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USAID Mekong Adaptation and Resilience to Climate Change (USAID Mekong ARCC)

Ecosystem Value Estimation

Technical Document

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INTRODUCTION

For more than a decade, the Greater Mekong Sub-Region has been experiencing a substantial increase in development investments, largely linked to natural resources. Key investment sectors involve mining, forestry, agriculture, hydropower and fishing. Regularly, these processes involve large-scale environmental degradation. This trend is set to continue.

The utilization and extraction of natural resources involves ecosystems to be degraded if not managed sustainably. The degradation of ecosystems implies the loss of ecosystem services, which are of high economic value to human societies. Ecosystem services are typically categorized into direct and indirect services, which emphasizes the anthropocentric perspective this utilitarian conceptualization applies. Direct services include provisioning, regulatory, and cultural services. Indirect services are typically referred to as supporting services, which an ecosystem receives as necessary support from other ecosystems to maintain its functionality, including nutrient cycling or primary production.

Many development decisions consider the immediate economic return without considering trade-offs, side effects or wider ripple effects. Even from a pure economic perspective, the losses in ecosystem services need to be accounted for; otherwise, decisions can be made where costs exceed returns, translating in a so-called negative return-on-investment.

While economic returns are typically instantly revealed as part of the investment offer, the ecosystem-related trade-off usually remains unknown and therefore unconsidered. This creates a substantial risk of resulting in negative return-on-investments. Revealing the economic value of ecosystems and their services involves the implementation of economic valuation methods. Such methods include:

- Market- based calculations
- Non-market valuation techniques
    - Revealed preferences
        - Travel-cost method
        - Hedonic price method
        - Averting investments
        - Output loss method
    - Stated preferences (Willingness to pay & Willingness to accept)
        - Contingent valuation
        - Choice modelling
    - Valuation of multi-functionality of systems

Conducting an economic valuation can involve several weeks. Cross-sector discussions, however, take place in much shorter time frames and decisions are often made without long assessments. Thus, the availability of quick estimates can provide critical ad-hoc guidance for understanding the broader economic picture, including ecosystem-based trade-offs.

Providing such first guidance is the goal of this ecosystem value estimator. The value ranges are based on economic valuation results available for the Greater Mekong Sub-region. Valuations published since 2000 were considered, with most recent results from 2013.

The Ecosystem Value Estimator does not intend to replace an actual economic valuation. Instead it only aims for the provision of a first guide to understand how economic losses are likely to relate to expected gains. Understanding this proportion is likely to point out the need for an actual economic valuation or even a cost benefit analysis of the decision making situation at hand.

This document provides all the technical details and assumptions made for this tool, including the database, the categorization and the data processing. This document also provides guidance for the interpretation of the estimates this tool results.

ECOSYSTEM SERVICES

Tansley (1935) was the first to conceptualize ecosystems as "the environment of the Biome—the habitat factors in the widest sense…with which they form one physical system". More recently, Willis (1997) defined ecosystem as "a unit comprising a community (or communities) of organisms and their physical and chemical environment, at any scale, desirably specified, in which there are continuous fluxes of matter and energy in an interactive open system."

Both definitions emphasize the dynamic interactions and dependencies. This implies that human habitats consist of many physical (and bio-chemical) factors, which provide an influx of matter and energy and allow for the outflux (or deposition) of material and energy. This dynamic interface can be perceived as (influx and outflux) services the natural environment provides to human societies. These ecosystem services are typically divided into direct and indirect services. Direct Ecosystem Services can be categorized into Provisioning, Regulatory and Cultural Services.

Provisioning services are the products obtained from ecosystems, including (Millennium Ecosystem Assessment (2003) pp 56-57):

- *Food and fiber*. This includes the vast range of food products derived from plants, animals, and microbes, as well as materials such as wood, jute, hemp, silk, and many other products derived from ecosystems.
- *Fuel*. Wood, dung, and other biological materials serve as sources of energy.
- *Genetic resources*. This includes the genes and genetic information used for animal and plant breeding and biotechnology.
- *Biochemicals, natural medicines, and pharmaceuticals*. Many medicines, biocides, food additives such as alginates, and biological materials are derived from ecosystems.
- *Ornamental resources*. Animal products, such as skins and shells, and flowers are used as ornaments, although the value of these resources is often culturally determined. This is an example of linkages between the categories of ecosystem services.
- *Fresh water*. Fresh water is another example of linkages between categories—in this case, between provisioning and regulating services.

Regulatory services are benefits obtained from the regulation of ecosystem processes, including (Millennium Ecosystem Assessment (2003) pp 57-*58)*:

- *Air quality maintenance*. Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality.
- *Climate regulation*. Ecosystems influence climate both locally and globally. For example, at a local scale, changes in land cover can affect both temperature and precipitation. At the global scale, ecosystems play an important role in climate by either sequestering or emitting greenhouse gases.
- *Water regulation*. The timing and magnitude of runoff, flooding, and aquifer recharge can be strongly influenced by changes in land cover, including, in particular, alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas.
- *Erosion control*. Vegetative cover plays an important role in soil retention and the prevention of landslides.

