WORLD RESOURCES INSTITUTE

WORKING PAPER

The Triple Dividend of Building Climate Resilience: Taking Stock, Moving Forward

Harald Heubaum, Carter Brandon, Thomas Tanner, Swenja Surminski, and Viktor Roezer

CONTENTS

Working Papers contain preliminary research, analysis, findings, and recommendations. They are circulated to stimulate timely discussion and critical feedback, and to influence ongoing debate on emerging issues.

Version 1.0, November 2022

Suggested Citation: Heubaum, H., C. Brandon, T. Tanner, S. Surminski, and V. Roezer. 2022. "The Triple Dividend of Building Climate Resilience: Taking Stock, Moving Forward." Working Paper. Washington, DC: World Resources Institute. Available online at https://doi.org/10.46830/wriwp.21.00154.

EXECUTIVE SUMMARY

Highlights

- The triple dividend of resilience (TDR) is an approach that considers avoided losses (first dividend), induced economic or development benefits (second dividend), and additional social and environmental benefits (third dividend) of adaptation actions. The second and third dividends are especially important since they accrue regardless of whether the actual climate risk materializes.
- The second and third dividends are often highly significant. They can exceed the value of avoided losses and can generate project benefit-cost ratios (BCRs) greater than 1 even when the value of avoided losses is not considered.
- Accounting for the full range of benefits demonstrates higher BCRs for adaptation investments than are often assumed. In turn, this can help increase access to project finance, improve project design, and improve ex post monitoring and evaluation.
- Researchers and practitioners are developing more effective appraisal tools for analyzing the benefits of climate resilience investments and are generating more information useful in decision-making.
- Investors in the public sector stand to benefit from increased use of the TDR by having more consistent and comparable assessments across sectors and donors. The private sector stands to benefit by better understanding both second dividend financial benefits and third dividend nonmarket benefits that flow from investing in resilience.

Background

More than six years after the Paris Agreement called for strengthened and adequately funded global efforts to address climate adaptation and resilience, it remains clear that neither the magnitude nor the direction of financial flows are adequate to enable countries around the world to anticipate, prepare for, and effectively respond to climate-induced risks (UNEP 2021). Mobilizing public and private finance to support adaptation and resilience-building efforts requires a shift in understanding of the full value of resilience interventions. In its call for greater efforts to prepare for the impacts of climate change, the Global Commission on Adaptation (2019) emphasized that effectively scaling up adaptation actions will require a better understanding and quantification of these benefits.

This working paper contributes to this endeavor by reviewing the literature relating to the multiple dividends of climate change adaptation and resilience-building. It presents the current state of research and analysis on the topic and highlights recent attempts to quantify benefits across dividends. The paper can guide researchers assessing practical and conceptual challenges of using TDR approaches in both theory and practice, as well as policymakers and investors considering the kind of interventions needed to build adaptive capacity and resilience to the impacts of climate change around the world.

Key Takeaways

An improved understanding of the TDR can help scale up climate adaptation and resilience interventions. A shift in approach is needed for both the public and private sectors to mobilize sufficient funds and catalyze greater investment in resilience interventions. More investment will be forthcoming if the benefits of adaptation and resilience-building are more fully quantified, pointing to the importance of research and analysis to guide key choices in the years to come.

Analysis of the TDR shows that for a wide range of adaptation investments, economic, social, and environmental benefits accrue regardless of whether the climate risk actually occurs. They are highly significant and often account for more than half of total benefits. Climate adaptation investments can reduce systemic risk in urban, industrial, and agricultural water supplies or of periodic flooding, thereby inducing investment in properties that would otherwise get flooded or lack water access (the second dividend). Also, many water-related adaptation investments increase resilience through natural ecosystem services, such as those provided by wetlands, intact hillside ecosystems, and coastal mangroves, and have high levels of environmental benefits (the third dividend). In fact, the second and third dividends, by themselves, can generate benefit-cost ratios greater than 1 even without including the value of avoided losses. This working paper presents case studies in coastal flooding and drought management showing that over half of total benefits were due to the second dividend. In urban stormwater management projects using nature-based solutions, over half of total benefits were associated with the third dividend.

Accounting for the full range of benefits can show higher benefit-cost ratios for adaptation investments than are often assumed—which in turn can facilitate access to project finance, help improve project design, and lay the foundation for improved monitoring and evaluation of ex post investment impacts. In the sample studied in this paper, the three dividends combined can show benefits several times greater than when only one dividend is quantified. These findings confirm the importance of integrating the second and third dividends, wherever possible, in evaluating the impacts of adaptation-related investments. The identification and quantification of key benefits across all three dividends enable long-term observations of dividend values over time, thereby improving the available evidence on the impacts and effectiveness of adaptation interventions on the ground.

Triple dividends are increasingly recognized and quantified, but knowledge gaps remain. Research has evolved from defining and establishing the concept of the TDR toward applying it to adaptation and resilience interventions in practice. However, the number of projects that systematically quantify their full costs and benefits is still relatively small. Although appraisal tools that assess climate-adaptation and resilience-building measures have developed considerably, accounting for the many varied benefits of resilience interventions remains complex. Recent research has begun to address both existing data and methodological challenges, and provides evidence in support of doing so, including for the more difficult quantification of nonmarket social and environmental benefits.

This working paper lays out five strategies to help promote a shift in thinking about the triple dividend approach:

- Grow the evidence base (including longitudinal monitoring and evaluation).
- Improve methodology and data collection (including for social equity and private sector aspects of adaptation).
- Build broad-based analytical capacity to conduct TDR analysis.
- Communicate TDR data to inform different decision-making contexts.
- Move toward a more standardized TDR framework for donors and governments.

Promoting these strategies would facilitate more consistent analysis of projects among development practitioners and governments, foster improved comparative research on financial and economic benefits, promote understanding of induced development benefits of potential interest to private investors, and support more rigorous ex post evaluation of impacts. More standardized approaches would help avoid both bias in the selection of individual benefits to consider and under- or overvaluation of those benefits. Finally, by allowing solutions to be effectively understood, catalyzed, and scaled, these approaches could help fundamentally shift capital flows toward adaptation efforts.

