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Assessing the Economic Value of Natural Infrastructure in Coastal Ecosystems for Disaster Risk Reduction, Response and Coastal Resilience in APEC Region

GAP ANALYSIS REPORT

U.S.-APEC Technical Assistance to Advance Regional Integration (US-ATAARI)

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ASSESSING THE ECONOMIC VALUE OF NATURAL INFRASTRUCTURE IN COASTAL ECOSYSTEMS FOR DISASTER RISK REDUCTION, RESPONSE AND COASTAL RESILIENCE IN APEC REGION

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EXECUTIVE SUMMARY

The APEC region is vulnerable to natural disasters, which can have devastating effects and result in significant economic costs for member economies. However, an adequate management of natural infrastructure in coastal ecosystems can help reduce the adverse impacts and costs of natural disasters.

In this sense, in 2014 the United States proposed to develop the study "Assessing the Economic Value of Natural Coastal Infrastructure in Coastal Ecosystems for Disaster Risk Reduction and Response and Coastal Resilience". This project aims to increase understanding of the value of natural coastal infrastructure (NCI) to better inform policy decision with regards to the management of coastal resources as well as improve disaster risk reduction strategies. This project consists of a two phase assessment: Phase 1: Gap Analysis Report which focusses on identifying knowledge and policy gaps related to the economic value of NCI services for disaster risk reduction, response and coastal resilience; based on a literature review and a survey of APEC member economies; Phase 2: NCI valuation study which will provide an initial assessment of the economic value of services provided by NCIs in coastal ecosystems in the APEC region for the purposes of disaster risk reduction and response, and coastal resilience.

In this Gap analysis Report a literature review of existing economic valuation methods and studies was conducted. The studies and valuation methods reviewed in the report were undertaken at varying geographic scales and locations, and the applicability and effort required to undertake them varies significantly. For instance, the economic valuation studies using the Benefit Transfer method can be the least costly to undertake, but require the existence of comprehensive valuation studies previously undertaken in similar contexts and scales to base their value on. In the other end, studies such as the Damage Cost Avoided, Replacement Cost, and Substitute Cost methods can effectively estimate the economic value of disaster risk reduction (DRR) ecosystem services of NCIs, but can be very costly, as they require sophisticated loss models and on-site assessments. Additionally, a survey of APEC member economies for the identification of knowledge gaps and regulatory barriers was carried out. This survey found that the degree of policy and interagency and organizational collaboration efforts aimed at closing existing knowledge gaps and removing regulatory barriers vary widely across member economies. The survey responses also reveal that there is a consistent need for funding of programs and efforts that consider NCI management and protection across most member

economies. Through the activities undertaken in this report, a series of critical policy and knowledge gaps were identified, which include the following:

- A need for more valuation studies covering different types of NCIs and geographical areas, including small scale studies undertaken at the local levels.,
- A lack of data for measuring/tracking certain types of NCIs at small geographic scales, and more precise climate and disaster-related parameters (including reef and wave characteristics, frequencies of hurricanes, and effects of NCI cover decline on flood damages during extreme events) are needed in order to undertake more accurate valuation studies
- A lack of studies that focus on measuring the value of DRR services provided by NCIs.
- A need for greater interagency coordination for protecting and managing NCIs
- A need for increased awareness about economic value of NCI ecosystem services among policymakers
- A need to enhance technical capacity to design and implement disaster risk reduction programs, which incorporate NCIs.
- A need for laws that can effectively protect NCIs while providing proper compensation to resource owners

Based on these gaps, the study provides an initial set of recommendations. APEC economies should promote the dissemination of information regarding existing valuation studies as well as facilitate the development of more economic studies covering different types of NCIs as well as different geographical areas, including small scale studies undertaken at the local levels. The importance to build capacity among member economies to develop economic valuation studies of NCIs, by increasing the knowledge and understanding of different methodologies and procedures used, as well as facilitating the availability and access to relevant information and data necessary to undertake these studies is also highlighted. APEC economies should continue raising awareness among the general public and policymakers of the importance of NCIs for disaster risk reduction, response and coastal resiliency.

GAP ANALYSIS REPORT INTRODUCTION

Coastal populations and their built environments are particularly vulnerable to destructive impacts from natural disasters such as storms, hurricanes, and tsunamis. Due to climate change, many of these natural events will be taking place with more frequency, making mitigation practices crucial for the resilience of coastal settlements.

With sea levels rising, coastal populations will be more vulnerable to natural disasters. As of 2008, the total population of poor living near the coast was estimated at 252 million[1] and is increasing at twice the global population growth rate.[2] A large portion of people vulnerable to coastal disasters live in the APEC member economies.

According to a study of natural disasters by UN ESCAP (2015), between 1970 and 2014, Asia and the Pacific accounted for 56.6% of global fatalities due to natural disasters. The region also experienced over 6 billion of citizens being affected by natural disasters, accounting for 88% of the global total. In this time frame, 1.15 trillion US Dollars were lost from natural disasters; 92% of which are attributed to earthquakes, tsunamis, floods and storms. Statistics may also suggest that investment into disaster resilience is necessary as economic losses increased nearly 15 times since 1970, while the Asia Pacific Region's GDP only grew 5 times.[3]

In this context, the protection of Natural Coastal Infrastructures (NCIs) is increasingly being thought of as an effective form of coastal defense strategy. However, there remains, a pressing need to better understand the roles that ecosystems can play in defending coasts.[4]

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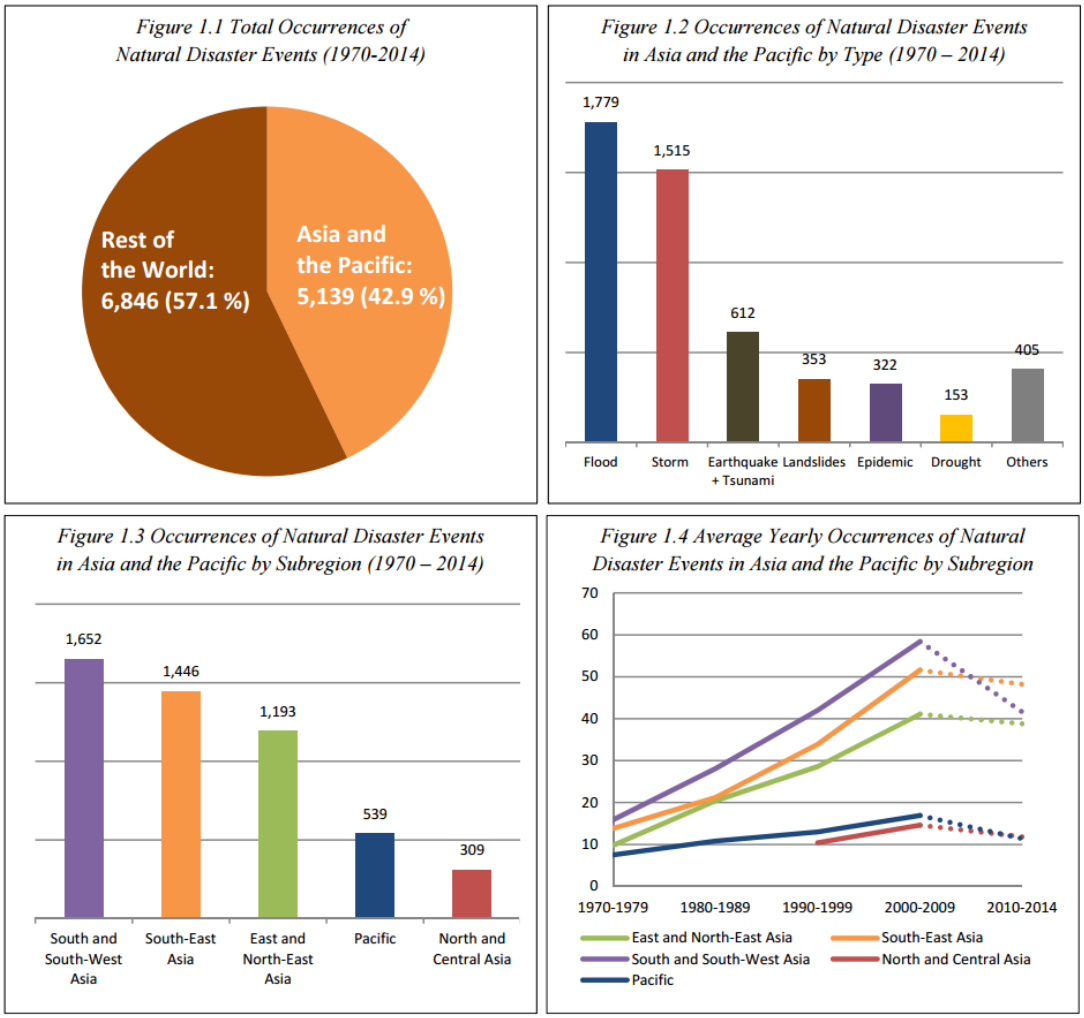
[1] "Ecosystem Services for Poverty Alleviation: Marine & Coastal Situational Analysis: Synthesis Report." NTRC. (2008). http://www.nerc.ac.uk/research/funded/programmes/espa/marine-and-coastal-synthesis-report/

[2] The Rockefeller Foundation. Vulnerable Natural Infrastructure in Urban Clusters (2013). https://www.rockefellerfoundation.org/app/uploads/Vulnerable-Natural-Infrastructure-in-Urban-Coastal-Zones.pdf

[3] "Overview of Natural Hazards and Their Impacts in Asia Pacific, 1970-2014." UN-ESCAP. (2015). http://www.unescap.org/sites/default/files/Technical%20paper-Overview%20of%20natural%20hazards%20and%20their%20impacts_final.pdf

[4] McIvor, Anna, Iris Moller, Tom Spencer, and Mark Spalding. "Reduction of Wind and Swell Waves by Mangroves." (2012). http://www.wetlands.org/Portals/0/publications/Report/reduction-of-wind-and-swell-waves-by-mangroves.pdf

Figure 1: (1.1-1.4) Natural Disaster Events in the Asia Pacific Region



Source: UN ESCAP

Natural Coastal Infrastructure (NCIs) are natural (non-anthropogenic) ecosystem features that are a part of an economy's shoreline environments. The terms NCI and Green Infrastructure differ from each other in the sense that the latter refers to a similar or same type of natural infrastructure that is strategically planned and managed (such as constructed wetlands, planted forests, and green roofs). NCIs may provide benefits of reducing adverse impacts that may be associated with coastal disaster events (including erosion, storm surges, wave actions, etc.). NCI offer protection to coastal settlements by reducing the speed and extent of flood surges during storms or tsunamis (in the case of mangroves and salty marshes), reducing the intensity of tsunamis (in the case of coral reefs), and by providing shelter from strong winds during coastal storms.

For example, mangroves or salt marshes can offer protection to coastal settlements through disaster resilience as they can attenuate and dissipate waves, stabilize shorelines, and retain soil. Coral Reefs can also attenuate wave energy through

breaking offshore waves.[5] NCIs not only increase disaster resilience, but also offer ecosystem services, such as serving as a habitat for biodiversity and recreation.

In the APEC context, member economies recognize that healthy NCIs are critical in mitigating disasters by reducing vulnerability and thereby increase the resilience of coastal populations.

In 2014, through the Xiamen Declaration, the APEC Ocean-Related Ministers called for *"the establishment of more integrated, sustainable, inclusive and mutually beneficial partnership through ocean cooperation among APEC members, that implement previous commitments, and focuses efforts on collaborated and concerted actions in the following four priority areas: (1) Coastal and marine ecosystem conservation and disaster resilience; (2) The role of the ocean on food security and food-related trade; (3) Marine science, technology and innovation; and (4) Blue Economy.*[6]

As a result, APEC has completed a number of projects in the past concerning marine ecosystems. Ranging from the Preparedness, Response and Assessment of Oil Spill (PRAOS) Phase I Project, to the Marine Ecosystem Assessment and Management in the Asia-Pacific Region Phase III.

In order to obtain a better appreciation of the economic value of services provided by NCIs in coastal ecosystems in APEC region the United States is implementing the project "Assessing the Economic Value of Natural Coastal Infrastructure in Coastal Ecosystems in Disaster Risk Reduction and Response, and Coastal Resilience". The first phase of this project aims identify knowledge gaps related to the economic value of coastal green infrastructure benefits and services for disaster risk reduction and response and coastal resilience in the APEC region. This report contains a Gap Analysis that is based on a review of existing literature and studies which estimate the economic value of services provided by NCIs, and surveys undertaken by APEC member economies with the goal of identifying critical knowledge gaps and regulatory barriers of valuing NCIs' services for disaster risk reduction, response and coastal resilience in the APEC region.

After this, the second phase of this project will consist of developing a Valuation Study that will aim to provide an initial assessment of the economic value of the benefits and services provided by NCIs in coastal ecosystems for the purposes of disaster risk reduction and response and coastal resilience in the APEC region.

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5 "Performance of Natural Infrastructure and Nature-based Measures as Coastal Risk Reduction Features." EDF. (2015) https://www.edf.org/sites/default/files/summary_ni_literature_compilation_0.pdf

6 "Fourth APEC Ocean-Related Ministerial Meeting-AOMM4 Towards New Partnership through Ocean Cooperation in the Asia Pacific Region." MDDB, APEC. (2014). http://mddb.apec.org/Documents/2014/MM/AOMM/14_aomm_jms.pdf

LITERATURE REVIEW

There is an increasing amount of studies that examine natural, built and hybrid coastal infrastructure and their contribution to disaster risk reduction and resilience at global, regional and local levels. This section presents a summary of the literature review covering a diverse sample of economic valuation studies[7] undertaken using different types of valuation methods that are applied to various types of NCIs at different geographic extents and regions around the world. Some studies focus on one type of NCI while other studies focus on multiple types. The types of NCI ecosystem services valuated in these studies also varies, as some analyze NCI's contributions in the form of market and non-market services to surrounding communities. Examples for market services include tourism and fisheries, while non-market services include biodiversity and future value. Continuing efforts to recognize and quantify the protective benefits of NCIs improve our understanding and promote an adequate consideration of ecosystem services in the planning and decision making with respect to coastal resilience and risk-reduction strategies.

This section, starts by discussing different types of valuation methodologies that have been most widely applied to estimating the economic value of DRR services provided by NCIs. This is followed by , a summary of existing literature on the value of NCIs; including a collection of previous studies that have applied these valuation methods to estimate the economic value of NCIs. Finally, this section discusses knowledge gaps identified in this literature review.

The main goal of this literature review of methodologies and their applications is to identify the most important knowledge gaps that remain to be bridged. This literature review finds that specific valuation methods have been more widely applied towards estimating the economic value of a few types of NCIs and there is small number of methods that have been used with more frequency than others. While the application of these valuation methods varies, many knowledge gaps have yet to be bridged in understanding NCI's contribution in risk reduction and resilience.

Valuation Methodologies and their Applications

Different valuation methods have been used to estimate the economic value of NCI ecosystem services. These methodologies vary widely in terms of the amount of data and types of indicators used. Most ecosystem valuations assess the willingness of citizens to pay (WTP) for a specific plot of land base upon its real and perceived values. This produces the key challenge of understanding the complete ecosystem and biodiversity services provided by ecosystems. Furthermore, most assessments analyze

[7] This literature review covered 16 studies.

the current stock of the NCI today and do not account for long term changes to NCIs and their relative benefits. Ecosystems provide not only services which are traded on markets and can be quantified, but also psychological and ecological services that should be taken into account in valuation methodologies.

Below is a list of the valuation methodologies that have been most widely applied towards NCIs' ecosystem services in disaster risk reduction. Each valuation methodology listed in this section presents their description, required inputs, applicability, advantages, and disadvantages, and an example where each was applied in one or more of the articles included in this literature review. Under the required inputs to undertake these valuation methods, various data sources are referenced. Annex I further elaborates on the accessibility and applicability of these data sources and on the tools necessary to analyze this data when applying an economic valuation method. The type of data referenced includes, socioeconomic and market data, as well as satellite imagery and other geo-referenced data. A summary table of the information presented in this section is included in Annex II.

