# Integrated Spatial Cost-Benefit Analysis of Large-Scale Mangrove Conservation and Restoration in Indonesia: Supplementary Information

## Valuation of coastal protection

Coastal protection is valued using the Avoided Damage Cost approach, which is commonly used in engineering and insurance sectors and recommended for the assessment of coastal protection services from habitats. The flood protection benefits provided by mangroves are assessed as the flood damages avoided to people and property by keeping mangroves in place. The approach couples offshore storm models with coastal processes and flood models to measure the flooding that occurs with and without mangroves under different storm conditions. These flood extents are used to estimate the avoided flood damages to people and property and hence the expected benefits of mangroves in economic terms by quantifying the avoided damages to properties that can be attributed to the presence of mangroves.

The coastal protection values for mangroves used here are the first global estimates of flood risk reduction benefits provided from process-based models. This work represents the state of the art in global flood risk and benefits assessment and has been shown to provide better estimates than replacement cost approaches (Barbier, 2015; World Bank, 2016). Following the expected damage function approach, the role of mangroves in coastal protection is examined by measuring the economic impacts of coastal flooding on people and property under two scenarios: with and without mangroves. The “without mangroves” scenario assumes complete loss of the habitat and the consequent erosion of the intertidal area into a smooth sandy surface.

We extracted estimates of avoided damage costs from a global analysis conducted by Menendez et al. (2020). This applies a probabilistic, process-based valuation of mangroves’ effects in protecting people and property in coastal communities. This analysis involved five steps:

1. Estimating and characterizing offshore dynamic conditions (e.g., Wave height, wave period, storm surge and astronomical tide) produced from tropical cyclones and regular climate conditions
2. Applying process-based models to downscale the offshore dynamics to the nearshore location of mangrove areas.
3. Evaluating the role of mangroves in nearshore dynamics to obtain the flood height behind these ecosystems at the shoreward end of each section
4. Estimating the amount of land flooded by storms or high water by intersecting the flood height at the shoreline with inland topography
5. Calculating biophysical interactions between hydrodynamic conditions and mangroves and then contrasting expected impacts of flooding on populations, land and property, with and without, the presence of mangroves. Industrial and residential property are included in this calculation, and the difference between the two scenarios equals coastal protection service from mangroves. Relative damages to properties are estimated using so-called depth-damage functions.

For further details on the valuation of the coastal protection value of mangroves, we refer to Menedez et al. (2020). Spatially explicit data are provided for each 20 kilometers of coastline with mangrove presence.

Valuing the coastal protection value of mangroves by quantifying avoided damages to residential and industrial property naturally introduces a strong spatial variation of values. Mangroves along coastlines that are not developed, have a low coastal protection value, whereas in coastal areas that are developed a small mangrove belt might represent a significant coastal protection value per hectare.

## Valuation of climate regulation

This assessment calculates the value of Indonesian mangroves for carbon storage and sequestration in two ways: reduced greenhouse gas (GHG) in the atmosphere from mangrove restoration and avoided GHG emissions from conservation of existing mangrove ecosystems. Restoration reduces GHGs because, as they regrow, mangroves take carbon from the atmosphere, sequester it in their biomass and bury it in the soil. Restoration also reduces baseline GHG emissions, because mangroves typically replace land uses that generate GHG emissions, whether these are farms, fishponds or mudflats. The averted annual GHG emissions from such land uses is part of the blue carbon value of mangrove restoration.

**We estimated blue carbon sequestration by calculating how much mangrove restoration reduced CO2 concentrations in the atmosphere.** We used measurements reported in Cameron et al. (2019) of GHG emissions of t 17 ± 5.6 tCO2e per year from partially inundated aquaculture ponds in Indonesia with no mangrove coverage. Then, we added a 15 ± 5 tCO2e per year biomass sequestration rate from mangrove restoration (average 35 years) as estimated by Cameron et al. (2019). Finally, we added the soil carbon burial estimated at 6.5 ± 2.1 tCO2e per year by Alongi (2016) to estimate a total blue carbon reduction per year per hectare of 38.5 ± 12.7 tCO2e.

**We estimated blue carbon storage by calculating CO2 emissions that the conservation of existing mangroves (i.e. carbon stocks) avoided.** Mangroves allocate 50–90% of their carbon pool below ground and store the remainder in aboveground biomass. There is uncertainty about the share of stored blue carbon that mangrove deforestation or degradation will release into the atmosphere. To value blue carbon storage in mangrove conservation areas, this assessment used a conservative approach. It assumed that conservation would avert a loss of only 25% of mangroves’ carbon stock (Jakovac et al., 2020). Considering a mean carbon density per hectare in mangroves of 1,083 tCO2e (Murdiyarso et al., 2015), estimated avoided GHG emissions per hectare from conservation are 271 tCO2e.

