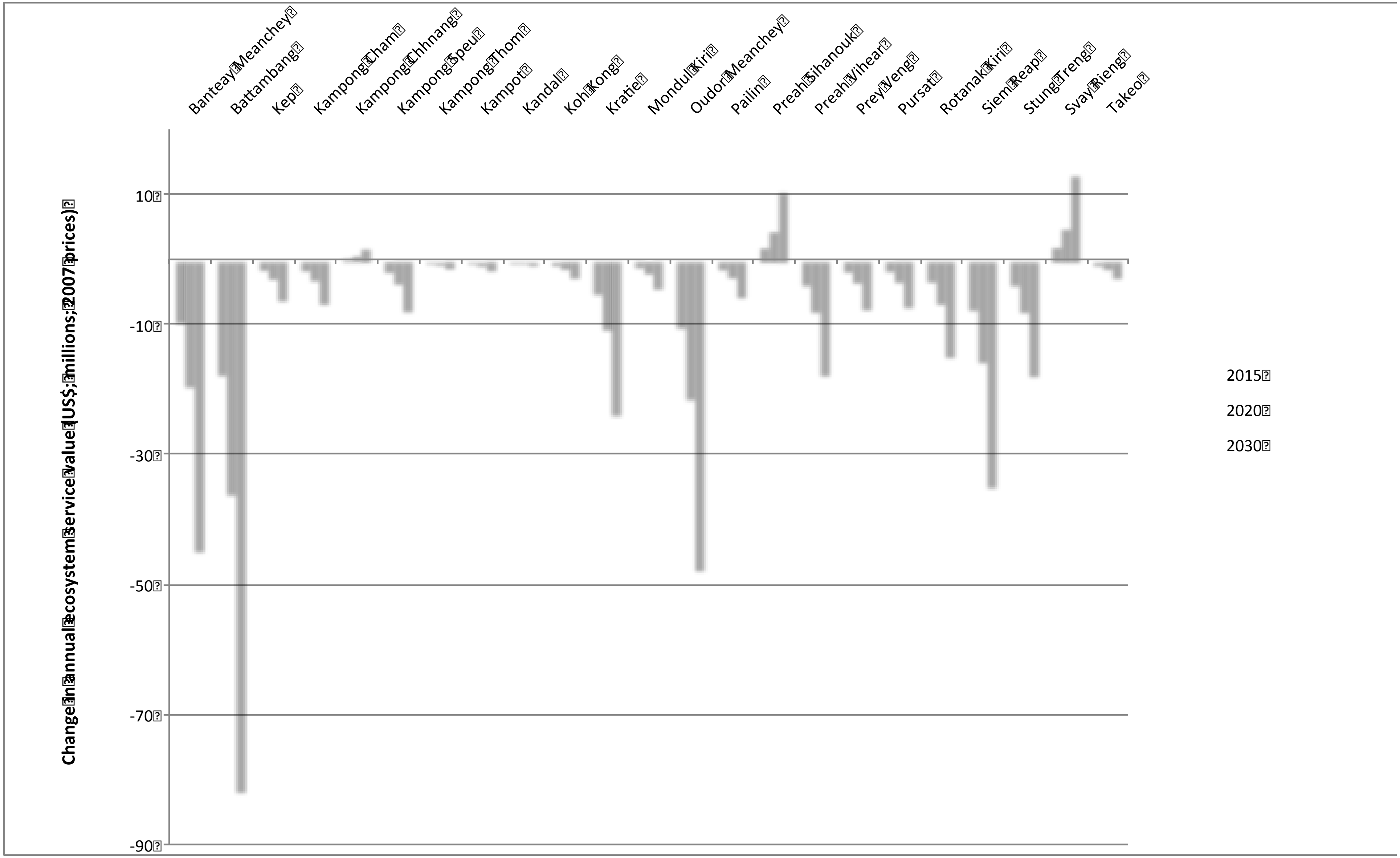

Figure 3a. Change in annual value of forest ecosystem services by province (US$; 2007 prices)