Total Economic Value (TEV) Methodology

The TEV Methodology aggregates a range of different value types that represent ecosystem services, and requires statistical analyses that produce meta-analytic value functions that can be used to estimate total values of mangroves as well as freshwater and non-mangrove coastal wetlands. The methodology classifies multiple "value types," or in other words, types of ecosystem services (such as recreational benefits, food production, and disaster mitigation). Value types can be classified into "Use Values" and "Non-use Values". Use Values are further divided into "Direct-use Values," referring to benefits from using or experiencing the natural resources such as food production and recreation, and "Indirect-use Values," which refer to the ecosystem's ability to ensure stable delivery of services as a result of the ecosystem's ability to self-regulate. Non-use Values refer to the psychological or emotional benefits from ecosystems.[8] This methodology was used by Florian V. Eppink, et. al. in the study "An Initial Assessment of the Economic Value of Coastal and Freshwater Wetlands in West Asia", which uses a scenario analysis to find the present value of the regional economic loss of not protecting wetlands by 2050.[9]

Applicability

- Primarily used to estimate a broad economic value of wetlands and mangroves;

[8] Turner, R.K.; Paavola, J.; Cooper, P.; Farber, S.C.; Jessamy, V.; Georgiou, S. "Valuing nature: Lessons learned and future research directions." *Ecol. Econ* 46.3 (2003): 493–510.

[9] Eppink, Florian V. et. al. "An Initial Assessment of the Economic Value of Coastal and Freshwater Wetlands in West Asia." Land 3.3 (2014): 557-73. http://www.wwfus.org/science/data.cfm

Values

- Recreation, research, education, harvesting of crops, fisheries, and aquaculture;
- Ecosystem services from NCIs, such as self-regulation in terms of pest control, water regulation and purification, and soil fertility;
- Cost of policy inaction to conserve stock of natural capital;
- Willingness to pay;
- Location and extent of NCI;
- Infrastructure conditions including type of adjacent settlements and transport networks.

Data Sources

- Global Database of Lakes, Reservoirs and Wetlands;[10]
- Guidance Manual for TEEB Country Studies;[11]
- Surveys of users of environmental goods and services;
- Satellite imagery; USGS Global Visualization Viewer;[12]
- Data on infrastructure conditions: available from municipal offices, multiple listing services, and other sources, and crowdsourcing websites such as Open Street Map.[13]

Advantages

- A cost effective means for monetizing natural resources;
- Transferability: can take value estimates from one or more study sites and applies them to a site of interest;
- Can be used for scaling up from localized changes to larger geographic areas.

Shortcomings

- Measurement: unreliable data, analyst errors;
- Publication Selection: editorial preference for stat. sig. results, policy interest;
- Generalization: values for study sites are transferred to policy sites that are different but not realized (wetland scale, quality, demand for services);
- Does not account for the intrinsic value of biodiversity in its own right, independent from the value placed on it by people;
- A static methodology: NCIs are valuated at a particular point in time, while risks due to sea level rise are dynamic.

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10 Lehner, B.; Döll, P. Development and validation of a global database of lakes, reservoirs and wetlands. *J. Hydrol.* 2004, *296*, 1–22.

11 The Economics of Ecosystems and Biodiversity (TEEB). "Guidance Manual for TEEB Country Studies," Version 1.0; TEEB: Geneva, Switzerland, (2013). http://www.teebweb.org/media/2013/10/TEEB_GuidanceManual_2013_1.0.pdf

12 USGS Gloval Vizualization Viewer. http://glovis.usgs.gov/

13 Open Street Map. www.openstreetmap.org

Market Price Method

The Market Price Method solely estimates the services and products of an ecosystem which can be traded on commercial markets using price and quantity data to identify producer and consumer surpluses. The sum of such services and products of an ecosystem is the total net economic benefit of the ecosystem. This method derives a demand function for both the consumer surplus and the producer surplus (total revenues – total variable costs) for the before and after disaster situation at hand in order to generate a dollar value for total economic effect of the change. An example of the use of this method is found in the study by R. Mamiit and K. Wijayaweera titled "The Economic Value of Coastal Ecosystems in Reducing Tsunami Impacts: The Case of Mangroves in Kapuhenwala and Waduruppa, Sri Lanka."[14] This study estimated the value of mangrove ecosystems as shoreline buffers in the event of extreme disasters and the results indicated that costs of damages where approximately ten times higher in areas with degraded mangrove ecosystems. In addition to the Market Price Method, the TEV and the Damage Cost Avoided Methods were also used in this study.

Applicability

This method is particularly useful for the valuation of mangroves and is more reliable at small to medium scales than at regional scales. The method is also best suited for evaluating specific episodic disaster scenarios.

Values

- Value of fisheries: price and quantity data;
- Value of timber: price and quantity data;
- Household survey responses;
- Location and extent of NCI;
- Infrastructure conditions including type of adjacent settlements and transport networks.

Data Sources

- Market data on timber and fish from a Member Economy's source;
- Data revealed though household surveys;
- Satellite imagery; USGS Global Visualization Viewer;[12]
- Data on infrastructure conditions: available from municipal offices, multiple listing services, and other sources, and crowdsourcing websites such as Open Street Map[13].

[14] Mamiit, R. and Wijayaweera, K. "The economic value of coastal ecosystems in reducing tsunami impacts: The case of mangroves in Kapuhenwala and Waduruppa, Sri Lanka." (2006). http://www.webmeets.com/ere/wc3/prog/viewpaper.asp?pid=670

Advantages

- Good assessment of the willingness to pay (WTP) for specific plots of land;
- Data is relatively easy to obtain from established markets.

Shortcomings

- Market data may be spotty and unreliable in informal or rural economies;
- Seasonality is crucial;
- Cannot be easily used to assess a larger scale change (i.e. a wiped out ecosystem) that will alter supply and demand of the good;
- Market value of shared goods or benefits is difficult to measure;
- Where no market information can be acquired, economists resort to survey techniques to elicit people's intended behaviour;
- May not account for other resources used to bring the good to market, distorting and overstating the price.

Hedonic Pricing Method

The Hedonic Price Method estimates economic values for ecosystems that directly affect market price (i.e. variation in housing prices that reflect value of local environmental attributes). This method is mainly applied to variations in property prices that can reveal implicit values or reflect demand for ecosystem services, which may include air quality, proximity to a body of water, aesthetic views or recreational sites. The required inputs are used to create a function that relates property values to the property characteristics, including the distance to the NCI. The resulting function measures the portion of the property price that is attributable to each factor.[15] A good example of this method can be observed in the study by S. Sarkis et al., and the Bermuda Department of Conservation Services, which used a variety of valuation methods to derive the value of coral reef ecosystems in Bermuda.[16] This study also estimated the contribution of reefs to the amenity value of real estate using a hedonic price model applied to data from 593 house and condominium sales.

Applicability

- This method is particularly useful for the valuation of multiple types of NCIs including mangroves, wetlands, sand dunes, and coral reefs, and is applicable at multiple scales.

Values

- Index of the environmental amenity of interest;

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15 The Hedonic Pricing Method. http://www.ecosystemvaluation.org/hedonic_pricing.htm

16 Sarkis, S., van Beukering P. J.H., and McKenzie E. "Total Economic Value of Bermuda's Coral Reefs." Bermuda Department of Conservation Services (2010). http://www.conservation.bm/coral-reef-economic-valuation/

- Price per square meter (or foot);
- Cross-section and/or time-series data on property values and property and household characteristics for a well-defined market area that includes homes with different levels of environmental quality, or different distances to an environmental amenity, such as open space or the coastline;
- Location and extent of NCI;
- Infrastructure conditions including type of adjacent settlements and transport networks.

Data Sources

- Data on housing/property prices: available from municipal offices, multiple listing services, and other sources;
- Local property records;
- Satellite imagery; USGS Global Visualization Viewer;[12]
- Data on infrastructure conditions: available from municipal offices, multiple listing services, and other sources, and crowdsourcing websites such as Open Street Map.[13]

Advantages

- The method's main strength is that it can be used to estimate values based on actual choices;
- Property markets are relatively efficient in responding to information, so can be good indications of value;
- Property records are typically very reliable;
- Data on property sales and characteristics are readily available through many sources, and can be related to other secondary data sources to obtain descriptive variables for the analysis.

Shortcomings

- The method will only capture people's willingness to pay for perceived differences in environmental attributes, and their direct consequences;
- The method assumes that people have the opportunity to select the combination of features they prefer, given their income. However, the housing market may be affected by outside influences, like taxes, interest rates, or other factors;
- The method is relatively complex to implement and interpret, requiring a high degree of statistical expertise;
- Depends heavily on model specification, large data collection process;
- Property values are determined primarily by short term market conditions, making it difficult to assess long term NCI benefits using this method.

Damage Cost Avoided, Replacement Cost and Substitute Cost Methods

The Damage Cost Avoided, Replacement Cost, and Substitute Cost Methods estimate values of ecosystem services based on either the costs of avoiding damages due to lost services, the cost of replacing ecosystem services, or the cost of providing substitute services. These methods assume that the costs of avoiding damages or replacing ecosystems or their services provide useful estimates of the value of these ecosystems or services. For instance, if people incur costs to avoid damages caused by lost ecosystem services, or to replace the services of ecosystems, then those services must be worth at least what people paid to replace them. These methods require baseline and projected ecological flood protection assessments before and after restoration.

In the case of the Damage Cost Avoided Method, the results can be used to estimate potential damages to property if floods were avoided, or, in when using the Replacement Cost Method, to determine whether nearby property owners have spent money to protect their property (i.e. though insurance or basement reinforcement) and use these avoidance expenditures to estimate benefits. Finally, the Substitute Cost Method is used to estimate the costs of providing a substitute for the affected services (i.e., in this case a retaining wall or a levee might be built to protect nearby properties from flooding). A good example of the use of one of these methods is in the study conducted in Sri Lanka by R. Mamiit and K. Wijayaweera, where the Damage Cost Avoided Method was used in conjunction with the TEV and the Market Price Methods to estimate the value of ecosystem services provided by mangroves.

Applicability

This method is particularly useful for the valuation of multiple types of NCIs including mangroves, wetlands, sand dunes, and coral reefs, and is applicable at multiple scales but best suited for small geographic scales.

Values

- Baseline and projected ecological flood protection assessments before and after restoration (cost of preservation measures, or estimated costs from damages incurred);
- Location and extent of NCI (before and after restoration efforts);
- Infrastructure conditions including type of adjacent settlements and transport networks.

Data Sources

- NOAA: Billion Dollar Weather and Climate Disasters;[17]
- National and local government websites; municipal offices;

[17] "Billion Dollar Weather and Climate Disasters: Overview." NOAA. (2015). https://www.ncdc.noaa.gov/billions/

- Satellite imagery; USGS Global Visualization Viewer; [12]
- Data on infrastructure conditions: available from municipal offices, multiple listing services, and other sources, and crowdsourcing websites such as Open Street Map;[13]
- Insurance company models and FEMA HAZUS tools.

Advantages

- When compared against other valuation methods, this method provides a relatively accurate estimation of ecosystem services from NCIs that are closely related to disaster mitigation.

Shortcomings

- This method can be very costly, as it requires sophisticated loss models that can determine both the physical impact and the economic value of the losses.

Contingent Valuation Method (CVM)

The Contingent Valuation Method (CVM) estimates all kinds of ecosystem and environmental services, use and non-use values by surveying a population's willingness to pay is for a specific services based on a contingent scenario. A study by Premachandra Wattage and Simon Mardle titled "Total Economic Value of Wetland Conservation in Sri Lanka Identifying Use and Non-Use Values," is a good example of the use of this method.[18] In this study, the CVM was implemented to measure the stakeholder willingness to pay towards the conservation of fish, mangroves, and water in a Sri Lankan wetland.

Applicability

- This method can be used to value all types of NCIs including mangroves, wetlands, sand dunes, and coral reefs, and is applicable at multiple scales.

Values

- WTP for every type of NCIs' ecosystem service based on a contingent scenario;
- Location and extent of NCI.

Data Sources

- On-site, phone, mail, or electronic surveys;
- Satellite imagery; USGS Global Visualization Viewer. [12]

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18 Wattage, P. and Mardle, S. "Total Economic Value of Wetland Conservation in Sri Lanka Identifying Use and Non-Use Values." Wetlands Ecol Manage 16.5 (2007): 359-69. Web.

Advantages

- Applicable for Non-use Values, which cannot be calculated by market demand.

Shortcomings

- Can be very costly between survey design, implementation, and specification, all for what might be simply hypothetical information;
- The conceptual, empirical, and practical problems associated with developing dollar estimates of economic value on the basis of how people respond to hypothetical questions about hypothetical market situations are debated constantly.

Benefit Transfer Method

The Benefit Transfer Method is used to estimate economic values for ecosystem services by transferring available information from studies already completed in another location and/or context. First, one must identify previous studies and valuations for disaster resilience that focus on the NCIs one is trying to valuate. Then, one must determine whether the degree of comparability is an acceptable one by analyzing the NCIs' factors that can be substituted and transferred from the existing study (or combination of studies) and applied towards the new study. The quality of the existing relevant study (or studies) must be evaluated. Finally, once the relevant existing studies have been selected, one must adjust their values to better reflect the values for each site under consideration (such as type of NCI and size). A good example of the use of this valuation method is found in the study by Brenner, J. et al. titled "An assessment of the non-market value of the ecosystems services provided by the Catalan coastal zone, Spain".[20] In this study, a value-transfer method was used to generate a baseline estimate of value of several ecosystem services in the Catalan coastal zone. The valuation approach was based on the six step method proposed by Troy and Wilson,[19] which consists of selecting the ecosystem services to be valuated, defining the study area, using GIS tools to classify the different types of ecosystems within the study area, conducting an analysis of previous valuation literature preferably applied to similar biophysical and socioeconomic contexts, then, estimating the value of each type of ecosystem service per area unit, and calculating the annual flow of the ecosystem service value based on the extent of each ecosystem type of the study site.

Applicability

This method can be used to value multiple types of NCIs including mangroves, wetlands, sand dunes, and coral reefs, and is applicable at multiple scales based on an adjusted economic value attained from a previous similar study, or from a combination of similar studies.

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[19] Troy A, Wilson MA. Mapping ecosystem services: practical challenges and opportunities in linking GIS and value transfer. Ecological Economics 60, no. 2 (2006): 435-49.

Values

- Location and extent of NCI;
- Demographic and socioeconomic data;
- Infrastructure conditions including type of adjacent settlements and transport networks;
- Valuation formula from previous similar study (or studies).

Data Sources

- Previous economic valuation studies where the context and conditions (including socioeconomic and climatic conditions, population size and density, and type of NCI) of their location are similar in the new study;
- Guidance Manual on Value transfer Methods[20];
- Satellite imagery; USGS Global Visualization Viewer[12]
- Data on infrastructure conditions: available from municipal offices, multiple listing services, and other sources, and crowdsourcing websites such as Open Street Map.[13]

Advantages

- A cost effective means of conducting an economic valuation study.

Shortcomings

- The method is only as accurate as the initial study;
- Adequacy of existing studies in a new and different context may be hard to analyse; one needs to be able be to measure and compare the same things across regions/studies;
- The unit value estimates can become dated quickly as climatic and socioeconomic factors change at the location of the existing study.

The analysis suggests that out of the valuation methods reviewed above, the most cost effective methodology is the Benefit Transfer Method as long as the economic value being transferred comes from a (or a combination of) comprehensive study(s) that was undertaken under similar geographic scales and socioeconomic contexts. In terms of a method's ability to assess the economic value of ecosystem services pertaining to DRR, the Damage Cost Avoided, Replacement Cost, and Substitute Cost methods provide the most accurate estimates. This is because these methods estimate the value ecosystem services based on costs that are directly related to natural disaster damages or NCI restoration efforts. However, this method can also be the most costly, as it requires baseline and projected ecological flood protection assessments before and after restoration. Other cost effective methods include the Market Price method and

20 United Nations Environment Programme (UNEP). "Guidance Manual on Value Transfer Methods for Ecosystem Services; UNEP: Nairobi, Kenya, (2013). http://www.gwp.org n

the Hedonic Pricing Method. However, because they assess the willingness to pay for the land based on market variables, such may not be an accurate indicator of the actual value that NCI ecosystem services provide. The next section provides a comprehensive review of studies that have used valuation methods outlined in this section (among other methods and techniques) to estimate the economic value of NCIs, and/or which have assessed the effectiveness of existing valuation methods.

Review of Studies and Literature on the Economic Value of NCIs

The review of relevant case studies that examine natural, built and hybrid coastal infrastructure and their contribution to disaster risk reduction, show that there is a general agreement in the scientific community that NCIs provide important benefits through disaster risk reduction ecosystem services; and on the need of promoting better understanding of the economic value of NCIs for disaster risk reduction policy making.

