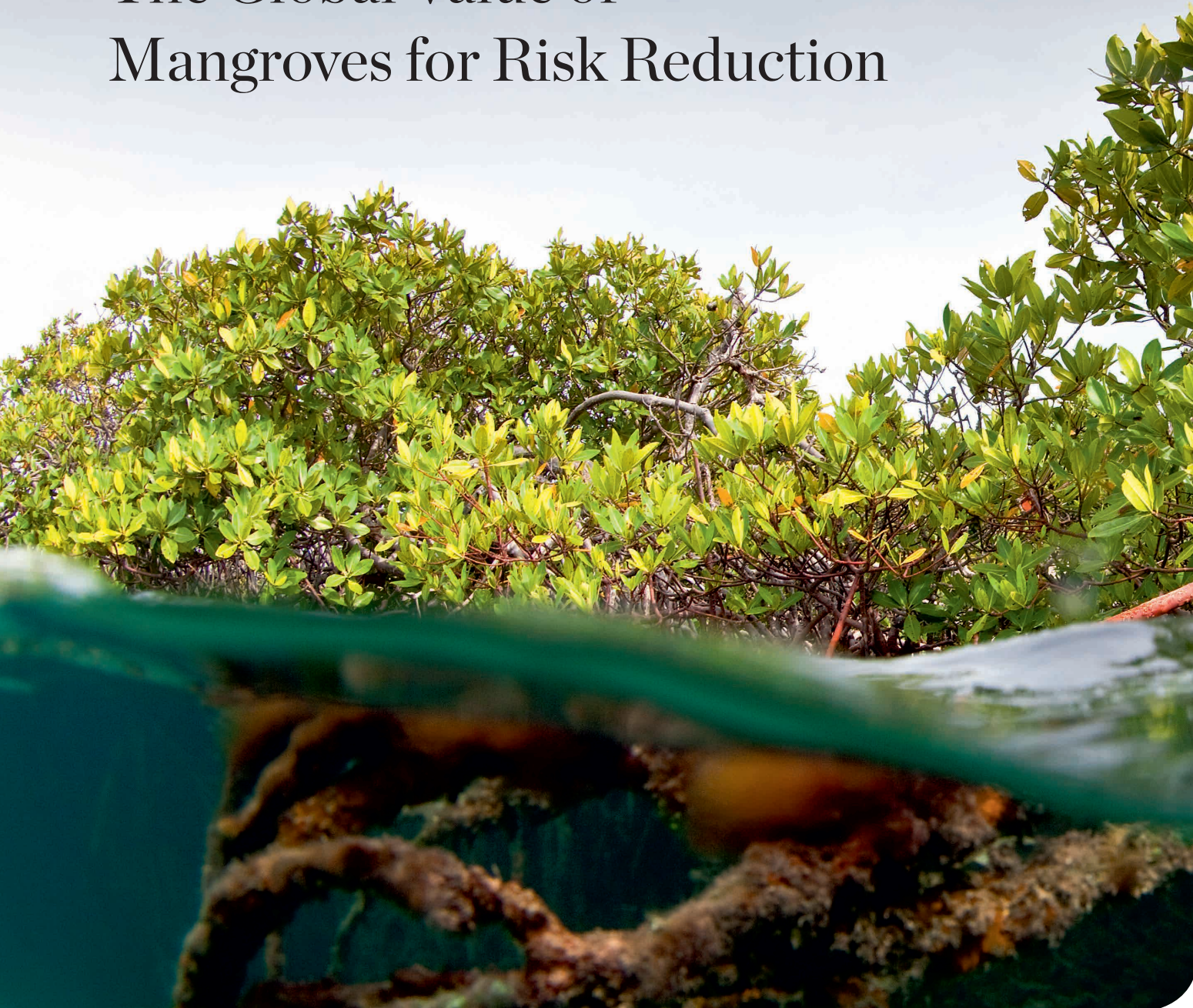


The Global Value of Mangroves for Risk Reduction





Mangroves protect coastlines by decreasing the risk of flooding and erosion.