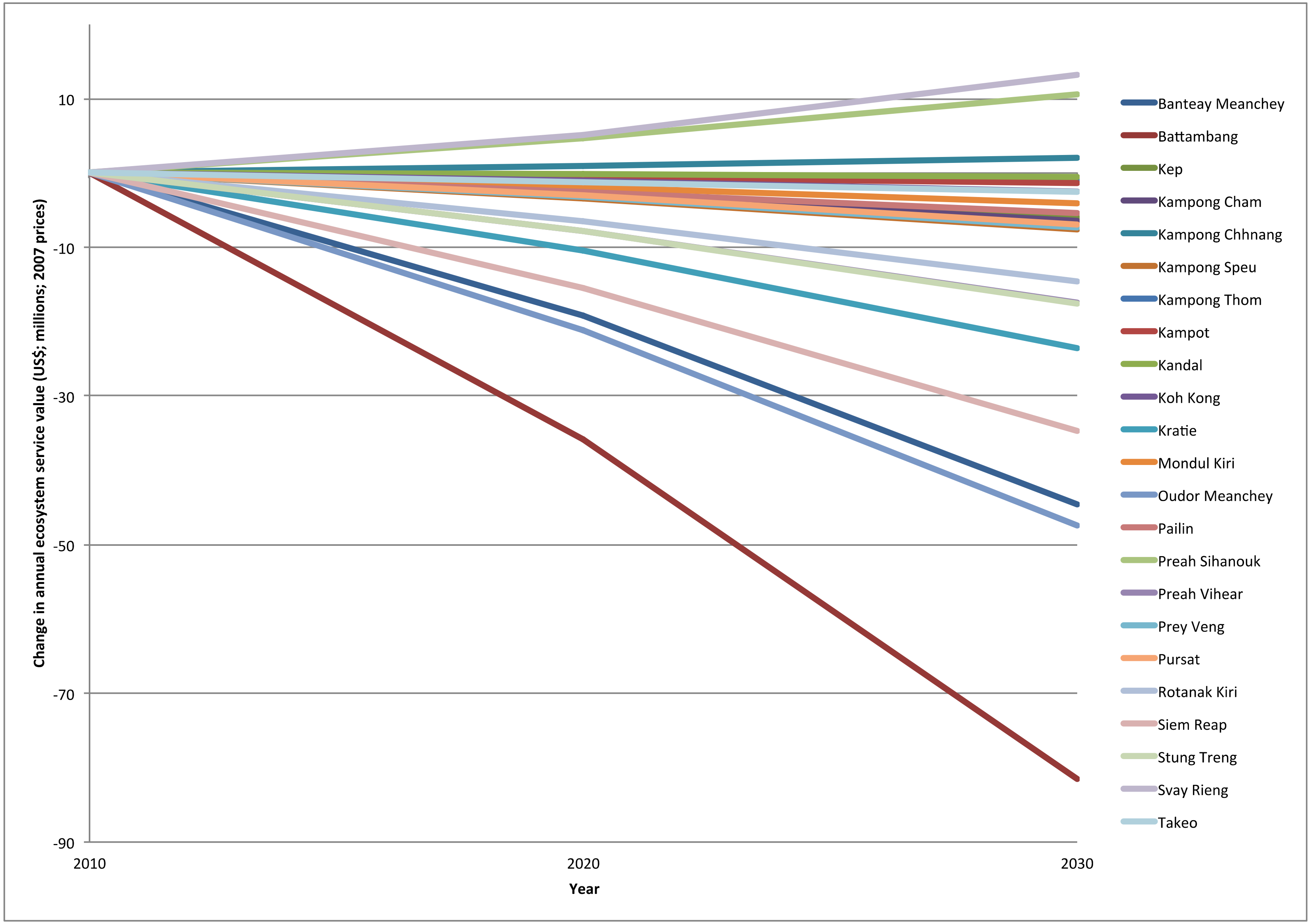

Figure 3b. Change in annual value of forest ecosystem services by province (US$; millions; 2007 prices)