- *Water purification and waste treatment*. Ecosystems can be a source of impurities in fresh water but also can help to filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems.
- *Regulation of human diseases*. Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes.
- *Biological control*. Ecosystem changes affect the prevalence of crop and livestock pests and diseases.
- *Pollination*. Ecosystem changes affect the distribution, abundance, and effectiveness of pollinators.
- *Storm protection*. The presence of coastal ecosystems such as mangroves and coral reefs can dramatically reduce the damage caused by hurricanes or large waves.

Cultural Services are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, including (Millenium Ecosystem Assessment (2003) pp 58-59):

- *Recreation and ecotourism*. People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.
- *Cultural diversity*. The diversity of ecosystems is one factor influencing the diversity of cultures.
- *Spiritual and religious values*. Many religions attach spiritual and religious values to ecosystems or their components.
- *Knowledge systems* (traditional and formal). Ecosystems influence the types of knowledge systems developed by different cultures.
- *Educational values*. Ecosystems and their components and processes provide the basis for both formal and informal education in many societies.
- *Inspiration*. Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising.
- *Aesthetic values*. Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, "scenic drives," and the selection of housing locations.
- *Social relations*. Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for example, differ in many respects in their social relations from nomadic herding or agricultural societies.
- *Sense of place*. Many people value the "sense of place" that is associated with recognized features of their environment, including aspects of the ecosystem.
- *Cultural heritage values*. Many societies place high value on the maintenance of either historically important landscapes ("cultural landscapes") or culturally significant species.

Figure 1 provides an alternative set of definitions and further examples to illustrate the concept of ecosystem services.

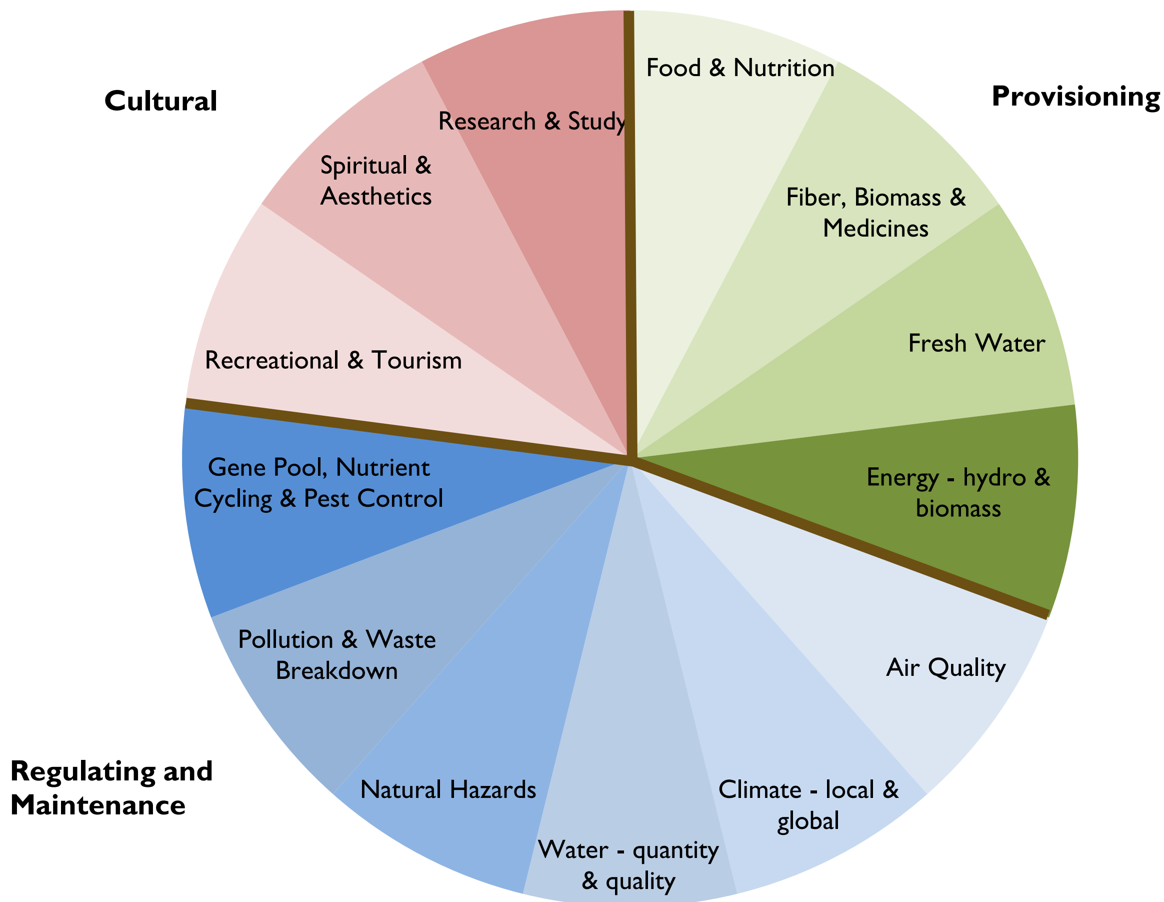

Figure 1: Types and Classification of Ecosystem Services

Indirect ecosystem services are supporting services ecosystems provide to each other. This involves typically fundamental support ecosystems need to deliver the direct services humans benefit from, such a primary production or nutrient cycles. These supporting services gain critical importance if one understands the system-wide dependencies. Typically, supporting services are not considered in economic valuations despite their high relevance for human societies. Given the lack of data this web-tool does not account for supporting services. Thus, values resulting from calculations based on this tool underestimate the economic value of ecosystems.

