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Financing Natural Infrastructure for Coastal Flood Damage Reduction

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FINANCING NATURAL INFRASTRUCTURE FOR COASTAL FLOOD DAMAGE REDUCTION

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First Page Photograph – An example of natural infrastructure: these coastal wetlands help protect the Florida coastline from the impact of severe storms and floods. (Credit: NOAA).

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EXECUTIVE SUMMARY

Wetland and mangrove habitats in Punta Gorda, Florida protect people and property from hazards. @ Carlton Ward Jr.

This paper explores financial tools for investing in natural infrastructure to reduce current and future risks from flooding. The key conclusions are:

1. **There is a large and growing pool of funding for natural infrastructure, but the availability is geographically uneven and providing sufficient resources will require significant actions by industry, government, scientists, and communities.**
   - There are both public and private sources that can fund natural infrastructure for flood risk reduction. Approaches vary among the U.S., Europe, and international development organizations. For example, funding for natural flood control infrastructure is a byproduct of other purposes in the U.S., but recognized as a specific purpose in Europe and by development organizations.
   - The opportunities for investments in natural infrastructure are shaped by various factors, including local geography, type and extent of ecosystems, knowledge about local flood risks, approaches to funding ecosystem conservation, the capacity of financing systems, and the socioeconomic status of communities.
   - The types and amounts of funding for natural infrastructure can be expected to grow because of innovations such as catastrophe bonds, but current institutional structures are often ill-suited to take advantage of existing and emerging opportunities and are not prepared to meet increasing risk.
2. **There is no single appropriate financing mechanism for natural infrastructure. Financing should reflect the distribution of public or private benefits of flood protection through the payment mechanism as determined by specific local conditions.**
   - The appropriate funding approach will depend on several factors, including local natural conditions (geography, ecosystems), local governance (including the socioeconomic status of communities), the condition of national financial systems (including the robustness of public or private property insurance markets), and public policies that explicitly support the use of natural infrastructure. We identify the key characteristics of these factors that should influence decisions on appropriate funding mechanisms.
3. **The largest opportunities for funding are in the redirection of post-disaster recovery funds to pre-disaster investments in risk reduction.**
   - Flood risk reduction should be undertaken before the flood occurs, but we currently spend much more on recovery efforts than on risk reduction. The greatest opportunities to increase resources for risk reduction lie in combining funds for risk reduction with funds for flood recovery. These investments will

further reduce damages to lives, properties, and communities over time.

- Recent innovations such as catastrophe and resilience bonds offer potential approaches to combining recovery and risk reduction, while green bonds may provide pre-disaster financing under appropriate conditions.

4. **The largest barriers for securing adequate resources are: identifying locations where natural infrastructure can play a significant role in flood risk reduction; developing the experience and standards to overcome institutional biases that favor gray infrastructure; and developing institutional arrangements capable of matching available funding with the needs of individual situations.**

   - To develop new financing, it is critical to develop a body of experience that would expand the existing foundation of natural systems management, risk assessment, and valuation analysis of natural infrastructure, and increase its acceptance and use. The identification of viable projects for nature-based risk reduction is critical for expanding pools of available funds. The identification of specific projects- including the location, the ecosystem restoration methods, the expected benefits, and the regulatory feasibility- will often need to be included in the up-front costs of the development of new financing vehicles.
   - Infrastructure banks are an example of institutions that can be structured to match funders with specific needs. These banks can pool the funding needs of different natural infrastructure projects to make them attractive to private capital markets. It will be necessary to create special purpose organizations that can capture the benefits of risk reduction in ways that support market-based finance.

The funding strategy to be used for any specific project will depend primarily on the geographic, economic, and institutional circumstances in each location. But it is possible to create a general framework to catalogue the different approaches to financing, from which locally-determined funding strategies can be formed. This paper proposes such a framework, then outlines and examines the options currently available under the framework, and concludes with an assessment of how funding may expand in the future.

NATURAL INFRASTRUCTURE AND FLOOD RISK REDUCTION

Wetlands can protect built infrastructure by reducing flooding and erosion. @ WBCSD

Damages from flooding comprise by far the largest losses from natural hazards. Worldwide, from 1995-2015, floods accounted for 46% of all natural hazard costs; when storm related damage, which can also include flooding, is added in, the total rises to 71% of hazard costs. Floods and storms together affected about 3 billion people and damaged or destroyed 87 million residences and 130,000 public buildings. Floods and storms accounted for over 98% of property losses, and these figures do not include commercial properties for which no damage data is available globally. There was an average of 171 flood events per year from 2005 to 2015, a 34% increases over the previous 10-year period (United Nations Office for Disaster Risk Reduction, 2016).

The threats from flooding, especially in coastal areas of the world, have been increasing for several reasons. More people live and work in coastal areas, increasing the absolute magnitude of properties and values at risk. The coastal regions where population is growing are highly dynamic in ways that increase flooding risks. Sea levels have been rising for more than a century and the pace of sea level rise is increasing (Wong et al., 2014). Moreover, in many coastal areas the shoreline is eroding at a pace exacerbated by human intervention. Upland dams starve shorelines of replenishing sediments, while efforts to curb erosion such as groins, jetties, and sea walls reduce erosion in some areas but cause dramatic increases in other areas. Upwards of 40% of the U.S. coastline (Platt, Beatley, and Miller, 1991) and 25% of the European coastline (Gremli et al., 2014) (European Environment Agency, 2006) is subject to ongoing erosion.

Socioeconomic changes alone in the 136 largest cities in the world are expected to account for a rise of global flood losses from $6 billion in 2005 to an estimated $52 billion in 2050. Given continued land subsidence, erosion, and increasing sea level rise, investments in flood risk reduction in these cities must reduce the annual probability of flooding well below current levels just to maintain damages in the $60 billion per year range (Hallegatte et al., 2011).

The combination of these social, economic, and physical trends is summarized by the Intergovernmental Panel on Climate Change: “For the 21st century, the benefits of protecting against increased coastal flooding and land loss due to submergence and erosion at the global scale are larger than the social and economic costs of inaction" (Wong et al., 2014).

The risk reduction measures required to adapt to increasing flood damages will primarily consist of three strategies:

- Modifications to structures to accommodate flooding;
- Barriers between structures and the water;
- Retreat, or moving structures away from flooded or potentially flooded areas.

Of these options, the construction of barriers presents interesting issues. Building and upgrading structural defenses like levees and seawalls to keep pace with rising sea-levels and higher storminess can prove prohibitively costly in the long-term (Coastal Protection and Restoration Authority, 2017; Jonkman et al., 2013). While individual structures may be protected with sea walls, it is well established that such individual "armoring" often increases the risks to nearby structures, causing increased erosion and damage to the surrounding shoreline (Griggs, 2005). Poorly designed structures on one stretch of the coast could aggravate flood risk along adjacent coastlines by interrupting the natural flow of water and sediments and damaging coastal ecosystems (Gittman et al., 2016; Hauser, Meixler, and Laba, 2015).

We now have substantial evidence on the ability of coastal ecosystems such as coral reefs, mangroves, and salt marshes to protect the coastline by reducing wave heights, building land, and, in some cases, reducing storm surges (Ferrario et al., 2014; Shepard, Crain, and Beck, 2011; McIvor et al., 2012). The key characteristics of reefs and wetlands that influence flood reduction are well-known. In general, natural ecosystems reduce coastal risk by acting as physical barriers and reducing the energy and volume of waves and storm surges before they enter the floodplain (Duarte et al., 2013).

For reefs, the most important characteristic is reef height, followed by roughness. Taller reefs under shallower water break more waves and dissipate more wave energy. Healthier, more corrugated reefs have greater friction and thus reduce more wave energy (Beck and Lange, 2016). For wetlands, the most important characteristic is vegetation band width, followed by plant density. Wider wetlands dampen surge and denser wetlands further reduce waves and surge through friction (Beck and Lange, 2016). Field studies have shown that mangrove or marsh wetlands can reduce surge heights from 10 to 70 centimeters per square kilometer of wetland (Krauss et al., 2009; Stark et al., 2015).

The use of these ecosystems as natural defenses against flooding has emerged as an alternative or complement to hard armored structures (Spalding et al., 2009; Shepard, Crain, and Beck, 2011; Cheong et al., 2013). It is now increasingly possible to compare the costs and benefits of natural infrastructure with that of conventional artificial or gray coastal defenses. The economic value of a coastal defense solution will depend on the value and distribution of at-risk assets that benefit from reduced flooding. To estimate this value, we measure the flood damages that result with and without a particular solution: the difference in these damages is equivalent to the value of that solution. This avoided damages approach is common when estimating the costs and benefits of artificial structural defense projects, and it is increasingly applied to value the flood reduction services of natural infrastructure (Barbier, 2013).

Using the avoided damages approach, an analysis of various risk-reduction measures for the U.S. Gulf Coast showed that natural infrastructure is very cost-effective in reducing some of the risk (Reguero, Bresch, and Beck, 2014). Another recent study in partnership with the insurance sector applied industry-standard flood and loss models to estimate that marsh wetlands in the northeastern U.S. avoided damages of more than $625 million during Hurricane Sandy (Narayan et al., 2016).

Natural infrastructure has also been valued in terms of the replacement cost of an artificial structure that would perform the same function (Sathirathai and Barbier, 2001). However, this approach is not easily transferable or scalable since it cannot account for variations in the physical environment.

However, the relative newness of these natural approaches to flood risk reduction also makes them more difficult to fund (Stanford Law School Coastal Policy Lab, 2015). Financing natural infrastructure is part of the much larger issue of finding funding resources to reduce flood damages. The stakes are high, and the financial resources needed are substantial. Fortunately, there are many existing options and promising innovations for financing natural infrastructure to reduce flooding risks. Bringing the full range of options to bear will require institutional change and evolved perspectives on what constitutes an effective investment in risk reduction.

FINANCING FLOOD RISK REDUCTION WITH NATURAL INFRASTRUCTURE

Wetlands like these in Portersville Bay, Alabama protect coastlines from flooding and erosion. @ Hunter Nichols

Although both historical and possible future damages from flooding are widely known, it remains difficult to amass the resources of both will and wallet to take the needed steps to reduce flooding risks. Flooding, like other natural hazards, inflicts both damages on specific individuals and cumulative damages on communities and regions. Individual risk-reducing actions may be insufficient to protect some communities and may just transfer risk from one place to another.