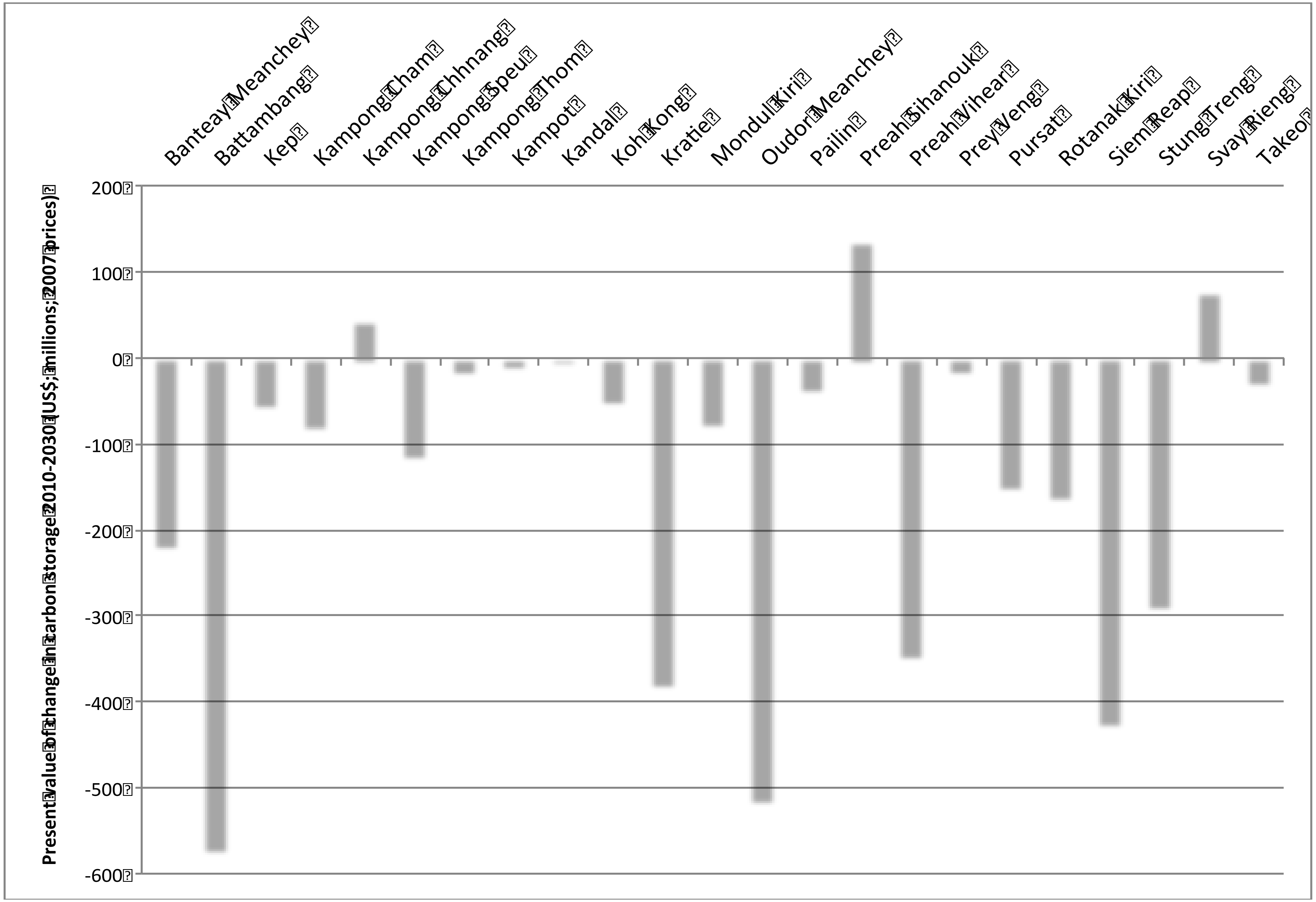

Figure 4. Present value of change in carbon storage 2010-2030 by province (US$; millions; 2007 prices)