DATABASE

A total of 508 data points were considered for the value ranges feeding into the Ecosystem Value Estimations. The largest number of values (209) was available for evergreen forests, followed by 105 entries for mangroves and 86 results for wetlands. Only 57 values were found for coasts or islands with coral reefs and 51 results for deciduous forests.

Annex 1-5 provide the references for all valuation results considered. Most studies provide multiple results as a range of services or aspects of services of a particular ecosystem was valuated. Given the diversity of terminology and methodology, these studies deployed their combination into a consistent database required challenging conversion, which are described in the following section.

DATA PROCESSING

The consolidated database was processed in five steps. First, calculations presented in the references informing the database were checked. Second, the variety of categories for ecosystems and for ecosystem services was mapped into a consistent list that allows for meaningful calculations without large overlaps. Third, currencies were converted into US dollars (US$) for the year the valuation result was published. Fourth, values were corrected for inflationary effects, which normalizes all values to 2015. Fifth, all extreme values were again checked for consistency and accuracy.

Step 1: Corrections

In a first step, the original documents/studies were reviewed to ascertain the values are correctly derived. Several values obtained in the initial data elicitation phase were identified as incorrect. These mistakes involved mostly wrong multiplication or addition or wrong dimensions (sometimes leading to values inflated or deflated by factor 1,000).

Step 2: Categorization

Valuations do not apply a consistent classification of ecosystems and ecosystem services. In order to obtain consistent value ranges for total economic value, for provisioning services, regulatory services and cultural services, results needed to be mapped into these broad categories. This step requires a meaningful approach to adding results without double-counting. For instance, many studies quantify the value of non-timber forest products (NTFPs) while others valuate individual non-timber forest products. Disaggregated values (i.e. food from forest, raw material from forest) needed to be considered and added-up to be comparable with values for aggregates (i.e. as NTFP).

The mapping affected (1) ecosystems as well as (2) ecosystem services. Ecosystems were mapped into five categories to simplify the use of the tool:

- evergreen forests,
- deciduous forests,
- wetlands,
- mangroves, and
- coasts or islands with coral reefs.

The majority of valuations followed similar ecosystems types. However, there were a large number of data points with uniquely defined categories, including

- river basin,
- plantation,
- terrestrial and marine ecosystems,
- lake,
- historic temples, or
- watershed

Hence, the majority of valuations were mapped into these five categories. Some studies were not considered because their aggregates could not be easily mapped into any of these five ecosystems. For instance, 'river basin' or 'watershed' were not included in cases where the economic values could not be attributed to either of the five ecosystem types. Other values we excluded focused on specific features that would make any transfer of valuation results into another context difficult (i.e. historic temples). A third group of data we excluded implies the explicit transformation of landscapes and the replacement of ecosystems (i.e. rice or rubber plantations), which means that ecosystem services would no longer be generated.

The mapping of ecosystem services was important because the tool aims to provide a total economic value as well as a value for provisioning, regulatory, and cultural services. Hence, results needed to be mapped into these four classes of values. The variety of terms used for ecosystem services and their aggregates created challenges. Despite the availability of global assessments such as the Millennium Ecosystem Assessment, there seems no convergence on a standardized terminology for ecosystem services.

Results were mapped into the three principle services (provisioning, regulatory, and cultural) or included as total economic value. Then the various entries were marked as valuating either the identical/similar aspect or a different aspect of any particular ecosystem. An example for similar terms is "non-timber forest products", "local non-timber forest products", and "forest products".

For the calculations the values for identical/similar aspects were combined in an OR relationship. In other words, among those results that valuate the same or similar ecosystem service the smallest was selected for the minimum value and the highest was selected for the maximum value. Results for different aspects of ecosystem services received an AND relationship. Technically, min/max values consider AND relationships as addition while for OR relationships the smallest/largest value was selected to obtain a meaningful and defensible value range. This approach leads to value ranges for the TEV that are not necessarily identical with the sum of the ranges for provisioning, regulatory and cultural services.

Step 3: Conversion

Conversion involved three key dimensions: currency, area, and time. This tool requires a standardized currency to allow results from many studies to be combined in one database. Many publications list economic values in a local currency. The standardized currency chosen is US$. The US$ value was calculated based on the (annual mean) currency conversion factor for the relevant publication year. For those values that were already published in US$ we considered that value.

Area related conversions involved several aspects. Some cases reported values in national metrics, such as rai for Thailand. All results were converted into a per hectare value to allow for the targeted comparison.