The price of carbon can vary significantly between countries, political contexts and financial mechanisms. The High Level Commission on Carbon Prices (HLCCP) found that about 75% of the emissions that are covered by a carbon price are priced below USD 10/tCO2. But it also found that, in order to achieve the GHG reductions needed to comply with the Paris Agreement and its temperature target, carbon prices should be around USD 40-80/tonCO2 by 2020, and USD 50-100/tonCO2 by 2030 (Stiglitz et al., 2017).

Other studies have considered different methodologies depending on whether they are determining values for carbon sequestration or carbon storage. For example, Hernández-Blanco et al. (2021) argues that, because carbon sequestration is a flow, a Social Cost of Carbon of USD 80/tonC as estimated by Tol (2011) is more accurate. This accounts for the cost of damage to human health, agricultural productivity and infrastructure caused by each ton of carbon emitted. On the other hand, the same study used a Marginal Abatement Cost of Carbon (MAC) of USD 125/tonC (as estimated by Jerath (2012) for the IPCC AR4 to value carbon storage, since MAC sums up the costs of eliminating each additional unit of carbon emissions. This can be translated to the economic benefit bestowed by maintaining stocks of carbon in the biosphere. The current array of methods and carbon prices can produce significant variations in the value assigned to mangroves’ climate regulation service.

In this study, we consider a very conservative lower-bound estimate of 5 USD per tCO2e, which is representative of the carbon prices traded on voluntary markets in the year this analysis was conducted (Forest Trends’ Ecosystem Marketplace, 2021)

## Value transfer for estimating the value of mangrove provisioning services

### Methodology

The valuation method used to estimate the value of provisioning services supplied by mangroves is meta-analytic function transfer, which uses a value function estimated from the results of multiple primary studies representing multiple study sites in conjunction with information on parameter values for the policy site(s) to calculate the value(s) of ecosystem services at the policy site(s) (Brander, 2013). The approach is represented in Figure 1. A value function is an equation that relates the value of an ecosystem service to the characteristics of the ecosystem and the beneficiaries of the ecosystem service. Since the value function is estimated from the results of multiple studies it is able to represent and control for greater variation in the characteristics of ecosystems, beneficiaries and other contextual characteristics (Stanley, 2001). This feature of meta-analytic function transfer provides a means to account for simultaneous changes in the stock of ecosystems when estimating economic values for ecosystem services (i.e., the “scaling up problem”). By including an explanatory variable in the data describing each “study site” that measures the scarcity of other ecosystems in the vicinity of the “study site”, it is possible to estimate a quantified relationship between scarcity and ecosystem service value. This parameter can then be used to account for changes in ecosystem scarcity when conducting value transfers at large geographic scales (Brander et al. 2012b).

In the specific context of Indonesian mangrove provisioning services, the methodology involved building a database of mangrove valuation results, estimating a value function using a meta-regression, and applying this to predict the value of provisioning services in Indonesia. The key steps applied in this approach are:

1. Construct global database of value estimates for mangrove “study sites”
2. Standardise values to USD/ha/year. Values reported in currencies other than USD are converted to USD using purchasing power parity adjusted exchange rates.
3. Use GIS to add spatial variables (e.g. mangrove area, population density, distance to towns, road density, night time light etc.)
4. Meta-regression to estimate a value function that explains variation in the dependent variable (value in USD/ha/year) by a set of explanatory variables (including spatial variables and dummy variables for the ecosystem services valued)
5. Construct database of “policy site” mangroves in Indonesia including same explanatory variables
6. Input policy site characteristics into value function to estimate site-specific values (USD/ha/year)
7. Multiply site-specific values by policy site areas
8. Aggregate to policy relevant spatial level (e.g., districts and provinces)

### Mangrove value data

A global database of valuation estimates for ecosystem services provided by mangroves was constructed based on existing databases described in Brander et al. (2012a) and Brander et al., (2024).

Table 1 provides an overview of the value data for provisioning services with the number of observations per ecosystem sub-service and the mean value in USD/ha/year at 2020 price level. In total, the database of primary valuation study results contains 267 observations on the value of provisioning services from mangroves. The most commonly valued sub-services are mangrove related fisheries, extraction of fuelwood and charcoal, and extraction of timber.