Moreover, both individuals and communities are poor judges of risk and often take few or no steps to protect their property and assets when faced with risks they have determined to be unlikely and remote (Kahneman and Tversky, 1979). Community decision-makers may be even more reluctant to act to reduce risks than individuals because it is often easier for groups to gravitate to the most risk-averse options. As a result, both individuals and communities are likely to under-invest in adaptive measures under most circumstances. This tendency to avoid acting to reduce risks is reinforced when combined with the daunting task of finding the financial resources to take action.

The path to taking effective action has two major steps. The first is to identify the magnitude of risks of a particular area, and the possible alternatives to reduce the risk. Once this assessment is complete, the search for funding resources will be shaped by the distribution of the benefits of, and responsibility for paying for, risk reduction and the choices regarding the most appropriate mix of possible sources.

The responsibility for addressing flood risks and damages is divided between public and private entities, but the boundaries are not clear. This division of public and private roles for flood risk reduction echoes a long-standing distinction in economics between public and private goods, which provides a way to describe funding possibilities based on the intersection between who pays for adaptation and who benefits from it.

Public goods are non-excludable in production and non-rival in consumption. Once the public good is produced, anyone can take advantage of it, and no one person’s consumption diminishes the ability of anyone else to consume the good. Public goods are

The factors that shape each at-risk region's approach to flood risk reduction projects:

- **Geography:** the spatial relationship between development and ecosystems;
- **Ecosystems**: the types and conditions of ecosystems present;
- **Known flood risks:** historical information about the frequency and severity of floods;
- **Existing approaches for funding natural infrastructure**;
- **Financing system capabilities**: Well-developed and functioning banking, public finance, and insurance systems;
- **Socioeconomic status of communities**: the financial ability of the community to contribute towards funding risk-reduction measures.

the fundamental reason that government provides many of the services it does. National defense is the most often cited example, but public goods can describe any situation where the benefits are broadly distributed and it is difficult or impossible to match anyone's share of the benefits to the costs that they should pay. Private goods, on the other hand, are both excludable and rival; they can be produced in the exact proportion needed to satisfy consumption and any one person's consumption diminishes the amount available to others by the exact amount consumed. Markets are the most appropriate way to organize the production and distribution of private goods because the amount that people pay can be matched to what they consume and the costs of production. Table 1 identifies four possible general arrangements for financing based on this framework.

In Table 1, Box 1 describes the classic public goods funding, with broad use and broad funding from general taxation. Funding may be through annual expenditures or may be in the form of general obligation debt (bonds). In Box 2, private funds are used but the beneficiaries extend beyond those who receive the funding. This describes the growing field of impact investing, and in the current context, the subfield of green bonds. Box 3 is like Box 1 except that tax expenditures (tax subsidies which only eligible individuals/organizations may access) are used in place of direct expenditures. Box 4 contains two different approaches. One is "semi-public infrastructure" where a specific area imposes taxes or fees on residents to pay for specific services that directly benefit them, such as water and sewer districts. Also in box 4 is insurance-related funding where the pool of premiums funds the payouts in the event of covered events. Substantial change is occurring in insurance through the development of market risk instruments such as catastrophe bonds.

		Who Pays?	
		Public	**Private**
Who Benefits?	**Public**	**Box 1** Projects have broad benefits that cannot be assigned to any specific beneficiary and are funded from broad general taxes.	**Box 2** Private funds provide benefits that are greater than the usual return on investment and thus decisions about what to fund mix both expectations of private return and broader benefits.
	Private	**Box 3** Benefits accrue to a narrow group but are supported by public expenditures, either directly or through tax subsidies.	**Box 4** *Infrastructure-based*: Private organization created to share benefits among organization members/ funders. *Insurance-based*: Private charges for service in proportion to private benefits.

Table 1. Financial arrangements based on potential beneficiaries and payees.

There are several factors noted above that affect decisions about what funding sources to use for flood risk reduction. But the choice of the specific funding ultimately depends on who pays and who benefits, and this will be influenced by geographic characteristics, the relative costs of natural infrastructure, and socio-economic and institutional capacities.

FUNDING OPTIONS FOR NATURAL INFRASTRUCTURE

Reef blocks (background) used to restore the structure and benefits from coral reefs. @ Curt Storlazzi

This section provides an overview of funding options for natural infrastructure in the United States and Europe, as well as options employed by international development organizations globally. Funding sources in Asia are not included. The descriptions are meant to provide general information only, and do not constitute specific advice for any one situation. The catalog is incomplete, and virtually all the funding sources discussed are undergoing constant evolution in funding targets and amounts.

Box 1: Public Financed Sources

Pre-Disaster Options

In the United States, engineered structures for coastal protection are generally the responsibility of the **U.S. Army Corps of Engineers**, which has broad responsibilities for flood control, though most of this effort is directed at riverine flooding.[1] State and local governments sometimes contribute to funding, in some cases because of budget constraints and in others because of limitations on the eligible uses of Army Corps funds.

Natural infrastructure in the form of wetlands can be funded by the **Coastal Wetlands Trust Fund**[2] managed by the U.S. Fish & Wildlife Service and programs under the **Estuary Habitat Restoration Act of 2000**[3], which is administered by the U.S. Army Corps of Engineers. A special fund is available for **Louisiana Coastal Wetlands Restoration**[4] under a federal act of 1990 directed at addressing the special needs of the lower Mississippi delta. The Federal Emergency Management Agency (FEMA) administers a **Pre-Disaster Mitigation Grant Program**[5] for areas covered by the National Flood Insurance Program. Funding levels for these programs can be volatile from year to year. For

1 http://www.iwr.usace.army.mil/Missions/Flood-Risk-Management/Flood-Risk-Management-Program/

2 https://wsfrprograms.fws.gov/subpages/grantprograms/CW/CW.htm

3 http://www.usace.army.mil/Missions/Environmental/Estuary-Restoration/

4 https://lacoast.gov/new/

5 https://www.fema.gov/pre-disaster-mitigation-grant-program

example, the funding for the FEMA Pre-Disaster grant program in 2016 was $90 million, a significant increase from previous years.

At the state and local levels, governments typically use bonds to finance infrastructure projects. These bonds, termed “municipal bonds” when issued by any unit of government other than the federal government, are a special type of public finance in the United States, as the interest from these bonds is exempt from income tax at the federal and usually state and local levels as well (when the bond buyer has taxes owed to the issuing government).

Another potential source of funds in the U.S., though unrelated directly to flood risk reduction, are those available for **wetlands restoration as a result of oil spills**, such as the funding that followed the Deepwater Horizon spill in 2010. This funding was primarily directed at removing oil contamination from wetlands, including beaches, but the process of restoring these wetlands also offered an opportunity to enhance flood risk benefits, though the precise extent of flood risk reduction has not been assessed. Louisiana is taking advantage of these funds to supplement existing wetlands restoration funds (Coastal Protection and Restoration Authority, 2017).

Under the **Clean Water Act**, the United States has a policy of “no net loss” of wetlands. This policy requires that development that resulting in the loss or degradation of wetlands must be accompanied by compensation through the restoration or protection of other wetlands (U.S. EPA, 2008). The largest type of development affected by the no-net-loss or mandatory compensation policy is transportation facilities, particularly highways. Highways are particularly likely to confront wetland issues because wetlands offer flat land to build on. Highway construction usually includes several types of wetlands mitigation funding, often including the “banking” of conserved wetlands, which can be used to offset losses from multiple projects. Fees are also paid into funds for wetlands conservation in lieu of specific offsetting wetlands purchases (The Environmental Law Institute, 2002). Estimates of the size of wetlands mitigation funds that could be available for natural infrastructure purposes are not available, but as a rough guide, a study of highway projects in 2013 in Washington State found that an average of 13.4% of total costs of projects affected by the Clean Water Act went to wetlands mitigation of one type or another (Washington State Department of Transportation, 2013). The U.S. Federal Highway Administration is developing new pilot green infrastructure programs that will expand opportunities throughout the U.S.[6]

A key innovation in public sector finance is the **infrastructure bank.** Thirty-two states currently have some version of an infrastructure bank (Sloane, 2010)**.** These are a recent innovation established primarily to issue bonds for transportation improvements like roads and ports, but they can also be used to procure funding for many types of infrastructure if given the appropriate legal authority. The scope of activities of infrastructure banks varies significantly from state to state, but most can provide a flexible vehicle that combines public and private funds for infrastructure projects. A proposal has been made for a federal infrastructure bank, but it has not advanced beyond the proposal stage (Congressional Budget Office, 2012). The flexibility of creating financing packages for a project from both public and private sources is an important recent innovation in public finance in the U.S., and while there are not any known projects related to natural infrastructure finance yet, infrastructure banks may play an important role in the future.

In Europe, infrastructure finance arrangements vary from country to country, but are generally the responsibility of national governments and the European Union. There is some specific financing for natural infrastructure in Europe, as opposed to the United States, where financing comes from a variety of programs designed for other purposes. Under the LIFE program, the **European Investment Bank (EIB)** administers the **Natural Capital Financing Facility,** which is designed to provide a “pipeline of bankable projects” involving natural capital, including natural infrastructure as adaptation to climate change. Funding comes from the EIB, the

6 https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/green_infrastructure/index.cfm#Project_information

European Commission, and national governments (European Commission, 2016; European Investment Bank, 2016).

For low-income countries, the World Bank, along with other regional development banks, is a major source of assistance for infrastructure development. The World Bank administers the **Green Climate Fund**, a pilot program for investments in climate resilience (The World Bank, 2012). The Global Environment Facility also runs a **Small Grants Program**.[7]

Some middle-income countries have their own resources for climate adaptation, such as Mexico, which administers **FOPRDEN**, the Fund for Disaster Prevention (The World Bank, 2013).

This discussion focuses on funding directed towards flood-related projects. Globally, there is significant spending that occurs on a regular basis for development, redevelopment, and maintenance of public facilities. While the costs of flood protection are rarely in the budget for routine maintenance, there are opportunities to address flood risks in new construction and redevelopment that may be appropriate for natural infrastructure projects.