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Pg 1: Mangrove roots under water. Jardines de la Reina, Cuba. © I. Shive;
Pg 2: Mangroves on Lembongan Island, Bali. © K. Arnold;
Pg 7: Children planting mangrove seedlings. © UNISDR;
Pg 9: Enipein Mangrove Forest Reserve, Pohnpei, Micronesia. © N. Hall;
Pg 10 Insert: Planting mangroves in Siargao, Philippines. © U. Meissner, Background: Mangroves along Mahé
Island, Seychelles. © J. Houston;
Pg 12: Mangroves near Tarobi village, West New Britain, Papua New Guinea. © M. Godfrey

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The Global Value of Mangroves for Risk Reduction and Climate Adaptation

Mangroves act as natural defenses that protect people and property from flooding, reducing coastal risk. Yet these protective benefits are often not fully accounted for in policy and management decisions, and mangroves continue to be lost. This work rigorously values the social and economic coastal protection benefits provided by mangroves. By identifying where these natural coastal defenses provide the greatest flood reduction benefits, this work informs policies for adaptation, sustainable development, and environmental restoration.

Key Points

- + This work uses a rigorous integrated hydrodynamic approach to value the flood protection services of mangroves, and identifies where mangroves provide the greatest benefits.
- + Mangroves reduce exposure and vulnerability. These combined benefits are most important for countries in West and East Africa, Central America and the South Pacific.
- + Mangroves reduce annual flooding to more than 18 million people. Without mangroves 39% more people would be flooded annually, and flood damages would increase by more than 16% and US \$82 billion.
- + Mangrove restoration can be a highly cost effective strategy for risk reduction. Hundreds of thousands of hectares have already been restored.
- + Vietnam, India, Bangladesh, China, and the Philippines receive the greatest benefits from mangroves in avoided flooding of people.
- + These results can inform strategies for adaptation and risk reduction, including the development of tools that use the risk reduction benefits of mangroves to pay for their restoration.
- + China, USA, India, Mexico and Vietnam receive the most benefits in terms of annual avoided damages to property.

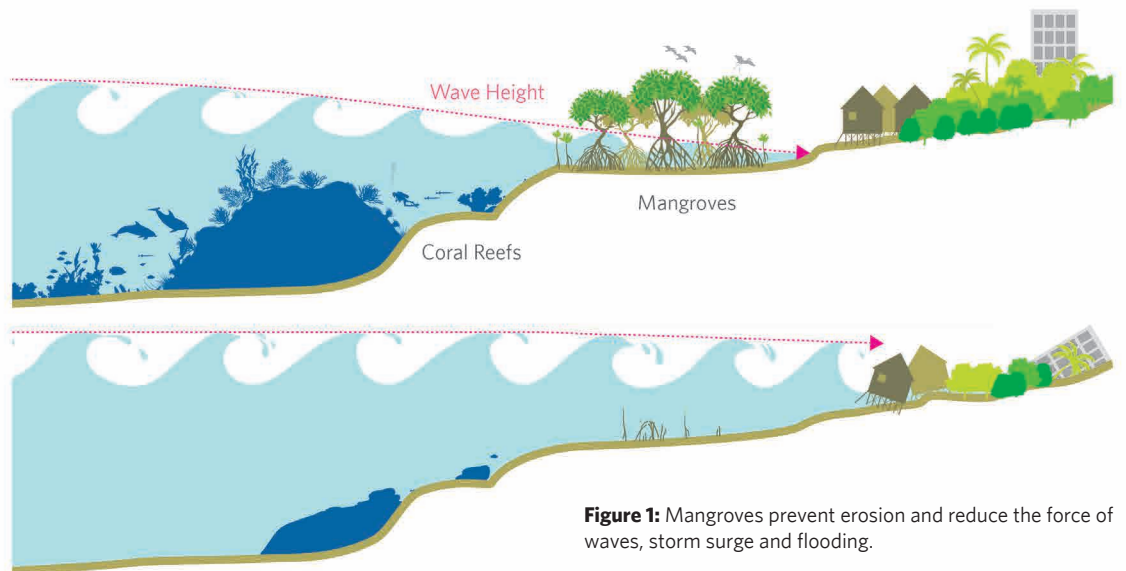


Figure 1: Mangroves prevent erosion and reduce the force of waves, storm surge and flooding.

Coasts at Risk

More than 60% of the world's population lives on the coast. Coastal development and climate change are dramatically increasing the risks of flooding, erosion, and extreme weather events for millions of vulnerable people, important infrastructure, and trade. In the last 30 years, the amount of the world's Gross Domestic Product (GDP) annually exposed to tropical cyclones has increased by more than US \$1.5 trillion. Insurers alone have paid out more than US \$300 billion for coastal damages from storms in the past 10 years¹.