Table 1. Provisioning (sub)services sample size and mean value (USD/ha/year; 2020 prices)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| TEEB ecosystem sub-service | N | Mean | S.D. | Median |
| Fish | 125 | 8,133 | 18,983 | 966 |
| Meat | 5 | 150 | 291 | 23 |
| Plants / vegetable food | 12 | 639 | 670 | 222 |
| NTFPs [food only] | 9 | 396 | 537 | 52 |
| Food [unspecified] | 1 | 92 | . | 92 |
| Other | 4 | 3 | 3 | 3 |
| Drinking water | 2 | 56 | 39 | 56 |
| Timber | 32 | 647 | 1,648 | 175 |
| Fuel wood and charcoal | 53 | 2,715 | 8,973 | 105 |
| Fodder | 11 | 1,272 | 1,701 | 303 |
| Other raw materials | 7 | 1,467 | 2,165 | 189 |
| Raw materials [unspecified] | 6 | 2,215 | 5,140 | 12 |
| Total | 267 |  |  |  |

### Meta-analytic value function

A value function was estimated using an OLS regression model in SPSS 25. Table 2 provides the results of the meta-regression. The dependent variable is the natural log of ecosystem service value in USD/ha/year. The key explanatory variables are the extent of the mangrove ecosystem study site, distance to nearest city, extent of protected area within 50 km radius, and length of road within 10 km radius.

Table 2. Provisioning services meta-regression (dependent variable: ecosystem service value in USD/ha/year; 2020 price level; natural log)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | B | Std. Error | t | Sig. |
| Constant | 9.309 | 1.584 | 5.876 | 0.000 |
| Area\_ha\_ln | -0.321 | 0.050 | -6.418 | 0.000 |
| GDPC\_ln | 0.022 | 0.155 | 0.142 | 0.887 |
| Dist\_City\_ln | -0.120 | 0.123 | -0.982 | 0.327 |
| Man\_16\_10\_ln | -0.130 | 0.042 | -0.307 | 0.759 |
| PA\_ha\_50\_ln | -0.108 | 0.039 | -2.749 | 0.006 |
| Road\_10\_ln | -0.237 | 0.077 | -3.072 | 0.002 |
| SubES\_Fish | 1.560 | 0.381 | 6.717 | 0.000 |
| SubES\_Timber | 0.019 | 0.506 | 0.393 | 0.695 |
| SubES\_Fuel | 0.026 | 0.440 | 0.584 | 0.560 |
| SubES\_NTFP | -0.452 | 0.815 | -0.555 | 0.580 |
|  |  |  |  |  |
| N | 266 |  |  |  |
| Adjusted R2 | 0.28 |  |  |  |

### Indonesian mangrove provisioning service values

The constructed database of Indonesian mangroves includes 7,445 mangrove patches covering an area of 2.67 million hectares. The characteristics of each individual patch are inputted into the value function to estimate a patch specific mean value per hectare for each provisioning sub-service, which is subsequently multiplied by the area of the patch to compute the total annual value of each provisioning sub-service. The results are summarised by province in Table 3. It is notable that mangrove related fisheries has the highest estimated value, accounting for almost 64% of provisioning service value.

For Indonesia as a whole, the mean value of provisioning services per hectare of mangrove is estimated to be 347 USD/ha/year and the total value is over 900 million USD/year. To put this in context, the values of mangrove provisioning services found in the literature are summarised in Annex 1. These values, standardised to annual values per hectare, span a similar range as the values predicted using the meta-analytic value function.