For instance, a study undertaken by Sutton-Grier et al. in the US titled "Future of Our Coasts: The Potential for Natural and Hybrid Infrastructure to Enhance the Resilience of our Coastal Communities, Economies and Ecosystems," highlights that in 2011, coastal shoreline counties contributed 6.6 trillion dollars to GDP and that there is evidence that natural habitats (wetlands, dunes, barrier islands, sea grasses, corals, etc.) reduce the risk of flooding while providing other social and economic benefits.[21] This study compiles several case studies undertaken in the US and analyzes studied NCI's strengths and weaknesses of the coastal protection benefits as well as identifying policy challenges for the implementation of coastal resilience policies. The case studies analyzed by Sutton-Grier et al. consider benefits provided by multiple types of NCIs including coral reefs, wetlands, salty marshes, mangroves, and sea grasses. Findings in the US case studies analyzed state that benefits from NCIs include wave attenuation, and flood and storm surge mitigation, which were estimated to provide $23.2 billion per year in storm protection. This estimate is derived from one of the case studies analyzed by Sutton-Grier et al., which was undertaken by Costanza et al. based on a regression model of 34 hurricanes in the US between 1980 and 2008.[22]

An issues paper by Morse-Jones et al. titled "Ecosystem Valuation: Some Principles and a Partial Application," also looks at multiple economic valuation case studies applied to a wide range of types of NCIs and geographies. In this paper, rather than attempting to identify best practices on valuation methodologies, the authors outlined a series of considerations about the nature and geographic extent of a study that researchers must take into account to avoid calculation errors.

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[21] Sutton-Grier, Wowk, Bamford., Future of our coasts: the potential for natural and hybrid infrastructure to enhance the resilience of our coastal communities, economies and ecosystems, 2015

[22] Costanza et al., The value of coastal wetlands for hurricane protection, AMBIO, 2008, 37, pp. 241–248

In another article titled "The Economic Value of Coastal Ecosystems in Reducing Tsunami Impacts," Mamiit and Wijayaweera use a combination of economic valuation techniques to estimate the value of the protective function of mangroves from natural disasters in Sri Lanka. The findings of this study indicate that threatened mangroves reduce the protection afforded to inland properties, community infrastructures and livelihood by US$ 2,109 per household.[23]

In a study undertaken by Brenner, J. et al. titled "An Assessment of the Non-market Value of the Ecosystems Services Provided by the Catalan Coastal Zone, Spain," a spatial value transfer method was used which takes value estimates from previous valuation studies applied to the same types of natural and semi-natural coastal ecosystems under similar biophysical and socioeconomic conditions to estimate a baseline value estimate of ecosystem services in the Catalan coastal zone.[24] This study valuates several types of ecosystem services including atmospheric gas and climate regulation, disturbance regulation, freshwater regulation, freshwater supply, erosion control, soil formation, nutrient regulation/cycling, waste treatment, etc. The specific types of NCIs in this study include seagrass beds, beaches/sand dunes, saltwater wetlands. The ecosystem services value estimate for these NCIs was estimated at US$67,400/hectare/year for beaches/sand dunes, and at US$766 for saltwater wetlands, while there was not enough value data to generate estimates for seagrass beds.

A similar study to the one undertaken by Brenner, J. et al. is titled "Ecosystem Service values for Mangroves in Southeast Asia: A meta-analysis and value transfer application", as it also employs a value transfer method to generate an ecosystem services value estimate. [25] In this study Brander, L. et al. use 130 value estimates from previous studies, which estimate mangroves in Southeast Asian economies: Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, Philippines, Thailand, and Viet Nam. The study estimates the mean and median values of mangroves' ecosystem services in the region at US$4185 and US$239/hectare/year respectively. The study also estimates forgone annual benefits in 2050, assuming a business as usual scenario of not preserving NCIs, which amounts to $2.2 billion as a result of policy inaction that results in natural decline of these ecosystems.

A paper written by Van Zanten et al. titled "Coastal Protection by Coral Reefs: A Framework for Spatial Assessment and Economic Valuation," developed an analytical framework for spatial assessment and valuation of coastal protection services by coral reefs. This analytical framework was tested in the United States Virgin Islands with the use of flood insurance rate maps, reef typology, a wave model, and depth-damage

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23 Mamiit, R. and Wijayaweera, K., The Economic Value of Coastal Ecosystems in Reducing Tsunami Impacts: The case of mangroves in Kapuhenwala and Waduruppa, Sri Lanka, 2006

24 Brenner, J., et. al. "An Assessment of the Non-market Value of the Ecosystem Services Provided by the Catalan Coastal Zone, Spain." Ocean & Coastal management 53, no. 1 (2010)

25 Brander, L. et al, "Ecosystem Service Values for Mangroves in Southeast Asia: A meta-analysis and value transfer application", 2012

model.[26] The resulting coastal protection value of coral reef ecosystems in the USVI is estimated at an annual value of US$1.2 million. The authors also highlight weaknesses of previous economic valuation studies on coral reefs.[27]

A NOAA study titled "The Economic Value of U.S. Coral Reefs[28]," summarizes work undertaken to estimate the economic value of coral reefs in seven US jurisdictions using different approaches over different time periods between 2001 and 2011. As a result of variations in approaches and in the range of ecosystem services accounted for, these studies produced a wide range of values. The studies confirm the importance and benefits these ecosystem services provide to their respective coral reef jurisdictions, which include Florida, Hawaii, American Samoa, Commonwealth of the Northern Mariana Islands (SNMI-Saipan), Guam, Puerto Rico, and the US Virgin Islands. Estimates of total economic values for each jurisdiction in this study are presented in 2012 US dollars.[29] The studies conducted in Guam and in the US Virgin Islands consider the economic value of shoreline protection services, among other ecosystem service values, such as recreation/tourism, education and research, and fisheries, among others. This review of economic valuation studies concludes that tourism/recreation activities were more highly valued than individual activities, and non-use values for coral reefs were found to be significantly higher than other values.[30] The following table summarizes the estimated economic value for each of the studies during their respective years.[31]

Table 1: Economic Value of Coral Reefs by Study

Location	Study Year	Value (2012$ Million/Year)
Florida	2001	324
Hawaii	2002	455
American Samoa	2004	11
CNMI – Saipan	2006	68
Guam	2007	150
Puerto Rico	2008	1,161
US Virgin Islands	2011	210

Source: Edwards, NOAA

26 Van Zanten, Pieter van Beukering, Alfred Wagtendonk. *Coastal protection by coral reefs: A framework for sptial assessment and economic valuation*. 2014. Journal of Ocean & Coastal Management

27 Ibid.

28 Edwards, P. "The Economic value of U.S. Coral Reefs." NOAA. (2013). http://docs.lib.noaa.gov/noaa_documents/CoRIS/Economic_Value_US_Coral_Reefs_Summary_2013.pdf

29 Edwards, P. "The Economic value of U.S. Coral Reefs." NOAA. (2013). http://docs.lib.noaa.gov/noaa_documents/CoRIS/Economic_Value_US_Coral_Reefs_Summary_2013.pdf

30 Ibid.

31 As explained later in this report, use values refer to benefits from using natural resources such as food production and recreation, and to the ecosystem's ability to ensure stable delivery of environmental flows, while non-use values refer to the psychological or emotional benefits people receive from the ecosystems.

A study titled "An initial assessment of the Economic Value of Coastal and Freshwater Wetlands in West Asia," by F. Eppink et al., used a scenario analysis (along with other valuation methods) to find the present value of the regional economic loss of not protecting wetlands by 2050 in West Asia.[32] In this study, West Asia is defined as defined as the Arabic countries of the Arabian Peninsula plus Turkey and Iran. The study finds that these losses range between US$2.3 billion and US$7.2 billion (in 2007 US dollars).[33]

A study undertaken by Das et al., titled "Effects of Coastal Vegetation Species and Ground Slope on Storm Surge Disaster Mitigation," assessed the effectiveness of coastal vegetation against cyclonic storm surge based on species composition, forest width and near-shore run-up slope revealed by field investigations and numerical simulations. The authors used a series of equations and models to simulate the storm surge mitigation effected by two types of coastal vegetation; a mangrove species (Rhizophora apiculata), and a beach vegetation species (Casuarina equisetifolia).[34] This analysis conveys how specific size and distribution characteristics of the two species decrease weight height and velocity to varying extents. The results of the study are of particular value to policy and decision makers for coastal landscape planning, rehabilitation and coastal resource management.

In a study undertaken by P. Wattage and S. Mardle titled "Total Economic Value of Wetland Conservation in Sri Lanka Identifying Use and Non-Use Values," the authors employed a Contingent Valuation Method (CVM) in order to assess stakeholder willingness to pay towards the conservation of fish, mangroves, and water in a Sri Lankan wetland. The study found an estimated median willingness to pay for of Rs. 264.26. The authors also calculate the of non-use values from the total estimated value, which is found to be between 45%-55%.[35]

A study undertaken by S. Sarkis et al., and the Bermuda Department of Conservation Services titled "Total Economic Value of Bermuda's Coral Reefs," used a combination of several valuation methods to derive the value of coral reef ecosystems in Bermuda. The authors calculated the economic value of Bermuda's reefs based on the value of six types of ecosystem services including tourism, coastal protection, recreation and cultural, amenity, fishery, and research and education. The study found that the annual value of coastal protection ecosystem services amounted to US$265.9 million, which represents 37% of the total economic value of ecosystem services provided by coral reefs in Bermuda.[36] This study also estimated the contribution of reefs to the amenity

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32 Eppink, F., et al., "An initial assessment of the Economic Value of Coastal and Freshwater Wetlands in West Asia" (2014).

33 Ibid.

34 Das, Shamal Chandra, Kosuke Iimura, Norio Tanaka. *Effects of coastal vegetation species and ground slope on storm surge disaster mitigation.* 2010. Coastal Engineering.

35 Wattage, P. and Mardle, S. "Total Economic Value of Wetland Conservation in Sri Lanka Identifying Use and Non-Use Values." Wetlands Ecol Manage 16.5 (2007): 359-69. Web.

36 Sarkis, S., van Beukering P. J.H., and McKenzie E. "Total Economic Value of Bermuda's Coral Reefs." Bermuda Department of Conservation Services (2010). http://www.conservation.bm/coral-reef-economic-valuation/

value of real estate using a hedonic price model applied to data from 593 house and condominium sales.

A study undertaken by Ferrario and Beck titled "The Effectiveness of Coral Reefs for Coastal Risk Reduction and Adaptation," analyzed the effectiveness in disaster risk reduction provided by coral reefs at a global scale. Through a meta-analysis, this study found that coral reefs provide protection against natural hazards by reducing wave energy by an average of 97%.[37] The study stated that there are 100 million or more people who may receive risk reduction benefits from reefs or have to bear hazard mitigation and adaptation costs if reefs are degraded, and that reefs can provide a comparable amount of wave attenuation benefits to artificial defenses such as breakwaters.[38] The study highlighted that reefs face growing threats from population growth. Although, there is opportunity to guide adaptation and hazard mitigation investment towards the restoration of reefs to strengthen coastal defense against natural disasters.[39] In the following table, this study summarizes the number of people who may receive risk reduction benefits from coral reefs.

Table 2: Number of People who May Receive Risk Reduction Benefits from Coral Reefs

<10 m Elevation and <10 km from reef		<10 m Elevation and <50 km from reef	
Economy	**No. of people**	**Economy**	**No. of people**
Indonesia	19	Indonesia	41
India	17	India	36
Philippines	12	Philippines	23
Brazil	6	China	16
United States	3	Viet Nam	9
Viet Nam	2	Brazil	8
Tanzania	2	United States	7
China	2	Malaysia	5
Haiti	2	Sri Lanka	4
Cuba	2	Chinese Taipei	3
Sri Lanka	2	Singapore	3
Singapore	1	Cuba	3
Japan	1	Hong Kong, China	2
Saudi Arabia	1	Tanzania	2
Kenya	1	Saudi Arabia	2
Top 15	74	Top 15	163
Global	100	Global	197

Values are the number of people living below 10 m elevation and within 10 or 50 km from reefs (No. of people x 1,000,000).

Source: Ferrario et al.

A report undertaken by Anna McIvor, et al. titled "Reduction of Wind and Swell Waves by Mangroves," focused on mangrove forests and their role in reducing wind and swell waves. The report highlighted mangroves' wave attenuation properties as they can significantly reduce natural disaster damage by reducing wave energy and height.[40]

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37 Ferrario, Filippo, Michael Beck. *The effectiveness of coral reefs for coastal risk reduction and adaptation.* 2014. Nature Communications.

38 Ibid.

39 Ibid.

40 McIvor, Anna, Iris Moller, Tom Spencer, and Mark Spalding. *Reduction of Wind and Swell Waves by Mangroves.* 2012. http://www.wetlands.org/Portals/0/publications/Report/reduction-of-wind-and-swell-waves-by-mangroves.pdf

Through the use of tested wave simulation and propagation models, among other statistical analyses, the authors found that mangroves can reduce the height of wind and swell waves over relatively short distances, with wave height potentially being reduced by between 13% and 66% over 100 m of mangroves.[41] The findings in this report can serve as inputs to estimate potential damages caused by waves in specific locations where mangrove forests are threatened poor management and protection practices.

A research paper useful for tracking distribution and extent of mangroves was undertaken by C. Giri et al.,"Status and distribution of mangrove forests of the world using earth observation satellite data." In this paper, the authors mapped the status and distributions of global mangroves using Global Land Survey (GLS) data and satellite imagery from the Landsat archive (later discussed in Annex I). The objective of this paper was to improve the scientific understanding of the extent and distribution of mangrove forests of the world, which according to the authors is inadequate.[42] Analyzing approximately 1000 satellite images scenes, the authors estimated a total area of mangroves in the year 2000 to be 137,760 km2 in 118 economies and territories in the tropical and subtropical regions of the world. Based on this analysis, the authors also found that 75% of world's mangroves are found in just 15 economies, and only 6.9% are protected under the existing protected areas network (IUCN I-IV).[43]

Finally, a comprehensive report undertaken by the US National Science and Technology Council titled "Ecosystem Service Assessment: Research Needs for Coastal Green Infrastructure (CGI)," provides recommendations on types of research that should be conducted to improve understanding and application of CGI, including metrics, ecological production functions, ecosystem-services valuation approaches, and support for decision making.[44] This study considers ecosystem services provided by multiple types of NCIs (in this study, referred to as CGIs), including salt marshes, mangroves, reefs, seagrass beds, and sand beaches and dunes, as well as hybrid approaches that strategically combine one or more of these features with non-natural structures within the US. This report also identified knowledge gaps that impede a more widespread adoption of coastal green infrastructure strategies.

Knowledge Gaps on DRR Contributions of NCIs

Information and knowledge gaps were identified in most of the studies covered in this literature review. This section summarizes these gaps, while the Gap Analysis chapter

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41 Ibid

42 Giri, C. et al., "Status and distribution of mangrove forests of the world using earth observation satellite data." 2011, *Global Ecology and Biogeography*, *(Global Ecol. Biogeogr)* **20**, 154–159

43 Ibid

44 "Ecosystem-Service Assessment: Research Needs For Coastal Green Infrastructure." Committee on Environment, Natural Resources, and Sustainability of the National Science And Technology Council. (2015). https://www.whitehouse.gov/sites/default/files/microsites/ostp/cgies_research_agenda_final_082515.pdf

discusses them further along with other knowledge and information gaps identified throughout the study.