Governments worldwide are dedicating billions of dollars to reduce risks from disasters and

climate change. Unfortunately, most of our global investments in coastal protection are destined for “grey infrastructure”, such as seawalls, that remain vulnerable to coastal risks and fail to adapt to changing environments².

In this report *Risk* is measured by considering *Exposure* to natural hazards such as floods, and *Vulnerability* which considers social, economic and governance aspects. The WorldRisk-Index has consistently identified that the most at-risk nations are all tropical, coastal developing nations where habitats such as mangroves and coral reefs can play significant roles in reducing risk³.

The Coastal Protection Services of Mangroves

Mangroves protect coastlines by decreasing exposure to flooding and erosion. The aerial roots of mangroves retain sediments and prevent erosion, while the roots, trunks and canopy reduce the force of oncoming wind and waves and reduce flooding⁴ (Figure 1). A 500-meter wide mangrove forest can reduce wave heights by 50–100%. In low lying areas, even relatively small reductions in water levels can reduce flooding and prevent property damage. Mangroves also decrease vulnerability by supporting livelihoods, ecotourism and trade, and providing multiple social and economic services.

But mangroves are being lost at an alarming rate — 19% of the world's mangroves were lost between 1980-2005⁴ — resulting in more people and property directly at risk from the impacts of storms, floods, erosion, and sea level rise, in part because we have not adequately valued these natural defenses. Conventional approaches to measuring wealth focus mainly on built infrastructure. Currently, only a subset of the extractive benefits provided by natural ecosystems are valued. Many critical goods and services, such as flood protection, which rely on keeping ecosystems intact, are rarely valued⁵.

This lack of consideration encourages short-term over-exploitation and degradation. Better valuations of the protection services of coastal habitats can ensure that these services are

accounted for in policy and management decisions, halting the loss of our natural capital and ensuring the provision of critical ecosystem services.

Methods: The Expected Damage Function

To value the coastal protection benefits provided by mangroves, this work follows the Expected Damage Function approach, commonly used in engineering and insurance sectors and recommended for the assessment of coastal protection services from habitats (Figure 2)⁶. The protection benefits provided by mangroves are assessed as the flood damages avoided by keeping mangroves in place. The results are presented in terms of the number of people and the value of property flooded with and without mangroves.

The models also consider the wave reduction effect from adjacent coral reefs.

This work combines relevant data for coastal dynamics from IH Cantabria and for assets from various sources^{7–9}. To calculate exposure, data on population and built capital (residential and industrial property) are calculated in 1 km² grids globally. The assessment includes global vulnerability damage functions for population and built capital based on HAZUS¹⁰ and JRC¹¹.

Hydrodynamic models are used to calculate the flooding that occurs globally under current mangrove and no mangrove scenarios (i.e. assuming all mangroves are lost). The models calculate flooding under regular storm conditions by analyzing more than 30 years of wave and water level data, and also flooding under the most extreme events by analyzing the historical data and spatial distribution of 7,170 cyclones.

This assessment also identifies where mangroves provide the greatest overall risk reduction benefits. Data on annual expected benefits from mangroves (exposure reduction) is combined with vulnerability scores from the WorldRiskReport and Index³ (see Table 1) to produce a ranking of countries that receive the greatest risk reduction benefits from mangroves overall.