Table 3. Provisioning service values for Indonesian mangroves

| Province | Mangrove patches | Area (ha) | Timber (USD/year) | Fuelwood (USD/year) | NTFPs (USD/year) | Fisheries (USD/year) | Other (USD/year) | Total (USD/year) | Mean (USD/ha/year) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Aceh | 139 | 25,590 | 1,902,828 | 1,913,896 | 1,187,014 | 8,876,800 | 1,865,336 | 13,880,539 | 542 |
| Bali | 44 | 1,687 | 169,185 | 170,169 | 105,540 | 789,256 | 165,851 | 1,234,150 | 732 |
| Banten | 23 | 2,302 | 192,540 | 193,660 | 120,110 | 898,210 | 188,746 | 1,404,520 | 610 |
| Bengkulu | 10 | 1,773 | 116,920 | 117,600 | 72,937 | 545,439 | 114,616 | 852,896 | 481 |
| Dki Jakarta | 20 | 323 | 80,066 | 80,532 | 49,946 | 373,512 | 78,488 | 584,056 | 1,808 |
| Gorontalo | 266 | 8,237 | 2,009,563 | 2,021,253 | 1,253,598 | 9,374,727 | 1,969,968 | 14,659,141 | 1,780 |
| Jambi | 55 | 6,301 | 437,413 | 439,957 | 272,865 | 2,040,554 | 428,794 | 3,190,789 | 506 |
| Jawa Barat | 10 | 670 | 78,701 | 79,159 | 49,095 | 367,143 | 77,150 | 574,097 | 857 |
| Jawa Tengah | 16 | 7,407 | 258,746 | 260,251 | 161,410 | 1,207,064 | 253,648 | 1,887,470 | 255 |
| Jawa Timur | 45 | 14,224 | 762,704 | 767,141 | 475,787 | 3,558,059 | 747,676 | 5,563,691 | 391 |
| Kalimantan Barat | 128 | 104,095 | 5,676,881 | 5,709,903 | 3,541,329 | 26,482,972 | 5,565,028 | 41,411,084 | 398 |
| Kalimantan Selatan | 177 | 55,632 | 8,101,222 | 8,148,346 | 5,053,671 | 37,792,662 | 7,941,601 | 59,095,901 | 1,062 |
| Kalimantan Tengah | 50 | 17,150 | 1,165,828 | 1,172,609 | 727,262 | 5,438,653 | 1,142,857 | 8,504,352 | 496 |
| Kalimantan Timur | 366 | 162,906 | 4,448,321 | 4,474,197 | 2,774,934 | 20,751,672 | 4,360,675 | 32,449,123 | 199 |
| Kalimantan Utara | 183 | 108,179 | 8,571,458 | 8,621,317 | 5,347,012 | 39,986,338 | 8,402,572 | 62,526,125 | 578 |
| Kepulauan Bangka Belitung | 211 | 63,967 | 2,921,666 | 2,938,661 | 1,822,582 | 13,629,737 | 2,864,099 | 21,312,646 | 333 |
| Kepulauan Riau | 688 | 49,594 | 3,074,825 | 3,092,710 | 1,918,124 | 14,344,231 | 3,014,240 | 22,429,891 | 452 |
| Lampung | 63 | 4,651 | 972,786 | 978,445 | 606,840 | 4,538,103 | 953,619 | 7,096,174 | 1,526 |
| Maluku | 559 | 144,637 | 6,017,141 | 6,052,142 | 3,753,588 | 28,070,305 | 5,898,584 | 43,893,177 | 303 |
| Maluku Utara | 697 | 42,594 | 6,036,100 | 6,071,211 | 3,765,415 | 28,158,747 | 5,917,168 | 44,031,472 | 1,034 |
| Nusa Tenggara Barat | 165 | 8,399 | 568,580 | 571,888 | 354,690 | 2,652,460 | 557,378 | 4,147,618 | 494 |
| Nusa Tenggara Timur | 241 | 17,435 | 1,235,739 | 1,242,928 | 770,874 | 5,764,795 | 1,211,391 | 9,014,336 | 517 |
| Papua | 474 | 826,880 | 27,235,118 | 27,393,540 | 16,989,699 | 127,053,370 | 26,698,496 | 198,671,727 | 240 |
| Papua Barat | 736 | 480,770 | 15,356,864 | 15,446,193 | 9,579,856 | 71,640,643 | 15,054,283 | 112,023,556 | 233 |
| Riau | 257 | 160,655 | 8,488,274 | 8,537,649 | 5,295,120 | 39,598,280 | 8,321,027 | 61,919,323 | 385 |
| Sulawesi Barat | 95 | 3,845 | 872,610 | 877,686 | 544,348 | 4,070,775 | 855,417 | 6,365,419 | 1,656 |
| Sulawesi Selatan | 303 | 17,129 | 3,578,595 | 3,599,411 | 2,232,384 | 16,694,349 | 3,508,085 | 26,104,740 | 1,524 |
| Sulawesi Tengah | 394 | 41,875 | 3,653,248 | 3,674,499 | 2,278,954 | 17,042,611 | 3,581,267 | 26,649,313 | 636 |
| Sulawesi Tenggara | 364 | 66,917 | 3,454,484 | 3,474,578 | 2,154,962 | 16,115,362 | 3,386,419 | 25,199,386 | 377 |
| Sulawesi Utara | 248 | 11,351 | 2,376,777 | 2,390,603 | 1,482,672 | 11,087,802 | 2,329,947 | 17,337,854 | 1,527 |
| Sumatera Barat | 91 | 15,433 | 1,018,540 | 1,024,465 | 635,382 | 4,751,549 | 998,472 | 7,429,936 | 481 |
| Sumatera Selatan | 156 | 160,304 | 4,067,744 | 4,091,406 | 2,537,524 | 18,976,258 | 3,987,596 | 29,672,931 | 185 |
| Sumatera Utara | 171 | 38,015 | 2,226,677 | 2,239,630 | 1,389,037 | 10,387,576 | 2,182,804 | 16,242,920 | 427 |
| Total | 7,445 | 2,670,927 | 127,128,146 | 127,867,632 | 79,304,558 | 593,060,016 | 124,623,302 | 927,360,351 | 347 |