More challenging was the conversion of livelihood-focused results, particularly relevant for forest areas. Many studies report values for households, for instance how much income a household generated from a patch of forest. In a few cases the actual area these households utilized was quantified, which made the conversion into per hectare value easy. In other cases the area was not disclosed, which required a general assumption on area utilized. Otherwise economic values for scarcely populated forests would be very low while densely populated forest areas would be of high economic value. A concept allowing for a standardization is carrying capacity of forests (Arrow et al., 1995; Fearnside, 1985; Keith et al., 2010;

Prato, 2001). Based on Daly (1996) we selected an average of 25 households per kilometer square. This is consistent with studies in the database that reported on per household value and on the area utilized by households.

Time-related conversion was required where values were only provided as multi-year results, often discounted. For these cases an annual value needed to be calculated to allow for the targeted meta-study comparison.

Step 4: Inflation correction

Comparing economic values over time requires the consideration of price effects as the same amount of money does not allow the purchase of exactly the same amount of goods and services. The increase of prices for the same physical bundle of goods is referred to as inflation while the price reductions over time is referred to as deflation. Introducing these price corrections for valuations we considered since the year 2000 allows utilizing the results in the same value range expressed in today's prices.

For this purpose we took IMF's consumer price index and normalized it for the year 2000 with a starting value of 100 in all GMS countries. This results in values for each year until 2015. A value of 200 for the year 2015 means that for the same bundle of goods and services that cost in 2000 only US$100, we would need to pay in 2015 US$200. Inflationary effects vary between the GMS countries. As the database does not contain results from valuation exercised in China and Myanmar we identified only price index values for Cambodia (190.39), Lao PDR (268.31), Thailand (144.32) and Vietnam (308.52). The resulting average is 227.89, which translates into an average annual increase of 8.53. Based on this average, we corrected annual price change for all values.

It is important to emphasis that this average price index change resembles a linear change. This is different from calculating changes based on annual inflation rates, which would lead to an exponential change if calculated as a year-by-year increase. An average inflation rate of 5.645% leads to the same increase of the consumer price index listed above.

This approach assumes GMS-wide averages instead of applying country specific price correction because this value estimation tool should be applicable across the GMS and should allow for transferring results between the countries independent from their origin. Given that the goal of this tool is not to replace an actual valuation but to provide quick estimates we believe that this is the best approximation for price corrections.

Step 5: Final check of extreme values

In a final step all minimum and maximum value were again checked for consistency, in particular if the calculations considered a meaningful combination and addition of ecosystem service elements. During this process a few results needed to be corrected or discarded due to inconsistencies. This step involved further consultations with ecosystem service and valuation experts, for instance the International Union for Conservation of Nature (IUCN) in Bangkok.

RESULTS

The conversion of the valuation results provides dollar values for the total economic value for one hectare of each main type of ecosystem. This is an annual figure, which means that one hectare of any of the five main ecosystem types is likely to provide every year a total economic benefit that ranges between the minimum and maximum values listed in Table 1.

Table 1: Value ranges and average value of total economic value for one hectare of main ecosystem types

Total Economic Value (TEV)			
	MIN	Mean	MAX
Evergreen forest	$7,241	$17,578	$27,916
Deciduous forest	$6,665	$13,306	$19,946
Mangroves	$9,692	$20,324	$30,956
Wetland	$9,906	$12,776	$15,646
Coasts/Islands with coral reefs	$31,235	$44,173	$57,110

Typically, valuation exercises disaggregate total economic value into the three main service dimensions – provisioning, regulatory and cultural services. These values indicate what level of direct benefits communities derive from ecosystems, for instance in the form of tangible products such as non-timber forest products or fish. Normally this translates into household income in the form of traded goods or in the form of subsistence production, which equals avoided household expense.

Table 2: Value ranges and average value of provisioning services for one hectare of main ecosystem types

Provisioning Services			
	MIN	Mean	MAX
Evergreen forest	$2,816	$8,703	$14,589
Deciduous forest	$9,421	$14,131	$18,842
Mangroves	$2,133	$11,661	$21,188
Wetland	$324	$2,505	$4,685
Coasts/Islands with coral reefs	$237	$325	$413

Table 3 lists the economic value for regulatory services the respective ecosystems provide.

Table 3: Value ranges and average value of regulatory services for one hectare of main ecosystem types

Regulatory Services			
	MIN	Mean	MAX
Evergreen forest	$4,290	$8,740	$13,191
Deciduous forest	$193	$581	$970
Mangroves	$7,398	$7,881	$8,364
Wetland	$9,580	$10,088	$10,595
Coasts/Islands with coral reefs	$500	$13,350	$26,199

The sequestration of carbon is a regulatory service that plays an important role in international negotiations related to climate change. Table 4 lists the value ranges studies published for ecosystems as carbon sink.

Table 4: Value ranges and average value of carbon sequestration for one hectare of main ecosystem types

Carbon Sequestration			
	MIN	Mean	MAX
Evergreen forest	$71	$1,522	$2,974
Deciduous forest	$60	$449	$837
Mangroves	$2	$123	$245
Wetland	N/A	N/A	N/A
Coasts/Islands with coral reefs	N/A	N/A	N/A

Table 5 summarizes values ecosystems provide in the form of cultural services. The value ranges for this category are narrow if compared to the other results due to the small number of studies on cultural services.