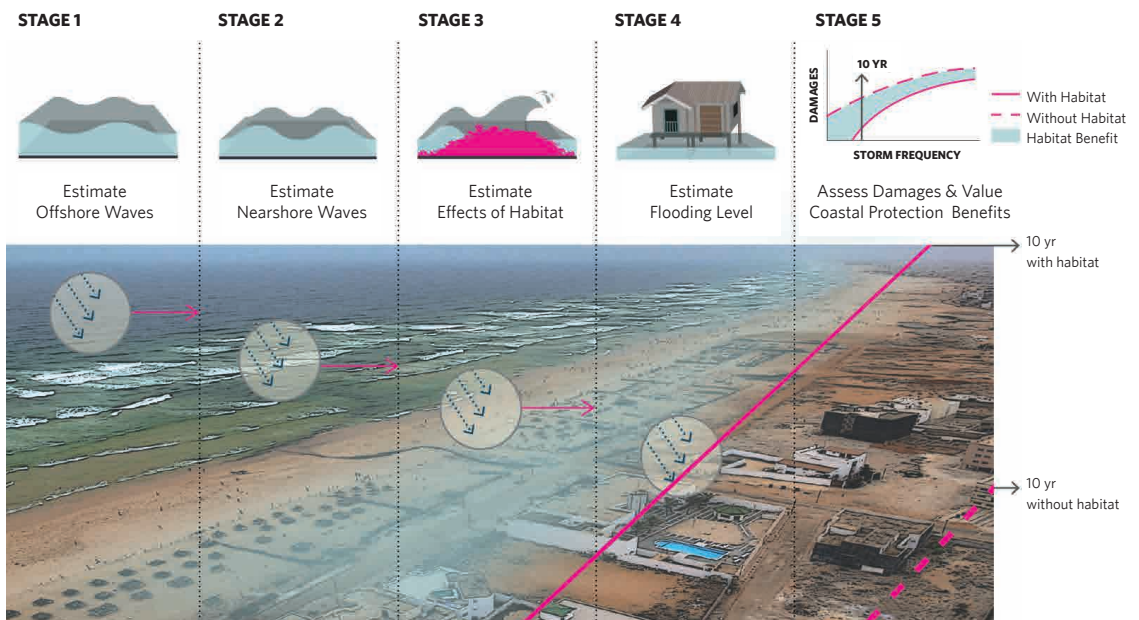


Figure 2: The key steps for estimating the coastal protection benefits provided by mangroves, following the Expected Damage Function approach⁶.

Key Findings

Mangroves provide important protection benefits for people and property across the globe.

- + Mangroves provide significant flood reduction benefits to people and property in critical 'hotspots' around the world. Protection benefits to people are highest in key areas in the Indian Ocean and East Pacific, protection benefits to property are more evenly distributed globally (Figure 4).
- + Without mangroves, more than 18 million people would be flooded every year, an increase of more than 39%. The annual damages to property would increase by 16% and US \$82 billion (Figure 3).
- + Mangroves provide greater protection for events in regular climate conditions than for tropical cyclones. Though low in intensity of damage, these events are more frequent. If mangroves were lost, 32% more people would be flooded under 1 in 10 year events, and 16% more people would be flooded under 1 in 100 year events.
- + China, USA, India, Mexico and Vietnam receive the most benefits in terms of annual avoided damages to property. Per GDP, Guyana, Belize, Bahamas, Suriname, and Mozambique receive the greatest flood protection benefits for avoided flooding (Table 1).
- + In addition to reducing flood exposure, mangroves can reduce vulnerability. The countries that receive the greatest overall risk reduction benefits from mangroves are Guinea, Mozambique, Guinea-Bissau, Sierra Leone and Madagascar (Table 1 and Figure 5).

Countries Where Mangroves Provide the Greatest Annual Flood Exposure Reduction					Countries Receiving the Greatest Risk Reduction Benefits from Mangroves	
People Protected (millions)	Property Protected (US \$ Billions)	Property Protected per GDP			Vulnerability (WorldRiskIndex)	Overall Risk Benefits
Vietnam	8.1	China	19	Guyana	Haiti	Guinea
India	3.3	United States	13	Belize	Liberia	Mozambique
Bangladesh	1.3	India	9	Bahamas	Sierra Leone	Guinea-Bissau
China	0.8	Mexico	9	Suriname	Mozambique	Sierra Leone
Philippines	0.7	Vietnam	7	Mozambique	Guinea	Madagascar
Brazil	0.4	Guyana	7	Vietnam	Madagascar	Benin
Nigeria	0.4	Mozambique	2	Guinea-Bissau	Guinea-Bissau	Guyana
Indonesia	0.3	Saudi Arabia	2	Madagascar	Nigeria	Solomon Islands
Mozambique	0.3	Bangladesh	2	Benin	Comoros	Liberia
Mexico	0.3	Bahamas	2	Sierra Leone	Togo	Cote d'Ivoire

Table 1: On the left, countries receiving greatest benefits in flood exposure reduction from mangroves. On the right we combine information on vulnerability from the WorldRiskIndex with our flood exposure reduction data to estimate the countries that receive the greatest overall risk benefits from mangroves. The countries in the Vulnerability column are the top 10 most vulnerable countries from the WorldRiskIndex that have mangroves.