Table 4. Review of primary valuations for provisioning services from Indonesian mangroves (standardised to USD/ha/year; 2020 price level)

|  |  |  |  |
| --- | --- | --- | --- |
| **Study site** | **Ecosystem service valued** | **Standardised value 2020 (USD/ha/year)** | **Reference** |
| Wringinputih Village | Food and drinks |  5.96  | Ariyanto, A., Hidayati, E., & Iswandi, W. (2020). Managing Mangrove Essential Ecosystem Area: A Strategy Analysis in Pangpang Bay Area, Wringinputih Village, East Java, Indonesia. Journal of Saemaulogy, 5(2), 33-64. |
| Wringinputih Village | Capture fisheries |  1,356.84  | Ariyanto, A., Hidayati, E., & Iswandi, W. (2020). Managing Mangrove Essential Ecosystem Area: A Strategy Analysis in Pangpang Bay Area, Wringinputih Village, East Java, Indonesia. Journal of Saemaulogy, 5(2), 33-64. |
| Wringinputih Village | Aquaculture |  497.01  | Ariyanto, A., Hidayati, E., & Iswandi, W. (2020). Managing Mangrove Essential Ecosystem Area: A Strategy Analysis in Pangpang Bay Area, Wringinputih Village, East Java, Indonesia. Journal of Saemaulogy, 5(2), 33-64. |
| Wringinputih Village | Shellfish culture |  113.22  | Ariyanto, A., Hidayati, E., & Iswandi, W. (2020). Managing Mangrove Essential Ecosystem Area: A Strategy Analysis in Pangpang Bay Area, Wringinputih Village, East Java, Indonesia. Journal of Saemaulogy, 5(2), 33-64. |
| Wringinputih Village | Crab Culture |  159.84  | Ariyanto, A., Hidayati, E., & Iswandi, W. (2020). Managing Mangrove Essential Ecosystem Area: A Strategy Analysis in Pangpang Bay Area, Wringinputih Village, East Java, Indonesia. Journal of Saemaulogy, 5(2), 33-64. |
| Wringinputih Village | Ecotourism |  12.52  | Ariyanto, A., Hidayati, E., & Iswandi, W. (2020). Managing Mangrove Essential Ecosystem Area: A Strategy Analysis in Pangpang Bay Area, Wringinputih Village, East Java, Indonesia. Journal of Saemaulogy, 5(2), 33-64. |
| Wringinputih Village | Fishing Tour |  30.42  | Ariyanto, A., Hidayati, E., & Iswandi, W. (2020). Managing Mangrove Essential Ecosystem Area: A Strategy Analysis in Pangpang Bay Area, Wringinputih Village, East Java, Indonesia. Journal of Saemaulogy, 5(2), 33-64. |
| Wringinputih Village | Education and Research |  5.18  | Ariyanto, A., Hidayati, E., & Iswandi, W. (2020). Managing Mangrove Essential Ecosystem Area: A Strategy Analysis in Pangpang Bay Area, Wringinputih Village, East Java, Indonesia. Journal of Saemaulogy, 5(2), 33-64. |
| All mangroves | Support to fishery |  1,076.85  | Burbridge, P. W., & Maragos, J. E. (1985). Coastal resources management and environmental assessment needs for aquatic resources development in Indonesia. Washington, DC: International Institute for Environment and Development. |
| All mangroves | Input to charcoal and woodchip production |  269.21  | Burbridge, P. W., & Maragos, J. E. (1985). Coastal resources management and environmental assessment needs for aquatic resources development in Indonesia. Washington, DC: International Institute for Environment and Development. |
| All mangroves | Fisheries Production |  7,442.18  | Emerton, L. (2014). Assessing, demonstrating and capturing the economic value of marine & coastal ecosystem services in the Bay of Bengal Large Marine Ecosystem. |
| All mangroves | Fuel Wood |  665.71  | Emerton, L. (2014). Assessing, demonstrating and capturing the economic value of marine & coastal ecosystem services in the Bay of Bengal Large Marine Ecosystem. |
| All mangroves | Aquaculture |  6,883.89  | Emerton, L. (2014). Assessing, demonstrating and capturing the economic value of marine & coastal ecosystem services in the Bay of Bengal Large Marine Ecosystem. |
| All mangroves | Maintenance of nursery populations & habitat |  2,517.28  | Emerton, L. (2014). Assessing, demonstrating and capturing the economic value of marine & coastal ecosystem services in the Bay of Bengal Large Marine Ecosystem. |
| All mangroves | Carbon storage, sequestration & avoided emissions |  383.82  | Emerton, L. (2014). Assessing, demonstrating and capturing the economic value of marine & coastal ecosystem services in the Bay of Bengal Large Marine Ecosystem. |
| All mangroves | Tourism |  398.58  | Emerton, L. (2014). Assessing, demonstrating and capturing the economic value of marine & coastal ecosystem services in the Bay of Bengal Large Marine Ecosystem. |
| Balikpapan Bay | Wood production |  180.65  | Lahjie, A. M., Nouval, B., Lahjie, A. A., Ruslim, Y., & Kristiningrum, R. (2019). Economic valuation from direct use of mangrove forest restoration in Balikpapan Bay, East Kalimantan, Indonesia. F1000Research, 8. |