Some gaps are consistent across certain types of NCIs that are more difficult to assess than others due to the lack of accessibility of data required to undertake accurate economic valuation studies or due to the fact that some NCIs are more difficult to track and measure than others. In the study undertaken by J. Brenner et al. on the valuation of ecosystem services provided by the Catalan coastal zone in Spain, the authors explain that data gaps in literature led to the underestimation of ecosystem services in certain areas that could not be accounted for, and that filling these data gaps, by integrating further literature's best practice, can lead to higher value estimates. The authors also stress that these types of data gaps are not unique, as multiple authors have previously experienced difficulties in integrating value data from heterogeneous sources.[45] Some examples of these difficulties, the authors explain, include accessibility to data and quality of previous valuation studies. In the case of this study, there was not enough data to generate value estimates of disturbance regulation services by seagrass beds. Across existing literature, we observed that there was a far greater number of economic valuation studies conducted for mangroves, coral reefs, and wetlands, than for other types of NCIs, such as sand dunes and seagrass beds. As seen in the summary table 1 below, among the relevant studies that were selected for this literature review, 4 focus on mangroves, 4 focus on coral reefs, and 2 focus on a wetlands, and 6 focus on a combination of multiple types of NCIs. In the section of this report that reviews the surveys completed by APEC economies, there is a similar trend in terms of the types of NCIs that have been studied and/or protected more than others. This could be due to data and information being more widely available for mangroves, coral reefs, and wetlands as a result of those NCIs being easier to measure and track than others. For example, in most cases higher satellite image resolutions are needed to measure and track changes in land area of sandy beaches. Moreover, tracking the changes in size of NCIs over time is a fundamental task, especially for the application of certain economic valuation methods. While many assessments analyze the current stock of the NCI today, they often don't account for long term changes to NCIs and their relative benefits.

Another good example of a critical knowledge gap on valuation studies identified in this review is the one highlighted in the study titled "An Initial Assessment of the Economic Value of Coastal and Freshwater Wetlands in West Asia," by F. Eppink et al.[46]. In this study, the authors stress that results from valuation studies like theirs, which are applied at a large/regional scales, and should not be treated as absolute and are only as useful when looking to assess the value of the same ecosystem services at a smaller/local geographic scales. This is because the data and models at large spatial

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45 Brenner, J., et. al. "An Assessment of the Non-market Value of the Ecosystem Services Provided by the Catalan Coastal Zone, Spain." Ocean & Coastal management 53, no. 1 (2010)

46 Eppink, F., et al., "An initial assessment of the Economic Value of Coastal and Freshwater Wetlands in West Asia" (2014).

scales would not be able to capture domestic realities and variations in economic and infrastructural development at a local scale. As a result of potential value transfer inaccuracies from applying valuation results from larger scales to smaller scales, the authors in this study recommend that detailed localized studies should be conducted to attain more accurate value estimates that can in turn inform local policy makers' decisions. In reviewing the existing literature, one can find far more economic valuation studies applied at medium to large spatial scales (such as regional or economy-level scales) than at small spatial scales (such as city or neighborhood scales). This makes it difficult to use the benefit transfer method for areas with small geographic scales when an economic valuation study at a similar scale with similar conditions has not been undertaken. With the above in mind, a more robust variety of valuation studies undertaken at such scales will be a key factor in helping to close existing knowledge gaps in the economic value of NCIs for DRR.

In the paper written by Van Zanten et al., "Coastal Protection by Coral Reefs: A Framework for spatial assessment and economic valuation," The authors highlight weaknesses of previous economic valuation studies on coral reefs.[47] These weaknesses referred to studies resorting to assumptions in critical parameters due to lack of data on such parameters, including reef and wave characteristics, and climate and coastal development.[48] Other information access and uncertainty issues found in valuation studies includes uncertainties concerning the frequencies of hurricanes, which results in large ranges of value estimates, and the lack of knowledge of the effects of NCI cover decline on flood damages during extreme events, which, according to the authors, is particularly valuable to policy makers.

In the National Science and Technology Council report referenced earlier in this literature review titled "Ecosystem Service Assessment: Research Needs for Coastal Green Infrastructure (CGI)," knowledge gaps that impede a more widespread adoption of coastal green infrastructure strategies are identified, including the need for further research to improve methodologies for non-market valuation of ecosystem services. To address these knowledge gaps, the authors recommend prioritizing research needs to valuing the broad range of ecosystem services and co-benefits that are not usually traded in markets. Another knowledge gap highlighted in this report is the need to improve methodologies for benefit transfer valuation methods. To address this need, the authors recommend promoting/prioritizing the development of meta-regression models that will add to the increasing number and availability of existing valuation studies, and "to expand the range of scenarios of studies for which benefit transfer is

47 Ibid.
48 Ibid.

likely to serve as an appropriate valuation approach, including scenarios at various spatial scales."[49]

Finally, most economic valuation studies assess a combination of various types of ecosystem services provided by NCIs, rather than focusing on valuating DRR services only. In many cases, this makes it difficult for the reader to isolate the value pertaining to DDR services. With DDR becoming increasingly important around the world as the effects of climate change will affect the frequency of natural disasters, it will become increasingly important to bridge existing knowledge gaps in understanding the economic value of DRR services, and thus further research in this area should be promoted.

In summary, our literature review shows that multiple comprehensive economic valuation methods have been tested and applied, and have increased knowledge and understanding of NCIs' contributions to DRR. However, for the sake of attaining more consistent results of value range estimates for all NCIs, there is a need for research into a more diverse NCI base and at smaller scales.

The following table provides a summary of the studies reviewed in this section including the type of NCI and geographical coverage, the estimated value and knowledge gap identified.

Table 3: Summary of the literature review

Study	Type of NCI	Geographical coverage	Estimated Value of NCI	Type of Knowledge Gap Identified
Future of our coasts: the potential for natural and hybrid infrastructure to enhance the resilience of our coastal communities, economies and ecosystems	coral reefs, wetlands, salty marshes, mangroves, and sea grasses	Multiple case studies in the United States	$23.2 billion per year in storm protection	Information on the level of protection provided by various types of natural infrastructure. how natural infrastructure handles extreme events how these benefits vary with different types of storms non-linearity in the provision of services, such as seasonality Not enough studies on the value (monetary or non-monetary) of storm

[49] "Ecosystem-Service Assessment: Research Needs For Coastal Green Infrastructure." Committee on Environment, Natural Resources, and Sustainability of the National Science And Technology Council. (2015). https://www.whitehouse.gov/sites/default/files/microsites/ostp/cgies_research_agenda_final_082515.pdf

				protection services; many methods, not one most frequently applied
Ecosystem Valuation: some principles and a partial application	All types on NCIs	Multiple case studies in the United States	N/A	Valuing of marginal changes, measuring of nonlinearities in service benefits, considering the significance of non-convexities (threshold effects), and avoiding double counting of competing ecosystems
The economic value of coastal ecosystems in reducing tsunami impacts	Mangroves	Sri Lanka	Threatened mangroves reduce protection afforded to inland infrastructure by US$2,109 per household	N/A
An assessment of the non-market value of the ecosystems services provided by the Catalan coastal zone, Spain	Seagrass beds, Beaches & Sand Dunes, Saltwater Wetlands	Catalan Coast of Spain	Beaches & Sand Dunes: US$67,400/hectare/year Saltwater Wetlands: US$766/hectare/year Saltwater Wetlands: N/A	A lack of valuation data for several NCIs including seagrass beds
Ecosystem Service values for Mangroves in Southeast Asia: A meta-analysis and value transfer application	Mangroves	Southeast Asia	US$4185/hectare/year	Need for collaborative research that combines mangrove ecology and economics to jointly model the provision and value of ecosystem services from mangroves Value of ecosystem services make the assumption that the provision of services is a constant across all mangrove sites
Coastal Protection by Coral Reefs: A Framework for spatial assessment and economic valuation	Coral Reefs	US Virgin Islands	US$1.2 million per year	Limited information and data used in previous valuation studies on coral reefs

The Economic Value of U.S. Coral Reefs	Coral Reefs	Ecosystems within United States	Florida – US$324million per year Hawaii - US$455million per year American Samoa - US$11million per year CNMI (Saipan) - US$150million per year Guam - US$150million per year Puerto Rico - US$1.16billion per year US Virgin Islands – US$210million per year	Limited information: (1) the limited geographical coverage of some state/ territory level TEV estimates, (2) the limited set of services that is valued for some states and territories. (3) The scant information on non-use values is likely to constitute the largest missing component of TEV
An initial assessment of the Economic Value of Coastal and Freshwater Wetlands in West Asia	Wetlands	West Asia (Arabic countries plus Turkey and Iran)	Economic loss of not protecting wetlands by 2050 – range from range of US$2.3 billion and US$7.2 billion	Lack of Information: The availability and reliability of data and models at large spatial scales, which may not capture very well the domestic realities and variations in economic and infrastructural development An additional challenge is that there is little information about the value of West Asian ecosystems publicly available. It would be of immense value if more case studies were performed in the region and published.
Effects of Coastal Vegetation Species and Ground Slope on Storm Surge Disaster Mitigation	Mangroves and Beach Vegetation	N/A	Double layers of wide vegetation belts (300 m) on mild slope (1:500) in the vertical direction with R. apiculate (Mangroves) and C. equisetifolia	Lack of Information: The study found that in order to design an effective landscape with coastal vegetation, more study is needed on a wide range of cyclonic storm

			(Beach Vegetation) exhibited a strong potential to decrease surge wave height and velocity reduction	surge conditions, coastal topography and forest characteristics.
Total Economic Value of Wetland Conservation in Sri Lanka Identifying Use and Non-Use Values	Wetlands	Sri Lanka	Stakeholder willingness to pay (WTP) towards the conservation of fish, mangroves and water in a Sri Lankan wetland area us$1.82 (considered reliable when considering average income of community	N/A
Total Economic Value of Bermuda's Coral Reefs	Coral Reefs	Bermuda	US$265.9 million per year	Lack of Data and Information: Accuracy of study is dependent on limited data access and/or availability
The effectiveness of coral reefs for coastal risk reduction and adaptation	Coral Reefs	Global	Study reveals that coral reefs provide protection against natural hazards by reducing wave energy by an average of 97%	Lack of Data and Information: (1) Parameters such as when do reefs fail during high-energy events, and how long do they need to recover. (2) Reef Restoration: need for better accounting for maintenance costs and longer term measures of the success of restoration efforts (3) Conservation efforts should also focus on reefs in closer proximity to people who will directly benefit from their management and restoration.
Reduction of Wind and Swell Waves by Mangroves	Mangroves	Various	Wave height potentially being reduced by between 13% and 66% over 100 m of mangroves	Lack of Information and Data: More research is needed concerning mangroves attenuating wind and the swelling of waves
Status and distribution of mangrove forests of the	Mangroves	Global	Analyzing approximately 1000	The remaining area of mangrove forest in the

world using earth observation satellite data			satellite images scenes, the authors estimated a total area of mangroves in the year 2000 to be 137,760 km2 in 118 economies and territories in the tropical and subtropical regions of the world. Based on this analysis, the authors also find that 75% of world's mangroves are found in just 15 economies, and only 6.9% are protected under the existing protected areas network (IUCN I-IV)	world is less than previously thought. Study's estimate is 12.3% smaller than the most recent estimate by the Food and Agriculture Organization (FAO) of the United Nations
Ecosystem Service Assessment: Research Needs for Coastal Green Infrastructure (CGI)	Salt Marshes, Mangroves, Reefs, Seagrass Beds, and Sand Beaches & Dunes	Global	Provides recommendations on types of research that should be conducted to improve understanding and application of coastal green infrastructure, including metrics, ecological production functions, ecosystem-services valuation approaches	Lack of information and data: The study Identified knowledge gaps that impede a more widespread adoption of coastal green infrastructure strategies

APEC SURVEY FOR THE IDENTIFICATION OF KNOWLEDGE GAPS AND REGULATORY BARRIERS

In August 2015, a survey was distributed to APEC member economies through the OFWG and the Emergency Preparedness Working Group (EPWG), with the aim of collating information on existing knowledge gaps and regulatory barriers for valuing the ecosystem services that NCIs provide, with particular focus on services that contribute to disaster risk reduction and response and coastal resilience.

This survey covered topic areas including the characterization of NCIs present in each economy and description of their protective services, availability of studies or analyses on the value of NCIs, the role of NCIs in disaster risk reduction and coastal resilience policies, etc. The survey results are summarized under each of the survey topic areas listed below. The complete survey that was sent to the APEC Economies is included in Annex III.

1) NCI types and geographical coverage, areas being protected by NCIs, and research undertaken to assess their efficiency in protecting communities from natural disasters.
2) Previous studies, including methodologies and techniques for assessing the economic value of NCIs for disaster risk reduction and coastal resiliency, and organizations involved in undertaking these studies.
3) Disaster risk reduction and coastal resiliency policies that consider NCIs, and whether NCIs are required by the economy to enhance disaster risk reduction and coastal resiliency.
4) Barriers which may prevent the inclusion of NCIs in disaster risk reduction and coastal resiliency policies.
5) Agencies or authorities in charge of planning, funding, implementing, managing, and studying NCIs, and their activities for overseeing and guiding the protection/implementation of NCIs.
6) Budget and main sources of funding for managing, and studying NCIs.

Seven APEC member economies submitted responses to the survey, including: China; Japan; Mexico; Papua New Guinea (PNG); Singapore; Thailand and the United States. Even though the level of response to the survey was not as high as expected, the information provided by respondents provide evidence of the importance for understanding NCI's economic contributions to disaster risk reduction in APEC

economies, and for the need of economies to address remaining knowledge gaps to inform coastal resilience policies. The survey findings under each question are summarized below:

1) **NCI types and area coverage, areas being protected by NCIs, and research undertaken to assess their efficiency in protecting communities from natural disasters**

The main types of NCIs reported by the responding economies were mangroves, coral reefs and wetlands. These NCIs protect different types of coastal areas, including urban and rural, densely or sparsely populated areas. Some of the respondents indicated that certain types of NCIs provide most protection in rural areas.

Total area coverage of different types of NCIs was reported by some economies that completed the survey. These numbers varies widely by economy. For instance, for instance, the U.S. reported the highest coral reef area, with 1,618,743 hectares, while Papua New Guinea reported the second highest area with 1,384,000 hectares. In terms of Mexico reported the largest area, with 764,786 hectares, and Papua New Guinea the second largest with approximately 420,000 hectares. In terms of wetlands, the U.S. reported the highest area with approximately 16,100,000 hectares, followed by Thailand with 3,761,600 hectares. In terms of oyster beds, and seagrass, Thailand was one of few economies reporting estimates, with 87,500 hectares and 25,573 hectares respectively.

2) **Previous studies, including methodologies and techniques for assessing the economic value of NCIs for disaster risk reduction and coastal resiliency, and organizations involved in undertaking these studies**

Some economies indicated that a significant amount of research has been conducted on coastal ecosystems and on the level of coastal protection provided by them, while other economies reported that limited to no research on this area has been carried out. The survey results also indicate that the level of involvement by organizations in undertaking these studies varies across economies. Some economies have more than one organization involved in such efforts. For example:

In **Mexico**, the Mexican Secretariat of Environment and Natural Resources (SEMARNAT), Mexico's environment ministry, has funded and published several economic valuation studies. Such have included studies that assess meteorological events that could cause damages and negative impacts on the coasts, and have found that such impacts have led to economic losses, and have ended up affecting the government budget. Most valuation studies conducted in Mexico have focused on assessing a combination of several values including coastal damages, impacts on threatened and endemic species, socioeconomic impacts in coastal populations, and impacts on the fishing and tourism/recreation industries. The objectives of studies undertaken by SEMARNAT include helping the government make informed decisions about coast recovery measures, mitigation and reparation from damages caused by erosion and natural disasters, and for the preservation of Wetlands and mangroves that serve as natural barriers from major flooding. In 2007, the National Institute of Ecology,

later renamed the National Institute of Ecology and Climate Change (INECC), published a good review of past economic valuation studies conducted in Mexico. Relevant valuation studies supported by SEMARNAT include:

- Economic Valuation of Ecosystem Services Provided by Wetlands, Enrique Sanjurjo Rivera, 2001;
- Economic Valuation of the links between Mangroves and Fisheries, Sanjurjo, E., Cadena, K., Erbstoesser, I., 2005; and
- Experiences by the National institute of Ecology in Economic Valuation of Ecosystems for Public Policy Decision Making: http://www2.inecc.gob.mx/publicaciones/gacetas/523/experiencias.pdf.

In **Thailand**, the Department of Marine and Coastal Resources (DMCR), which is the entity in charge of managing and restoring coastal and marine resources, has also undertaken economic valuation studies. Recently, the DMCR conducted a study to compile data and information on the economic values of mangroves, coral reefs and sea grass, including the economic value of their coastal protection services. The study highlighted key benefits of NCIs and made recommendations on future investments in coastal infrastructures. The study also recommended that it should be mandatory to undertake a cost-benefit analysis of all possible development options that would affect mangroves, coral reefs, and sea grass. The results of this study helped in determining the importance of coral reefs as barriers that protect the coast from coastal erosion and served as a foundation for conducting further studies on the economic values of coastal and marine ecosystems. The estimates of economic benefits of mangroves and coral reefs were made using the Replacement Cost Method with information on the costs of replacing mangroves, coral reef and on the other coastal ecosystems. This information was derived from investment costs of developing physical infrastructures that could replace the coastal and shoreline protection services of mangroves and coral reefs.