Annual Expected Damages With and Without Mangroves

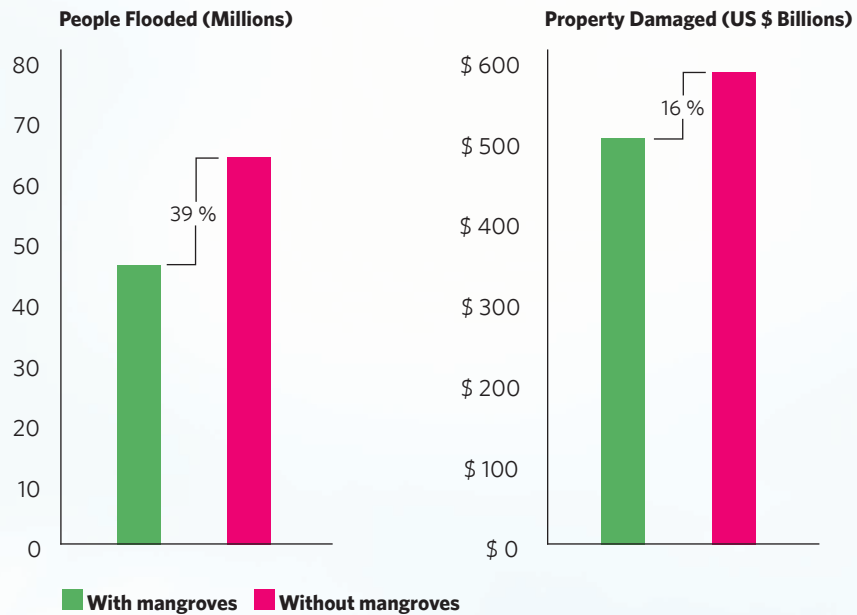


Figure 3: The bars show the global annual expected damages from flooding with current mangroves and without mangroves, including percent damages currently averted by mangroves.