Among the public expenditures which could be high priorities for incorporating natural infrastructure are transportation, public facilities, and water and sewer infrastructure. Opportunities arise from new construction, reconstruction, and maintenance activities. Taking steps to decrease flood risk during these regular activities presents one of the largest potential opportunities (Colgan, Kartez, and Sheils, 2016). Nonetheless, the incremental costs for flood risk reduction may be difficult to incorporate into budgets unless the threat of flooding is specifically assessed.

Public expenditures for land conservation are another significant opportunity. Such expenditures may be made to make lands available for recreation (parks), for wildlife habitat (wildlife refuges), or for ecosystem preservation (estuarine reserves). It is possible that conserved lands, together with privately-funded conserved lands, currently comprise the majority of "natural infrastructure", although only a small portion of publicly conserved lands are likely to have been purchased and maintained for that purpose alone. But flood risk reduction is likely to play a more visible role in the future of public (and private) land conservation investments due to the increased attention to flood risks.

Post-Disaster Options

In both the U.S. and Europe, post-disaster funds are generally special outlays from national budgets enacted on an event to event basis (Jackson, 2013). The terms and conditions of this assistance are usually set for the specific situation, and may or may not permit use of the funds for flood risk reduction. For example, the responses of the U.S. and state governments to the 2012 Hurricane Sandy disaster provided some flexibility for risk-reducing measures. The FEMA Hazard Mitigation Grants Program received about $1.86 billion in additional funding after Hurricane Katrina[8] and $822 million after Hurricane Sandy.[9]

The funding from these two disasters point to the large difference between funds available before and after disasters. In these two cases, the Federal Government provided nearly $2.7 billion in funding for risk reduction, most of it in six states (New York, New Jersey, and Connecticut for Sandy; Louisiana, Mississippi, and Alabama for Katrina). In contrast, the FEMA hazard mitigation program had $90 million available for one year, which represented the total funding in that program for the entire United States.

Beyond these event-specific funding packages, the U.S. Federal Emergency Management Agency provides grants under the **Flood Mitigation Assistance Program** to communities that have been designated as federal disaster sites, but for which no special appropriations have been authorized.[10] FEMA also provides other assistance

[7] https://sgp.undp.org/

[8] https://www.fema.gov/news-release/2013/08/28/louisiana-recovery-eight-years-after-hurricanes-katrina-and-rita

[9] https://www.fema.gov/sandy-recovery-office

[10] https://www.fema.gov/flood-mitigation-assistance-grant-program

specifically related to the National Flood Insurance Program discussed below.

The World Bank administers the **Global Facility for Disaster Risk Reduction and Recovery**, a multi-donor partnership to provide grants to low-income countries for disaster recovery and risk reduction (The World Bank, 2013). The World Bank's **Crisis Response Window** provides immediate funding for emergency responses to disasters, including repair of infrastructure.[11] A similar World Bank program is the **Catastrophe Draw Down Option** (CAT-DDO), a loan for post-disaster recovery/resilience projects, made available contingent on the existence of a disaster management plan (The World Bank, 2011). Mexico also provides an example of a low-middle-income country with a specific funding arrangement for post-disaster recovery: **FONDEN**, the Fund for Reconstruction (The World Bank, 2013).

Box 2: Public Benefits Provided by Private Investments

This class of financing comprises two major areas: traditional land conservation through philanthropy and the emerging impact investment markets. In this box, there is really no distinction based on disasters, as the projects undertaken through this funding can be pre- or post-disaster.

Land conservation has traditionally been funded through philanthropic actions, either by individuals or by organizations which cumulate small gifts from private individuals and corporate donors to purchase land. Such purchases are sometimes mixed with public funds (Clark, 2007). International organizations such as the Nature Conservancy or the World Land Trust, national organizations such as the Conservation Trust in the UK, and state/provincial and local conservation organizations and land trusts comprise a large network of potential funding sources for natural infrastructure, but little is done for that purpose. Private conservation investments have historically been undertaken for general purposes of preserving natural systems, although flood risk reduction can be a co-benefit. The extensive holdings of privately conserved lands may form the basis for expansion of flood risk reduction in the future.

Impact investing is at the forefront of the growing trend towards attracting private investment to conservation and other social benefit purposes. Such investments are expected to yield both a financial return and a social impact (J.P. Morgan Global Research & The Rockefeller Foundation, 2010) These private investments work on their own or as supplements to philanthropy. Land conservation impact investment requires developing revenue streams from conserved lands to make conservation "investable" (Credit Suisse, McKinsey and Company & World Wildlife Fund, 2014).

The term that is often applied to environmentally related impact investing is **green bonds**. The largest type of green bonds is funding related to climate change, predominantly for projects designed to reduce greenhouse gas emissions (World Economic Forum, 2013; The World Bank, n.d.; Credit Suisse and McKinsey Center for Business and Environment, 2016).

To access the green bond market, natural infrastructure projects need to meet two conditions: (1) a revenue source to repay the bond buyers; and (2) a set of performance standards to demonstrate attainment of flood risk reduction goals. Repayment of the bonds can come from funding in either box 1 or box 4. Green bonds may be repaid either by general tax revenues (box 1) or by revenues from special purpose districts (box 4), which are described in more detail in the next section.

Green bonds, and impact bonds in general, have been able to create significant pools of capital because they are well-suited to the needs of certain types of investors who are looking for long-term, steady, and relatively low-risk investments (The Economist, 2013; Credit Suisse and McKinsey Center for Business and Environment, 2016). Pension funds are a good example of such investors, particularly in countries such as Canada and Australia where public pensions funds have been converted in part to privately-financed funds. (Inderst, 2014)

[11] https://ida.worldbank.org/financing/crisis-response-window

What distinguishes "green bonds" and "impact investments" from other types of debt instruments is the expectation of realizing both a market rate of return on the bond and specific environmentally-oriented outcomes. The environmental outcomes are generally defined by standards published by different groups, such as the Climate Bonds Initiative[12], and the bonds' performance in meeting the standards is monitored during the life of the funded projects, usually by third party "certifiers", to assure bond buyers that the impact objectives they expect are being accomplished. Such performance expectations, or impacts, are quite different than standard bonds, where only financial performance is of interest.

The International Capital Management Association's widely cited "Green Bond Principles" define the elements of the process to be used in issuing green bonds, as well as a scope for green bonds, which includes renewable energy, energy efficiency, pollution prevention, biodiversity, and several other environmental areas. Climate change adaptation is one of the enumerated purposes, though the most recent edition of the principles refers to adaptation as "information support systems such as climate observation and early warning systems" (International Capital Market Association (ICMA), 2016). This indicates that flood risk reduction and natural infrastructure are still in the early stages of becoming uses for green bonds.

The green bond market has been steadily growing, to the point where bonds issued just for climate-related uses in 2015 are estimated to total $694 billion (The Climate Bonds Initiative, 2016). Of this total, $118 billion are explicitly identified as climate bonds, while the remaining $576 billion is described as "climate aligned". The largest use of the bonds is for transportation (e.g. high-speed rail) and renewable energy-related projects. The bonds are generally quite large; the specifically climate-purpose bonds are often between $10 million and $100 million, while the climate "aligned" bonds are between $100 million and $500 million. Chinese and U.S. public and private institutions (excluding the federal government) are the largest issuers.

12 https://www.climatebonds.net/

The Climate Bonds Initiative identifies a "Water Climate Bonds" category, which totaled $18 billion in outstanding bonds in 2016 and included bonds related to flood protection ($4.7 billion), climate resilience ($10.3 billion), conservation ($0.5 billion), and water quality ($2.5 billion). U.S. state and local water agencies are among the largest issuers in this category, although water boards in the U.K. were the top two issuers.

In the U.S., green bonds are not issued by the federal government but have been issued by various state and local governments. The **Commonwealth of Massachusetts** has issued two series of green bonds for which land acquisition, preservation of open space, and restoration are eligible uses (Office of the State Treasurer, 2015). Green bonds have also been issued by California state and local governments (Chiang, 2017) and by the New York Metropolitan Transit Authority (MTA, 2016). However, the tax-exempt status of bonds issued by state and local governments in the U.S. reduces the pool of capital for U.S. municipal green bonds. The tax exemption reduces the interest rates borrowing governments must pay, which reduces the market for such bonds to U.S. residents or anyone subject to U.S. income taxes.

Europe has been a very active market for green bonds with a diversity of issuers including the **European Investment Bank**. However, climate adaptation has only been a small part of the purposes for which European green bonds are issued (Inderst, 2013).

The **World Bank** has also been a major issuer of green bonds for climate change adaptation, both on its own and through the **regional development banks** (World Economic Forum, 2013).

There are some important limitations on the uses of green bonds for natural infrastructure used in flood protection. One is the lack of performance standards for such purposes, further detailed below. But green bonds may be used for other purposes which could have the same effect as using natural infrastructure for flood control. For example, an area of increased attention in the U.S. is the management of stormwater flows, which most sewer systems are not designed to accommodate (Kartez and Merrill, 2016). Stormwater projects that incorporate elements such as wetlands may also serve flood control purposes.

Another issue with green bonds is that investors looking to purchase such bonds are usually looking for bonds in fairly large amounts. The ability to fund groups of projects rather than single projects will be key to fully tapping the growing pool of capital that is looking for opportunities to invest in environmentally productive projects (Chiang, 2017). Such pooling may be most difficult in the U.S. because borrowing by state and local governments is affected by the federal tax exemption on municipal bonds. Such bonds generally command lower interest rates than other bonds and are attractive only to buyers who can take advantage of the special tax treatment.

The green bond market is well established but also still evolving. There are some expectations that a price premium for such bonds will emerge; that is, a higher price for bonds that yield environmental gains, which would result in lower interest rates for borrowers. But such premiums have not emerged; this may be because the concept of green bonds is still too new. Until such a price premium does occur, green bonds will have to compete with all other bonds of similar amount, maturity, and risk, which in turn means green bonds will be priced based more on the borrower than the purpose.