INTRODUCTION AND METHODOLOGY

The impacts of global climate change are already evident in higher temperatures and acidifying oceans, while increasingly frequent and more extreme weather events like wildfires, droughts, hurricanes, and floods undermine food supplies. The recent United in Science report (WMO 2022) shows that climate- and water-related disasters have increased by a factor of five in the past 50 years, and are continuing to worsen.

These and other climate impacts put human lives and livelihoods at risk, and jeopardize economic growth and sustainable development around the world. They also carry an ever-higher price tag. According to insurance company Aon (2020), natural hazard–related catastrophes caused US$2.98 trillion in inflation-adjusted losses between 2010 and 2019, 50 percent higher than the previous decade (2000–2009). Simulating a 2–2.6°C rise in temperatures by 2050, Guo et al. (2021) project a reduced global economic output by then of 11–14 percent relative to growth levels without climate change, with GDP losses in developing economies (e.g., 33–36 percent in Thailand, Malaysia, and the Philippines) far greater than those in developed economies (e.g., 6–7 percent for the United States, Canada, and the United Kingdom).

The case for making investments that enhance resilience and adaptation to climate change impacts has traditionally been that they reduce risks and minimize the costs associated with climate-related (and other) shocks and stresses, thereby protecting economic and social processes, assets, and citizen well-being. Increasingly, however, they are also being seen as a development opportunity.

The triple dividend of resilience (TDR) approach categorizes and captures three distinct types of values. It considers avoided losses (first dividend), induced economic or development benefits (second dividend), and social and environmental benefits (third dividend) of adaptation and resilience-building actions and helps improve their investment business case (Tanner et al. 2015; Surminski and Tanner 2016) (see Box 1). The approach uses a cost-benefit framework and is suited to analysis of the full range of potential adaptation actions, ranging from projects to programs to policy reform.

Box 1 | Investing in adaptation provides a triple dividend

Dividend 1: Avoided Losses

- Early warning systems (EWS) save lives and assets worth at least 10 times their cost. Just 24 hours warning of a coming storm or heat wave can cut the ensuing damage by 30 percent. Spending $800 million on EWS in developing countries would avoid losses of $3 billion to $16 billion.
- Infrastructure that is more climate-resilient can add around 3 percent to the upfront costs yet provides benefit-cost ratios of around 4:1. With $60 trillion in projected infrastructure investment between 2020 and 2030, the potential benefits from early adaptation are enormous.

+ Dividend 2: Economic Benefits

- Reducing flood risks in urban areas lowers financial costs, increases security, and makes high-climate risk investments more viable. London invested in Thames River flood protection, making investments in Canary Wharf and other East London developments viable.
- Drip irrigation technologies developed for water scarcity are now used widely because they lead to higher crop productivity than traditional irrigation systems.

+ Dividend 3: Social and Environmental Benefits

- Mangrove forests provide over $80 billion per year in avoided losses from coastal flooding and protect over 18 million people. They contribute $40 billion to $50 billion yearly in nonmarket benefits in fisheries, forestry, and recreation. Combined, the benefits from protecting and restoring mangroves are up to 10 times greater than the costs.

= A Triple Dividend

Source: Global Commission on Adaptation (2019).

The first dividend of building resilience, saving lives and avoiding economic losses is the basic rationale and common motivation for adaptation and resilience investments. However, the uncertainty around whether and when climate impacts may occur means that decision-makers may not find such investments attractive. Therefore, it is important to also consider other more immediate benefits in the second and third dividends, which provide benefits even in the absence of a shock or stress.

The second dividend of building resilience concerns induced economic benefits arising from the adaptation investment, regardless of whether the climate impact materializes. By reducing and better managing potential risk, households, firms, and governments may make more productive decisions, increase capital investments, create jobs, and boost land and property values. The cost of economic activity—such as the cost of insurance, flood protection, or backup power systems—is reduced by the adaptation investment, thereby inducing increased investment and economic output. The second dividend consists of changes in economic activity, which means that the value of its various elements can be estimated using market prices.

The third dividend of building resilience concerns additional social and environmental benefits accruing as a consequence of the intervention, such as flood levees also used as leisure and amenity venues, flood-protecting wetlands with biodiversity benefits, storm shelters that double as community centers, or improved economic and social equity across neighborhoods shielded from the impacts of urban heat island (UHI) effects. Unlike the first and second dividends, benefits falling under the third dividend are called externalities because they are typically valued not in economic markets but rather through techniques such as contingent valuation or hedonic pricing used to value externalities.

While adaptation actions can generate triple dividends, the broad concept of financial, economic, social, and environmental benefits of actions to improve climate resilience is only beginning to be applied more widely. As a result, the full benefits to society of undertaking adaptation-related policy reform and making physical investments are still often underestimated in economic appraisal and decision-making processes.

Approach and methodology

This working paper combines qualitative and quantitative methods: a nonsystematic review of relevant literature, an in-depth examination of a set of sector-based case studies, and a survey of adaptation and resilience researchers and practitioners.

Literature review

The nonsystematic review in Section 1 combines an analysis of peer-reviewed academic articles focusing on the TDR as an integrated approach or the valuation of individual dividends with project-specific gray literature examples, such as program and project design reports by international organizations, development banks, and independent consultants. We chose publications based on their relevance to the TDR approach and cost-benefit assessments of adaptation and resilience interventions more broadly. We intend this review not to be all-encompassing but rather to inform readers of the current state of play in the field. Although most of the existing TDR literature stems from the Global North (United States, United Kingdom, Australia) and China, we also cite infrastructure projects from Bangladesh, Ecuador, Haiti, Myanmar, and the Philippines.