3. DISCUSSION AND CONCLUSIONS

The analysis presented in this report provides an estimate of how forest ecosystem service provision in Cambodia will change during the period 2010-2030 under a continuation of current trends. The projected change in the extent of forests during this period is approximately 1.2 million hectares or 12%. The present value of ecosystem services that are lost due to declining forest cover is approximately US$ 4.8 billion. This reflects the loss in human welfare due to continued deforestation.

The results reveal that carbon storage is a highly valuable ecosystem service provided by Cambodian forests. The value of carbon storage (measured as the social cost of carbon emissions) is relatively high compared with other forest ecosystem services. The benefits of carbon storage, however, are global and do not accrue to land users/owners in Cambodia. Carbon storage is clearly an important ecosystem service but its value is difficult to capture for the practical purposes of providing incentives to forest communities, land owners or Government to invest in forest conservation. Markets for carbon storage are under development but, in the absence of an international climate agreement, remain weak and prices are generally low. Such markets may provide some incentive to maintain stocks of forest carbon but not to the extent warranted by their global value.

The estimated values for non-carbon ecosystem services are also substantial and accrue directly to Cambodia. The present value of changes in forest ecosystem service provision over the period 2010-2030 is approximately US$ -1.6 billion (2007 prices). There is large regional variation in the distribution of these ecosystem service losses. Battambang and Oudor Meanchey are expected to experience the highest rates of deforestation and suffer annual losses in 2030 of US$ 82 million and US$ 47 million respectively. The assessment of how these losses in ecosystem services are distributed across different socio-economic groups in Cambodia is a subject for future analysis.

This information on the economic value of future land use change provides evidence of the need for careful management of Cambodia’s forest resources. Allowing even modest deforestation results in substantial loss of valuable ecosystem services. This cost of land use change needs to be recognised and included in Government decision making regarding forest conversion and conservation investments.

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Annex 1: Value transfer method

Value transfer is the procedure of estimating the value of an ecosystem (or goods and services from an ecosystem) by applying an existing valuation estimate for a similar ecosystem (Navrud and Ready, 2007). The ecosystem of current policy interest is often called the "policy site" and the ecosystem from which the value estimate is transferred is called the "study site". This procedure is also known as benefit transfer but since the values being transferred may also be estimates of costs or damages, the term value transfer is arguably more appropriate (Brouwer, 2000).

The use of value transfer to provide information for decision making has a number of advantages over conducting primary research to estimate ecosystem values. From a practical point of view it is generally less expensive and time consuming than conducting primary research. Value transfer can also be applied on a scale that would be unfeasible for primary research in terms of valuing large numbers of sites across multiple countries. Value transfer also has the methodological attraction of providing consistency in the estimation of values across policy sites (Rosenberger and Stanley, 2006).

The transfer of values using a meta-analytic value function, in which policy site characteristics are plugged into a value function estimated from the results of multiple primary studies, appears to offer the most promising means to explicitly control for the specific characteristics of each policy site in the transfer process. By utilising information from multiple studies, a meta-analytic value function includes greater variation in both site characteristics (e.g. size, service provision) and context characteristics (e.g. abundance of other forest sites, number and income of beneficiaries) that cannot be generated from a single primary valuation study.