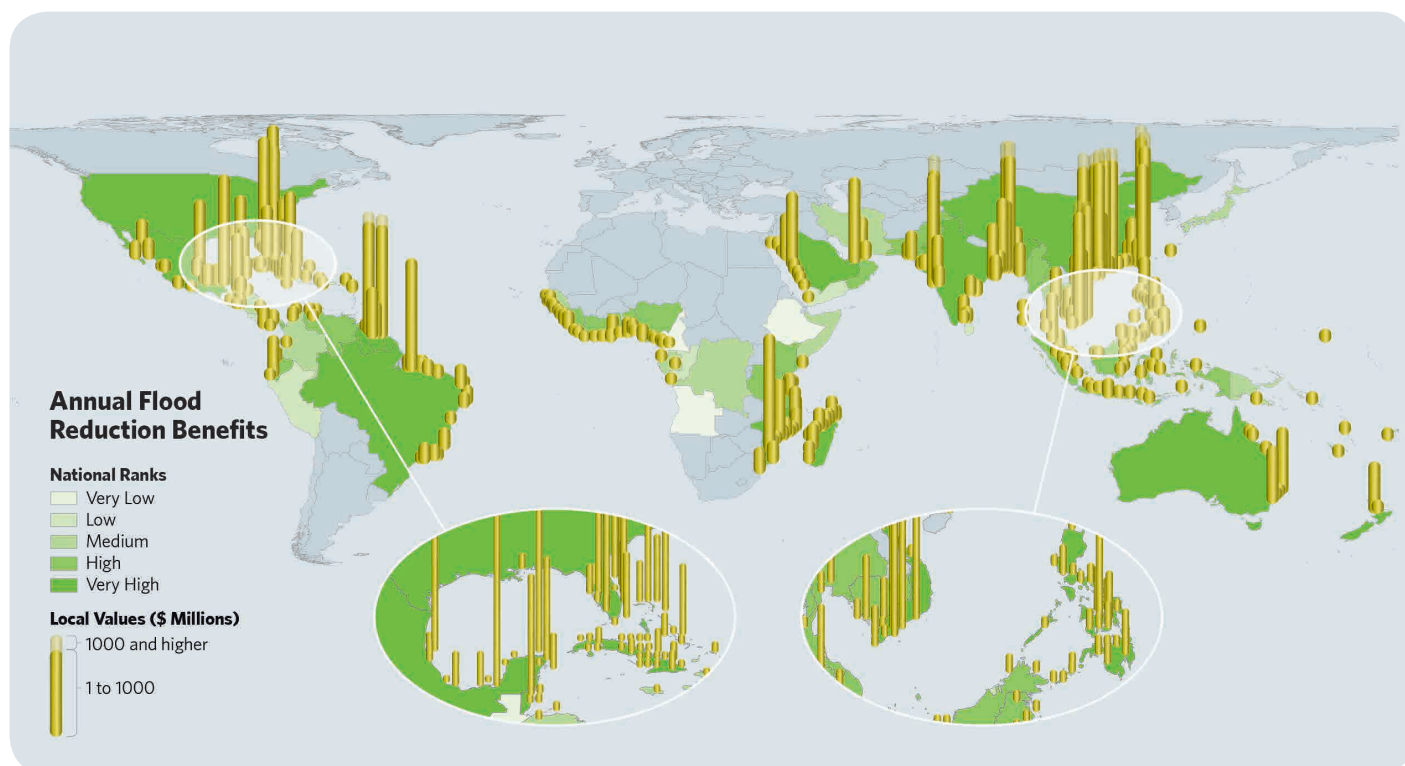


Figure 4: The map shows where mangroves provide the greatest flood reduction benefits for property. The values represent the difference in annual expected damages in US \$ millions with and without mangroves per 100 km of coast.