Table 5: Value ranges and average value of cultural services for one hectare of main ecosystem types

Cultural Services			
	MIN	Mean	MAX
Evergreen forest	$135	$135	$135
Deciduous forest	$135	$135	$135
Mangroves	$160	$782	$1,404
Wetland	$1	$183	$365
Coasts/Islands with coral reefs	$30,498	$30,498	$30,498

Above results are annual benefits expressed in 2015-US$ values. However, ecosystems provide these economic benefits in the long-term. Also investments in the replacement or the conservation of ecosystem services have long-term effects. The loss of ecosystems triggers a loss of these long-term benefits, which means that only considering the annual value is misleading. For this tool we consider a 25 year period to approximate the impact on benefits received by the next generation.

Considering long-term benefits is typically done as net present values, which translates future benefits into today's value. This involves the application of a social discount rate when converting future benefits. Such a conversion into net present value considers the fact that people have a strong preference for present consumption (Rubinstein, 2003; Sozou, 1998). The longer the benefit is placed in the future the less people value these benefits or costs. However, experiments have shown that the rate by which people discount future benefits drops the further one steps into the future. This means that people see a lot of difference between receiving a benefit now or in one year (hence the need to discount in the first place). But people do not distinguish (much) between receiving a benefit in twelve years or in thirteen years. Therefore, the social discount rate decreases the further we step into the future. This type of social discounting is referred to as hyperbolic discounting (Rubinstein, 2003; Sozou, 1998).

For our calculation we assume the following to approximate hyperbolic discounting:

- *for the next 5 years: 4% discount rate*
- *for the ten years thereafter an annual drop of the discount rate by 0.4%*
- *for the ten years thereafter no further discounting is applied*

Table 6 summarizes the long-term per hectare value of ecosystems as net present value based on the aforementioned assumptions.

Table 6: Value ranges and average value of the long-term total economic value for one hectare of main ecosystem types

Total Economic Value (TEV)			
	MIN	Mean	MAX
Evergreen forest	$140,224	$340,426	$540,628
Deciduous forest	$129,076	$257,682	$386,288
Mangroves	$187,690	$393,599	$599,507
Wetland	$191,840	$247,421	$303,002
Coasts/Islands with coral reefs	$604,909	$855,465	$1,106,020

MEANING

The results shown above summarize and combine available valuation results, involving some data processing necessary to allow for this meta-study comparison. Hence, this tool only provides context-free estimates. As this tool focuses on the provision of ad-hoc guidance to inform debates and negotiations, the interpretation of these estimates and the understanding of the limitations of this tool gain much importance.

The interpretation of value ranges must consider that this draws from very different contexts, which might not resemble the particular characteristics of the context at hand. Hence a statement such as

> *"The economic value of the ecosystem at stake is likely to range between [min value] and [max value]"*

is an acceptable understanding, while

> *"The economic value of the ecosystem at stake will vary between [min value] and [max value] depending on its condition."*

is incorrect. The tool does not replace a context-specific valuation nor should its results be interpreted as a range depending on the condition (or level of degradation) of the ecosystem.

Value ranges can be used in the following sense:

> *"The ecosystem at stake provides economic benefits that are likely to range between [min value] and [max value]."*
>
> *"Losing the ecosystems at stake are likely to translate into a loss of economic benefits between [min value] and [max value]."*
>
> *"This decision has to consider trade-offs based on natural assets, involving economic losses that are likely to range from [min value] to [max value]."*
>
> *"Replacing the benefits these ecosystems provide might cost us between [min value] and [max value]."*

Minimum values provide guidance on likely lower bounds of economic losses. But also contextual factors can translate into gross over- or under-estimations. Hence it would be incorrect to say

> *"The loss of these ecosystems will create economic losses of at least [min value]."*

Rather, it is acceptable to say:

> *"The loss of these ecosystems is likely to create economic losses of [min value] or more."*

Alternatively, one could say

> *"The loss is likely to put economic benefits of [min value] or more at risk."*

> *"This loss is likely to put economic benefits of at least [min value] at risk."*

Assuming cross-sector negotiations in which ecosystems are to be replaced by other land uses, such as agricultural production, a mine or urban development, the decision would need to consider that

> *"…most likely [min value] or more in economic benefits created by the current land use."*

The maximum value can be used similarly by stating, for instance that

> *"This loss of the ecosystems at stake is likely to risk the loss of up to [max value] in economic benefits."*

or

> *"Any decision that affects these ecosystems needs to consider economic losses of up to [max value]."*

or

> *"These ecosystems are likely to generate economic benefits of up to [max value]."*

The mean value is generally a difficult concept if significant contextual uncertainty applies. At the same time it is always tempting to reduce a complex issue to one single number. Thus it is important to avoid a statement like

> *"This ecosystem creates benefits of [mean value]."*

Instead, we recommend a statement such as

> *"The ecosystem we discuss is most likely generating economic benefits of around [mean value], which needs to be considered as a trade-off when thinking about replacing it."*

or

> *"The loss of this ecosystem is most likely resulting in income losses or necessary replacements of naturally provided services that might cost our society around [mean value]."*

or

> *"The loss of this ecosystem is likely to involve economic trade-offs or around [mean value]."*

CONCLUSIONS

Economic valuation provides critical information for the understanding of positive and negative trade-offs societies can cause by changing ecosystems. There is a gap in tools available to quickly assist practitioners in understanding these tradeoffs and which this tool aims to minimize.