Meta-analysis is a method of synthesizing the results of multiple studies that examine the same phenomenon, through the identification of a common effect, which is then 'explained' using regression techniques in a meta-regression model (Stanley, 2001). Meta-analysis was first proposed as a research synthesis method by Glass (1976) and has since been developed and applied in many fields of research, not least in the area of environmental economics (Nelson and Kennedy, 2009). It is widely recognised that the large and expanding literature on the economic value of ecosystem services has become difficult to interpret and that there is a need for research synthesis techniques, and in particular statistical meta-analysis, to aggregate results and insights (Stanley, 2001; Smith and Pattanayak, 2002; Bateman and Jones, 2003). In addition to identifying consensus across studies, meta-analysis also provides a basis for transferring values from studied sites to new policy-sites. (Rosenberger and Phipps 2007). It is for this purpose that we develop the meta-analysis presented in this report.

An important consideration in estimating the value of changes to a biome across a large geographic area, such as we propose to do in this case study, is that changes in the stock of the resource may affect the unit values of each individual patch. Localised changes in the extent of an individual ecosystem may be adequately valued in isolation from the rest of the stock of the resource, which is implicitly assumed to be constant. When valuing simultaneous changes in multiple ecosystem sites within a region (e.g., changes in forest extent in Cambodia for the period 2010-2030), it is arguably not sufficient to estimate the value of individual ecosystem sites and aggregate without accounting for the changes that are occurring across the stock of the resource. We therefore follow the method proposed by Brander et al. (2012) to include spatial information in the meta-analytic value function on the abundance of forest ecosystems in the broader surroundings of each study site. This variable is intended to capture the effect of changes in the availability of substitute or complementary forest sites in the vicinity of each forest patch. In addition, a number of other characteristics of each case study location derived from spatial data are included in the analyses as potential determinants of ecosystem value.

Annex 2: Spatial data for Cambodian forests

The process by which each variable in the database of Cambodian forests was produced is described below.

Field Name	Notes
GIS_ID	GIS unique value of each forest patch is the base field name that can be linked to other tables.
Area (in hectares) of each forest patch	Calculate of area in hectares for each forest patch in Cambodia by forest cover 2010 with 30m resolution by selecting forest classes such as evergreen forest, semi-evergreen forest, and deciduous forest, other forest, woodland-wet and dry and using ArcGIS 10.1 and XtoolPro to calculate the area.
Area (in hectares) of other forests within 50km radius of each forest patch	The result of this column was developed by creating buffer 50km around each forest patch, intersecting other forests within selecting each 200 of 21364 buffer of 50km, dissolving based on GIS_ID and calculating area in hectares by using ArcGIS 10.1, Arc toolbox and XtoolPro and then exporting to excel main database.
Population living within 50km radius of each forest patch	The result of this column was developed by intersecting commune population 2011 within a 21364 buffer of 50km, dissolving based on GIS_ID and sum population value by using ArcGIS 10.1, Arc toolbox and XtoolPro and then exporting to excel main database.

Length of roads (in km) within 50km radius of each forest patch	The result of this column was developed by intersecting road2008 within a 21364 buffer of 50km, dissolving based on GIS_ID and calculating length of road by using ArcGIS 10.1, Arc toolbox and XtoolPto and then exporting to excel main database.
Province(s) in which each forest patch is located	The result of this column was developed by intersecting provincial boundaries within 21364 forest patches, dissolving based on GIS_ID and calculating area in hectares by using ArcGIS 10.1, Arc toolbox and XtoolPto and then exporting to excel main database.
Indicator of whether each forest is a protected area	The result of this column was developed using ArcGIS 10.1, Arc toolbox and XtoolPto and then exporting to Excel main database.

Annex 3: Forest types

Evergreen forest: Evergreen forests are usually multi-storied forests where trees maintain their leaves during the whole year. They comprise the lowland tropical rain forests, the hill evergreen forests and the dry evergreen forest and along streams and rivers (gallery forests).

Semi-evergreen forest: Semi-evergreen forests contain variable percentages of evergreen and deciduous trees, the percentage of evergreen trees varying from 30% to 70%. Semi-evergreen forests continue to appear evergreen throughout the year, even when the percentage of deciduous trees is high.