| Balikpapan Bay | Seafood production |  247.96  | Lahjie, A. M., Nouval, B., Lahjie, A. A., Ruslim, Y., & Kristiningrum, R. (2019). Economic valuation from direct use of mangrove forest restoration in Balikpapan Bay, East Kalimantan, Indonesia. F1000Research, 8. |
| Bintuni Bay | Timber production |  561.82  | Ruitenbeek, H. J. (1991). Mangrove management: an economic analysis of management options with a focus on Bintuni Bay, Irian Jaya. School for Resource and Environmental Studies, Dalhousie University. |
| Bintuni Bay | Traditional uses: hunting, fishing, gathering and manufacturing |  186.90  | Ruitenbeek, H. J. (1991). Mangrove management: an economic analysis of management options with a focus on Bintuni Bay, Irian Jaya. School for Resource and Environmental Studies, Dalhousie University. |
| Bintuni Bay | Erosion control |  65.61  | Ruitenbeek, H. J. (1991). Mangrove management: an economic analysis of management options with a focus on Bintuni Bay, Irian Jaya. School for Resource and Environmental Studies, Dalhousie University. |
| Bintuni Bay | Timber production |  293.31  | Ruitenbeek, H. J. (1991). Mangrove management: an economic analysis of management options with a focus on Bintuni Bay, Irian Jaya. School for Resource and Environmental Studies, Dalhousie University. |
| Bintuni Bay | Fishery products |  500.62  | Ruitenbeek, H. J. (1991). Mangrove management: an economic analysis of management options with a focus on Bintuni Bay, Irian Jaya. School for Resource and Environmental Studies, Dalhousie University. |
| Bintuni Bay | Food: Sagu |  268.50  | Ruitenbeek, H. J. (1991). Mangrove management: an economic analysis of management options with a focus on Bintuni Bay, Irian Jaya. School for Resource and Environmental Studies, Dalhousie University. |
| Bintuni Bay | Biodiversity |  52.38  | Ruitenbeek, H. J. (1991). Mangrove management: an economic analysis of management options with a focus on Bintuni Bay, Irian Jaya. School for Resource and Environmental Studies, Dalhousie University. |
| Bori Masunggu, Pangkep District, South Sulawesi Province | Fisheries (shrimp, fish, crab and shellfish) |  9,204.71  | Tantu, A. G., Salam, S., & Budi, S. (2012). The Economic Valuation and the Use of Mangrove Resource at the Coast of Pangkep District, South Sulawesi Province. International Journal of Marine Science, 2(3). |
| Bori Masunggu, Pangkep District, South Sulawesi Province | Fire wood |  184.90  | Tantu, A. G., Salam, S., & Budi, S. (2012). The Economic Valuation and the Use of Mangrove Resource at the Coast of Pangkep District, South Sulawesi Province. International Journal of Marine Science, 2(3). |
| Pundata Baji, Pangkep District, South Sulawesi Province | Fisheries (shrimp, fish, crab and shellfish) |  20,505.68  | Tantu, A. G., Salam, S., & Budi, S. (2012). The Economic Valuation and the Use of Mangrove Resource at the Coast of Pangkep District, South Sulawesi Province. International Journal of Marine Science, 2(3). |
| Bonto Manai, Pangkep District, South Sulawesi Province | Fisheries (shrimp, fish, crab and shellfish) |  11,574.54  | Tantu, A. G., Salam, S., & Budi, S. (2012). The Economic Valuation and the Use of Mangrove Resource at the Coast of Pangkep District, South Sulawesi Province. International Journal of Marine Science, 2(3). |
| Kanaungan, Pangkep District, South Sulawesi Province | Fisheries (shrimp, fish, crab and shellfish) |  18,509.15  | Tantu, A. G., Salam, S., & Budi, S. (2012). The Economic Valuation and the Use of Mangrove Resource at the Coast of Pangkep District, South Sulawesi Province. International Journal of Marine Science, 2(3). |
| Pundata Baji, Pangkep District, South Sulawesi Province | Fire wood |  349.52  | Tantu, A. G., Salam, S., & Budi, S. (2012). The Economic Valuation and the Use of Mangrove Resource at the Coast of Pangkep District, South Sulawesi Province. International Journal of Marine Science, 2(3). |
| Bonto Manai, Pangkep District, South Sulawesi Province | Fire wood |  209.93  | Tantu, A. G., Salam, S., & Budi, S. (2012). The Economic Valuation and the Use of Mangrove Resource at the Coast of Pangkep District, South Sulawesi Province. International Journal of Marine Science, 2(3). |
| Kanaungan, Pangkep District, South Sulawesi Province | Fire wood |  183.03  | Tantu, A. G., Salam, S., & Budi, S. (2012). The Economic Valuation and the Use of Mangrove Resource at the Coast of Pangkep District, South Sulawesi Province. International Journal of Marine Science, 2(3). |