The other major evolving issue is the need for the development of standards for the risk-reduction benefits of natural infrastructure. Green or "climate" bonds that result in reductions in greenhouse gas emissions associated with renewable energy or energy efficiency are relatively straightforward calculations where the expected results are achieved upon executing the project. But adaptation as barriers against flooding is much more complex from the perspective of bond buyers, since it is difficult to determine the timing of flooding and the exact effectiveness of natural infrastructure at the time of investment. Performance measures for most green bonds are built around annual effects such as tons of carbon removed. The effectiveness of such bond-financed projects will require new approaches to the setting of performance standards. The risk industry has significant experience in identifying annual expected risks and loss costs and the benefits from many types of risk-reduction actions. These may be adapted for the performance of wetlands and other ecosystems in flood risk reduction (S. Narayan et al., 2016; Beck and Lange, 2016). Efforts to create such standards are underway, but will take time to reach maturity (The Climate Bonds Initiative, 2016).

Box 3: Public Funding of Private Actions through Tax Expenditures

Post-Disaster Options

In both the U.S. and Europe, national income tax laws generally permit deductions of disaster losses in excess of insurance reimbursements in determining taxable income. This reduction in taxes due provides some funding for recovery, the use of funds being left to the taxpayer's discretion(Internal Revenue Service, n.d.).

Another example of such funding is the tax treatment of private organizations' charitable contributions that fund conservation actions. Contributions to eligible NGOs for the conservation of natural features that could provide flood risk reduction are generally tax-deductible, meaning the public is partially supporting such private decisions.

Box 4 Private Payments for Private Benefits

Funding opportunities in this group are potentially the most relevant to natural infrastructure funding and the most difficult to work with because of the need to reorganize institutions and financing arrangements. These sources can be divided into two groups. One is financing of infrastructure with payment for the infrastructure made by the users, while the other group comprises insurance. What unites these two approaches to funding in Box 4 of the current framework is that there is generally a direct connection between who pays and who benefits.

Special Purpose Districts and Public-Private Partnerships

Special purpose districts manage "semi-public" infrastructure. Special purpose districts are common in the U.S. and to a lesser extent in Europe. There is a wide variety of options for the structure, financing, and governance of such districts. Because they directly link the beneficiaries of infrastructure to the financing of the infrastructure, special purpose districts are likely to be a key strategy for financing flood control infrastructure, for example by providing the revenue flows that would back green bonds.

In the U.S., the overwhelming majority of special purpose districts are at the state and local level and are typically used for (toll) roads, water, and sewer systems. They may also be used for some functions normally funded through general revenues such as fire protection. Flood-related districts include **Stormwater Districts** (Colgan, Kartez, and Sheils, 2016)**,** which manage the non-point pollution from rainwater runoff, and **Levee Districts**, which use locally raised funds to pay the maintenance costs of levees in the southeastern U.S. Levees are flood control structures built along rivers. Some states, such as California, allow local governments a great deal of flexibility in shaping special purpose districts (California Tax Data, 2016).

The funding for levees varies by state, with different combinations of federal, state, and local resources being used. Federal and state funds often pay for the capital costs of constructing, reconstructing, or expanding levees, while regular operations and maintenance funds come from all levels of government. Local levee boards in Mississippi and Louisiana may, depending on their authorizing legislation, raise funds for operations and maintenance from surcharges on property taxes or from fees (Miller, 2012).

Tax increment financing (TIF) districts are used throughout the United States (Greifer, 2005). In TIFs, the property tax revenues from a new (or expanded) development are diverted from the general revenue pool of the taxing authority to a special fund whose eligible uses vary significantly from state to state. In its earlier forms, TIFs were used to fund infrastructure such as new roads or water and sewer lines. As the concept has evolved over the years, TIF funds have been used to rebate taxes directly to the developed property owners, or for other unrelated public investments (Peterson, 2014).

TIF revenues can be used to support a revenue bond and thus support capital investments. Such bonds are used in almost all states (Provus, n.d.). Typical investments supported by TIF revenues include convention centers or downtown revitalization efforts, but improvements in flood defenses could be used as the basis for increased property values and thus TIFs.

This provides a possible analogy to the financing of flood control infrastructure, including nature-based infrastructure. In order to use tax increment financing for this purpose, there must be a rigorous approach for assessing the improved property values resulting from expected flood risk reduction as the basis for identifying the tax revenues committed to the TIF district. The models and values provided by the risk and insurance industry provide a basis for these assessments, which would need to be transferred into property value assessing.

Special purpose districts also exist in Europe for purposes similar to most common uses in the U.S. such as water and sewer facilities and (in some instances) roads, though the more unitary tax system[13] in most of Europe mean local governments may have fewer incentives or authorities to create such districts (Slack and Côté, 2014).

The “private goods” nature of Box 4 blurs the line between public and private ownership of infrastructure. Being able to link payments for benefits opens the door not only for “special purpose” public districts but also for private ownership of infrastructure. Transportation provides numerous examples from privately financed toll roads (Poole and Samuel, 2006) to private administration of parking meters (Fisher, 2010). In fact, complex new arrangements between the public and private sectors, known as **public-private partnerships (P3s)**, are growing significantly worldwide as an infrastructure financing option. Public-private partnerships are very diverse and common in both Europe and the U.S. The World Bank also encourages the creation of public-private partnerships in its projects (World Bank, 2012; Dinapoli, 2013; Boothe et al., 2015; McNichol , 2013).

[13] In unitary systems, tax laws are determined solely or predominantly at the national level.

The expanding use of mixed financing structures has implications for using this approach to finance flood protection and natural infrastructure. On the positive side, financial institutions and governments are gaining valuable experience in the structuring of such arrangements. That experience will be an important foundation for the use of such approaches as the need grows. At the same time, the choice between traditional public finance (box 1) and the special purpose districts, and public-private partnerships of box 4 is not an easy one. Complex evaluation systems have evolved to compare the alternatives (Boothe et al., 2015), including methodologies to determine the "value for money" to be gained from incorporating private finance (Martin ,2013; Weaver, Portabales, and Flor, 2015).

Nonetheless, the emergence of different and more flexible approaches to combining public and private funds, as evidenced by green bonds, special purpose districts, and P3 arrangements, indicates that the pool of funds for natural infrastructure is likely to be much larger than the specific programs discussed in box 1 would indicate. But tapping this pool of resources will require the evolution of institutional capacities to collect the benefits of adaptation and use them to attract investment. This will be a complex task because current infrastructure and infrastructure finance institutions tend to be highly specialized with substantial organizational frictions that impede innovative and creative approaches. New organization forms like the infrastructure banks discussed above may be essential in breaking through the silos of current finance.

Insurance and Other Post-Disaster Funding

Insurance is the linchpin around which financing for flood risk reduction must be organized. This is partly because of the magnitude of resources involved in insurance and partly because decisions about what will or can be insured, and at what level, shape individual choices about what to invest in risk-reducing adaptation. It is also because disaster insurance is undergoing important transformations that can increase the role of insurance in risk reduction investments. Insurance also plays a number of important roles in disseminating knowledge and awareness of risks, costs, and options for reducing risks, both through pricing signals and through the interactions between insurance providers, policymakers, and consumers (Warner et al., n.d.).

The role of disaster insurance in funding the reduction of flood risk is shaped by the basic structure of the insurance enterprise. This includes the forms of insurance, the relative roles of the public and private sectors, and differences in the structure of insurance in different parts of the world. There are three principal components to the flood insurance system:

- The frontline property and casualty insurers from whom policyholders purchase their insurance. For flooding, these insurers are both private (especially in Europe) and public (in the United States). Their role is to cover "normal" losses, defined as losses expected based on historical levels of risk. For example, in the U.S. the "normal" expected flood is that which has a 1% chance of occurring each year based on historical records (also known as the "100-year flood"). The purchase of property and casualty insurance may be mandatory (generally so in Europe and under certain circumstances in the U.S) or voluntary (in many countries and sometimes in the U.S.). Property and casualty flood insurance is common in developed countries, but rare in lower-income countries (Michel-Kerjan, 2010; Bernstein et al., 2006; Surminski, 2014). In very low-income countries, all levels of insurance are essentially provided by international aid donors.
- Reinsurance, the second tier, is provided by a separate industry from property and casualty insurance. Reinsurance is insurance for the extreme events (above the "normal" risks). It is a highly specialized industry because it deals with the risks that are, by definition, beyond usual expectations. Reinsurance has primarily been provided by private firms who develop the expertise to cover tranches (segments) of the higher risk levels. There are two types of reinsurance: facultative reinsurance which is applied to a specific property or properties and treaty reinsurance that covers the entire portfolio (book) of a primary insurer. (Munich Re, 2010).

Reinsurance is also undergoing rapid changes because of the advent of catastrophe bonds, which create a securitized and standardized approach to the sector (Jarzabkowski, Bednarek, and Spee, 2015).
- Retrocession, the third tier, is reinsurance for the reinsurers. Because this type of insurance is furthest from the property owners, it will likely play only a minor role in risk reduction infrastructure, at least in the near future, and will not be addressed further here.

There is one other special case of insurance: self-insurance, which applies to most publicly owned property and small amounts of private property. The choice to self-insure for public property means that public resources (box 1) will be the exclusive source of recovery and future risk reduction.

Within this framework, the opportunities to access insurance-related resources can be identified in separate discussions of pre- and post-disaster roles. There are two types of pre-disaster insurance-related investments: direct investments by insurance companies in damage-reducing actions and incentives to policyholders to take risk-reducing actions in return for reduced premiums. Public flood insurance schemes are more likely to make pre-disaster investments, as in the FEMA pre-disaster Hazard Mitigation Program discussed in box 1.

An example of an incentive-oriented approach is the **FEMA Community Rating System** (Landry and Li, 2010; National Flood Insurance Program, 2006). CRS provides discounts on insurance premiums on properties insured by the National Flood Insurance Program in communities that take some combination of risk-reducing actions specified by FEMA. The discounts range from 5% to 45% depending on which combination of eighteen specified actions are implemented by the community. The actions are assigned points, with the highest points awarded for construction of flood barriers and for adoption of local policies encouraging retreat from the flood zone. Using natural areas and open space for reducing flood risks are relatively high-scoring actions. The maximum discounts are available in "special flood hazard areas", which are the highest risk areas.[14]

An estimated 1,095 communities participate in the CRS, which represents approximately 5% of the more than 20,000 communities covered by the National Flood Insurance Program.[15] One of the reasons CRS may not be widely used is that it requires public actions (with sometimes high transaction costs) in order to create private benefits for property owners. Nonetheless, the CRS provides a clear structure for the evaluation of anticipated benefits from flood risk reduction actions. Natural infrastructure could clearly be part of these steps, though specific examples are not known. With appropriate agreement by communities and FEMA, it might be possible to accumulate a portion of the premium savings resulting from a natural infrastructure project to contribute to the funding of a natural infrastructure project, perhaps through a special purpose district. Under the right circumstances, the premium savings capitalized as a funding stream for a green bond could fund a natural infrastructure project.