In **Japan**, the Ministry of the Environment is the government entity in charge of global environment conservation, pollution control, and nature conservation.[50] In 2008, the Ministry of the Environment conducted an economic valuation study on coral reefs in Japan's coastlines. The study estimated a total value of coastal protection services provided by coral reefs to all of Japan's coastlines of approximately 7.52~83.9 billion Japanese Yen/year. The study also concluded that this number may be an underestimate of the actual protection value that coral reefs provide. The aforementioned value of coral reefs in protecting Japan's coastlines was calculated in the following manner:

1) A calculation of the cost of creating artificial reefs that would substitute all of Japan's existing coral reefs;

50 "About Us," The Ministry of The Environment, Government of Japan, https://www.env.go.jp/en/aboutus/index.html

2) The total cost of creating artificial reefs was divided by the number of years they would last to estimate their annual cost.[51]

In the **United States**, multiple organizations are involved in undertaking economic valuation studies of benefits provided by NCIs, in protecting and managing NCIs, and in promoting their role in mitigating natural disasters. Such organizations include the National Oceanic and Atmospheric Administration (NOAA), the U.S. Army Corps of Engineers (USACE), and multiple state environmental protection agencies. Several important valuation studies and initiatives that have been undertaken at the economy, state, and city levels include the following:

- The National Oceanic and Atmospheric Administration (NOAA) is currently collecting data to support further studies, research and implementation of NCIs. As mentioned in the literature review section, in 2013, NOAA published a document that summarizes major findings from multiple valuation studies of US coral reefs undertaken between 2001 and 2011 in order to provide an overall report on the value of US coral reefs.[52] The study provides several valuation techniques that are appropriate for calculation the total value of coral reefs' coastal protection services. The results of the studies indicate total economic values of coral reefs that range from USD$11 million/year in American Samoa to USD$1,161 million/year in Puerto Rico. NOAA also provides publicly available data and resources including technical reports on several natural resource valuation approaches;[53]
- Another initiative includes the North Atlantic Coast Comprehensive Study, which was released by the U.S. Army Corps of Engineers (USACE). This study promotes the use of economic valuation for coastal protection ecosystem services provided by NCIs;[54]
- Louisiana's Coastal Protection and Restoration Authority (CPRA) developed and implemented the 2012 Coastal Master Plan with the support of Federal, State, and local Government. Through a series of computerized peer-reviewed models, the Plan concluded that an annual budget of approximately USD$1 billion per year over the next 50 years, which includes restoration of NCIs and implementation of Green Infrastructure along Lousiana's coast, would prevent annual damages from flooding of up to USD$18 billion.[55] The 2017 Coastal Master Plan will build on the 2012 Coastal Master Plan by building upon technical tools to create more accurate scenario updates and re assess the needs of future Master Plan projects.[56] Both Master Plans conclude with a series of key policies and programs needed for successful implementation.

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51 "The Action Plan to Conserve Coral Reef Ecosystem in Japan." Ministry of the Environment, Japan. (2010). https://www.env.go.jp/nature/biodic/coralreefs/pamph/pamph_full-en.pdf

52 Edwards, P. "The Economic value of U.S. Coral Reefs." NOAA. (2013). http://docs.lib.noaa.gov/noaa_documents/CoRIS/Economic_Value_US_Coral_Reefs_Summary_2013.pdf

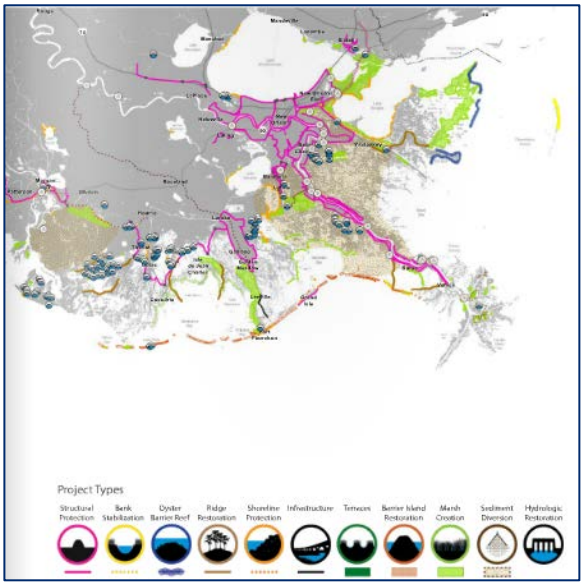
53 NOAA Coral Reef Information System. http://www.coris.noaa.gov/geoportal/rest/find/document?searchText=group%3Apublication&max=25&f=searchPage

54 "North Atlantic Coast Comprehensive Study Report." US Army Corps of Engineers. http://www.nad.usace.army.mil/CompStudy

55 "Louisiana's Comprehensive Master Plan for a Sustainable Coast." State of Louisiana. (2012). https://issuu.com/coastalmasterplan/docs/coastal_master_plan-v2?e=3722998/2447530 (pages 28 and 93)

56 "2017 Coastal Master Plan." Consistency Guidelines. Coastal Protection and Restoration Authority. http://coastal.la.gov/2017-coastal-master-plan/

Figure 2: Map of ongoing and planned projects for the Louisiana 2012 Coastal Master Plan



Source: Coastal.LA.gov

3) Disaster risk reduction and coastal resiliency policies that consider NCIs, and whether NCIs are required by the economy to enhance disaster risk reduction and coastal resiliency

Responses pertaining to this topic area reveal that respondent economies consider NCIs as part of their DRR and resiliency policies at varying degrees. While some economies are undertaking more policy efforts considering NCIs, others experience strong interagency collaboration that allows them to execute their policies.

Papua New Guinea has many atolls (reef islands) and low lying islands that are already suffering from the negative effects of rising sea levels. Hence, efforts are being undertaken to rehabilitate and strengthen NCIs. For example, the National Disaster Mitigation Policy of 2010 provides a mechanism for shaping disaster mitigation, vulnerability reduction, and emergency response, and a basis upon which programs can be coordinated and integrated.[57] The National Climate Compatible Development Management Policy of 2014 aims at achieving PNG's vision to build a climate resilient pathway through sustainable economic development.[58] As far as recent initiatives on disaster risk reduction, there are a few cases of NGOs educating and preparing coastal communities in Papua New Guinea. For instance, in January of 2012, USAID's office of U.S. Foreign Disaster Assistance (USAID/OFDA) funded the Adventist Development and Relief Agency (ADRA) to train flood prone communities in the Morobe Province on disaster mitigation and management strategies. The trainings led to the formation of

57 "National Disaster Mitigation Policy." National Disaster Center Department Of Provincial & Local Government Affairs, Papua New Guinea. http://www.preventionweb.net/files/8142_mitigationpolicy.pdf

58 "Disaster Management Reference Handbook." Center for Excellence in Disaster Management & Humanitarian Assistance. (2016). http://reliefweb.int/sites/reliefweb.int/files/resources/disaster-mgmt-ref-hdbk-png.pdf

community disaster management committees who engaged in creating disaster maps and developing further disaster risk reduction plans for the province's villages.[59]

A good example of existing efforts in part of a member economy to enhance disaster risk reduction and coastal resiliency through protecting NCIs is the Law of Ecological Balance and Ecosystems Protection (*Ley General de Equilibrio Ecológico y Protección y la Protección al Ambiente* in Spanish) in **Mexico**. This law requires interagency collaboration to achieve environmentally safe development practices and establishes specific requirements to preserve the natural resources in the economy and achieve risk reduction and coastal resiliency among others.[60]

Thailand's Office of Natural Resources and Environmental Policy and Planning has previously prioritized multiple climate change adaptation efforts into the member economy's strategy, including the development of a marine conservation and coastal rehabilitation plan to protect marine ecosystems and enhance climate proofing infrastructure to strengthen coastal protection against erosion.[61] There are a number of laws which serve as guidelines for the use of NCIs, such as the Act of Promotion of Management on Marine and Coastal Resources, and the National Park Act.

In the **US**, NCIs have been frequently considered in disaster risk reduction government initiatives. For instance, the White House recently published the "U.S. Government Research Needs for Coastal Green Infrastructure," which lays an agenda on future government plans and strategies to achieve greater coastal resiliency.[62] In addition, the White House Council on Environmental Quality will be releasing a guidance memo to federal agencies on incorporating ecosystem services into decision-making. Another relevant Federal Government action includes the White House the Priority Agenda for Climate and Natural Resources, which identifies NCIs as key solutions to enhance coastal and inland resilience.[63] Many of these key solutions address previous management efforts. A good example of these efforts includes the Hurricane Sandy Rebuilding Task Force, which was created by President Obama after Hurricane Sandy with the goal of identifying and working to remove obstacles to achieve coastal resiliency, and rebuilding and promoting long term sustainability of communities and ecosystems in the region affected by the 2012 hurricane. The Task Force provided 69

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59 "Disaster Risk Reduction – East Asia and the Pacific." USAID. (2012). https://www.usaid.gov/sites/default/files/documents/1866/eastasia_drr_fs01_09-30-2012.pdf

60 "Ley General Del Equilibrio Ecológico y la Protección al Ambiente." Gobierno de México. 2015. http://biblioteca.semarnat.gob.mx/janium/Documentos/Ciga/agenda/DOFsr/148.pdf

61 "Thailand's Intended Nationally Determined Contribution." Office of Natural Resources and Environmental Policy and Planning, Thailand. (2015). http://www4.unfccc.int/submissions/INDC/Published%20Documents/Thailand/1/Thailand_INDC.pdf

62 "Ecosystem-Service Assessment: Research Needs for Coastal Green Infrastructure." Committee on Environment, Natural Resources, and Sustainability of the National Science And Technology Council. (2015). https://www.whitehouse.gov/sites/default/files/microsites/ostp/cgies_research_agenda_final_082515.pdf

63 "Priority Agenda Enhancing the Climate Resilience of America's Natural Resources." (2004). https://www.whitehouse.gov/sites/default/files/docs/enhancing_climate_resilience_of_americas_natural_resources.pdf

recommendations, which include a regionally coordinated infrastructure investment, and capacity building in local governments.[64]

The Coral Reef Conservation Act and the Coastal Zone Management Act regulate the use of NCIs. The Clean Water Act Section 404 permit requirements make it more difficult and time and cost consuming to implement new types of DRR approaches, such as NCIs. Permitting of NCIs is much more difficult than for traditional built structures, such as grey infrastructure. However, some states are issuing general permits for living shorelines that are helping with some of the existing permitting issues. An example of such cases happened in Virginia, where a general permit rule was recently passed.

NOAA as well as partners at other agencies and non-profit organizations (including Restore America's Estuaries, The Nature Conservancy, and Conservation International) continuously promote the use of living shorelines and other NCIs and Green Infrastructure coastal resilience measures. In 2008, Maryland passed a law to support these approaches called the Living Shorelines Protection Act, which requires the use of non-structural shoreline stabilization methods in tidal wetlands.[65] Support of coastal protection uses of NCIs is also rising in Virginia, North Carolina, New Jersey, New York, Connecticut, Rhode Island, and Mississippi. Another good example of implementation at the local level includes the City of New York Department of City Planning's 2013 Urban Waterfront Adaptive Strategies.[66]

4) Barriers which may prevent the inclusion of NCIs in disaster risk reduction and coastal resiliency policies

This section highlights common legal, political, financial, technical, and any other type of barriers that member economies reported in the survey, which may prevent the inclusion of NCIs in disaster risk reduction and coastal resiliency policies.

Legal barriers were highlighted on the survey as a common issue among respondent member economies. For example, an issue reported by one economy was when traditional resource owners with customary rights might seek compensation when an NCI protection program denies the owner's rights to develop on her/his land. This often hinders NCI protection programs.

Political barriers were also reported as commonly present hindrances to NCIs by member economies. One economy reported that provincial and local level governments often do not support the inclusion of disaster risk reduction and coastal resiliency policies. Generally this lack of policies that support NCIs, often becomes the source of failures in passing legislation and enforcing laws on such matters. A commonly reported reason behind prevalent political barriers in the survey was the

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64 "Hurricane Sandy Rebuilding Strategy." US HUD. (2013). http://portal.hud.gov/hudportal/documents/huddoc?id=hsrebuildingstrategy.pdf

65 "Water Management Administration – Living Shoreline Protection Act of 2008." Maryland Department of Natural Resources. (2008). http://www.dnr.state.md.us/ccs/pdfs/ls/dnr/scm/2008_LSPA.pdf

66 "COASTAL CLIMATE RESILIENCE Urban Waterfront Adaptive Strategies." NYCDP. (2013). http://www.nyc.gov/html/dcp/pdf/sustainable_communities/urban_waterfront_print.pdf

issue of conflicting interests between economic development and environmental protection advocates. Some economies reported that a source of this problem is often the fact that many policy makers lack the awareness and understanding of the economic value of NCIs. Another problem was that, due to this lack of understanding, disaster risk reduction and coastal resiliency policies are often not included in social-economic development plans at economy, regional and local levels. Other prevalent challenges include the bias or restricted focus resulting from single agency control, and limited interagency coordination.

Protection, maintenance, monitoring, and recovery of NCIs can require significant spending, which can make government implementation plans difficult to implement. A prevalent, underlying source of the commonly reported issue of lack of funding is the need for more information (i.e. studies and research undertaken) and a better understanding on the economic value of NCI coastal protection services.

Another commonly reported barrier, especially among developing economies, is the lack of technical capacity to implement disaster risk reduction programs, more frequently at the provincial or local level. In cases where NCIs are already highly damaged, the technical capacity to implement protection measures through reconstruction, and designing and building green infrastructure is often insufficient. A greater understanding of the economic value of DRR services provided by NCIs would direct more public support towards training programs in underserved communities that would help enhance the technical capacity needed for proper management and mitigation measures in coastal communities. Several member economies reported that the lack of technical capacity in this area is correlated with the lack of engineers and architects in these economies.

Finally, another issue is conflicting views regarding the economic value of NCIs' coastal protection services which can be found not only among politicians, but also within the general public. This leads to a divided opinion on whether to support policies and laws that protect NCIs.

5) Agencies or Authorities in Charge of Planning, Funding, Implementing, Managing, and Studying NCIs, and their activities for overseeing and guiding the protection/implementation of NCIs

While some economies have several agencies involved in planning, regulating and managing NCIs; others like Mexico and Singapore, have only one agency that concentrates most of the policy decisions. This section lists the agencies tasked with such responsibilities in each Member Economy that completed the survey and describes their respective responsibilities for overseeing and guiding the protection/implementation of NCIs.

PNG has a number of authorities that manage issues related to NCIs at the international, domestic and local level. These authorities are specifically involved in planning, regulating, funding, implementing, maintaining, and studying NCIs. At the international level, PNG is supported by three organizations; the Secretariat of the Pacific (SPC), Coral Triangle Initiative (CTI), and the Melanesian Spearhead Group

(MSG). At the domestic level, PNG relies on the Conservation and Environment Protection Authority (CEPA), the National Fisheries Authority (NFA), and the Coastal Fisheries Development Agency (CFDA). CFDA was established by a National Executive Council Policy Division which provides research, extension services and basic infrastructure to support the livelihood of coastal communities. Locally, PNG relies on provincial and local governments in addition to resource owners of the land, coastal and inshore areas and reefs. The private sector also plays a part in managing NCIs at times in the form of public private partnerships. PNG also reported that NFA, CEPA, and provincial and local governments are involved in setting site selection guidelines for NCIs. The NFA is also mandated to manage fisheries within the coastal and inshore areas.

The government requires monitoring and evaluation (M&E) of NCIs on all government and donor funded public investment projects to make sure projects achieve overall goals in the National Vision 2050. PNG also requires the inclusion of NCIs for shoreline development for tourism. PNG is also very careful in not exploiting NCIs as they are not only maintained for shoreline protection purposes, but also they represent an invaluable resource for the survival and subsistence of local coastal and island communities.

In **Mexico** the main entity responsible for overseeing and managing NCIs at the domestic and local levels is the Secretariat of Environment and Natural Resources (SEMARNAT), which is specifically tasked with planning, regulating, funding, implementing, maintaining, and studying NCIs. SEMARNAT conducts monthly and annual studies on coastal zones to measure physical and chemical parameters. The use of NCIs for DRR is mandated by SEMARNAT.