Case studies

We selected the seven cases presented in Section 2 for the topical and regional spread of their interventions as well as their data availability across all three dividends. All but one quantify first, second, and third dividend benefits directly, setting them apart from most other studies currently available. The one study that did not quantify the third dividend (Tahoe National Forest) had sufficient project-level data for us to complete the analysis. In the majority of cases, the data come from ex ante project appraisals or monitoring documents prepared during implementation. In two cases (Tahoe National Forest and Kunshan), the data are based on ex post project evaluations; in one case (Felixstowe), they are a mix of both ex ante and ex post assessments. The case study analyses do not follow a uniform methodology, either in terms of the selection of benefits considered or how those benefits are valued. We did not critically review the calculations done in each paper but rather relied on each paper's publication review process. Still, our review is the most complete compilation to date of the range, importance, and diversity of the triple dividend concept in practice.

Practitioner survey

To better understand the state of play of the TDR approach among practitioners, we circulated a survey among 70 adaptation and resilience experts from academia and nongovernmental organizations (NGOs), as well as among donors. We selected survey recipients through a process of snowball sampling in which existing connections provided referrals to recruit further participants with expert knowledge of project design and cost-benefit analysis (CBA) in donor organizations and climate change adaptation and resilience-building interventions more generally. In addition, we contacted authors of relevant literature.

Open-ended and multiple-choice questions based on information drawn from the literature review probed respondents' understanding and use of the TDR approach and gave them an opportunity to provide examples of the triple dividend in action. For details on the questionnaire, see Appendix B. We received responses from 30 respondents, a response rate of 43 percent. Responses reflect the views of individual participants and not their organizations.

1. TAKING STOCK: A REVIEW OF THE RECENT LITERATURE

This section reviews the rapidly expanding literature on climate adaptation and economic and financial analysis. It shows how the broader concepts of avoided losses, economic gains, and social and environmental benefits—the three dividends comprising the TDR conceptual framework—are increasingly being valued and incorporated. It also addresses specific challenges that have arisen, including the valuation of nonmarket benefits, and ends by observing the advantages of taking a unified approach across the triple dividend. In this working paper, we assume the standard approach to financial and economic analysis to be cost-benefit analysis, which strives for full valuation of financial and economic costs and benefits for projects, programs, and policy reform options.

1.1 The first dividend

Valuing potential avoided losses for a given adaptation investment is a generally well-understood approach, developed through feasibility studies of disaster risk management investments in various countries and sectors (World Bank 2013). This review thus focuses more on analysis of the second and third dividends. In a cost-benefit framework, avoided losses are the share of total potential losses projected to be avoided by the proposed investment.

Increases in climate change adaptation investment today are largely driven by the high cost of climate-induced damages. While the bulk of economic valuations of the impacts of natural disasters and climate change have traditionally focused on the value of lost lives and assets, more recent assessments have further estimated total damages by adding in lost livelihoods, lost education, health impacts, and other welfare losses due to social disruption. Botzen et al. (2019) show that the indirect costs of extreme events (defined as losses in economic production and consumption) are significant and in extreme cases can exceed the value of direct costs (defined as the damage to assets and human life at the time of the disaster). To better understand avoided losses, the World Meteorological Organization, in its 2021 *Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes*, calls for more relevant data and better disaster loss accounting to show how adaptation and resilience-building interventions can produce tangible benefits.

In the current literature, most examples of avoided losses are associated more with extreme events, such as fires, storms, floods, or droughts that occur periodically, as opposed to slow-onset impacts, such as gradual loss of agroclimatic suitability for a given crop or sea level rise. Therefore, the examples of avoided losses in this working paper, including the two examples immediately below, are associated with extreme events. This does not mean that the TDR approach of valuing the full dividends of adaptation investments cannot be applied to investments in the face of slow-onset impacts. However, the time frame of slow-onset events introduces greater uncertainty and makes effective quantification more difficult.

Assessing the avoided loss benefits of flood protection along Europe's coasts, Vousdoukas et al. (2020) find that at least 83 percent of flood damages in Europe out to 2100 could be avoided by elevating dykes in an economically efficient way along up to 32 percent of the continent's coastline. The authors employ a probabilistic framework that integrates dynamic simulations of extreme sea level rise and flood inundation, impact modeling, and a cost-benefit analysis of raising dams and seawalls. With a discount rate of 5 percent applied to the European Union's 15 cohesion countries (i.e., those with per capita incomes slightly below the EU average) and 3 percent applied to all others, Vousdoukas et al. (2020) find a mean benefit-cost ratio (BCR) of the investments ranging from 8.3 to 14.9, and country-level BCRs ranging between 1.6 and 34.3.

In a separate example, combining spatially explicit analyses with economic modeling, Menéndez et al. (2020) find that mangroves provide global flood protection benefits exceeding US$65 billion in avoided property damage per year (see Table 1). They further find that 15 million more people would be flooded annually if mangroves were lost, with such impacts concentrated in Bangladesh, India, and Vietnam. Annual expected benefits are relatively consistent over return periods of 10, 25, 50, and 100 years. While benefits become more valuable during more intense events that are likely to occur more frequently as the return period increases, longer return benefits are also discounted more.

Table 1 | **The flood protection benefits of mangroves**

	LAND FLOODED (x 1,000 KM²)			PEOPLE AFFECTED (MILLION)			PROPERTY LOSS (BILLION US$)		
	With	Without	Benefit	With	Without	Benefit	With	Without	Benefit
Annual Expected	122	157	35	53	68	15	732	797	65
10-yr	176	221	45	82	103	21	1,200	1,293	93
25-yr	209	262	53	107	129	22	1,558	1,662	104
50-yr	249	318	69	138	166	28	1,953	2,092	139
100-yr	326	423	97	192	229	37	2,714	2,984	270

Source: Menéndez et al. (2020). Values are the flooded land, affected people, and property damages with and without mangroves annually for catastrophic events with a 1-in-10-year return period.

1.2 The second dividend

A growing literature is focused on the second dividend: induced economic benefits from interventions even if the disaster or climate impact does not materialize. Studies have assessed such economic benefits for specific types of avoided risk (e.g., flooding, droughts, or wildfires) and over different spatial scales. For example, the Thames Barrier protects over 1.4 million people and half a million properties worth over £321 billion (UK Environment Agency 2021). It has sufficiently reduced flooding risk to help stimulate investments in Canary Wharf, London City Airport, and elsewhere in East London (Penning-Rowsell et al. 2013).