Deciduous forest: Deciduous forests comprise dry mixed deciduous forests and dry Dipterocarp forests. Deciduous forests drop their leaves more or less completely during the dry season. Human impact such as fire is usually much higher compared to other forest types. Dry Dipterocarp forests naturally have an open character. As undisturbed deciduous forests may have a crown-cover of only 40%, soil and grass may have a significant impact on reflections from these forests. As a result, it is difficult to separate deciduous forests from shrub land during the dry season.

Other forests: This land cover type includes regrowth, stunted forests, mangrove forests, inundated forests, and forest plantations. Regrowth of secondary forests is representative of a continuous, usually dense, layer of smaller trees. Stunted forests grow very slowly because of poor site conditions on hydromorphic soils and rock outcrops. Heavily disturbed forest like mosaics of forest, regrowth, and cropping, corresponding to shifting agriculture in which the percentage of forest is more than 40%, and areas of old regrowth and young secondary forest in the process of regenerating after clear cutting, are also included in this category.

Wood and shrub land evergreen: Wood and scrubland is a mixture of shrubs, grass and trees, the trees cover however remaining below 20 percent. This class can be found mainly on shallow soils, on the top of mountains under climax conditions or as a result of non-sustainable land use. Theoretically there is a chance of becoming forest again. The signature remains light red during the whole year. Young regrowth after shifting cultivation is also included in this class when the shifting cultivation mosaic becomes invisible. There is usually a dense layer of shrub and grass with some trees.

Wood and shrub land dry: A 'Dry' variant of this class can be found in dry plateaus, but also on dry and sun exposed slopes. The signature is light grey during the dry season and light brownish grey to violet during the wet season, the texture is medium to rough.

Bamboo: Large areas of dense bamboo are usually discernible due to their pink and orange colour and their typical texture. A sparse bamboo coverage or small bamboo will not be discernible and will remain in one of the other classes.

Non forests: This category merges agricultural areas, urban areas, water bodies, grass land and barren land.

Annex 4: Uncertainty analysis for non-carbon ecosystem service values

This annex presents the results of an uncertainty analysis for the transferred values for non-carbon ecosystem services by computing 95% confidence intervals around each value estimate using the method proposed by Osborne (2000). The confidence intervals provide an indication of the precision with which the estimated value function can predict out-of-sample values. They do not, however, reflect a number of other sources of uncertainty in the analysis, including inaccuracies in the land use data used to construct the database of forest ecosystems in Cambodia and the assumptions used to describe the baseline change in the extent and spatial distribution of forests.

Table A4.1 Annual value of change in forest ecosystem service provision in 2015 with 95% confidence interval (US$/year; 000's; 2007 prices)

Province	95% lower bound	2015	95% lower bound
Banteay Mean Chey	-8,103	-9,370	-10,637
Battambang	-15,693	-17,404	-19,115
Kaeb	-1,159	-1,253	-1,346
Kampong Cham	-1,195	-1,356	-1,517
Kampong Chhnang	339	412	484
Kampong Spueu	-1,487	-1,589	-1,691
Kampong Thum	-175	-210	-244
Kampot	-183	-283	-383
Kandal	-74	-113	-152
Koh Kong	-452	-520	-587
Kratie	-4,571	-4,968	-5,364
Mondul Kiri	-773	-858	-943
Oudor Meanchey	-9,370	-10,195	-11,019
Pailin	-973	-1,182	-1,390
Preah Sihanouk	1,612	2,139	2,666
Preah Vihear	-3,327	-3,650	-3,974
Prey Veng	-1,264	-1,541	-1,818
Pursat	-1,268	-1,459	-1,649
Rotanak Kiri	-2,892	-3,048	-3,205
Siem Reab	-6,957	-7,395	-7,834
Stung Treng	-3,418	-3,668	-3,917
Svay Rieng	1,550	2,226	2,902
Takeo	-286	-536	-880
Total	-60,120	-65,819	-71,612