At the domestic level, **Singapore** relies primarily on the National Parks Board when planning, regulating, funding, implementing, maintaining, and studying NCIs. In addition to the National Parks Board, the Urban Redevelopment Authority, and the Ministry of National Development also assists in various capacities. The Institute of Higher Learning (IHL) also contributes to investing and studying NCIs and their impacts. Singapore's private sector is also engaged in managing and maintaining NCIs. Public Private Partnerships, such as International Coastal Cleanup Singapore also play a vital role in monitoring and clearing marine debris among Singapore's NCIs.

In **Thailand** the Ministry of Natural Resources and Environment, a cabinet Ministry in the Government of Thailand, mandates the use of NCIs. Within the Ministry of Natural Resources and Environment, the Department of Marine and Coastal Resources (DMCR), and the Department of National Park (DNP) both plan, regulate, fund, implement, and maintain NCIs. In addition to both the DMCR and the DNP, Universities are highly involved in undertaking research and studying NCIs and their economic benefits. In addition to shoreline protection, NCIs are considered valuable to Thailand as they also contribute to Thailand's tourism, culture, and fisheries.

Under the Chinese Ministry of Environmental Protection (MEP), which is a cabinet level ministry in charge of protecting the economy's air, water, and land from pollution and

contamination,67 the Department of Nature and Ecology Conservation is tasked with developing ecosystem plans, supervising the implementation of domestic policies, laws and regulations, and developing standards on conservation practices for natural resource reserves including NCIs, biodiversity, and environmental safety management of bio-technologies at the economy level.[68]

In the **United States**, the National Oceanic and Atmospheric Administration (NOAA) is the nation's leader in observing, measuring, assessing, protecting and managing coastal areas. The private sector in the United States plays a role in NCI management. The private sector is also involved in the promotion of shorelines and other NCI coastal resilience. Public private partnerships, state, local and non-governmental organization partnerships also contribute to NCI management.

6) Budget and main sources of funding for Managing, and Studying NCIs

Four of the seven economies that responded the survey reported that they have a budget for protecting/implementing NCIs. For example, PNG reported that the NFA has allocated one million dollars each year from 2010 to 2014 to its budget for developing and implementing NCIs, while provincial and local governments have allocated half a million dollars. In addition to government funding, from 2010 to 2014, the Asian Development Bank (ADB) has budgeted one million dollars under the Climate Change Trust Fund. In 2014, PNG allocated 1.5 million dollars towards studying, repairing, rehabilitating and maintaining NCIs.

67 Ministry of Environmental Protection, The People's Republic Of China, http://english.mep.gov.cn/

68 The US-China Business Coucil, "Ministry of Environmental Protection (MEP)," https://www.uschina.org/sites/default/files/MEP%202013.08.pdf

GAP ANALYSIS

This section provides an overview of the knowledge and policy gaps that were identified in this report based on the literature review and the survey responses by APEC member economies. Despite the fact that multiple comprehensive economic valuation methods have previously been tested and applied, and have contributed towards narrowing the knowledge gap on the economic value of NCIs' contributions to DRR, several knowledge and policy gaps remain to be closed. The most critical gaps identified in this study, and which are further explained in this section, include the following:

- A need for more valuation studies covering different types of NCIs and geographical areas, including small scale studies undertaken at the local levels.
- A lack of data for measuring/tracking certain types of NCIs at small geographic scales, and more precise climate and disaster-related parameters (including reef and wave characteristics, frequencies of hurricanes, and effects of NCI cover decline on flood damages during extreme events) are needed in order to undertake more accurate valuation studies.
- A lack of studies that focus on measuring the value of DRR services provided by NCIs.
- A need for greater interagency coordination for protecting and managing NCIs.
- A need for increased awareness about economic value of NCI ecosystem services among policymakers.
- A need to enhance technical capacity to design and implement disaster risk reduction programs, which incorporate NCIs.
- A need for laws that can effectively protect NCIs while providing proper compensation to resource owners.

Knowledge Gaps

One of the most consistent knowledge gaps identified across the literature review was the need for a greater number of valuation studies undertaken at a diverse range of geographic scales and locations. This would not only lead to a greater body of knowledge in this field, but would also facilitate the development of further studies, especially those that use the Benefit Transfer valuation method, which as explained earlier in this report, relies on a value that is transferred from studies already completed in a similar location and/or context. Some authors expressed that there is a particular need for valuation studies undertaken at smaller geographic scales because such can take into consideration social and economic factors of their respective localities, which can vary widely even within an economy, and are usually not captured by studies that valuate ecosystem services at larger economy or regional scales. As F. Eppink et al. stated in one of the reviewed studies, scientists should be cautious when using a value transfer method due to inaccuracies that can arise from applying valuation results from larger scales to smaller scales, and that localized studies should

be conducted to attain more accurate value estimates that can better inform local policy makers' decisions.[69]

Other gaps frequently found across the reviewed studies included a lack of data available on critical parameters needed to undertake more accurate valuation studies. Such parameters include reef and wave characteristics, frequencies of hurricanes (which result in large ranges of value estimates), and the lack of knowledge of the effects of NCI over decline on flood damages during extreme events. Additionally, lack of data and information on certain types of NCIs such as sand dunes and sea grass beds result in significant knowledge gaps on the understanding of their economic value. Moreover, tracking the changes in size of NCIs over time is a fundamental task, especially for the application of certain economic valuation methods. While many assessments analyze the current stock of the NCI today, they often don't account for long term changes to NCIs and their relative benefits. Finally, satellite imagery required to conduct reliable assessments of NCIs (in present day and over time) is widely accessible at resolutions that are applicable to medium to large geographic scales (city, economy, and regional scales). However, imagery with higher resolutions is much more difficult to attain, making accurate measurements of NCIs at smaller scales more difficult and costly to undertake for the scientific and academic communities. Annex I provides a detailed description of the data and information accessibility and requirements for undertaking these more detailed assessments of NCIs.

Through reviewing and comparing the most commonly applied economic valuation methods, it can be noted that the above mentioned information knowledge gaps can affect some methods more than others. Many ecosystem valuation methods assess the willingness of citizens to pay (WTP) for a specific plot of land based upon its real and perceived values, which can produce the key challenge of not considering the actual ecosystem and biodiversity services provided by the NCIs. However, these kinds of valuation methods are usually less costly and time consuming. For instance, the Hedonic Pricing Method can be a practical means for conducting economic valuation studies due to property records being typically very reliable, as market data can be relatively easy to obtain from established markets. However, such data may be spotty and unreliable in informal or rural economies. Under such cases, economists often have to resort to surveying techniques to elicit people's intended behavior. It is also important to point out that the housing market may be affected by outside influences, like taxes, interest rates, or other factors that are not always accounted for in economic valuation studies using the Hedonic Pricing Method.

The advantage of the Damage Cost Avoided, Replacement Cost, and Substitute Cost methods is that they provide an accurate estimation of ecosystem services from NCIs that are directly related to DRR. However, this method can be very costly, as it requires sophisticated loss models that can determine both the physical impact and the economic value of the losses. Comparing solutions over longer time periods and

69 Eppink, F., et al., "An initial assessment of the Economic Value of Coastal and Freshwater Wetlands in West Asia" (2014).

implementing damage and impact modelling as well as cost models makes the implementation of such methods more comprehensive.

The Benefit Transfer Method is one of the least costly methods and can produce accurate value estimates as long as the values used were transferred from a comprehensive study undertaken at similar geographic scales and contexts. Such method may become the most widely used and applicable method once a greater knowledge base on the subject has been built, particularly in developing economies that lack the technical capacity or resources to undertake studies using costly valuation methods.

A major hurdle in bridging these knowledge gaps include the lack of studies that focus on measuring the value of DRR services alone, rather than on a combination of multiple types of ecosystem services provided by NCIs. In many instances, when studies only report the aggregated total value of multiple types of ecosystem services (i.e. psychological effects from leisure and recreation, the economic value of fisheries, etc.) the reader cannot isolate the economic value that pertains to DRR services alone. With DRR becoming increasingly important around the world, due to the effects of climate change affecting the frequency of natural disasters and population growth in coastal areas, it will become increasingly important to bridge existing knowledge gaps in understanding the economic value of DRR services that preserved/protected NCIs provide.

Policy Gaps

Securing substantial funds needed to protect NCIs and to further understand the DRR benefits of NCIs is a major challenge that requires substantial political support. Protection, maintenance, monitoring, and recovery of NCIs can require significant amount of resources, which can make government implementation plans difficult to implement. Based on the analysis undertaken in this report, there is a lack of policy support for protecting NCIs across many member economies, which is often the source of failures in passing legislation and enforcing laws on such matters.

A common issue that hinders political support is conflicting interests between economic development and environmental protection advocates, which is rooted in the fact that many policy makers lack the awareness and understanding of the economic value of NCIs. Due to this lack of understanding, disaster risk reduction and coastal resiliency policies are often not included in social-economic development plans at economy, regional and local levels. Another prevalent problem that prevents the closing of policy gaps is the bias or restricted focus that results from single agency control, and limited interagency coordination.

An important barrier that can be addressed through policies, especially among developing economies, is the lack of technical capacity to implement disaster risk reduction programs, which is more frequently present at the provincial level. In cases where NCIs are already highly damaged, the technical capacity to implement

protection measures through reconstruction, or designing and building green infrastructure is often insufficient. Significant political support for addressing NCIs under threat should be directed towards training programs in underserved communities that would help enhance the technical capacity needed for proper management and mitigation measures in coastal communities. Several member economies reported that the lack of technical capacity in this area is correlated with the lack of engineers and architects in these Economies. Legal barriers were also highlighted on the survey as a critical issue among respondent member economies. For instance, an issue reported by one of the respondent economies was when traditional resource owners with customary rights might seek compensation when an NCI protection program denies the owner's rights to develop on her/his land. This often hinders NCI protection programs.

In conclusion, most of the policy gaps identified exist in part as a result of the existing knowledge gaps on the economic value of DRR contributions provided by NCIs. Thus, bridging these knowledge gaps can effectively aid in bridging policy gaps that were mentioned above, such as lack of funding and political support to protect and appropriately manage NCIs that provide DRR services. Other policy gaps, such as need for laws and regulations that can effectively protect NCIs while providing proper compensation to resource owners, and a need for greater interagency coordination can also be addressed directly through adequate policy and legal frameworks. The next section provides some initial recommendations for bridging these gaps.

INITIAL RECOMMENDATIONS FOR BRIDGING EXISTING GAPS

This section aims to provide an initial set of recommendations that APEC economies may consider to help bridge the knowledge and policy gaps identified in the previous section. More detailed recommendations will be provided after the valuation study (second phase of this project) is completed.

In terms of knowledge gaps, APEC economies should promote the dissemination of information regarding existing valuation studies as well as facilitate the development of more economic studies covering different types of NCIs as well as different geographical areas, including small scale studies undertaken at the local levels, focusing on disaster risk reduction, response and coastal resilience.

In this sense, the economic valuation study that will be carried out as part of the second phase of this project will contribute to bridge this gap by developing an initial assessment of the economic value of the services provided by NCIs for DRR in the region. However, it would be important to build capacity among member economies to develop economic valuation studies of NCIs, by increasing the knowledge and understanding of different methodologies and procedures used, as well as facilitating the availability and access to relevant information and data necessary to undertake these studies.

In terms of policy gaps, APEC economies should continue raising awareness among the general public and policymakers of the importance of NCIs for disaster risk reduction, response and coastal resiliency. Moreover, economies should collaborate to enhance the technical capacity to design and implement disaster risk reduction policies and programs that incorporate NCIs; especially, by increasing the capacity of policy makers to use economic valuation of the NCIs' ecosystem services to better inform their policy decisions with respect to planning and management of natural coastal resources in the region.

ANNEX I: INFORMATION & ANALYTICAL TOOLS

Socioeconomic and Market Data

Reliable information about market and socioeconomic characteristics of member economies is a fundamental element for conducting economic valuation studies of NCIs. Market data is necessary for the determination of the economic value that is assigned to the NCI. Information on the socioeconomic characteristics of the study area help provide an understanding of the context in which NCIs are providing ecosystem services, and thus required for determining whether economic values are transferrable to similar contexts. Socioeconomic characteristics such as employment, gender participation in the labor force, and demographic trends may affect the perceived value of NCIs; and thus, become critical inputs for a valuation method (i.e. the TEV Method). Historical socioeconomic indicators are useful for estimating natural disaster impacts before and after the event.

As mentioned earlier, market data can be relatively easy to obtain from established markets, however, it may be spotty and unreliable in informal or rural economies. Real estate market data is mostly accessible through multiple listing services, and municipal offices. Other useful data sources for real estate market data, including property prices statistics include the Bank for International Settlements[70] and Global Property Guide.[71] Production by industry data may be acquired through member economies' agency websites, the World Bank, and the United Nations.[72]

Good sources for global socioeconomic data include the World Bank Data Catalog[73], and UN-data.[74] Since most of the existing global data sources only provide information at a member economy scale, economy/local/municipal sources, usually available through a member economy agency website, tend to be better for accessing market and socioeconomic data at smaller scales (i.e. city, neighborhood). For example, the U.S. Census Bureau (in the US) and INEGI (in Mexico) provide comprehensive databases of socioeconomic and industry data at multiple scales. A useful source for attaining social and

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70 "Residential Property Statistics. Bank for International Settlements." (2016). http://www.bis.org/statistics/pp.htm

71 Global Property Guide. (2015). http://www.globalpropertyguide.com/about-us

72 UN List of Industrial products. (2015). http://unstats.un.org/unsd/industry/commoditylist2.asp

73 World Bank Data Catalog. http://datacatalog.worldbank.org/

74 UN Data: Data Mart Info. (2016) http://data.un.org/DataMartInfo.aspx

economic value estimates of specific NCIs around the world is "Mapping Ocean Wealth," a partnership composed of the National Oceanic and Atmospheric Administration (NOAA) and several global organizations including the World Resources Institute (WRI) and Fisheries Economics Research Unit of the University of British Columbia that is developing maps of the social and economic value of multiple ecosystem services from local to global scales. Such data can be easily accessed through an interactive web map.[75]

Table 5 provides a summary of various market and socioeconomic data sources that provide useful information for economic valuation studies of NCIs. Relationships between this type of information and NCIs can be analyzed through the use of GIS technology by overlaying multiple layers on a map. In order to undertake this type of analysis, market and socioeconomic data needs to be referenced to spatial data (geometric shapes, such as boundaries) as attributes. This geographic referencing process, also known as "geo-referencing," will be explained in more detail in the following section.

Table 4: Summary of Various Global Market and Socioeconomic Data Sources

Name	Source	Data
Bank for International Settlements	http://www.bis.org/statistics/pp.htm	market data; property prices & statistics
Global Property Guide	http://www.globalpropertyguide.com/about-us	market data; property prices & statistics
UN Statistics	http://unstats.un.org/unsd/industry/commoditylist2.asp	Production by industry
World Bank Data Catalog	http://datacatalog.worldbank.org/	Production by industry and Socioeconomic data
UN Data Mart Info	http://data.un.org/DataMartInfo.aspx	Socioeconomic data
Mapping Ocean Wealth	http://oceanwealth.org/	NCI value estimates

Source: The Consultant

[75] Mapping Ocean Wealth. The Nature Conservancy. http://oceanwealth.org/

GIS Technology and Data

GIS analysis tools are a commonly used by scientists and researchers for the study of ecosystems. Through the use of GIS software and publicly available data, researchers are able to estimate the total area of different types of ecosystems, and even vegetation species within ecosystems without requiring the use of field surveys. GIS tools must play a key role for both economic valuation studies and monitoring of ecosystems in the APEC region.

Accurate valuations of NCIs require accurate information about the type, size, and extent of the ecosystem service that are being studied, as well as reliable climate and socioeconomic data of the sites and regions that benefit from protected NCIs. There are multiple valuation studies (among which several have been cited in this report) that have taken advantage of the use of GIS technology to assess the supply of specific types of NCIs at local and regional scales. For instance, in the study mentioned earlier by J. Brenner et. al. on the valuation of ecosystem services provided by the Catalan coastal zone in Spain, the researchers used GIS modeling techniques to map the area of each type of ecosystem being studied. Then, the total area values (in hectares) for each type of ecosystem were used as inputs for the economic valuation formula, which produced a US Dollar / Hectare / Year value as the end result that reflected the total ecosystem service value that each type of ecosystem produced in one year.