The concept of **Resilience Bonds** captures this latter concept and represents another potential funding opportunity for natural infrastructure. The idea behind resilience bonds is to use the differences in bond prices between catastrophe bonds (see below) priced with and without taking into account specific risk-mitigating actions. These savings bring the CRS premium incentive concept into the reinsurance pool. The savings from risk reduction would be reflected in the prices of catastrophe bonds, and those savings can then be diverted into risk-reducing projects (Vajhala and Rhodes, 2015). Resilience bonds are an innovation that taps into the pool of funds used for recovery from disasters to reduce the economic consequences of those disasters. But resilience bonds are a complex reorganization of insurance markets that has yet to be deployed.

Resilience bonds do, however, point to what is possibly the most significant opportunity for

[14] https://www.fema.gov/special-flood-hazard-area

[15] http://www.msdlouky.org/programs/crssite/crsprog.html

financing natural infrastructure, which lies in enabling the use of flood recovery funding for resilience building initiatives. Financing for recovery (post-disaster) is substantially greater than funding for building resilience (pre-recovery) despite the cost-effectiveness of pre-disaster financing. Post disaster, the major question is how payments that have traditionally been meant only for recovery to the pre-disaster status quo can be used to expand or reinforce risk mitigation for the future, including the deployment of natural infrastructure protection. This approach is not new. The expanded funding for the FEMA Hazard Mitigation Grant Program that was part of the recovery from Hurricane Sandy is an example, and Europe is also considering ways to better merge recovery and risk reduction (Gremli et al., 2014).

Currently, there are five pools of funds for post disaster insurance resources that could play a role in supporting flood risk reduction:

(1) Primary property & casualty payments. Recovery is the purpose of this insurance so its use for risk reduction may be limited. But there are many possible variations on the flood insurance "product" that people purchase. Insurance policies could be configured and priced to provide funds to reduce future risks as part of payouts, like automobile policies that offer "new car replacement" coverage that ignores depreciation of vehicle value. Such policies could be offered on an optional basis.

A special issue is the problem, at least in the in the public insurance system used by the United States, of the over-insured. The National Flood Insurance Program covers many so-called "repetitive loss properties" (RLPs). These are properties that have two or more claims exceeding $5,000 within a ten year period or that have two or more claims in excess of the value of the property (King, 2005). Both legislation and FEMA policies have been directed at reducing the program's exposure to these properties with special resources available to support changes in these repetitive losses such as flood proofing or relocation.

Repetitive losses decrease resources that could be more broadly used, and the successful reduction in repetitive loss properties is itself a form of risk reduction. Strategies for dealing with clusters of RLP's may include natural infrastructure, though the extent to which this is a solution is dependent on local circumstances.

(**2) Catastrophe bonds** (or "cat" bonds) are a new and rapidly growing class of insurance that can flexibly combine the functions of both primary insurance and reinsurance for certain extreme events such as hurricanes. Cat bonds may be particularly useful in countries without developed property and casualty insurance markets. A catastrophe bond is essentially an instant insurance company created for one particular situation facing a well-defined set of risks over a specific period. The bond can be issued by any entity including governments or private organizations. The bond buyer is paid a defined sum over the period of the bond; the interest payments on the bond are the equivalent of insurance premiums. The bond's proceeds are put in escrow for the term of the bond (usually three years) and should defined events or specific damages occur, the bond's escrow is liquidated and used to pay for damages. If the defined events do not occur, the bond proceeds are returned at the end of the term to the buyer (Alvarez, 2015; Jarzabkowski et al., 2015).

Catastrophe bonds are an important innovation in insurance for at least two reasons. First, at a time when the demand for insurance against the "beyond normal" events is expected to greatly increase, catastrophe bonds will bring significant new capital into the insurance market. Second, catastrophe bonds are highly flexible in their terms and uses. As an insurance policy customized for specific situations (e.g., hurricane and earthquake risk in Mexico), there is no need to tailor the terms of the insurance for a broad market where minimizing risks and payouts are the critical factors in determining return on capital. Most importantly, the bond can be sized to cover both recovery and resilience investments in the wake of disasters.

Catastrophe bond buyers have an incentive to reduce risk in order to reduce the price paid for the bonds, but the relationship between risk reducing actions and bond prices is not yet clear as the market is still in early stages. The resilience bond concept discussed above encourages catastrophe bond buyers to divert a portion of the proceeds to risk reduction but resilience bonds have not yet been market tested. An open question is whether investments in risk reducing infrastructure will be the first choice of catastrophe bond buyers, who have the alternative of simply reducing the share of risk for which they offer coverage (that is they buy a smaller bond, leaving other shares of risk to other buyers).

(3) Self-insurance, primarily used by public facilities (box 1). Such expenditures allow for recovery and risk reduction and can be easily packaged together. Nonetheless, the availability of catastrophe bonds has opened a new approach for insuring public facilities. For these facilities, the bond-based insurance could substitute for general tax funded disaster relief. A cat bond could finance recovery and perhaps some share of risk reduction, leaving publicly funded disaster funds to focus on investments in risk reduction.

(4) Disaster relief of the types described in box 1 comprises the fourth pool of post-disaster funding and goes beyond the self-insurance for public facilities. As noted above, these funds are usually thought of as extraordinary budget outlays rather than as reinsurance for primary property and casualty insurance. The terms and conditions set in each iteration of disaster funding can accommodate both recovery and resilience if the appropriate policy choices are made. The use of post-disaster public funding to reduce future risks comprises a very large pool of resources. The nearly $2.9 billion in Federal Hazard Mitigation Funds appropriated for risk reduction in the wake of Hurricanes Katrina and Sandy is much more money than these jurisdictions are likely to see in the near future through normal appropriations to this fund.

(5) Risk pools, or residual markets, are a hybrid of primary insurance and reinsurance in which insurance companies pool a share of premiums from policy holders with their own resources to pay claims that exceed normal levels. Risk pools may be backed by reinsurance and/or catastrophe bonds for extreme risks. There are two broad types of risk pools. One is the recent development of international risk pools for developing countries. The forerunner of this is the Caribbean Catastrophic Risk Insurance Facility (CCRIF), which provides an array of insurance products for damages from hurricanes, excess rainfall, and earthquakes. CCRIF has sixteen member nations in the Caribbean basin and one member in Central America. The CCRIF addresses resilience and flood risk reduction through a small grants program and through special post-disaster grants.

An example of a risk pool in a developed country is Flood Re, a risk pool specifically designed for flooding in the United Kingdom. Flood Re is a reinsurance policy on flooding funded by a combination of premiums paid by homeowners and a pool of contributions from all property insurers.[16] The Flood Re organization currently addresses risk reduction by providing information about flood proofing and risk reduction to policyholders and by holding out the prospect of a significant increase in rates in the future if risks are not reduced.

Flood Re is only authorized for 25 years, after which flood insurance is intended to fully reflect the risk on each property. Property owners are thus provided an incentive to take risk reducing steps so that when exposed to premiums that reflect actual risks, the property owner will in theory be able to keep premiums level as a result of their actions. Flood Re recognizes the resilience concept, but places the burden on individuals to take appropriate actions. Solutions like natural infrastructure could be used under this arrangement. There is a review of the Flood Re program every five years and at some point in the program lifespan, insurers and the government will have to consider whether more direct support for risk reduction will be needed and whether such support should include measures such as natural infrastructure.

A final example of risk pools are the FAIR and beach/wind pools operated by thirty-five states in the U.S. These risk pools were originally established in the 1960s to reduce costs of property insurance for low income communities in urban centers, but the concept was gradually extended to cover losses from storms in coastal areas related to wind and beach loss (as flooding was covered elsewhere). Insurance for coastal properties has become the

[16] http://www.floodre.co.uk/

primary use of such insurance. Many of these risk pools are underfunded relative to the growing risks to coastal properties. This could be a significant problem because it is ultimately state governments and taxpayers that are backing these risk pools (Hartwig & Wilkinson, 2016).

Natural infrastructure is not well suited to minimizing wind damages in most cases, although managing beach erosion is one use of the residual pools in many states (including all U.S. states south of Virginia and on the Gulf of Mexico, the states primarily at risk from hurricanes). But strategies for reducing risks from coastal flooding will include replacement of developed shorelines with natural shorelines (retreat), which is something that overextended state residual pools are likely to encourage in some cases. The complex mix of insurance in the U.S. for coastal properties will interact in unpredictable ways to shape individual and public decisions about flood risk reduction.

Constraints on Post-Disaster Spending on Natural Infrastructure

No matter which post-disaster funding opportunity is selected, there is a consistent anti-resilience bias in current policies that must be addressed. This bias has two sources. The first is budgetary pressure. Incorporating risk-reducing actions in recovery funding raises the size (and cost) of catastrophe bonds, traditional insurance, and public post-disaster funding. This becomes particularly visible in the case of Box 1 (public funds appropriated for disaster relief) where the pressure on government budgets may encourage focusing resources only on recovery. This bias could be reduced if governments budget for disasters over longer terms that consider the likely costs of multiple disasters. Such viewpoints would encourage investment in cost-effective risk reduction measures.