There are well-tested and robust methods available for trained practitioners to derive economic values for ecosystems and their services. Also available are tools that guide a practitioner through a valuation process in the form of a standardized protocol the user can follow. Equally available are context-specific results. Currently, tools do not exist that allow non-experts to derive quick and robust estimations.

This tool aims to close this gap by estimating value ranges to inform negotiations and debates quickly. This tool does not aim to replace actual valuations of ecosystem services. We expect estimated value ranges to stress the importance of proper valuation exercises and that these context-specific studies are worth the expense. We hope that the availability of this tool will prevent quick decisions on replacing existing ecosystems by other agricultural, industrial or urban land uses as they risk the loss of tangible economic benefits already provided by the ecosystems at stake.

Taking existing valuation results out of their contexts bears the risk of misinterpretation and misguided decision-making, especially if the ecosystem at stake is particularly unusual. Any unique feature is likely to increase the real value beyond the estimated maximum value. Such unique features include:

- Water flows to critically fragile and important adjacent systems;
- Livelihoods of households that would otherwise have no alternative income; and;
- Biodiversity values due to the occurrence of unique plant and animal species, which in many cases are of high value to medical research and pharmaceutical industries.

These points also raise the fact that ecosystems have to be understood in a broader systems perspective. A wetland, for instance, can provide direct benefits to a forest or a lake system. However, these normally translate indirectly into economic benefits for agricultural production or fisheries. These indirect benefits are referred to as supporting services. Some studies include some aspects of supporting services (partly as a dimension of regulatory services) but only very few results are available for supporting services. Also, the more indirect these system relationships, the less likely that these economically valuable connections are considered. As such, the vast majority of results provided by this estimator is likely to underestimate the real value as such system-wide ripple effects are not considered.

Another limitation of this tool and its underlying valuations is the effect of cumulative effects, which are often not considered. In cases where a decision-making situation involves multiple areas in the same basin (or otherwise connected social-ecological system) and values are derived in isolation, results are likely to grossly underestimate the economic value. Values are likely to be underestimated because connected ecosystems, for instance three connected wetlands, are likely to have higher benefits than the same areas in isolation. Understanding these synergetic relationships requires context-specific valuation.

Similarly, economic values can be substantially higher if other nonlinearities are considered, for instance the existence of tipping points. These tipping points can exist for social, economic, physical or ecological variables. Three examples to illustrate this limitation:

- The loss of parts of an existing forest can push the income of many households under what they need for their existence. Up to this tipping point, reductions might not cause much response. But once this tipping point is crossed, a sudden and large outmigration is likely to occur.
- The loss of parts of an existing wetland can lead to a disproportional reduction in water quality, which can have substantial downstream impacts on human health or fisheries. Equally, flood mitigation effects can respond in a non-linear way when small areas of a wetland are lost and suddenly, previously un-experienced floods occur downstream.
- Many species require a minimum area of a particular habitat to allow their survival. Just a small land use change that reduces the habitat size under this minimum requirement (or tipping point) is likely to lead to the extinction of the species.

Tipping points and system-wide ripple effects emphasize the importance of a dynamic understanding of such social-ecological systems. Such a perspective requires very different methodology, in particular simulation models that genuinely link social, economic, physical, and ecological variables, and their dynamically changing feedbacks. As such, a simplifying tool as this estimator can only provide rough estimates and should not be understood as alternatives to methods that actually consider the contextual complexities of reality.

Applying an effective systems perspective to the understanding of ecosystems and their economic values reveals that most estimates provided by this tool are underestimating the economic value of ecosystem services. However, this tool is based on actual valuation exercises. The more valuation studies undertaken that consider these vital system-wide benefits and the non-linearity of these responses, the more estimates by this tool will improve.

Despite these limitations, we believe that this tool plays an important role in decision-making processes, which are often made very fast and without much evidence. Providing such economic estimations might quickly slow down the decision making process by showing what is economically at stake. We hope that winning time and revealing the economic stakes would trigger further investigations and research in the form of, for instance, contextual valuations or proper simulation modeling.