Table A4.2 Annual value of change in forest ecosystem service provision in 2020 with 95% confidence interval (US$/year; 000's; 2007 prices)

Province	95% lower bound	2020	95% lower bound
Banteay Mean Chey	-16,708	-19,243	-21,777
Battambang	-32,376	-35,813	-39,250
Kaeb	-2,447	-2,643	-2,839
Kampong Cham	-2,516	-2,852	-3,189
Kampong Chhnang	721	875	1,028
Kampong Spueu	-3,147	-3,359	-3,572
Kampong Thum	-371	-444	-517
Kampot	-385	-595	-805
Kandal	-155	-236	-317
Koh Kong	-959	-1,101	-1,242
Kratie	-9,633	-10,456	-11,278
Mondul Kiri	-1,639	-1,818	-1,996
Oudor Meanchey	-19,509	-21,191	-22,873
Pailin	-2,021	-2,445	-2,870
Preah Sihanouk	3,447	4,580	5,714
Preah Vihear	-7,031	-7,704	-8,376
Prey Veng	-2,601	-3,164	-3,728
Pursat	-2,686	-3,086	-3,486
Rotanak Kiri	-6,119	-6,446	-6,772
Siem Reab	-14,563	-15,458	-16,354
Stung Treng	-7,228	-7,745	-8,263
Svay Rieng	3,498	5,033	6,568
Takeo	-600	-1,125	-1,847
Total	-125,029	-136,436	-148,042

Table A4.3 Annual value of change in forest ecosystem service provision in 2030 with 95% confidence interval (US$/year; 000's; 2007 prices)

Province	95% lower bound	2030	95% lower bound
Banteay Mean Chey	-39,150	-44,579	-50,009
Battambang	-74,158	-81,514	-88,871
Kaeb	-5,546	-5,986	-6,425
Kampong Cham	-5,684	-6,436	-7,189
Kampong Chhnang	1,650	2,000	2,350
Kampong Spueu	-7,157	-7,626	-8,095
Kampong Thum	-846	-1,011	-1,176
Kampot	-870	-1,345	-1,819
Kandal	-353	-530	-707
Koh Kong	-2,187	-2,506	-2,825
Kratie	-21,811	-23,614	-25,418
Mondul Kiri	-3,738	-4,138	-4,538
Oudor Meanchey	-43,864	-47,483	-51,102
Pailin	-4,574	-5,487	-6,401
Preah Sihanouk	7,955	10,609	13,264
Preah Vihear	-15,977	-17,453	-18,930
Prey Veng	-6,064	-7,328	-8,592
Pursat	-6,116	-7,013	-7,910
Rotanak Kiri	-13,917	-14,641	-15,365
Siem Reab	-32,778	-34,697	-36,615
Stung Treng	-16,427	-17,561	-18,695
Svay Rieng	9,130	13,169	17,208
Takeo	-1,353	-2,534	-4,159
Total	-283,836	-307,705	-332,018

Annex 5: Sensitivity analysis of carbon storage values

This annex presents the results of a sensitivity analysis for the estimated values of carbon storage. We compute four possible combinations of parameter values for net carbon storage and social cost of carbon (SCC):

1. low carbon emissions (72.5 tC/ha); low social cost of carbon (US$ 10 tCO_2-e);
2. high carbon emissions (130.5 tC/ha); low social cost of carbon (US$ 10 tCO_2-e);
3. low carbon emissions (72.5 tC/ha); high social cost of carbon (US$ 22 tCO_2-e);
4. high carbon emissions (130.5 tC/ha); high social cost of carbon (US$ 22 tCO_2-e).