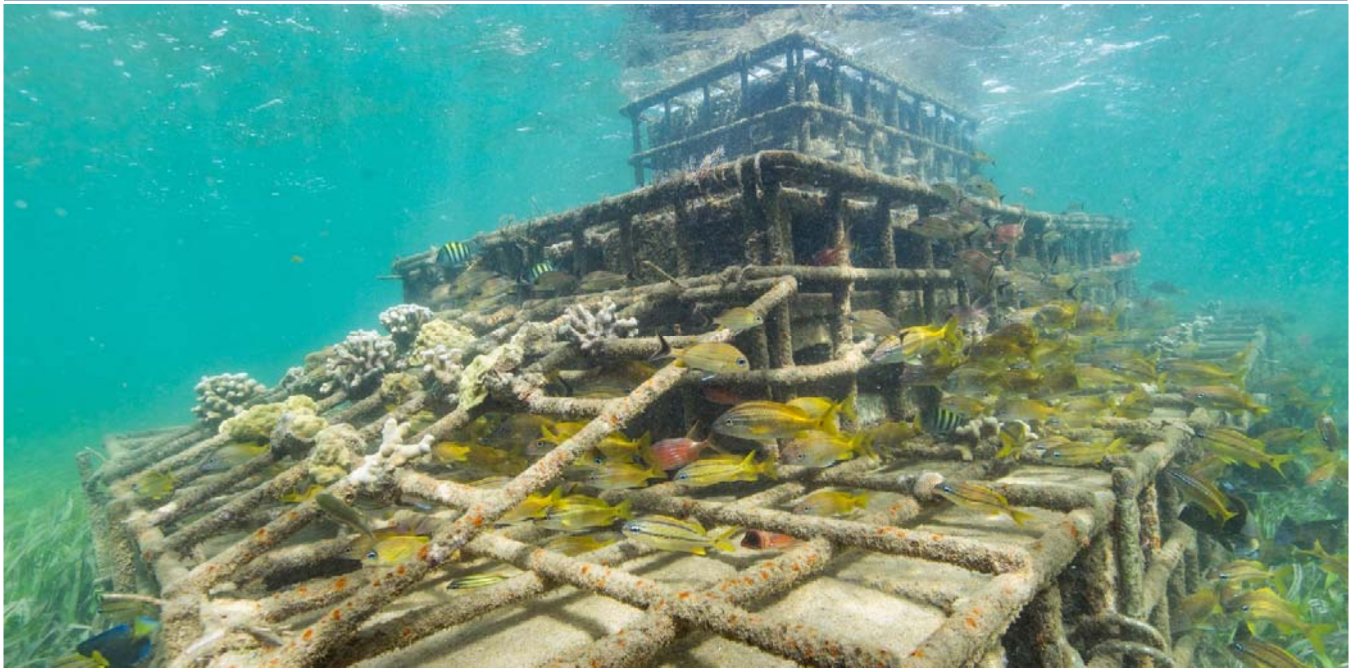
The second source of the anti-resilience bias is that, following a disaster, all organizations want to repair the damage and put things back "as they were" quickly. This is a general problem in supporting rebuilding in the same high-risk areas and following the same approaches. Environmental reviews of structure repairs may be expedited to meet these demands for a quick recovery. Further use of new approaches such as building natural infrastructure projects may be difficult under these time constraints.

There are two means of addressing this bias. One is to gain experience with natural infrastructure so that its impacts can be evaluated more quickly. This need for experience has been emphasized by a number of studies (Huwyler et al., 2014; Gremli et al., 2014). Another is for jurisdictions intending to rely on post-disaster funding to support risk-reducing projects to design, evaluate, and perhaps "pre-permit" specific actions so that they can be implemented quickly as part of the "recovery to pre-disaster" process.

Table 2 presents a summary of the various funding sources discussed in this section.

Table 2. Summary of funding sources.

Who Benefits?	Who pays? — Public	Who pays? — Private
Public	**Box 1** **General Infrastructure Spending that Could Incorporate Flood Protection** Transportation Water related infrastructure Energy **Pre-Disaster Flood/Natural Features** United States Army Corps of Engineers Coastal Wetlands Restoration Fund Estuary Habitat Restoration Act Funds Louisiana Coastal Wetlands Restoration FEMA Pre-Disaster Mitigation Grants Oil Spill Wetlands Restoration Funds State Infrastructure Banks Europe Natural Capital Financing Facility Developing Countries World Bank Green Climate Fund Global Environmental Facility Small Grants Mexico Fund for Disaster Prevention **Post-Disaster Funding** United States FEMA Flood Mitigation Assistance Program World Bank Global Facility for Disaster Risk Reduction & Recovery Crisis Response Window Catastrophe Draw Down Option (CAT-DDO) Mexico Fund for Reconstruction	**Box 3** **Pre and Post Disaster Funding** Green Bonds U.S. State and Local Governments National Governments European Investment Bank World Bank Regional Development Banks
Private	**Box 2** **Tax Expenditures** Disaster Recovery Deductions Deductions for Contributions to Conservation	**Box 4** **Infrastructure Finance** United States Special Purpose Districts: Flood Control Districts Storm water Districts, Tax Increment Financing Districts All Areas Public-Private Infrastructure Partnerships **Insurance – Pre-Disaster** United States FEMA Community Rating System **Insurance – Post-Disaster** All Areas Insurance and Reinsurance Payouts Catastrophe Bonds, Resilience Bonds Developing Countries Risk Pools (e.g. Caribbean Catastrophic Insurance Facility)



This artificial reef section in Grenada is part of a pilot project to deliver risk reduction and conservation benefits. @ Tim Calver

The catalog of available funding sources for flood risk reduction (Table 2) shows that there is a very large array of choices from which those seeking to reduce risks can assemble resources and from which those seeking to deploy capital for risk reduction can devise viable strategies. But, as noted above, there are many factors that shape the circumstances in which risk reduction and funding decisions will be made. We briefly discuss a few key factors and elaborate on these using case-studies from two distinct at-risk geographies: The Northeastern U.S. and The Philippines. Depending on the local configuration of these factors, some types of funding are more or less likely to be usable. Also as noted, these factors are complex and multidimensional, and thus require specific local analysis. Nonetheless, it is possible to examine each of the factors and some of their principal elements as they relate to the general funding strategies discussed.

Geography

There are two principal dimensions to the geographic factor. The first is location of property at risk relative to shoreline and shoreline ecosystems. This is most easily visualized as the difference between urban and rural areas. Urban areas typically have very high levels of property values at risk. Rural areas may have shoreline property but it is likely to be much less dense and lower in total value. The second geographic feature is shoreline characteristics such as being composed of enclosed features such as embayments, the composition of the shoreline, and its elevation relative to sea level. Shorelines may also be eroding or accreting.

Ecosystems

The type, location, and extent of ecosystems in an area are major factors in determining what role natural infrastructure could play in flood risk reduction. The key characteristics of living ecosystems that most influence erosion and flood reduction are known. Reef height and roughness are critical, as are the width and vegetative density of wetlands. Overall, coral reefs are likely to provide the most protection, followed by mangroves and marshes. Oyster reefs can provide erosion reduction and protection of shorelines but will have limited influence on flood reduction.

Known flood risks

Data on past floods, including their periodicity, extent, and damages are essential to the risk modeling that underlies flood insurance. This ranges from the accurate mapping of the 100-year flood (the standard for the U.S. National Flood Insurance Program) to the sophisticated risk models used to price catastrophe bonds and reinsurance. Such data is also important in helping communities understand the risks they face and the importance of actions to reduce them, though rising sea levels and changing weather patterns mean that the past is an imperfect guide to the future. Such data is also more likely to be available in developed than in developing countries.

Existing approaches for funding natural infrastructure

Where public funds are available to acquire or restore ecosystems for flood risk reduction, a key question is whether such funds are specifically designated for flood risks or are designated for other purposes. In Europe and some U.S. states, public money for wetlands and other ecosystems is specifically authorized for flood risk reduction. International development organizations increasingly have dedicated risk reduction funds. But there are also many funding programs related to wetlands and related resources in the U.S., Europe, and among development organizations related to ecosystems that are targeted for other purposes, such as habitat preservation, that could be coupled with risk reduction.

Financing system capabilities

Many of the possible funding sources for natural infrastructure require relatively sophisticated finance and insurance systems. These include governmental grant systems, a well-functioning local government borrowing system, and a property and casualty insurance system capable of handling flood and natural disaster risks. Such systems characterize almost all developed economies, but are unevenly distributed among developing countries, though these capacities may evolve in the future.

Socioeconomic status of communities

Flood risk reduction may be funded by many different local and international sources, but the responsibility for taking steps to reduce risks often rests with local communities and governments. Higher-income communities have more resources to contribute to funding risk reduction and are also more likely to have the capacity to manage the process of investing to reduce risks. Lower-income communities will have to rely more on outside resources and may lack the organizational capacity to plan and execute risk reduction strategies.

Case Study 1: The Northeastern U.S.

Overview

The coastline of the northeastern U.S., from Cape Elizabeth, Maine to Virginia Beach, Virginia, is a flat, low-lying, heavily developed area with many rivers, beaches and marshes. With more than 28,000 linear kilometers, this coastline is home to one-third of the coastal population of the U.S., with twice the population density of any other coastal region. This highly urbanized coastline includes the cities of Boston, New York, Philadelphia and Norfolk-Newport News, but also has significant amounts of natural areas, mostly in federal, state, and local reserves (Nickerson et al., 2011; NOAA, 2013; Titus et al., 2009).

Known Flood Risks

The northeastern U.S. coastline is highly prone to flooding and flood damage from storms, hurricanes and extra-tropical cyclones (Lin, Emanuel, Oppenheimer, & Vanmarcke, 2012). Estimated annual flood damages from hurricane and storm surges vary from $59 to $129 million in New York City alone (Aerts, Lin, Botzen, Emanuel, & de Moel, 2013; Neumann et al., 2014). Hurricane Sandy – the second costliest hurricane in U.S. history – caused over $50 billion in damages in the U.S., spread across 12 coastal states. (Blake, Kimberlain, Berg, Cangialosi, & Beven II, 2013). This risk will increase in the next 30 – 100 years as sea levels rise, especially for major cities like Washington D.C., New York City, and Boston with dense development within one meter of current sea levels (Folger & Carter, 2016).

State of Ecosystems

The coastline of the northeastern U.S. has extensive areas of salt marsh and other temperate coastal wetlands. These wetlands have declined drastically over the past century due to human impacts, including conversion to agricultural or urban land-uses, construction of ditches and dykes, pollution, and canal dredging. Regional and global forces such reduced sediment supplies and rising sea levels are also reducing the extent of wetlands (Hartig, Gornitz, Kolker, Mushacke, & Fallon, 2002). Today, the total area of coastal and estuarine wetlands in this region is approximately 300,000 hectares. The shorelines of Delaware Bay and Chesapeake Bay have seen rapid loss of marsh land over the past century due to local shoreline submergence driven by sea-level rise, and to subsidence due to groundwater withdrawal (Kennish, 2001). However given space and adequate sediment supply, marshes can keep pace with increases in sea level (Kirwan & Megonigal, 2013).