A review of resilience-building measures in three large regions of the United States by McCormick and Marshall (2015) estimates the benefits of resilient landscaping, design, and construction. Alongside reduced losses from storm and flood damage, reported second dividend benefits include lower-cost and more extensive insurance coverage, access to investment due to decreased risks, marketing advantages, and reputational gains for companies. The owners of a conference center in South Florida report that resilience strategies have boosted their competitive advantage not only by reducing losses and shortening recovery times following storms but also through the resort's improved branding and image, with the project manager reporting that "many groups make their plans one to two years in advance, and this resilience gives them the confidence that the facility will be online and available even if there had been a hurricane six months before" (McCormick and Marshall 2015, 29).

Hallegatte et al. (2019) show that investments in infrastructure resilience in low- and middle-income countries create benefits of $4 for every $1 invested in 96 percent of 3,000 scenarios returned in scenario modeling exercises that consider the power, transport, and water and sanitation sectors. These benefits—reduced operation and maintenance costs over the lifetime of assets, better-quality services, higher utility revenues, and positive financial flows enabling future investment—accumulate even in the absence of a natural hazard or disaster and broadly correspond with the second dividend of resilience.

In Myanmar, Yaron and Wilson (2020) find that resilience interventions to protect local communities against natural hazards such as riverine and flash flooding generate induced economic benefits that significantly outweigh project costs. To understand changes that have occurred, they combine evidence from participatory methods with more formal economic modeling; for example, using published data on the value of a statistical life, value of paid workdays, savings from microfinance, savings in water purchase, and pig breeding benefits. Using a base discount rate of 6 percent, the authors find BCRs of nearly 11 in case study sites where community-planned small-scale infrastructure was used to limit regular annual flooding in addition to improving livelihood opportunities.

Evidence for greater entrepreneurial activity as a result of investments in resilience in a particular location or sector constitutes an important but underexplored component of the second dividend. Globally, a 1 percent increase in disaster events is associated with a 4–5 percent decrease in start-up activity. Resilience investments that prevent impacts on assets and economic activity could therefore prevent such reductions in entrepreneurial activity (Boudreaux et al. 2019). The Multi-hazard Mitigation Council (2019) finds that investments in building greater resilience to natural hazards in the United States—for example, through enhanced new building codes or private sector retrofits—not only avoids deaths and economic losses but also can lead to greater entrepreneurial activity in the construction-materials industry. For example, designing new buildings to exceed 2015 international building codes would result in the creation of 87,000 jobs and a 1 percent increase in the use of domestically produced construction materials. Implementing all resilience interventions in line with 2018 codes would result in a BCR of over 10.

In reviewing the role of resilient infrastructure, Braese et al. (2019, 17) highlight the importance of the quality and reliability of infrastructure for competitiveness and enterprise activity, rather than just its availability. They note that "reducing the prevalence of disruptions by increasing the resilience of infrastructure therefore provides a powerful tool to increase longer-term capital investments and entrepreneurship and can lead to sustainable economic benefits far exceeding the primary effects of avoided disruptions." For industries facing unreliable power provision such as in Africa, the additional cost of self-provision per kilowatt-hour is about three times the grid-supplied energy cost and includes significant direct and indirect costs (Oseni 2019). Levels of entrepreneurship can therefore be increased through more resilient power supplies, with World Bank Enterprise Survey data for 23 African countries suggesting that power outages reduced the likelihood of start-ups by as much as 44 percent (Mensah 2018).

1.3 The third dividend

Integrating the values of nonmarket externalities into CBA has long been standard theory but less so established practice. There is growing interest in valuing and incorporating nonmarket environmental and social values in adaptation-related decision-making. However, identifying and quantifying the third dividend, environmental and social benefits, has proved challenging. Much of the literature has captured additional resilience dividends more qualitatively than quantitatively. At the simplest level, this can be done by examining the coherence of resilience and adaptation interventions with other environmental, social, and development goals.

Methodological approaches to monetizing environmental and social values are well rehearsed in economics, including contingent valuation approaches using stated and revealed preferences, or benefits transfer using existing studies to elicit values (Turner et al. 2019). Monetary value assignment may be inappropriate or problematic, as environmental and social benefits are not traded in the market or always comparable across cultures and contexts. Other decision and valuation techniques therefore attempt to include nonmonetary values but without explicitly generating monetary values. Examples include multicriteria decision analysis and composite risk indices, which often use formal scoring and weighting for nonmonetary aspects, while qualitative and semiquantitative methods rely less on formal aggregation and more on user-oriented analysis to compare and evaluate the effects of different policy choices (UNFCCC 2013; Bertilsson et al. 2019; Olazabal et al. 2019). McNamara and colleagues (2021) report on studies of planned relocation efforts in Fiji, Papua New Guinea, and the Solomon Islands which suggest that such anticipatory actions can renew local communities' sense of hope, dignity, everyday agency, and control of their fate. Similarly, Serdeczny (2019) highlights the example of a program of "migration with dignity" to support early emigrants from the Pacific Island nation of Kiribati. This program supports the preservation of agency, community ties, and social cohesion. The approach fosters these values, without quantifying or monetizing such benefits.

Oberholzer et al. (2017) aim to understand resilience dividends in infrastructure by combining a snapshot assessment known as SuRe SmartScan with sustainability and resilience benefits analysis to provide a benchmark and a set of infrastructure-specific indicators to track the sustainability and resilience levels of infrastructure projects over time. The approach makes some quantified estimates of second and third dividends in the case of a disaster, considering six forms of capital: financial, human, natural, physical, political, and social dividends. In addition, it provides qualitative examples of nondisaster contexts in terms of environmental, social, economic, and institutional benefits (Table 2).