The results of this sensitivity analysis are presented in Figure A5.1. Note that the resulting values are total present values of avoided climate change damage and not annual values (i.e. they represent the cumulative change in carbon storage). The results are clearly highly sensitive to these parameters and the estimated range of values for the change in carbon storage by 2030 spans US$ -3–12 billion (2007 prices).

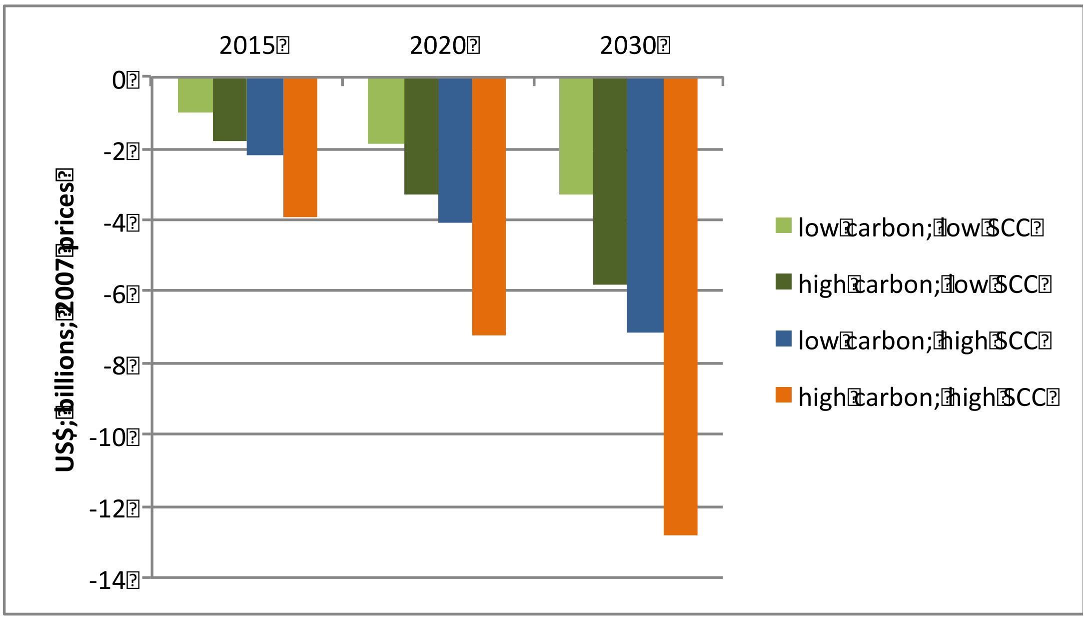

Figure A5.1. Change in value of carbon storage under alternative parameter values for carbon emissions and social costs of carbon (US$; billions; 2007 prices).

The Global Mechanism's Land, Private Finance and Investment Programme is designed to mobilize private sector finance for sustainable land management, through innovation, partnerships and champions.

Specifically, the Programme promotes land degradation neutrality by the business community across all land intensive sectors through improved access to private capital, including commercial finance.

To achieve this, the Programme analyses the root causes of land degradation, develops alternative land-use scenarios, engages key stakeholders through partnerships and cutting edge initiatives, and promotes responsible business models, as well as sustainable production and consumption.

Offering Sustainable Land-use Options

Founded by the Global Mechanism of the United Nations Convention to Combat Desertification, The OSLO consortium is a global partnership of leading research and academic institutions, international organizations and UN agencies that aims to promote responsible land-use by demonstrating the total economic value of terrestrial ecosystems and generating socio-economically viable and environmentally sustainable land use options.

The OSLO approach involves assessing the net socio-economic benefits of sustainable land and ecosystem management, and reducing the risks and uncertainties associated with eco-system smart policies and investments. Through this, benefits in sustainable economic growth and poverty reduction, reversing land degradation and strengthening the protection of ecological integrity may be realized.

Through in depth assessments of land value, OSLO is able to demonstrate that sustainable land management approaches are economically rational and can encourage investment from public and private sectors alike.