## Value transfer for estimating the value of mangrove tourism

The number of observations for the value of cultural ecosystem services provided by mangroves is limited and does not support the estimation of a meta-analytic value function. We therefore apply a unit value transfer method to estimate the value of tourism service provided by mangroves (Brander 2013; Schägner et al. 2016). This approach involved the following steps:

1. Compute the median value of mangrove related tourism from primary valuation studies in Southeast Asia (876 USD/ha/year; 2020 price level)
2. Identify mangrove sites in Indonesia that support tourism. This step uses point locations from Spalding and Parrett (2019) and identifies mangroves within a 20 km buffer
3. Estimate the extent of each mangrove tourist site using a GIS
4. Multiply the median value per hectare by the extent of each tourist site to obtain an estimate of the total value of the service per year.

The results of this estimation are presented in Table 5. In total, 319 mangrove tourist sites have been identified in Indonesia with an area of 53,925 ha. The total value of tourism at these sites is estimated to be just under USD 30 million per year.

Table 5. Tourism service values for Indonesian mangroves (USD/year; 2020 price level)

|  |  |  |  |
| --- | --- | --- | --- |
|  | Tourist Sites | Area (ha) | Total Value (USD/year) |
| Aceh | 0 | 0 | 0 |
| Bali | 44 | 1,687 | 1,477,812 |
| Banten | 0 | 0 | 0 |
| Bengkulu | 0 | 0 | 0 |
| Dki Jakarta | 18 | 306 | 268,056 |
| Gorontalo | 0 | 0 | 0 |
| Jambi | 0 | 0 | 0 |
| Jawa Barat | 4 | 525 | 459,900 |
| Jawa Tengah | 2 | 1,811 | 1,586,436 |
| Jawa Timur | 11 | 2,401 | 2,103,276 |
| Kalimantan Barat | 1 | 903 | 791,028 |
| Kalimantan Selatan | 0 | 0 | 0 |
| Kalimantan Tengah | 0 | 0 | 0 |
| Kalimantan Timur | 39 | 10,261 | 8,988,636 |
| Kalimantan Utara | 17 | 14,918 | 13,068,168 |
| Kepulauan Bangka Belitung | 0 | 0 | 0 |
| Kepulauan Riau | 51 | 5,263 | 4,610,388 |
| Lampung | 4 | 347 | 303,972 |
| Maluku | 20 | 1,322 | 1,158,072 |
| Maluku Utara | 0 | 0 | 0 |
| Nusa Tenggara Barat | 0 | 0 | 0 |
| Nusa Tenggara Timur | 40 | 1,751 | 1,533,876 |
| Papua | 6 | 214 | 187,464 |
| Papua Barat | 24 | 3,506 | 3,071,256 |
| Riau | 0 | 0 | 0 |
| Sulawesi Barat | 0 | 0 | 0 |
| Sulawesi Selatan | 0 | 0 | 0 |
| Sulawesi Tengah | 0 | 0 | 0 |
| Sulawesi Tenggara | 0 | 0 | 0 |
| Sulawesi Utara | 17 | 2,953 | 2,586,828 |
| Sumatera Barat | 21 | 5,757 | 5,043,132 |
| Sumatera Selatan | 0 | 0 | 0 |
| Sumatera Utara | 0 | 0 | 0 |
| Total | 319 | 53,925 | 47,238,300 |

## References

Alongi, D. M., Murdiyarso, D., Fourqurean, J. W., Kauffman, J. B., Hutahaean, A., Crooks, S., ... & Wagey, T. (2016). Indonesia’s blue carbon: a globally significant and vulnerable sink for seagrass and mangrove carbon. *Wetlands ecology and management*, *24*, 3-13.

Barbier, E. B. (2015). Valuing the storm protection service of estuarine and coastal ecosystems. *Ecosystem Services*, *11*, 32-38.

Brander, L. M., Wagtendonk, A. J., Hussain, S. S., McVittie, A., Verburg, P. H., de Groot, R. S., & van der Ploeg, S. (2012a). Ecosystem service values for mangroves in Southeast Asia: A meta-analysis and value transfer application. *Ecosystem services*, *1*(1), 62-69.

Brander, L. M., Bräuer, I., Gerdes, H., Ghermandi, A., Kuik, O., Markandya, A., ... & Wagtendonk, A. (2012b). Using meta-analysis and GIS for value transfer and scaling up: Valuing climate change induced losses of European wetlands. *Environmental and Resource Economics*, *52*(3), 395-413.