Types of GIS Data

There are two primary types of GIS data. These are Spatial data and Attribute data. Spatial data represents information about the locations and shapes of geographic features.[76] Attribute data is information appended in tabular format (i.e. excel table) to the Spatial data for the purpose of providing information about the spatial features' characteristics. Spatial data can come in two forms; "Raster data" and "Vector data." Raster data consists of a matrix of cells (or pixels), where each pixel contains a value such as temperature or elevation.[77] This data can come in the form digital aerial maps, scanned maps, or satellite imagery. Vector data is comprised of geometric features which can be displayed as points, lines and polygons on a map. Spatial Data in both Raster and Vector forms are useful for analyzing and valuating NCIs. Data in Vector form may represent city, state, and economy boundaries that contain key attribute information (i.e. population, demographics, income, etc.), various types of transportation systems, or climate and weather data such as

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[76] Dempsey, C. "Attribute Data Types of GIS." GIS Lounge. (2013). https://www.gislounge.com/attribute-data-types-gis/

[77] "What is Raster Data?" Arc GIS. (2008). http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=What_is_raster_data%3F

temperature zones and 100 year flood zones. These boundaries can be overplayed with Raster data such as satellite imagery to allow the researcher to analyze the relationships that exist between ecosystems and factors affecting their economic value.

Satellite Imagery Analysis

The types of GIS data required to identify and map existing ecosystem services comes from satellite imagery. There are several GIS softwares that can be used for the interpretation and modeling of natural resources data acquired from satellite imagery. Such include ESRI ArcGIS, ERDAS Imagine, and eCognition. Over the years, open source software, such as Quantum GIS has become more capable and reliable and today it is also a viable option for conducting this type of analysis, and one that save users the costs of yearly software license fees. Such software can be used to in several ways. One way in which GIS software can be used to map the location of ecosystems is by simply tracing polygons over a satellite image and assigning each completed polygon the type of ecosystem or natural resource that it represents. The disadvantage of this method is that it can be time consuming, particularly when using it to map an entire region. This method would also require previous knowledge/familiarity of the study area, or additional information collected through field land surveys, in order to allow the user to differentiate among types of ecosystems/natural resources while looking at the satellite imagery.

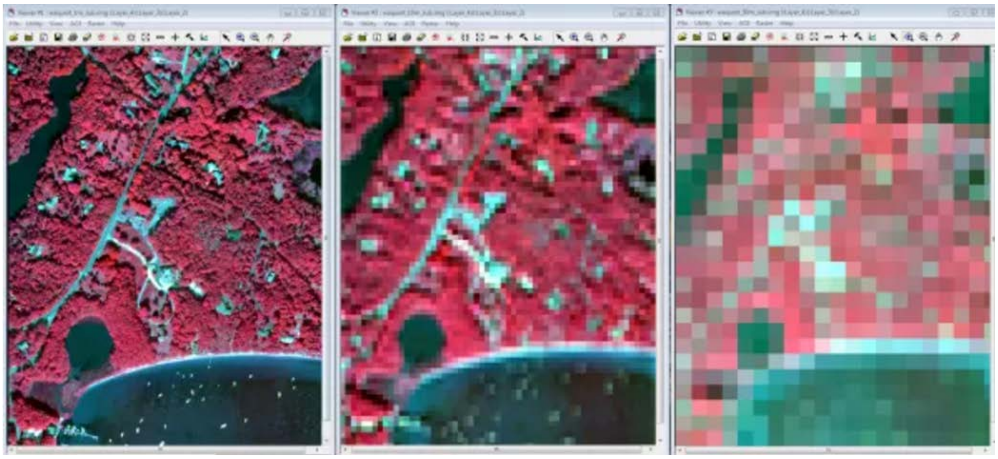
A more cost effective method for mapping and classifying types of ecosystems / natural resources is through satellite imagery classification tools. The end product from this mapping approach is an image that is classified by the type of land features the researcher wants to analyze. Once the image has been classified, the GIS software can be used to calculate the total area for each land feature type (or NCI) in the image.

How Satellite Imagery Classification Works

Since satellite imagery classification is one of the most useful tools for generating valuable data for mapping and monitoring NCIs, this subsection explains how this mapping technology works and which information gaps remain to make it more accessible and reliable. The degree of reliability of the analysis undertaken through the use of such tools corresponds with the type/quality features of the satellite imagery being used, such as spatial, temporal, and spectral resolutions. Spatial resolution refers to the level of detail of a satellite image, which is determined by the dimensions the image's pixels represent on the ground. For instance, a satellite image with a spatial resolution of 30-meter means that each pixel in the image represents a square-shaped area of 30x30 meters, or 900 square meters (m2) on the ground, displayed as one color. Satellite images with a 30-meter

resolution can achieve a reliable level of accuracy for the analysis (i.e. classification of land features) over a large geographic area, such as an entire city, a state, economy, or region. Imagery with a spatial resolution of 15 meters would be suitable for reliable analyses of ecosystems at a neighborhood scale, while imagery with a spatial resolution of 5 meters would be more appropriate for the assessments of ecosystems at the scale of a few city blocks or small protected areas of similar size. Spatial resolutions of 1 meter or less allow for reliable analyses at an even smaller scale, such as individual plots of land or protected areas of similar size. Figure 6 shows the difference between a 30-meter and a 5-meter resolution satellite image. Table 6 shows the ranges of spectral resolution best suited for analyzing ecosystems at various geographic scales. Temporal resolution refers to the frequency in which the satellite takes a picture of the same site. High temporal resolution allows researchers to track changes in the environment over a short period of time. Temporal resolution depends on the satellite taking the pictures, and can vary from a few days to a year for it to take a picture of the same location.

Figure 3: Comparison between 1-meter, 10-meter, and 30-meter (from left to right) spatial resolutions of satellite imagery



Source: Digital Coastal GeoZone Blog; "Teck Talk for the Digital Coast"

Table 5. Ranges of spectral resolutions best suited for analyzing ecosystems at various geographic scales

1. Spatial Resolution	Suitable Geographic Scale
2. 30 - meter	Coastline(s) covering an entire city, state, economy, or region
3. 15 - meter	Coastline covering a neighborhood or group of city blocks

4. 5 - meter	Coastline covering a small group of city blocks or a large plot of land
5. 1 – meter or lower	Coastline along a plot of land

Source: The Consultant

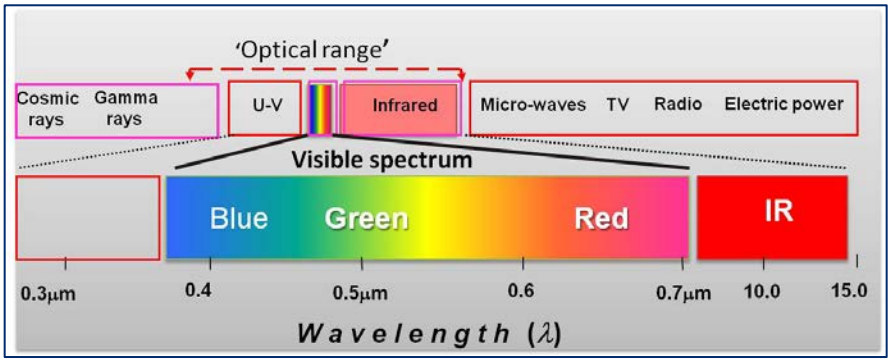
Finally, the term spectral resolution refers to the number of ranges of electromagnetic reflectance wave lengths a satellite is able to capture in one image. For instance, a regular camera captures images displaying colors reflected by solar rays (or "electromagnetic radiation") with wave lengths that range from .45 to .7 micrometers (μm) in size. This wave length range of reflected electromagnetic radiation is also known as the "Visible" wave length range, which is the same range at which the human eye is able to detect reflected light. The Visible range covers 3 classified wavelength ranges (also known as "bands") that are known as the blue band (.45-.52 μm), the green band (.52-.60 μm), and the red band (.63-.69 μm). Therefore, a satellite that can only capture images at the mentioned Visible wave length ranges (or bands) has a spectral resolution of 3. There are satellites that are able to capture images with spectral resolutions ranging from 1 to 220, detecting light at wavelength ranges not visible by the human eye. Commonly used and widely accessible satellite imagery comes with spectral resolutions of 1, 3, 4, 7, or 8. Satellite imagery with spectral resolutions of 7 or 8 bands display various degrees of infrared radiation and can further enhance the reliability of assessments of ecosystems as long as the spatial resolution of the imagery is suited for analyzing the geographic scale of the selected study area.

The above mentioned GIS software can be used to analyze imagery with high spectral resolution. Certain bands can highlight the location of certain features better than others. For instance, with imagery from the Landsat 4-5 Thematic Mapper, displaying band 1(or the "blue" band) can be useful for distinguishing soil from vegetation and deciduous from coniferous vegetation, while displaying band 6 (or the "thermal infrared" band) can be useful for estimating soil moisture.[78] The software can be used to highlight specific features through matching any band to any of the 3 color display channels of the computer (the red, green, and blue color display channels, which are also known as the "color guns"). Only 3 bands can be displayed at once. When each one of the color guns is matched to their respective band color, it means that the image is being displayed in "true color," otherwise, the image is being displayed in "false color" (i.e., if the blue color gun is matched to the green band, the green color gun is matched to the red band, and the red color gun is matched to the infra-red band). Figure 7 shows the different wave lengths in the electromagnetic spectrum. A good example of satellite imagery displayed in false color to

[78] United States Geological Survey (USGS). "What are the best spectral bands for my study?" http://landsat.usgs.gov/best_spectral_bands_to_use.php

better differentiate between vegetation, soil, water, and developed land features, is a visualization recently published by Mapbox, a mapping platform for web and app developers, which displays changes occurring to China's Northeast coastline between 1979 and 2015 using Landsat Satellite Imagery (see figure 8). Under such false color settings, brown and beige colors represent soil / exposed ground, red represents vegetation and bright red represents farmland, variations of grey represent concrete (industrial/urban development) or exposed rock, and blue represents water. This visualization shows how multiple factors including natural causes, flood management strategies, construction of dams, seawalls, and jetties, and other human induces changes such as agricultural development and population growth have contributed to the coastal delta's transformation over the decades.[79] APEC Economies could highly benefit from creating and publishing the same types of visualizations and applying them for tracking changes over time for specific NCIs that have been threatened by development pressures and poor land management practices, and which hold significant economic value in terms of natural disaster mitigation. Such visualizations would serve the purpose of providing valuable information to researchers interested in studying specific NCIs that are being threatened or mismanaged and would help in raising public awareness and generating political pressure to protect them.

Figure 4: Diagram of the Electromagnetic Spectrum



Source: charim.net[80]

[79] Virginia Ng. (2016). "Tracking Changes to China's Northeast Coastline with False-Color Landsat Imagery." © Mapbox. http://www.openstreetmap.org/copyright

[80] Caribbean Handbook on Risk Information management (CHARIM). "Satellite Data." http://www.charim.net/datamanagement/33

Figure 5: Web Visualization of Changes Occurring to China's Northeast Coastline Between 1979 and 2015 using Landsat Satellite Imagery

Source: © Mapbox, © OpenStreetMap[81]

With a higher spectral resolution, each pixel in the image will contain unique spectral reflectance properties, which through the use of the software allow the researcher to assign a set of pixels representing specific land features identified on the map (i.e. a Mangrove forest) a land feature value, and then use a classification tool to identify other pixels that share similar spectral properties in the entire image, and thus, creating a map of classified land features.

In conclusion, Spatial and Spectral Resolution are the most important elements of satellite imagery analysis for achieving precision and accuracy. Temporal resolution holds an important role as well, particularly for the purpose of allowing frequent monitoring of changes happening to coastal ecosystems from development pressures over a short period of time. Satellite imagery with varying degrees of spectral, spatial, and temporal resolution

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81 Virginia Ng. (2016). "Tracking Changes to China's Northeast Coastline with False-Color Landsat Imagery." © Mapbox, © OpenStreetMap. https://www.mapbox.com/blog/tracking-changes-with-landsat/, http://www.openstreetmap.org/copyright

is accessible to the public through a USGS web platform called the Global Visualization Viewer.[82] The imagery with the best combination of types of resolutions that is publicly available at no cost through this source is from the satellites Landsat Thematic Mapper (TM) 4-5, and Landsat TM 8. Imagery from the former has been orbiting the planet since 1985, has a temporal resolution of 16 days, has a Spatial resolution of 30-meters, and a spectral resolution of 6 bands. Imagery from Landsat TM 8 was launched into space in 2013, has a temporal resolution of 16 days, has a Spatial resolution of 15 to 30-meters (depending on the bands), and a Spectral resolution of 8 bands. Imagery from both Landsat Satellites has a combination of Spatial and Spectral resolutions that is reliable enough to enable researchers to map and analyze NCIs at medium and large geographic scales, meaning at city, state, economy, and regional levels. However, despite the fact that spectral resolutions of 6-8 bands is enough to allow for accurate studies at multiple scales, in order to make reliable NCI assessments at a sub-city scale (neighborhood, block, or plot levels), a significantly higher spatial resolution would be needed. Assessments of NCIs at such smaller scales would require spatial resolutions of 5 to sub-meter levels, depending on the size of the study area. While multi spectral imagery with such high resolutions exists, most of it is not yet available to the public or can only be accessed at a high cost. Table 7 shows some of the most widely known satellites that produce high resolution multispectral imagery, along with their respective accessibility levels. Making such imagery available or more affordable to the public would be highly beneficial to both the scientific, academic, and open source community as it would facilitate a significantly higher production of accurate ecosystems assessments, including economic valuation studies of NCIs in the APEC Region, and thus, help in closing the broad knowledge gap that exists.

Table 6: Satellites that Produce High Resolution Multispectral Imagery, Along with their Respective Sources and Levels of Accessibility

Name of Satellite	Spatial Resolution	Spectral Resolution	Temporal Resolution	Sources	Accessibility
Landsat TM 4-5	30-meter	7 bands	16 days	GloVis, EarthExplorer, or via the LandsatLook Viewer	Public / Free
Landsat TM 8	30-meters 15-meter (band 8)	8 bands	16 days	GloVis, EarthExplorer, or via the LandsatLook Viewer	Public / Free

82 USGS Gloval Vizualization Viewer. http://glovis.usgs.gov/

Aster	15-meter (bands 1-3) 30-meter (bands 4-9)	14 bands	16 days	Aster-Web[83]	Public / Free (as of April 1 2016)
Rapid Eye	5-meter	5 bands	1 – 5.5 days	e-Geos,[84] Satellite Imaging Corporation,[85] Landinfo,[86] or MapMart[87]	At cost: From US$1.08 to US$5.05 /1km²
World View (2-3)	1.24 – 1.85-meter	8 bands	<1 – 4.5 days	Satellite Imaging Corporation, Landinfo, or MapMart	At cost: 17 – 32 /1km²

Sources: The Consultant, landsat.usgs.gov, www.e-geos.it, Satellite Imaging Corporation, Landinfo, or MapMart

Analysis Using GIS Data in Vector Form

As mentioned earlier, GIS data in Vector form can play a fundamental role in conducting valuation studies of NCIs. Data in this form allows for the inclusion of key variables by assigning them geographic properties and including them in a map or spatial model that can be used to understand the relationships and dynamics played between such variables and neighboring NCIs. Key variables useful for conducting valuations studies can be represented as points, lines, and/or polygons on a map. Such variables may include extent of a specific type of ecosystem or NCI, extent of urban development and growth over time, city, state, and other administrative boundaries established by Member Economies, rivers, lakes, and water bodies, road and rail networks, transport hubs such as airports, multimodal transport stations, and flood zones. Characteristics of these variables can be appended to each Vector layer as attribute data. Such attributes could include types of urban development such as informal settlements, commercial, or industrial development, average real estate market prices per block or neighborhood, type of flood zone, and demographics. To conclude the subsection of the Gap Analysis on GIS Data and Technology, we summarize multiple types of GIS data (in both Vector and Raster forms) that can be useful for conducting valuation studies of NCIs in Table 8. The table shows the

83 "ASTER." NASA Jet Propulsion Laboratory. (2016) http://asterweb.jpl.nasa.gov/

84 "Price List of 2016." E-Geos. (2016). http://www.e-geos.it/products/pdf/prices.pdf

85 Sat Imagey Group. Satellite Sensors. (2016). http://www.satimagingcorp.com/satellite-sensors/other-satellite-sensors/rapideye/

86 "Buying Satellite Imagery." Landinfo. http://www.landinfo.com/satellite-imagery-pricing.html

87 "Satellite Imagery." Harris Map Mart. http://cms.mapmart.com/Products/satelliteImagery.aspx

various types of key indicators the data can represent, along with specific attributes each may contain.