Table 2 | **Resilience dividends from four infrastructure case studies**

INFRASTRUCTURE CASE STUDY	EXAMPLES OF DIVIDENDS 2 AND 3 IDENTIFIED	NOTABLE ASPECT
Expressway rehabilitation, Manila (Philippines)	▪ Alerts on weather, traffic congestion, etc. for the whole population due to traffic management system ▪ Reduced congestion allows more efficient business operation ▪ Roadside trees sequester carbon dioxide ▪ Role model for future public-private partnerships in infrastructure	Environmental costs flagged related to pollution caused by induced traffic
Urban resilience measures, Mathbaria (Bangladesh)	▪ Employment creation, positive long-term health impacts, institutional improvements ▪ Resilient water supply helps avoid arsenic contamination and high salinity in drinking water ▪ Increased safety, security, and dignity for women and female children with more privacy and open defecation stopped	Social costs expanded, highlighting the lack of a strategy to cope with the long-term stress of salinity
International airport, Quito (Ecuador)	▪ Neighboring communities benefit from training, employment, new businesses, sporting facilities, equipment, and education programs ▪ Water management improves quality and flood protection ▪ Socioeconomic development from growth in tourism, agriculture, and product exports ▪ Communal enterprise created for solid waste management	Environmental costs flagged related to noise pollution and environmental damage from infrastructure
International seaport, Port-au-Prince (Haiti)	▪ Improvements to nearby low-head dams ▪ Improved local skill base ▪ Direct and indirect employment opportunities estimated at 25,000	Social costs flagged related to the precarious employment conditions of other similar jobs created in free-trade zones

Source: Authors' summary from Oberholzer et al. (2017).

1.4 A unified approach

In their metareview of research conducted on the multiple benefits of disaster risk reduction and adaptation interventions, Mechler and Hochrainer-Stiegler (2019) argue that while the TDR framework has received attention from both academics and practitioners, relatively few case studies analyze and communicate tangible evidence for all three dividends. Yet new research is paying greater attention to the need for comprehensive understanding of the impact of adaptation and resilience-building measures and for identifying the full range of benefits they can bring. This includes studies that ground their empirical analyses in the TDR framework. One example is a recent WRI report assessing three very different climate adaptation case studies in China, all of which showed high rates of return (Ding et al. 2021). The case studies were (1) improved irrigation to increase resilience to drought in Ningxia Province, (2) creating urban flooding resilience through sponge city investments in the city of Wuhan, and (3) building coastal resilience against storm surges by investing in higher standards of coastal infrastructure in Shenzhen. We review the Ningxia drought resilience project in more detail in Section 2.

In its assessment of the triple dividend of global adaptation and resilience-building, the Global Commission on Adaptation (2019) argues that investments of $1.8 trillion by 2030 in improved early warning systems, resilient infrastructure and water resources, improved dryland agriculture, and better mangrove protection could generate benefits of $8.9 trillion, a BCR of 4.8, and a net present value (NPV) of $7.1 trillion. This assessment is based on an extensive literature review of the rate of return of investments in the five sectors over the past 10–15 years. The extent to which this study was able to value the full triple dividend is shown in Table 3. To estimate the NPV of investments by 2030, a 4 percent discount rate, consistent with estimates of long-run global returns to capital, was applied.

Table 3 | **The scope of assessing the triple dividend**

	ESTIMATED BENEFIT COST RATIO	AVOIDED LOSSES	ECONOMIC BENEFITS	SOCIAL AND ENVIRONMENTAL BENEFITS
Strengthening early warning systems	3–16	✓	Not done	Not done
Making new infrastructure resilient	3–7	✓	Sometimes done—sizable	Not done
Improving dryland agriculture crop production	2–10	✓	✓	Not done—sizable
Protecting mangroves	2–10	✓	✓	Not done—sizable
Making water resources management more resilient	2–6	✓	✓	Not done—sizable

Source: Global Commission on Adaptation (2019).

The commission's global assessment is supported by other more localized data and analysis. For example, Dicker et al. (2021) assess the benefits of investing in climate adaptation and resilience measures across six case studies, ranging from heat action plans in India to tackling urban flood risk in Mozambique. Drawing on existing evaluation reports assessing project impacts and supplementing this with other publicly available information and a series of expert interviews, the authors find a triple dividend of direct avoided losses, induced economic benefits, and wider environmental, social, and governance benefits. These include both quantified benefits, such as an 8 percent increase in annual household income in three Kenyan counties due to improved climate adaptation planning and financing (second dividend), and nonquantified benefits, such as the multipurpose use of cyclone shelters as schools and health centers or meeting venues for village councils and women's groups in Odisha, India (third dividend).

Apergi et al. (2020) find that investments in early warning systems in coastal areas of Tanzania offer benefits across all three dividends, including (1) reducing the number of deaths and damage to boats, (2) higher incomes for fishing communities and improved household economic planning, and (3) less damage to coastal areas. Fung et al. (2020) analyze the impacts of flood protection investment in Cedar Rapids, Iowa, following severe flooding in 2008. They find that these investments made the city more resilient to natural disasters and avoided losses, and also helped revitalize neighborhoods through commercial and residential development. These efforts, aimed at attracting a more dynamic workforce, provided second and third dividends in the form of benefits for the local economy and social systems. To quantify the second dividend, Fung et al. (2020) develop an ex ante Computable General Equilibrium model for the regional economy to compare how pre- and postresilience Cedar Rapids responds to the same simulated nondisaster shock (population growth, export demand, and total factor productivity), with a differential response to investment in greater resilience. Methodologically, rather than comparing the return on a resilient investment relative to a nonresilient investment, the authors calculate the resilience dividend as the net benefits associated with employment and income growth in the absence of a disaster event—this is the second dividend. The neighborhood revitalization benefits resulted in higher levels of employment in high-productivity sectors, such as business services and finance insurance, which increased total factor productivity by 37 percent between 2007 and 2015. Fung et al. (2020) also note that a new dual-purpose amphitheater, which serves as both flood levee and outdoor concert and event venue, likely yields additional amenity values, analogous to the third dividend of resilience.

The integrated approach enables a comparison of the relative size of the three dividends for different types of projects, which is the focus of the next section. It is worth asking whether a project with larger second and third dividends than first dividend might be called an "adaptation" instead of a "development" project. But more important than nomenclature here is the continuous spectrum of projects with lesser and greater ratios of second and third dividends to the first. The importance of this working paper lies in showing how all three dividends are integrated, and summing across them all can help stimulate greater financial flows toward climate adaptation.