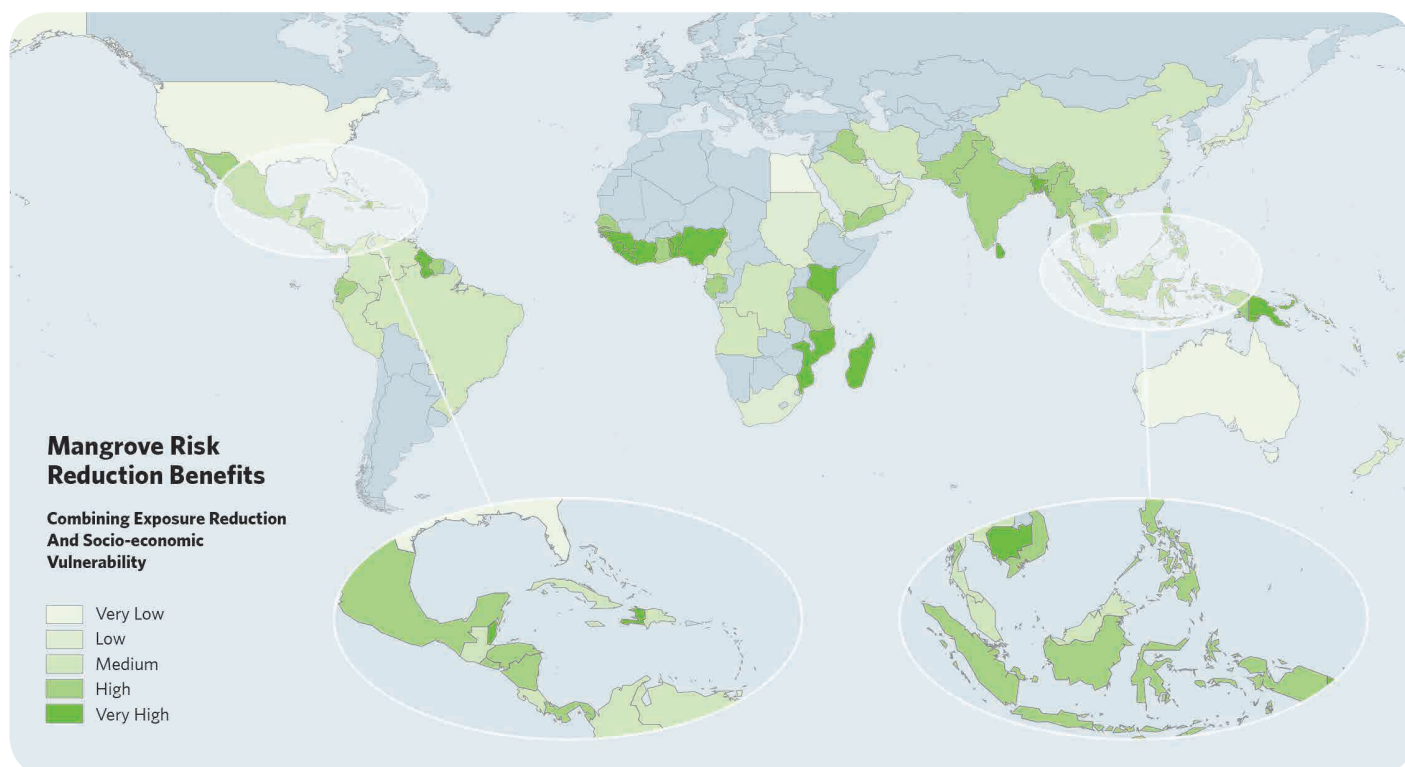


Figure 5: The map combines data on socio-economic vulnerability from the WorldRiskIndex³ with property flood reduction benefits from mangroves (Figure 4) to rank the countries that likely receive the greatest risk reduction benefits from mangroves. Higher scores (in darker green) indicate likely greater overall risk reduction benefits from mangroves. Countries in gray do not have mangroves and are excluded from the analysis.

Case Study

Flood Protection from Mangroves in the Philippines

The government of the Philippines commissioned a study to examine the flood reduction benefits provided by mangroves throughout the country, following the Guidelines for Valuing the Coastal Protection Services of Mangroves and Coral Reefs⁶. The Nature Conservancy, the Environmental Hydraulics Institute of Cantabria and the World Bank completed the study in August 2017^{12,13}.

In the Philippines, mangroves reduce annual flooding to people by 24% providing direct benefits to more than 600,000 people every year, many of whom live in poverty. Mangroves reduce annual damages to residential and industrial property by 28% providing more than US \$1 billion in annual averted damages. They also reduce flooding for 766 km of roads annually. One hectare of mangroves in the Philippines provides on average more than US \$3200/year of direct flood reduction benefits.

For catastrophic events, such as the 1-in-50 year storm, mangroves avert more than US \$1.7 billion in property damages. Based on the Philippines's current population, the mangroves lost between 1950 and 2010 have resulted in increases in flooding to more than 267,000 people every year. Restoring these mangroves would bring more than US \$450 million/year in flood protection benefits.

The study identified the spatial variation in the benefits provided by current and restored mangroves for every 90m². These results can inform local and national strategies for adaptation, risk management, and environmental management, and can help prioritize sites for mangrove restoration.

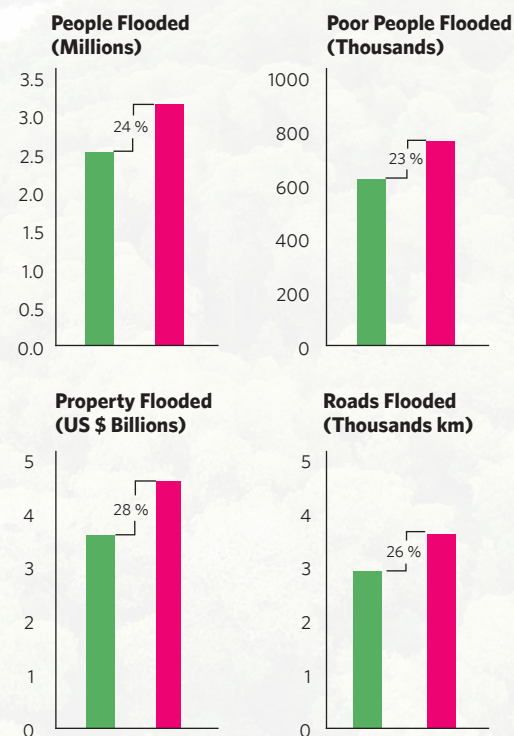


Figure 6: The annual expected damages from flooding in the Philippines under current (2010) mangrove cover (green) and no mangrove cover (magenta), including the annual benefits provided by mangroves (%).



Figure 7: The map identifies the areas where mangrove restoration will yield the greatest flood reduction benefits in the Dinagat Islands, the Philippines. The colors indicate the number of people per 90m² that could receive additional flood reduction benefits if mangroves were restored.