Interaction between Ecosystems and Flood Risks

In the aftermath of Hurricanes Katrina and Sandy, there has been growing attention to the role of natural and nature-based solutions for reducing coastal risk and enhancing resilience. Across the northeastern U.S., government agencies and NGOs are assessing and using natural infrastructure to increase coastal resilience. Activities range from assessments of vulnerability and risk reduction value, to outreach and education, to on-the-ground restoration projects (Bridges et al., 2015; Canick, Carlozo, & Foster, 2016; Hardaway C.S. & Duhring, 2010; The Nature Conservancy, 2013). Numerous studies have shown that natural coastal defenses can reduce wave heights and storm surges (Moller et al., 2014; Wamsley, Cialone, Smith, Atkinson, & Rosati, 2010; Zhang et al., 2012). Under the right conditions coastal ecosystems can also provide cost-effective coastal protection (Narayan et al., 2016a; Reguero et al., 2014). A few studies have looked specifically at the reduction of economic damages by these natural defenses. Coastal wetlands in the northeastern U.S. are estimated to have reduced property damages from Hurricane Sandy by 10%, totaling more than $625 million in avoided damages. These wetlands also reduced damages from annual flooding. For example marshes in Ocean County, New Jersey have reduced average annual losses by 20% (Narayan et al., 2016b).

Existing approaches for funding natural infrastructure

Coastal marshes in the heavily developed northeastern U.S. are conserved primarily through public ownership. Restoration activities to repair and extend coastal marshes are primarily undertaken through public programs for wetlands or, more commonly, as offsetting actions for development of wetlands under the “no net loss” policy. Such offset restoration is funded by both public and private sources. Beach restoration and nourishment is common in some states, primarily paid for by local assessments on property or by sales taxes, but the complex ownership patterns in the region make nourishment difficult. Post disaster funds have supported habitat restoration for risk reduction, specifically targeted funds for coastal restoration after Hurricane Sandy. Flood insurance has generally not played a role in supporting natural infrastructure except in some local jurisdictions that have taken advantage of the incentives in the Community Rating System.

Financing system capabilities

The U.S. has sophisticated tax, expenditure, philanthropic, and insurance systems that are capable of assembling funds for natural infrastructure through many approaches. But there are weaknesses in the systems. The National Flood Insurance Program (NFIP), the primary source of post-disaster funding, is significantly under-funded. The NFIP is in the early stages of expanding investments in risk reduction, but current activity is too small for both individual regions and the nation. State and local governments are highly constrained in making investments and rely on federal spending, which is currently declining. State and local governments have substantial flexibility to create special purpose districts to finance natural infrastructure, but flood risk reduction has not been a significant use of these funds.

Socioeconomic status of communities

Northeastern U.S. coastal communities are predominantly wealthy; many are among the wealthiest communities in the nation, with shorefront properties that are very highly valued. These communities should have the resources and the capacity to identify and implement financial tools that could improve the risk reduction benefits provided by natural infrastructure. But there are also many lower income communities with fewer resources and options that will rely on higher levels of government for funding for flood risk reduction.

Summary: The Northeastern U.S.

The northeastern U.S. is highly vulnerable to flooding, but annual flood risks are not yet as high as in the southeastern U.S. and the Gulf of Mexico, which is impacted more frequently by tropical storms. Natural infrastructure in the northeastern U.S. consists primarily of coastal marshes, many of which are in public ownership and dune systems, which are heavily developed and usually privately owned. Much of these ecosystems have been lost or are highly disturbed. The region generally has access to significant funding resources and strong governance, but the public and private financial institutions are not optimized for addressing flood risk reduction in general and natural infrastructure in particular.

Expanding natural infrastructure in the northeastern U.S. will require a focus on wetland restoration and expansion and preserving beach systems, coupled with hybrid solutions. State and local governments will play a leading role in identifying and organizing investments, but finance will have to come from improvements in capturing the value of risk reduction through mechanisms such as green bonds and catastrophe bonds, structured to allow risk reducing investments either before or after disaster. Special purpose districts, such as those being used to finance stormwater infrastructure, could be expanded in both geography and purpose. Improved flows of resources from the National Flood Insurance Program would accelerate the use of natural infrastructure significantly.

Case Study 2: The Philippines

Overview

The Philippines consists of over 7,500 islands in the western Pacific Ocean, with a coastline over 30,000 kilometers long and a population of nearly 101 million, of which 60% lives on the coast. The Philippine coastline is characterized by significant typhoon and storm activity with heavy rainfall, storm surges and high waves. Coastal populations are heavily dependent on coastal resources for their livelihoods and income (Combest-Friedman, Christie, & Miles, 2012; The World Bank, 2005). The coastlines of the Philippines are also undergoing rapid urbanization; 25 major cities in the country are located on the coastline.

Known Flood Risks

The Philippines is among the most at-risk countries in the world (Beck, 2014a; UNU-EHS & Budnis Entwicklung Hilft, 2016). Typhoons, storms and floods account for around 80% of the total losses from disasters, with estimates of annual average losses totaling nearly $3 billion (National Economic Development Authority, 2017a; UNISDR, 2015). The Typhoons take a heavy toll on coastal populations and economies: super typhoon Haiyan in November 2013 killed over 6,000 people and displaced approximately 4 million people (UN ESCAP, 2015). Climate change impacts such as sea level rise and higher storm frequency, coupled with greater populations and development at the coastline, and degradation of ecosystems will greatly increase the vulnerability of these populations to coastal hazards (Kreft, Eckstein, Junghans, Kerestan, & Hagen, 2014; National Economic Development Authority, 2017b; Yusuf & Francisco, 2009).

State of Ecosystems

The Philippines have a rich diversity of coastal ecosystems, including coral reefs, seagrasses, mangroves, estuarine wetlands, sandy beaches and rocky headlands. These ecosystems provide invaluable ecosystem services, including fisheries, tourism and coastal protection services. The Philippines' coastal populations are heavily dependent on these services and resources. However, land-use conversion and other human activity on the coastline have resulted in widespread degradation of coastal ecosystems like coral reefs and mangroves (Burke, Reytar, & Spalding, 2011; Samonte-Tan et al., 2007). The Philippines has lost approximately half of the mangrove habitat over the past century. Major causes of mangrove loss in the region include: (i) conversion to other land use such as oil palm plantations, mining, shrimp farms, infrastructure, and human settlements; (ii) over-harvesting for timber; (iii) pollution; (iv) decline in freshwater availability; (vi) reduction of silt deposition; (vii) coastal erosion due to subsidence and sea level rise; and (viii) disturbances due to cyclones and hurricanes (Giri et al., 2015).

Interaction between Ecosystems and Flood Risks

The proximity of populations and coastal ecosystems throughout the Philippines means that there is broad interest in natural capital accounting and in green investments for risk reduction. Coastal ecosystems like coral reefs and mangroves have been shown to provide critical risk reduction services to coastal populations in the Philippines (Filippo Ferrario et al., 2014; Anna L McIvor, Spencer, Möller, & Spalding, 2012). In addition to reducing the risk of flooding, these ecosystems also help reduce social vulnerability through the provision of a host of other ecosystem services (Barbier, 2013; Bosire et al., 2008; Das, Vincent, & Daily, 2009; Hutchison, Spalding, & Zu Ermgassen, 2014; Walters et al., 2008). Coral reefs in the Philippines help reduce annual flood damages by $590M/year (Beck et al., 2016 and in review). At the same time however, ecosystems in this region are facing severe threats due to global and local pressures from human activity (Strong & Minnemeyer, 2015). In the Philippines, mangroves annually reduce flooding for more than 613,000 people of which 23% are below poverty. They also provide annual benefits greater than U.S. $1 billion in averted damages to residential and industrial stock. Additionally, mangroves annually reduce flooding to more than 766 km of roads (World Bank 2017).

Existing approaches for funding natural infrastructure

The highly risk prone geography of the Philippines requires greater attention to flood risk reduction than in most countries, but as a lower income country, its internal resources are well short of meeting the needs. The Government of the Philippines has committed to restoring mangroves as part of its coastal protection strategy under the National Greening Program. A recently issued Executive Order "Expanding the Coverage of the National Greening Program" identified the critical role of forests including mangroves (National Economic Development Authority, 2017c). Many countries and multi-lateral institutions as well as NGOs (conservation and aid groups) provide support to the Philippines for disaster recovery; as in other countries there is also some limited support for pre-disaster mitigation.

Financing system capabilities

The Philippines has a diverse tax system administered primarily at the national level, with funding passed through to provincial and local governments. Flood insurance is privately provided and is generally only included in the most comprehensive (and expensive) property insurance policies. These polices are designed exclusively for damage recovery; the reinsurance provided for these policies might become a source of risk reducing funding, but flood insurance coverage in the Philippines is overall very low and primarily in urban areas. The majority of post-disaster recovery currently comes from publicly funded sources, either the national government or international sources.

Socioeconomic status of communities

The Philippines is a classified as a lower middle income country by the World Bank. The country is characterized by significant extremes from high income urbanized areas to extremely poor rural regions scattered among the thousands of islands that comprise the nation. Local resources are likely to be meager to non-existent in most of the country, requiring that most resources will need to come the national government or international sources.

Summary: The Philippines

The Philippines exhibits both extreme vulnerabilities and very high annual risks. Natural infrastructure is recognized as an important investment, but as a lower middle income country the resources to make substantial commitments to natural infrastructure are very limited, particularly in comparison with the needs. Large disparities in incomes across the nation lead to reliance primarily on national and international funding for flood risk reduction. At the same time, the geography of the Philippines provides a relative abundance of opportunities to use natural infrastructure. The result is a large amount of unrealized gains in flood risk reduction.