2. QUANTIFYING THE TRIPLE DIVIDEND: CASE STUDY EVIDENCE

This section takes a closer look at seven case studies in four countries assessing the first, second, and third dividend of adaptation and resilience-building interventions. The case studies span six adaptation projects targeting different categories of climate change impacts: forests and wildfires, urban flooding and drainage, stormwater management, coastal flooding, urban heat islands, and drought (see Table 4). All costs and benefits are taken from the source materials and given in present values. Estimated values are based on a mix of ex ante project analysis and ex post evaluations (see the note to Table 5 for details). Appendix A gives greater detail on how the triple dividend is calculated for one project, the urban heat island investment in Philadelphia (United States).

The following subsections provide brief summaries of each of the various categories of adaptation actions and a description of how each case generated first, second, and third dividends. This section concludes with a comparative economic and financial analysis across the cases, illustrating the relative importance of each dividend for each case study. The analysis shows that in all cases, valuing the three dividend types makes a significant difference in assessing total project benefits.

2.1 Forest resilience: Example from Tahoe National Forest (United States)

Forests store up to 65 percent of the world's terrestrial organic carbon and play an important role in mitigating climate change (Reichstein and Carvalhais 2019). More than 1.6 billion people depend on forests for subsistence, employment, and income generation, and the sector contributes roughly 1 percent to global gross domestic product (Campos Arce 2019). In the United States, forests remove 12–14 percent of the nation's greenhouse gas emissions each year through carbon sequestration (EPA 2022). However, as climate change increasingly threatens the range of ecosystem services provided by the world's forests—including wood and nontimber products, protection against natural hazards, nutrient cycling, water purification, and recreation—protecting and restoring forest landscapes has come into greater focus as a key adaptation strategy.

Table 4 | **Cases selected for full quantification of the triple dividend**

CATEGORY	CASE	FIRST DIVIDEND (AVOIDED LOSSES)	SECOND DIVIDEND (INDUCED ECONOMIC BENEFITS)	THIRD DIVIDEND (SOCIAL AND ENVIRONMENTAL BENEFITS)
Forests and wildfires	Tahoe National Forest (United States)	Reduces tree loss, and loss of water supply and hydropower	Increases renewable energy generated from biomass, creates employment	Mitigates climate change, conserves nature, improves health
Urban flooding and drainage	Kunshan Forest Park (China)	Reduces flood losses	Increases real estate and commercial values, decreases water consumption	Improves health, air quality, water, and biodiversity; mitigates climate change
Stormwater management	Princes Park (Australia)	Reduces tree loss, and loss of water supply	Saves water pre- and postdrought	Abates pollution, providing recreation and amenity, reduces temperature on hot days
Coastal flooding	Felixstowe (United Kingdom)	Reduces coastal property losses due to coastal erosion	Increases tourism to seaside town, gives pier redevelopment confidence it would not flood	Restores gardens and recreation
Urban heat islands	Washington, DC, and Philadelphia (United States)	Reduces death and sickness, reduces tourism loss	Increases tourism and employment, reduces energy use and costs	Improves health, reduces emissions
Drought	Ningxia (China)	Reduces crop yield loss	Reduces land degradation and increases water use efficiency	Reduces loss of soil nutrients and pollution from agricultural runoff

Following a series of record-shattering wildfire seasons, improving the resilience of forests and associated ecosystems is a key challenge in the American West. In California, 6–9 million acres of forest land urgently need restoration by removing excess vegetation. Yet insufficient funding is provided, and more intense and costly wildfires have forced the U.S. Forest Service to divert funds away from activities focused on fire prevention and forest restoration to activities for fire suppression. Intensified by climate change and poor forest management, the 2018 and 2020 fires, the two most destructive wildfire seasons on the West Coast to date, caused a combined $46 billion in economic losses, primarily through property damage and firefighting costs. In addition to the human lives claimed by the flames, smoke from the 2020 wildfires considerably worsened air quality in West Coast population centers, contributing to thousands of excess deaths (Burke at al. 2021).

In California, the financial innovation of the Yuba Forest Resilience Bond (FRB) brought public and private investors together to initiate forest restoration at a faster pace and scale. At the project's inception, the most immediate anticipated benefits were the reduced incidence of large and destructive forest fires and their associated costs through better vegetation management, including thinning trees, clearing brush, and ensuring diverse plant cover. Expected benefits also included water quality protection, the prevention of sediment and woody debris accumulation in freshwater supplies, increased streamflow by reducing forest water use, a reduction in flood risk due to exposed soils, reduced carbon emissions, and the promotion of rural community development. The FRB's annual impact reports for 2019 and 2020 show that after two years in operation, many economic, social, and environmental benefits had already been realized. Stretching across all three dividends, the total value of quantified actual benefits up to 2021 is nearly $23 million, resulting in a BCR of 5.75 (our calculations based on Burke et al. 2021).

2.2 Wetland resilience: Examples from Kunshan Forest Park (China) and Princes Park (Australia)

Wetlands have been referred to as a "three-for-one deal" for their ability to store and sequester large amounts of carbon (roughly a third of the terrestrial total), provide a range of ecosystem services, and play an important role in climate change adaptation, reducing the impact of natural hazards such as flooding, landslides, or storm surges (Ponzio et al. 2019). Investing in healthy and well-managed wetlands therefore presents a high-impact opportunity for both the public and private sectors.