Brander, L. (2013). Guidance manual on value transfer methods for ecosystem services. UNEP.

Brander, L.M., de Groot, R., Schägner, J.P., Guisado-Goñi, V., van ‘t Hoff, V., Solomonides, S., McVittie, A., Eppink, F., Sposato, M., Do, L., Ghermandi, A., Sinclair, M., Thomas, R. (2024). Economic values for ecosystem services: A global synthesis and way forward. *Ecosystem Services*, 66. <https://doi.org/10.1016/j.ecoser.2024.101606>

Cameron, C., Hutley, L. B., Friess, D. A., & Brown, B. (2019). Community structure dynamics and carbon stock change of rehabilitated mangrove forests in Sulawesi, Indonesia. Ecological applications, 29(1), e01810.

Cameron, C., Hutley, L. B., Friess, D. A., & Brown, B. (2019). High greenhouse gas emissions mitigation benefits from mangrove rehabilitation in Sulawesi, Indonesia. Ecosystem Services, 40, 101035.

de Groot, R., Brander, L., Van Der Ploeg, S., Costanza, R., Bernard, F., Braat, L., ... & Van Beukering, P. (2012). Global estimates of the value of ecosystems and their services in monetary units. *Ecosystem services*, *1*(1), 50-61.

Forest Trends’ Ecosystem Marketplace (2021). ‘Market in Motion’, State of Voluntary Carbon Markets 2021, Installment 1. Washington DC: Forest Trends Association.

Hernández-Blanco, M., Costanza, R., & Cifuentes-Jara, M. (2021). Economic valuation of the ecosystem services provided by the mangroves of the Gulf of Nicoya using a hybrid methodology. *Ecosystem Services*, *49*, 101258.

Jakovac, C. C., Latawiec, A. E., Lacerda, E., Leite Lucas, I., Korys, K. A., Iribarrem, A., Malaguti, G. A., Turner, R. K., Luisetti, T., & Baeta Neves Strassburg, B. (2020). Costs and Carbon Benefits of Mangrove Conservation and Restoration: A Global Analysis. Ecological Economics, 176. <https://doi.org/10.1016/j.ecolecon.2020.106758>

Jerath, M., Bhat, M. G., & Rivera-Monroy, V. H. (2012, January). Alternative approaches to valuing carbon sequestration in mangroves. In *Proceedings of the ISEE 2012 Conference on Ecological Economics and Rio* (Vol. 20).

Menéndez, P., Losada, I.J., Torres-Ortega, S. et al. The Global Flood Protection Benefits of Mangroves. Sci Rep 10, 4404 (2020). <https://doi.org/10.1038/s41598-020-61136-6>

Murdiyarso, D., Purbopuspito, J., Kauffman, J. B., Warren, M. W., Sasmito, S. D., Donato, D. C., Manuri, S., Krisnawati, H., Taberima, S., & Kurnianto, S. (2015). The potential of Indonesian mangrove forests for global climate change mitigation. Nature Climate Change, 5(12), 1089–1092. <https://doi.org/10.1038/nclimate2734>

Navrud, S., and Ready, R. (2007). Environmental Value Transfer: Issues and Methods. Springer, Dordrecht.

Schägner, J. P., Brander, L., Maes, J., & Hartje, V. (2013). Mapping ecosystem services' values: Current practice and future prospects. *Ecosystem Services*, *4*, 33-46.

Schägner, J. P., Brander, L., Maes, J., Paracchini, M. L., & Hartje, V. (2016). Mapping recreational visits and values of European National Parks by combining statistical modelling and unit value transfer. *Journal for Nature Conservation*, *31*, 71-84.

Schägner, J. P., Brander, L., Paracchini, M. L., Maes, J., Gollnow, F., & Bertzky, B. (2018). Spatial dimensions of recreational ecosystem service values: A review of meta-analyses and a combination of meta-analytic value-transfer and GIS. *Ecosystem Services*, *31*, 395-409.

Stanley, T. D. (2001). Wheat from chaff: Meta-analysis as quantitative literature review. *Journal of economic perspectives*, *15*(3), 131-150.

Stiglitz, J. E., Stern, N., Duan, M., Edenhofer, O., Giraud, G., Heal, G. M., ... & Winkler, H. (2017). Report of the high-level commission on carbon prices.

Spalding, M., & Parrett, C. L. (2019). Global patterns in mangrove recreation and tourism. *Marine Policy*, *110*, 103540.

Tol, R. S. (2011). The social cost of carbon. *Annu. Rev. Resour. Econ.*, *3*(1), 419-443.

World Bank Group. (2016). Managing Coasts with Natural Solutions: Guidelines for Measuring and Valuing the Coastal Protection Services of Mangroves and Coral Reefs. http://hdl.handle.net/10986/23775