Table 7: GIS Data used to Represent Key Variables and Attributes Useful for Economic Valuation Studies

Data Form	Types of Key Variables	Attributes that can be Attached to Key Variables	Sources
Raster	NCI Land Cover	• Area per land cover class, such as type of NCI	• USGS[88]
	Urban Land Cover	• Area per land cover class, such as urban / rural	• USGS
	Altitude	• Meters or Kilometres above sea level	• USGS
	Climate data	• Average temperature, monthly precipitation	• NOAA,[89] WorldClim – Global Climate Data[90]
Polygon (Vector)	NCI Land Cover	• Type of NCI • Ecosystem services provided • Estimated economic value	• ISCGM[91] • USGS
	Urban Land Cover	• Type of development; i.e. residential, commercial, industrial, informal settlements, etc.	• ISCGM • USGS
	Administrative Boundary	• Name of census tract, neighbourhood, city, county, state, or economy boundaries, etc. • Population size and density within boundary • Demographic data such as age, gender, and income numbers • Real estate market data ($/m^2) per tract or neighbourhood	• Natural Earth[92] • OpenStreetMap[93] • Member Economies' agency websites
	Flood Zones	• Area of 100 and 500 year flood zones	• FEMA (US)[94] • Darthmouth Flood Observatory[95]

88 USGS Global Visualization Viewer. http://glovis.usgs.gov/

89 "CPC GIS Data." NOAA Climate Prediction Center. http://www.cpc.ncep.noaa.gov/products/GIS/GIS_DATA/

90 "Global Climate Data." World – Clim. http://www.worldclim.org/

91 "Activity of Global Mapping Project." International Steering Committee for Global Mapping. http://www.iscgm.org/

92 "Free Vector and Raster Data." Natural Earth. http://www.naturalearthdata.com/

93 © Mapbox, © OpenStreetMap. http://www.openstreetmap.org/

94 "Mapping Information Plattform." FEMA. https://hazards.fema.gov/femaportal/wps/portal/NFHLWMS

95 http://floodobservatory.colorado.edu/

	Climate Data	• Mean temperatures • Annual precipitation	• WorldClim – Global Climate Data
	Lake or Other Water Body	• Name, size, fresh or salty water, etc.	• Natural Earth
Line (Vector)	Road Network	• Type of road • Road conditions • Segment length • Peak traffic	• Natural Earth • OpenStreetMap • Member Economies' agency websites
	Rail Network	• Type; freight, passenger, speed rail • Conditions • Segment length • Peak traffic	• Natural Earth • OpenStreetMap • Member Economies' agency websites
	River	• Type; creek, perennial, etc. • Water output • Silt discharge	• Natural Earth • OpenStreetMap • Member Economies' agency websites
Point (Vector)	Transport Stations	• Mode • Passenger traffic	• Natural Earth • OpenStreetMap • Member Economies' agency websites
	Airport	• Type (i.e. Origin and destination, Transfer hub) • Annual passenger traffic • Aircraft operations, and other statistics	• Natural Earth • OpenStreetMap • Member Economies' agency websites
	Location of Public Institutions	• Name and type of institution	• Natural Earth • OpenStreetMap • Member Economies' agency websites
	Polluting Source	• Type; power plant, factory, sewage discharge point	• National Athmospheric Emmissions Inventory • Member Economies' agency websites

Sources: The Consultant

ANNEX II: SUMMARY OF VALUATION METHODOLOGIES

Table 8: Summary of the valuation methodologies in the literature review

Valuation Method	Applicability	Values/Inputs	Advantages	Shortcomings
Total Economic Value (TEV) Methodology	Primarily used to estimate a broad economic value of wetlands and mangroves	Recreation, research, education, harvesting of crops, fisheries, and aquaculture Ecosystem services from NCIs, such as self-regulation in terms of pest control, water regulation and purification, and soil fertility Cost of policy inaction to conserve stock of natural capital Willingness to pay Location and extent of NCI Infrastructure conditions including type of adjacent settlements and transport networks	A cost effective means for monetizing natural resources Transferability: can take value estimates from one or more study sites and applies them to a site of interest Can be used for scaling up from localized changes to larger geographic areas	Measurement: unreliable data, analyst errors Publication Selection: editorial preference for stat. sig. results, policy interest Generalization: values for study sites are transferred to policy sites that are different but not realized (wetland scale, quality, demand for services) Does not account for the intrinsic value of biodiversity in its own right, independent from the value placed on it by people A static methodology: NCIs are valuated at a particular point in time, while risks due to sea level rise are dynamic
Market Price Method	Useful for the valuation of mangroves and is more reliable at small to medium scales	Value of fisheries: price and quantity data Value of timber: price and quantity data	Good assessment of the willingness to pay (WTP) for specific plots of land	Market data may be spotty and unreliable in informal or rural economies Seasonality is crucial

	than at regional scales. The method is also best suited for evaluating specific episodic disaster scenarios	Household survey responses Location and extent of NCI Infrastructure conditions including type of adjacent settlements and transport networks	Data is relatively easy to obtain from established markets	Cannot be easily used to assess a larger scale change (i.e. a wiped out ecosystem) that will alter supply and demand of the good Market value of shared goods or benefits is difficult to measure Where no market information can be acquired, economists resort to survey techniques to elicit people's intended behavior May not account for other resources used to bring the good to market, distorting and overstating the price
Hedonic Pricing Method	Useful for the valuation of multiple types of NCIs including mangroves, wetlands, sand dunes, and coral reefs, and is applicable at multiple scales	Index of the environmental amenity of interest Price per square meter (or foot) Cross-section and/or time-series data on property values and property and household characteristics for a well-defined market area that includes homes with different levels of environmental quality, or different distances to an environmental amenity, such as open space or the coastline Location and extent of NCI	The method's main strength is that it can be used to estimate values based on actual choices Property markets are relatively efficient in responding to information, so can be good indications of value; Property records are typically very reliable Data on property sales and characteristics are readily available through many sources, and can be related to other	The method will only capture people's willingness to pay for perceived differences in environmental attributes, and their direct consequences The method assumes that people have the opportunity to select the combination of features they prefer, given their income. However, the housing market may be affected by outside influences, like taxes, interest rates, or other factors The method is relatively complex to implement and interpret, requiring a

		Infrastructure conditions including type of adjacent settlements and transport networks	secondary data sources to obtain descriptive variables for the analysis	high degree of statistical expertise Depends heavily on model specification, large data collection process Property values are determined primarily by short term market conditions, making it difficult to assess long term NCI benefits using this method
Damage Cost Avoided, Replacement Cost and Substitute Cost Methods	Useful for the valuation of multiple types of NCIs including mangroves, wetlands, sand dunes, and coral reefs, and is applicable at multiple scales but best suited for small geographic scales	Baseline and projected ecological flood protection assessments before and after restoration (cost of preservation measures, or estimated costs from damages incurred) Location and extent of NCI (before and after restoration efforts) Infrastructure conditions including type of adjacent settlements and transport networks	When compared against other valuation methods, this method provides a relatively accurate estimation of ecosystem services from NCIs that are closely related to disaster mitigation	This method can be very costly, as it requires sophisticated loss models that can determine both the physical impact and the economic value of the losses
Contingent Valuation Method (CVM)	This method can be used to value all types of NCIs including mangroves, wetlands, sand dunes, and coral reefs, and is applicable at multiple scales	WTP for every type of NCIs' ecosystem service based on a contingent scenario Location and extent of NCI	Applicable for Non-use Values, which cannot be calculated by market demand	Can be very costly between survey design, implementation, and specification, all for what might be simply hypothetical information The conceptual, empirical, and practical problems associated with developing dollar estimates of economic value on the basis of how people respond to hypothetical questions

				about hypothetical market situations are debated constantly
Benefit Transfer Method	can be used to value multiple types of NCIs including mangroves, wetlands, sand dunes, and coral reefs, and is applicable at multiple scales based on an adjusted economic value attained from a previous similar study, or from a combination of similar studies	Location and extent of NCI Demographic and socioeconomic data Infrastructure conditions including type of adjacent settlements and transport networks Valuation formula from previous similar study (or studies)	A cost effective means of conducting an economic valuation study	The method is only as accurate as the initial study Adequacy of existing studies in a new and different context may be hard to analyse; one needs to be able be to measure and compare the same things across regions/studies The unit value estimates can become dated quickly as climatic and socioeconomic factors change at the location of the existing study

Source: The Consultant

ANNEX III: APEC SURVEY ON VALUATION OF NATURAL COASTAL INFRASTRUCTURES

Background: The United States is implementing the APEC Project "Assessing the Economic Value of Green Infrastructure in Coastal Ecosystems to Disaster Risk Reduction, Response and Coastal Resilience in the APEC region" (0FWG 03-2014A).

Objective: This survey aims to collect relevant information from APEC economies to identify critical knowledge gaps and regulatory barriers for valuing the ecosystem services that natural coastal infrastructures (NCIs) provide, especially as pertaining to reducing disaster risk and enhancing coastal resiliency.

Definitions:

Coastal Resilience ***refers to the ability of coastal ecosystems to stand up against, or quickly recover from, adverse risks or hazards (including flooding, high winds, drought, etc.) that may be associated with disaster events.***

Natural Coastal Infrastructures (NCIs) ***are natural (non-anthropogenic) ecosystem features that are a part of an economy's shoreline environments. NCIs may provide benefits of reducing adverse impacts (including erosion, storm surges, wave actions, etc.) that may be associated with coastal disaster events***. Examples of NCIs include coral reefs, mangroves, sand dunes, and salt marshes.

Respondent Profile: This survey covers topic areas including NCIs present in each economy, databases that capture knowledge regarding NCIs, the role of NCIs in protecting against disaster risks and events, as well as assessing the value of NCIs. As such, some research may be needed in deriving responses. Additionally, different respondents, or groups of respondents, may be more suitable to answer different questions. Therefore, subject matter experts from each economy should be sought, and relevant survey questions be deferred to them to respond. As possible, please provide a point of contact for each question for any follow-up questions.

1) ***This question is for the primary respondent – i.e., the representative in the working group who first receives this survey, or the official who compiles the responses, etc.***

a. Respondent Economy: _____

b. Respondent Name: _____

c. Respondent Email: _____

d. Respondent Organization: _____

e. Type of Organization *(check one of the following)*:

Public	
Private	

f. Position Held in Organization/ Title: _____

g. Main Characteristics of Your Role:

Administrative	
Financial	
Operations	
Research	
Project Implementation	
Policy Development	
Other *(describe)*	

2) Complete the following table for NCIs that exist in your economy:

Natural Coastal Infrastructure	**Yes**	**No**	**Not sure, or not qualified to respond**	***If Yes, please specify the following to the best of your ability:***		
				Area of Coverage (ha, acres, m^3)	Main types of coastal areas the NCI is protecting (urban or rural, densely or sparsely populated, commercial or industrial, etc.)	What research, if any, has been conducted to assess the efficacy of the NCI to protect communities from storm damages, flooding, etc.? What were the findings?
Coral Reefs						
Mangroves or Other Maritime Forests						
Sand Beaches/ Dunes						
Wetland Areas (i.e., Salt Marshes)						
Oyster and/or Mussel Beds						
Plant Cover and/or Seagrasses						
Others *[Please Specify]*						

Please complete the following for the primary respondent or point of contact for this question:

Name	
Organization	
Email	
Phone No.	

3) Is the economic value of NCI's analyzed or studied in your economy?

Yes ☐

No ☐

Not sure, or not qualified to respond ☐

If the value of NCIs is studied in your economy, what were the main findings of that research?

Are the results/outcomes used for policy-making related to disaster risk reduction and coastal resiliency?

	Please Select	*[Please elaborate]*
Yes		
No		
Not sure, or not qualified to respond		

Please explain the methodologies and techniques used to assess the value (economic, social, environmental) that NCI's contribute to reducing the risk of disasters and enhancing coastal resiliency. Please include information on data availability for the purposes of conducting these studies. (Main sources of data, as well as links if possible).

Please identify any other specialists and/or organizations from your economy and/or from the region who investigate the value and efficacy of natural coastal infrastructures and their role in enhancing resiliency and reducing the risks of disasters. Please also provide contact information (email, phone number).

Name of Specialist	Area of Expertise	Contact Information
		Email: Phone:
		Email: Phone:
		Email: Phone:

Please complete the following for primary respondent or point of contact for this question:

Name	
Organization	
Email	
Phone No.	

4) In your economy, do disaster risk reduction and coastal resiliency policies consider the use of NCIs? Are NCIs required by your economy to enhance disaster risk reduction and coastal resiliency?

	Please Select	*[Please elaborate]*
Yes		
No		
Not sure, or not qualified to respond		

Are there any barriers which may prevent the inclusion of NCIs in disaster risk reduction and coastal resiliency policies? If so, please describe:

Legal/ Regulatory:	
Political:	
Financial:	
Technical:	
Other:	

Is the use of NCIs for reducing the risk of disasters and enhancing coastal resiliency in your economy promoted by any specific cause (initiative, grass-roots groups, etc.)?

Yes ☐ Please describe: _____

No ☐

Not sure, or not qualified to respond ☐

Please complete the following for the primary respondent or point of contact for this question:

Name	
Organization	
Email	
Phone No.	

5) Who manages NCIs generally and at each level (international, domestic, or local/municipal/provincial)? Please identify the agency(ies) or authority(ies) that is(are) responsible for these NCIs by each category below, or say "not applicable":

	International/ Multi-Economy	Domestic	Local/ Municipal/ Provincial
Planning *(arranging for NCI development)*			
Regulating *(controlling NCI use, mandating inclusion)*			
Funding *(financing or subsidizing NCI installation and/or maintenance)*			
Installing *(deciding on locations, implementing plans)*			
Overseeing/ Maintaining *(cultivating and preserving established NCIs)*			
Investigating/ Studying *(new research and investigations into NCI impacts)*			

Does the private sector have a role in NCI management?

Yes ☐ Please describe: _____

No ☐

Not sure, or not qualified to respond ☐

Do partnerships between public and private groups exist for the management of NCIs? Please elaborate.

	Please Select	*[Please elaborate]*
Yes		
No		
Not sure, or not qualified to respond		

Please complete the following for the primary respondent or point of contact for this question:

Name	
Organization	
Email	
Phone No.	

6) With respect to overseeing and guiding the implementation of NCIs, please specify if the following are present for your economy:

	Mark if Yes	Please Provide Details
Site selection guidelines for NCIs		
NCI design/ construction specifics		
Monitoring and evaluation criteria		
Maintenance requirements		

Does your economy require the inclusion of NCIs for shoreline development?

Yes ☐

No ☐

Not sure, or not qualified to respond ☐

If NCIs are required by your economy, please also specify the agency or authority, as well as the policy or law that mandates the use of NCIs.

Are there other reasons why your economy promotes the use of NCI other than shoreline protection?

Please complete the following for the primary respondent or point of contact for of this question:

Name	
Organization	
Email	
Phone No.	

7) Does your economy have a budget for developing and implementing NCIs? What are the main sources of funding?

	NCI Budget?			**If Yes, Amount (USD)**	**Funding Source(s)** *[Please specify source and amounts (USD), if possible]*				
	Yes	**No**	**Not sure**		**Economy-level Government**	**Provincial/Local Government**	**Development Partner Loans**	**Private**	**Other(s)**
2014									
2013									
2012									
2011									
2010									

How is the budget allocated? Please include NCI restoration and maintenance funds in your considerations and complete the following table with this information.

	Budget Allocation *[Please specify recipients and amounts (USD), if possible]*				
	Investigations/ Study	**Maintenance**	**Repair/ Rehabilitation**	**New Development**	**Other(s)**
2014					
2013					
2012					
2011					
2010					

What types of funding and/or investments are anticipated/expected/planned for NCIs in future years?

Please complete the following for the primary respondent or point of contact for this question:

Name	
Organization	
Email	
Phone No.	

Thank you for taking the time to complete this survey. Your participation is greatly appreciated.