ANNEX 1: VALUATIONS CONSIDERED FOR EVERGREEN FOREST

ADB (2010)	Non-timber forest products; Watershed protection; Water quality regulation; Soil erosion control; Carbon storage;	Cambodia, Lao PDR, Vietnam
Ayumi and Chanhda (2009)		Lao PDR
Bann (1997)	Local non-timber forest products; Forest environmental services	Cambodia
Boscolo (2004)	Fuelwood; Charcoal; Resin	Cambodia
Delang (2005)	Local use of non-marketed wild edible plants	Thailand
Delang (2006)	Local use of non-marketed wild edible plants	Thailand
Emerton et al. (2002b)	Local non-timber forest products	Cambodia
Emerton et al. (2002a)	Local non-timber forest products (cash and subsistence); Commercial non-timber forest products and exports; Local and commercial woodfuel; Legal commercial timber; Local timber; Local fish and aquatic animals;	Lao PDR
Emerton (2005)	TEV; Food, Raw materials, Medicinal resources; Erosion prevention; Regulation of water flows; Moderation of extreme events; Habitat services; Genetic resources; Carbon sequestration	Lao PDR
Grieg-Gran et al. (2008)	Local non-timber forest products	Cambodia
Hansen and Top (2006)	TEV; Non-timber forest products; Sustainable timber; Non-timber forest products; Sustainable timber; Local non-timber forest products; Carbon sequestration; Soil conservation; water conservation; Upland Rice; Eucalyptus; Sugarcane	Cambodia
Heov et al. (2006)	Local non-timber forest products	Cambodia
Hinsui et al. (2008)	Local non-timber forest products cash income	Thailand
Hoa and Ly (2009)	Preservation;	Vietnam

ICEM (2003a)	NTFP; Opportunities for recreation & tourism; Catchment protection; Tourism; Economic value of Ream National Park to local communities; Value of local fisheries; Shells; Local fisheries; Prawns; Marine fish; Crabs; Small shrimp; Lobster; Squid; Freshwater fish; Value of other land and resource use; Firewood; Construction wood; Medicinal plants; Food; Roofing materials; Crops; Livestock; Mangrove conservation; Storm protection; Coastal erosion prevention; Carbon sequestration; Revenues for authorities (fees and parking charges); Tourist earnings for traders at Toek Chou Waterfall; Restaurants; Fruit tables; Shelters; Car parking fees, levies, fees from traders at Toek Chou (Department of Tourism); Motorcycle and car hire, hotels and restaurants (Kampot Town private sector); Taxes from hotels (Tax office); Hydro-electric generation; electricity sales; Value of watershed catchment protection services.	Thailand, Vietnam, Cambodia
Jensen (2009)	Ornamental resources;	Lao PDR
Khonchantet (2007)	Local non-timber forest products (wild vegetable plants, edible mushrooms, bamboo shoots, firewood, fodder, edible insects and ant eggs)	Thailand
Khonchantet 2008	Local fisheries	Thailand
Kuchelmeister (2003)	Watershed services to paddy, to micro-irrigation, and to fisheries; Enhanced paddy productivity; Reduced sedimentation of micro-irrigation facilities; Increased annual fish productivity in small village ponds; Optional values for forest land reserved for tree crop cultivation	Vietnam
Luangmany et al. (2009)	Biodiversity conservation and sustainability	Lao PDR
MARD (2008)	Water regulation for downstream hydropower; Retention of sediment	Vietnam
Nabangchang (2003)	Timber for house construction; NTFP.	Thailand
Phuong and Doung (2007)	Local non-timber forest products	Vietnam
Ratanak and Terauchi (2013)	Rattan;	Cambodia
Rosales et al. (2003)	Local non-timber forest products; Watershed protection	Lao PDR
Rosales et al. 2004	Local non-timber forest products; Flood control	Lao PDR
Rosales et al. (2005)	NTFP; Timber Revenues; Fisheries & aquatic resources; Agricultural Production; Micro-hydropower facilities; Potential hydropower supply; Flood Control; Conservation Expenditures (Biodiversity Conservation); Bioprospecting; Carbon Sequestration.	Lao PDR
The and Ngoc (2006)	Climate regulation, Erosion prevention, Habitat services	Vietnam
To et al. (2012)	TEV; Water, Regulation of water flows; Erosion prevention; Opportunities for recreation & tourism;	Vietnam

ANNEX 2: VALUATIONS CONSIDERED FOR DECIDUOUS FORESTS

Hansen and Top (2006)	TEV; Non-timber forest products; Carbon sequestration; Soil and water protection	Cambodia
ICEM (2003a)	Housing materials; Firewood; Bamboo shoots; Wild vegetables; Mushrooms; Wild fruits; Deer and wild pigs; Other mammals and reptiles; Birds; Fish; Insects and mollusks; Frogs; Agricultural home consumption; Total home consumption; Wood products (Home consumption); Wild plants (Home consumption); Wild meat and fish (Home consumption); Agriculture (Home consumption); NTFP (Cash income); Wood products (Cash income); Wildlife (Cash income); Agriculture (Cash income); Total NBCA value; Provincial, national and global economic benefits; Watershed catchment protection values; Medium hydro-power potential; Micro hydro-power potential; Irrigated agriculture; TEV; Future economic options for NBCA goods and services; Opportunities for recreation & tourism; Options for the downstream use of water resources; Options for the commercial development of wild species; Carbon sequestration; Tourism; Economic benefits to villages and districts; Value of National Biodiversity Conservation Areas (NBCA) resources for home consumption	Lao PDR, Vietnam
Soussan and Sam (2011)	TEV; Food, Raw materials, Medicinal resources; Water; Regulation of water flows; Erosion prevention	Cambodia