Kunshan Forest Park in China is subject to the same severe flooding that poses major risks to life, livelihoods, and economic activity across the country. In October 2021, the Shanxi Province floods displaced more than 1.7 million people and added to the RMB 65 billion price tag left by the Henan floods just three months earlier. The growing damages and losses from floods across China have resulted in attempts to increase local resilience and adaptative capacity, including investments in flood detention areas and restoring wetlands. In 2016, the Kunshan Forest Park Company initiated an ecological renovation project aimed at protecting and restoring the Kunshan forest urban wetland in order to increase its water drainage and storage capacity, improve water and air quality, and realize a range of other benefits. To do so, the company built several artificial lakes and wetlands with water circulation systems continuously pumping water from the lake through the wetlands to remove water pollutants, and then back to the lake via small solar pumps. The lake system doubles as a rainwater storage space to improve overall capacity and control flooding. Wishart et al. (2021) quantify all three dividends, including reduced flood losses (first dividend), increased real estate and commercial values (second dividend), and improvements in health, air quality, biodiversity, and carbon sequestration (third dividend). With an overall BCR of 49.6, the authors observe, the project's benefits far outweigh its costs. Its quantified third dividend benefits are nearly five times greater than its quantified first and second dividend benefits combined.

Princes Park in Melbourne, Australia, is a major metropolitan parkland and a prominent sports and recreational space that attracts heavy use well beyond the local community. The City of Melbourne identified Princes Park as a major water user and developed a stormwater harvesting scheme to significantly reduce the park's use of potable water for irrigation. Princes Park illustrates the importance of taking an encompassing view to building a more resilient water supply system: when only avoided losses are considered, the BCR drops to 0.6, meaning the costs outweigh the benefits. Yet using a CBA to quantify the various different benefits of the scheme and considering all three dividends, Morgan (2021) finds a BCR of 1.9. To reach this conclusion, a stakeholder workshop identified both development benefits valued with market prices (such as changes in savings or expenditures) and nonmarket social and environmental benefits (such as keeping sporting grounds open, maintaining the physical and mental health benefits of green spaces, and improving soil condition). Morgan then quantifies these social and environmental externalities using a relevant willingness-to-pay survey.

2.3 Coastal and flood resilience: Example from Felixstowe (United Kingdom)

Climate change is increasing the risks of flooding from severe rainfall and rising seas and rivers. Roughly 40 percent of the world's population lives within 60 miles of the coast, and more than 600 million people live in coastal areas less than 10 meters above sea level (United Nations 2017). As hurricanes and storms become more intense, storm and storm surge risks to coastal communities increase. Sea level rise further amplifies these risks and adds the threat of tidal flooding. According to McKinsey, with warming of 1.5°C, 11 percent of the global land area will experience a significant increase in flooding, while warming of 2.0°C almost doubles the area at risk (Woetzel et al. 2020).

The United Kingdom is one of the European countries most vulnerable to sea level rise and coastal flood risk. More than 6 million people live in flood-prone areas, with around a third of those exposed to frequent flooding from coastal, fluvial, or surface water sources (Sayers et al. 2017). Under a high-emissions scenario, the risk of storm surges and coastal erosion is increased by higher sea levels projected to rise to 0.90 meters in Edinburgh and 1.15 meters in London by the end of the century (Met Office 2022). For residential properties alone, expected annual economic losses from flooding are projected to more than triple, from £351 million in 2017 to £1.1 billion, by the 2080s (Sayers et al. 2017). Significant investments in adaptation and resilience are necessary to prevent further increases in flood risk and prepare for impacts, especially in low-lying seaside towns along the East Coast of England.

The town of Felixstowe, home to the United Kingdom's largest container port, is affected by the triple risk of coastal flooding, coastal erosion, and surface water flooding. In 2009, a seafront protection project was built, shielding the town's seafront over a length of 1.3 kilometers. Roezer et al. (2021) assess the costs and benefits over the project's 100-year lifetime by estimating avoided losses and damage to coastal properties and critical infrastructure, including commercial properties, amenity beaches, and recreational gardens. Taking into account the increasing coastal erosion and risk of storm surges due to sea level rise, they show that compared with a "do nothing" scenario, losses and damage to over 1,491 properties can be prevented, with a total NPV of £148.3 million. The total cost of the project over its lifetime, including maintaining the beach recharge every 20 years, is estimated at £12.7 million, resulting in a BCR of 11.3.

Roezer et al. (2021) also aim to better understand the project's additional second and third dividends, drawing on a study by Coastal Partnership East. A main factor in the decision to fund the project was the expected negative impact of coastal erosion and flood risk on Felixstowe's local tourism industry (which accounts for 13 percent of the income of the local authority district). Based on visitor gains between 2012 and 2015 (after the project was completed) and compared with a "no project" scenario, the initial benefits were increased by 87 percent, resulting in higher benefits. Coastal protection triggered major public and private investments in restoring Felixstowe as a resort town, including new and refurbished hotels, completion of major commercial developments that had stalled due to concerns over climate risks, restoration of the late-Victorian Spa Gardens, and other amenities like a new boardwalk, new retail, and pop-up businesses. With quantified third dividend benefits included, the project's overall BCR increases to 31.8.

2.4 Urban heat resilience: Examples from Washington, DC, and Philadelphia (United States)

Cities around the world are facing an enormous challenge improving their resilience to climate change impacts. Heat waves, often lethal to urban residents, have already struck cities from the United States to Europe, the Middle East, and India, and their frequency will rise as the planet warms. Urban parks, increased tree cover, green roofs, reflective pavements, and lower energy use can all help to reduce the urban heat island (UHI) effect—the excess heat that accumulates in urban areas.

Increased urban temperatures have largely negative knock-on effects on urban communities' resilience and quality of life through greater air pollution, decreased water quality, higher energy consumption, worse human health, and lower human (labor) productivity. Higher energy demand for cooling can overload systems and cause rolling brownouts or blackouts, multiplying the above effects while also driving up GHG emissions. A 2017 study of 1,692 cities around the world found that the

UHI effect is likely to add an additional 2°C on top of regular warming projections for the most populated cities by 2050, resulting in economic losses up to 2.6 times higher than average (Estrada et al. 2017). The study's cost-benefit analyses of UHI mitigation measures, such as cool roofs and pavements, showed these to be cost-effective. Yet they have not been widely adopted, partly due to a lack of data quantifying their benefits.