Case Study

Enabling Sustainable Management of Mangroves



Siargao is the most eastern island of the Philippines. Due to its location it is highly exposed to extreme natural hazards and climate change. It is also surrounded by the largest mangrove forest in the Philippines, which provides both flood defense and the main source of livelihood for local communities. Increasing storms leading to fewer fishing days at sea and unsustainable fishing practices have reduced fish harvests by 30% during the last ten years. Local communities fishing using traditional methods could no longer generate sufficient income. As a result, local fishermen have been pushed towards destructive fishing practices and illegal mangrove logging. In combination with weak economic and environmental governance and poor law enforcement, the rate of mangrove degradation and extraction was high. The unsustainable use of Siargao's natural resources exposed local families to hazards and increased their vulnerability.

To protect Siargao's mangroves forests and support sustainable resource management, the Center for the Development of Indigenous Science and Technology (SIKAT), in partnership with Misereor (a member organization of Bündnis Entwicklung Hilft), began a project in

2013¹⁴. SIKAT contributed to the formation of a network of community organizations and local authorities that would improve natural resource management and decrease the vulnerability of the coastal communities. With the support of SIKAT, the community established and maintains mangrove protectorates and mangrove nurseries, guarded by local fishermen. Working with churches and schools, SIKAT engages diverse community members to participate in mangrove plantings. To improve law enforcement teams, marine protection officers are empowered with equipment and training. Furthermore, SIKAT promotes alternative income opportunities, including drying fish, and mangrove crab fattening, which has been particularly successful: 18 families make a living by harvesting crabs, fattening them with fish waste, and selling them to hotels and other businesses.

As a result, more than 5,000 hectares of mangroves are now co-managed by community organizations and local governments, and more than 25 hectares of mangroves have been reforested. Illegal mangrove logging has declined significantly; no cases were reported in 2017. Increased community awareness and participation in mangrove management has influenced the public perception that communities, particularly those living near mangroves, are now safer from flooding, storm surge and sea level rise. The engagement of local government has improved law enforcement, and has also raised political attention, influencing decisions on disaster risk reduction and environmental protection in the region. In 2017 the Del Carmen municipality in east Siargao approved new disaster risk reduction and resource management plans. The case of Siargao shows that effective management of mangroves for multiple ecosystem services is possible.



The Way Forward

Opportunities in Policy and Practice

Mangrove conservation and restoration can be an important part of the solution for reducing the risks of coastal communities, especially as those risks increase with climate change. The coastal protection services of mangroves can be rigorously valued, and these values can inform strategies for adaptation and environmental management, and can help identify sustainable and cost-effective approaches for risk reduction. There are many actions we can take now to incentivize mangrove conservation for its risk reduction benefits:

- + Mangrove restoration projects for risk reduction should continue to be scaled up. While best practices are still evolving, mangrove restoration for risk reduction is well beyond the testing phase, and ready for large scale implementation.
- + Mangrove risk reduction benefits can now be integrated into National Accounts Systems, to ensure that national policies account for the benefits that accrue from keeping these ecosystems in place rather than harvesting them.
- + The risk reduction benefits of mangroves can be more widely incorporated in National Adaptation Plans of Action. Under the UNFCCC framework, full recognition of the risk reduction benefits of mangroves may mobilize political support and funding for their protection and restoration.
- + Mangroves should be included in public and private insurance (risk) models, maps, and data. By incorporating ecosystems into existing industry models, risk is more accurately portrayed, and risk reduction solutions that consider these habitats are supported.
- + Development policies, particularly the international risk reduction agenda, should mainstream use of mangroves as natural solutions for risk reduction. Natural defenses are now included in the UNISDR Sendai Framework, but they should be mainstreamed into national development policies and programmes.
- + Cost-benefit analyses for flood reduction solutions should consider artificial and natural defenses. Coastal engineers and risk modelers should assess the cost effectiveness of natural defenses when considering coastal protection alternatives; they are often more cost effective than grey solutions for risk reduction.
- + Land use and development plans should include the benefits of mangroves as natural defenses. A greater alignment between land use planning and risk management would help communities reduce risks.
- + These results can inform development of innovative finance tools, which use the risk reduction benefits of mangroves to pay for their restoration^{15, 16}.

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This Summary Report, and its accompanying Technical Report, may be found at:
[nature.org/GlobalMangrovesRiskReductionSummaryReport](https://www.nature.org/GlobalMangrovesRiskReductionSummaryReport) and **[nature.org/GlobalMangrovesRiskReductionTechnicalReport](https://www.nature.org/GlobalMangrovesRiskReductionTechnicalReport)**

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