ANNEX 3: VALUATIONS CONSIDERED FOR MANGROVES

Bann (1997)	Local fisheries; Local firewood; Local sustainable charcoal	Cambodia
Barbier et al. (2008)	Coastline protection and stabilization	Thailand
Christensen (1982)	Local use	Thailand
Emerton et al. (2002b)	Local subsistence products (excluding fish); Local fisheries.	Cambodia
Emerton (2005)	Food; Moderation of extreme events; Erosion prevention; Carbon Sequestration.	Cambodia
Hoa (2012)	Recreational Value	Vietnam
Kallesøe et al. (2008)	Mangrove products; Fish nurseries.	Thailand
Nhuan et al. (2003)	Timber; Fuel wood; Aquaculture; Marine product collection; TEV; Opportunities for recreation & tourism.	Vietnam
Norman-Lopez et al. (2008)	Timber; Fuel wood; Aquaculture; Organized fishing; Capture fisheries; Tourism.	Vietnam
Phan et al. (2000)	Timber; Firewood; Coal; Non-timber products; Aquaculture; Opportunities for recreation & tourism; Wild animals and plants; Preventing erosion; Mitigating waves and typhoons; Carbon storage; TEV.	Vietnam
Sathirathai (1998)	Local use	Thailand
Sathirathai and Barbier (2001)	Fish; Shrimp; Crab; Mollusks; Honey; Wood.	Thailand
Seenprachawong (2002)	Local use; Non-use values	Thailand
Seenprachawong (2003)	Tourism and recreation	Thailand
Seenprachawong (2008)	Flora and fauna; Recreation and tourism; Local livelihood; Fisheries; Ecological function; Flood protection; Rare and endangered species; TEV; Maintain fish stocks and marine lives.	Thailand
Tri et al. (1998)	Protection against extreme weather events	Vietnam
Tri et al. (2000)	Raw materials; Food; Opportunities for recreation & tourism; Medicinal resources; Habitat services;	Vietnam

ANNEX 4: VALUATIONS CONSIDERED FOR WETLANDS

ICEM (2003a)	Shells; Local Fisheries; Nursery protection;	Cambodia, Vietnam
Nhuan et al. (2003)	Timber; Fuel wood; Aquaculture; Marine products; Opportunities for recreation and tourism; TEV; Medical plants; Honey; Stabilising micro-climate; Air quality improvents; Water quality; Storm surge protection; Fishing; Coal.	Vietnam
Chong (2005)	Fish; Aquatic animals; Water birds; Building materials.	Cambodia
Do (2007)	Rice production; Wetland biodiversity.	Vietnam
Do and Bennett (2007a)	Biodiversity	Vietnam
Do and Bennett (2005)	Fuel wood; Mangrove timber; Melaleuca timber; Roofing; Household goods; Freshwater capture fisheries; Shrimp farming; Fish farming.	Vietnam
Do and Bennett (2007b)	Biodiversity	Vietnam
Emerton (2005)	TEV; Fishing; Water for cooking & washing; Transportation; Raw materials; Water; Medicinal resources; Ornamental resources; Food; Opportunities for recreation & tourism; Spiritual experience; Food; Moderation of extreme events; Waste treatment.	Cambodia
Gerrard (2004)	Flood protection; Wastewater treatment.	Lao PDR
Israel et al. (2007)	Freshwater aquatic resources	Cambodia
Muong (2004)	Food	Cambodia
Rab et al. (2006)	Fisheries	Cambodia
Tuan et al. (2009)	Aquaculture; Capture fisheries; Agricultural production; Sea grasses; Fresh water hydrophytes.	Vietnam
Pagdee et al. (2007)	Local use values	Thailand
Pagdee (2008)	Local use values	Thailand

ANNEX 5: VALUATIONS CONSIDERED FOR COASTS OR ISLANDS WITH CORAL REEFS

Asafu-Adjaye and Tapsuwan (2008)	Opportunities for recreation and tourism	Thailand
Christiernsson (2003)	Opportunities for recreation and tourism	Thailand
Cushman (2004)	Avoided Litter	Thailand
de Lopez et al. (2001)	Food; Raw materials; Medicinal resources; Opportunities for recreation & tourism; Food; Raw materials.	Cambodia
Doshi et al. (2012)	Opportunities for recreation and tourism	Thailand
Emerton (2005)	Food; Raw material; Medicinal resources	Cambodia
ICEM (2003b)	Total economic value; Fish; Shrimp; Oysters; Compost; Opportunities for recreation & tourism; Education and research	Cambodia, Thailand
Jin et al. (2010)	Conservation of marine turtle	China, Philippines, Thailand, Vietnam
Nam and Son (2001)	Opportunities for recreation & tourism	Vietnam
Nam and Son (2005)	Opportunities for recreation & tourism	Vietnam
Nam et al. (2005)	Opportunities for recreation & tourism; Food	Vietnam
Seenprachawong (2003)	Opportunities for recreation & tourism	Thailand
Seenprachawong (2001)	Tourism	Thailand

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