There is huge value in the existing natural infrastructure for risk reduction. This infrastructure – in reefs and mangroves – is potentially more valuable for risk reduction in the Philippines than in most (and possibly all) other countries. The country has some recognition of this value in mangroves (e.g., in the Greening Program) and a lot of experience in mangrove restoration – some of it explicitly for risk reduction purposes. At the same time, the Philippines (as with most countries) does not systematically measure the value of coral reefs for risk reduction and thus lags in efforts for reef conservation and restoration (Beck and Lange 2016).

In the near term, expansion of natural infrastructure will rely on national commitments to programs such as that for mangrove restoration and a small number of local initiatives addressing specific situations. In the longer term, the Philippines will need to become much more focused on converting damage-related expenditures for risk reduction purposes. Insurance through new vehicles such as catastrophe bonds, combined with assistance from international development organizations, would significantly expand the funding resources available to take advantage of the abundance of natural infrastructure opportunities throughout the Philippines.

Significant investment from multi-laterals and interest from the private sector in insurance could create possibilities for the development of public/private funding for risk reduction using catastrophe bonds and resilience bonds. There may also be opportunities for facultative reinsurance to support resilience building in reefs and mangroves particularly where there is significant investment in coastal tourism infrastructure (which is often centered around significant reef systems). Higher income urban areas will be best placed to take advantage of insurance-related funding; extending those resources to lower income rural areas will be the largest challenge for the Philippines.

EXPANDING FUNDING FOR FLOOD RISK REDUCTION & NATURAL INFRASTRUCTURE

Grand Isle, Barataria Bay, Louisiana. Oyster reefs offshore prevent erosion on the barrier island. @ Erika Nortemann

Both public and private funds are available for natural infrastructure investment. But many of these options have yet to be applied to natural infrastructure investments, or require additional institutional and policy development before they could be widely employed. The funding options can be organized into three groups:

- Currently Available Funding
- Emerging Funding
- Future Funding

Currently available funding options are primarily grouped under Box 1 and Box 4 in Table 1 above. There are public funding programs that could support natural infrastructure, including funds primarily directed at building or rebuilding infrastructure, and programs for wetland restoration either directly for habitat protection purposes or indirectly as part of compensation for wetland lost to development. In the U.S. such wetland funding is not usually for the specific purpose of flood risk reduction, while in Europe many funding programs explicitly fund natural infrastructure for flood protection. Private funds for specific natural infrastructure projects are largely untapped. The amount of private funding is unknown, but may grow as more people appreciate the advantages of natural infrastructure. Although current disaster recovery funds are substantial and offer opportunities for investing in resilience, the anti-resilience bias limits their use.

Currently available funding may be quite diverse and large, but utilizing it for natural infrastructure will require work to adapt it to the specific requirements of natural infrastructure for flood risk reduction.

Emerging funding options are those that are already established but have been applied to a limited extent to coastal flood protection and natural infrastructure. The most important funding source in this category is green bonds, a rapidly growing, flexible, direct source of capital that has broadly intended purposes, such as flood risk reduction. Green bonds are tied to specific environmental performance measures, thus the outcomes of natural infrastructure in terms of flood and erosion reduction must be apparent or measurable within the life of the bond. Establishing performance standards for natural infrastructure green bonds may take time.

The widespread use of green bonds may depend on the creation of special purpose districts that can repay the bond through capture of the benefits of flood protection. Special purpose districts have long been used, particularly in the U.S., to match the beneficiaries of infrastructure to the revenues to pay for them. There is an emerging role for such districts for climate-related activities that offer flood protection, such as stormwater management.

Catastrophe bonds are another type of emerging funding. Although well-established as a vehicle for providing additional capital to the reinsurance market, their role in investing in flood risk reduction has yet to be established. The "resilience bond" concept suggests such a role is possible. Catastrophe bonds offer an important opportunity for self-insured public infrastructure to take more control over the funding of post-disaster responses, including both recovery and risk reduction.

Future funding options consist of sources that either do not currently exist or are at levels too limited to be considered emerging. The most important category here would be a significant shift in the use of disaster recovery funds towards investments in risk reduction against future disasters. This large pool of funds becomes more attractive as awareness of the risks and vulnerabilities of coastal flooding grows. Expanding the use of these funds will require significant changes in current policies and programs. An example includes reorienting the U.S. Community Rating System to support risk-reducing investments.

The international community is also devoting more attention to finding ways to reduce the damages of climate change or compensate for losses, particularly in less developed countries. Funding for damage reduction and compensation has been a contentious issue between developed and less developed countries. However, in recent meetings of the Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC), there have been commitments to specific actions surrounding the loss and damage issue.

In 2007, the Bali Action Plan first mentioned the need for disaster risk reduction strategies to address loss and damage, particularly in vulnerable countries. In 2011, the Parties established the "Cancun Adaptation Framework", which identified specific measures to deal with "climate change risk reduction strategies", specifically including "risk assessment and management actions… including insurance" (UNFCCC, 2011). In 2013, the Warsaw International Mechanism for Loss and Damage Associated with Climate Change Impacts [17] was established for "Enhancing action and support, including finance, technology and capacity building, to address loss and damage associated with the adverse effects of climate change". In Paris in 2015, the COP agreed that the Warsaw Mechanism and the issue of addressing losses and damages, including risk reduction, would become a permanent part of the Framework Convention, thus the issue of adaptation was transformed from a set of side discussions into the core work of the Convention (United Nations Framework on Climate Change, 2016; Darragh, 2015). The "Mechanism" required by the COP in Warsaw is still under development with a report due in 2017. Flood risk reduction investments, including natural infrastructure, are likely to be included in such eligible uses, but detailed terms and conditions will probably take several years. Nonetheless, funding options in the billions of dollars, such as financial transaction, airline passenger, and bunker fuels taxes, have been proposed (Durand et al., 2016).

Based on the current, emerging, and future funding categories, the development of funding options for natural infrastructure should follow a three-part strategy: First, *make maximum use of existing programs*, such as wetland restoration programs that are well-suited for the purpose of risk reduction. Second, *focus efforts on expanding and refining the emerging categories of funding*, including green bonds, catastrophe bonds, and special purpose financing institutions. Third, *engage in reform of post-disaster funding*, particularly government investment for risk reduction. This would include changing policies on the use of recovery funds where needed, as well as planning for the use of natural infrastructure projects to be rapidly implemented during the recovery process.

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17 http://unfccc.int/adaptation/workstreams/loss_and_damage/items/8134.php

The key to expanding the availability of funding in the future lies in addressing some of the identified barriers, including:

- The need for more experience with natural infrastructure projects to normalize this approach for property owners, funders, and regulators.
- Public and private insurance systems that are insufficiently focused on reducing future risks.
- Funding organizations that are unaware of potential natural infrastructure opportunities and/or lack the flexibility to support the kind of creative financing approaches needed.

Strategies for overcoming these include:

1. **Gaining Experience** Investment in natural infrastructure for flood protection remains relatively rare, although there is a growing body of evidence attesting to both its effectiveness (Narayan et al., 2016a; Shepard, Crain, and Beck, 2011; Beck, 2014) and its cost-effectiveness (Narayan et al., 2016b, Newkirk et al., 2016; ENVIRON International Corporation, 2015). But people considering investing substantial amounts of public or private funds will tend to be skeptical of an uncommon technical approach. More projects are needed to demonstrate this approach and to develop a database of performance standards (including cost performance standards). A growing body of infrastructure projects looking for funding will need to be matched with a growing pool of funds looking for projects. Some funding programs, such as the European Natural Capital Finance Facility, were created mostly to fund projects that could provide the needed experience with natural infrastructure, but there are few other specific funding sources.

2. **Flood Insurance Reform** The flood insurance system, whether publicly or privately operated, is focused on recovery from flood disasters, but the growing magnitude of flooding risk is forcing greater attention on reducing risks as well as compensating for them. The relatively large upfront costs of natural infrastructure mean that the values to insurers and insured can be captured and cumulated to provide pools of investment capital. In the U.S., this might be done through changes in community-based risk programs, such as the FEMA-administered CRS program, or through innovations in catastrophe bonds, such as the "resilience bond" concept. Such approaches could also reduce the problems of over-insurance of repetitive loss properties. Catastrophe bonds could also serve as a partial substitute for the self-insurance that typically covers publicly owned properties, freeing up funds to be used for flood protection investments.

3. **Enabling Connecting Organizations** A major challenge for expanding the use of natural infrastructure for flood protection lies in connecting the many different types of funding and funding institutions with the many different places around the world where natural infrastructure could play a key role in reducing flood risks. Funders look for opportunities that are well-defined and ready for implementation, while those concerned with flooding threats try to navigate their way through the many possible funding sources. Long-term success for both can be enhanced through the evolution of intermediary organizations that identify potential projects and can provide links to potential funders. These could include conservation organizations, such as the Nature Conservancy, various iterations of the infrastructure bank concept evolving in both the U.S. and Europe, or possibly the Warsaw International Mechanism.

CONCLUSIONS

Port Fourchon, Louisiana, benefits from the protection provided by adjacent wetlands. @ Carlton Ward Jr.

This review of funding options for natural infrastructure for risk reduction from flooding finds that there is a large and growing pool of possible funds for this purpose. However, there are significant mismatches and limitations to making effective use of available funds. The largest amount of funding is connected to flood disaster recovery, but few of these funds are used to reduce future flood risks. New forms of finance such as green bonds and catastrophe bonds can provide significant resources, but the use of these funds for natural infrastructure is nascent, in large part because the number of natural infrastructure projects that could use such funding remains relatively small.

Expected increases in future flooding risks will likely greatly increase the demand for risk-reducing natural infrastructure. Fortunately, innovations such as green bonds, catastrophe bonds, and evolving policies in flood insurance have created a solid base for a future set of funding sources that can meet the needs for coastal adaptation to a much greater extent than today's array can.

The course to that future funding for natural infrastructure lies primarily in the increasing use of what is available today, in both established and new approaches, to implement emerging natural infrastructure projects. The most important innovations in finance are ones that now address responses to reducing flood risks by reducing the likelihood or magnitude of climate change, and have yet to be widely used for coastal adaptation in general and natural infrastructure in particular. The future pool of financing for natural capital will evolve primarily thanks to the knowledge we gain from the people who undertake natural infrastructure projects funded by creative combinations of resources.

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