Assessing the costs and benefits of citywide adoption of cool roofs, reflective pavements, photovoltaic solar, and increasing tree and vegetative cover in Washington, DC, and Philadelphia, Kats and Glassbrook (2018) find that such interventions create large net benefits across the second and third dividends. These benefits are especially strong for low-income neighborhoods, which are disproportionately and negatively affected by hotter temperatures and poor air quality and inherently less resilient to climate change impacts. The NPV of citywide adoption of the various surface technologies ranges from $1.8 billion for Washington, DC, to $3.6 billion for Philadelphia. The NPV rises to $4.9 billion for Washington, DC, and $8.4 billion for Philadelphia when losses due to avoided summer tourism are included.

Looking more closely at disadvantaged neighborhoods such as North Philadelphia and Ward 5 in Washington, DC, Kats and Glassbrook (2018) show how applying smart surface solutions on a citywide basis would greatly benefit low-income, predominantly ethnic and minority communities. For example, the health benefits to residents of Washington's mixed-income Ward 5 are 50 percent greater than for the average city resident. An absolute increase of 10 percent in tree canopy across Philadelphia's neighborhoods would result in twice as much benefit to North Philadelphians as to residents of the richer southern parts of the city, due to the comparative lack of tree cover in low-income areas. Low-income renters in the two cities spend a far greater share of their income on energy costs than do higher-income renters (10 percent compared to 2 percent). This means that the realized energy savings have five times greater social value in these disadvantaged neighborhoods, demonstrating the critical role triple dividend interventions can play in advancing an equity agenda.

2.5 Drought resilience: Example from Ningxia (China)

Drought frequency and severity are projected to increase across the Global South and North, with a significant intensification expected in dry, subtropical regions and extreme summer drought establishing itself a new normal by the end of the 21st century under the highest temperature scenarios (Balting et al. 2021). The effects of droughts can range from disrupting agricultural production to severe water and food shortages and, in the worst cases, competition and conflict over suddenly scarce resources. As the number of people and places affected by drought grows rapidly, drought adaptation strategies have increasingly been assessed to better understand their costs and benefits and establish their viability. For example, a 2021 cost-benefit analysis of water scarcity and drought adaptation strategies in the lower Teesta basin of Bangladesh found positive BCRs ranging from 1.07 to 4.7 for interventions such as employing different irrigation practices and shifting from rice to maize farming (Arfanuzzaman et al. 2021).

China is increasingly affected by drought and water scarcity. By assessing 55-year daily precipitation data, Zhang et al. (2019) find a climate-induced prolonging of consecutive dry-day and extreme summertime droughts in northern China since the 1990s. Projecting drought losses under different global warming scenarios, Su et al. (2018) find that a 1.5°C rise in global average surface temperatures will increase China's drought losses by a factor of 10 compared with the 1986–2005 reference period and a factor of three compared with 2006–15.

Ningxia is a water-stressed province in northwestern China, and its inhabitants suffer from chronic drought. The agricultural sector, the largest water user, is particularly vulnerable to a changing climate. Projecting mild and severe drought risks in the next 30 years and resulting in depressed crop yields of up to 30 percent, Ding et al. (2021) find that the Ningxia water-saving irrigation project generates high revenue overall and demonstrates good induced economic benefits from water savings and increased crop output. Indeed, the quantified economic benefits, using a shadow pricing method, are 15 times greater than avoided losses and third dividend benefits, such as reduced soil erosion and reduced agricultural pollution, combined, resulting in a BCR of 5.6.

2.6 Findings from the cases

The case study summary in Table 5 shows the value of more fully quantifying the triple dividend of adaptation investments in different sectors, scales, and country contexts.

All cases shown below are highly feasible, with BCRs ranging from 1.9 to 49.6. Even more important, in all cases, the second and third dividends alone generate BCRs greater than 1 even when the value of avoided losses is not included. Without including the second and third dividends, the BCRs of two of the projects (Princes Park and Ningxia drought management) drop below 1, and the projects become nonviable. It should be noted that some projected benefits may be too optimistic, as not all studies have benefited from ex post evaluation.

Table 5 | **Overview of triple dividend case studies and breakdown of the dividends**

CATEGORY	FORESTS AND WILDFIRES	URBAN FLOODING AND DRAINAGE	STORMWATER MANAGEMENT	COASTAL FLOODING	URBAN HEAT ISLANDS (TWO U.S. CITIES IN ONE STUDY)		DROUGHT
	Tahoe National Forest (United States)	Kunshan Forest Park (China)	Princes Park (Australia)	Felixstowe (United Kingdom)	Washington, DC	Philadelphia	Ningxia (China)
1. Project cost	$4 million	$1.2 million	$6.7 million	$20.3 million	$838 million	$2.38 billion	$1.97 billion
2. Project benefits	$22.9 million	$59.7 million	$12.7 million	$644.9 million	$5.75 billion	$10.78 billion	$11.05 billion
3. First dividend	$18 million	$6.8 million	$3.7 million	$307.1 million	$3.16 billion	$5.57 billion)	$0.11 billion
4. Second dividend	$3.3 million	$3.6 million	$1.7 million	$327.1 million	$1.7 billion	$2.21 billion	$10.36 billion
5. Third dividend	$1.6 million	$49.3 million	$7.3 million	$10.7 million	$885 million	$3.0 billion	$0.58 billion
6. Benefit-cost ratio: first dividend only (= 3/1)	4.5	5.6	0.6	15.1	3.8	2.3	0.06
7. Benefit-cost ratio: second and third dividends only (= (4 + 5)/1)	1.2	44.0	1.3	16.7	3.1	2.2	5.5
8. Benefit-cost ratio: all three dividends (= (3 + 4 + 5)/1)	5.7	49.6	1.9	31.8	6.9	4.5	5.6

Notes: All costs and benefits are taken from the source materials and given in present values. All dollar amounts US$. Totals may not add up due to rounding. Local currency amounts are converted to US$ equivalent using the International Monetary Fund's 2021 average exchange rates. Benefits in the Tahoe and Kunshan cases are based on ex post evaluations. The Felixstowe case represents a mix of ex ante projections done at the time of project appraisal and ex post values done at the time of project evaluation. Benefits in all remaining cases are based on ex ante projections.

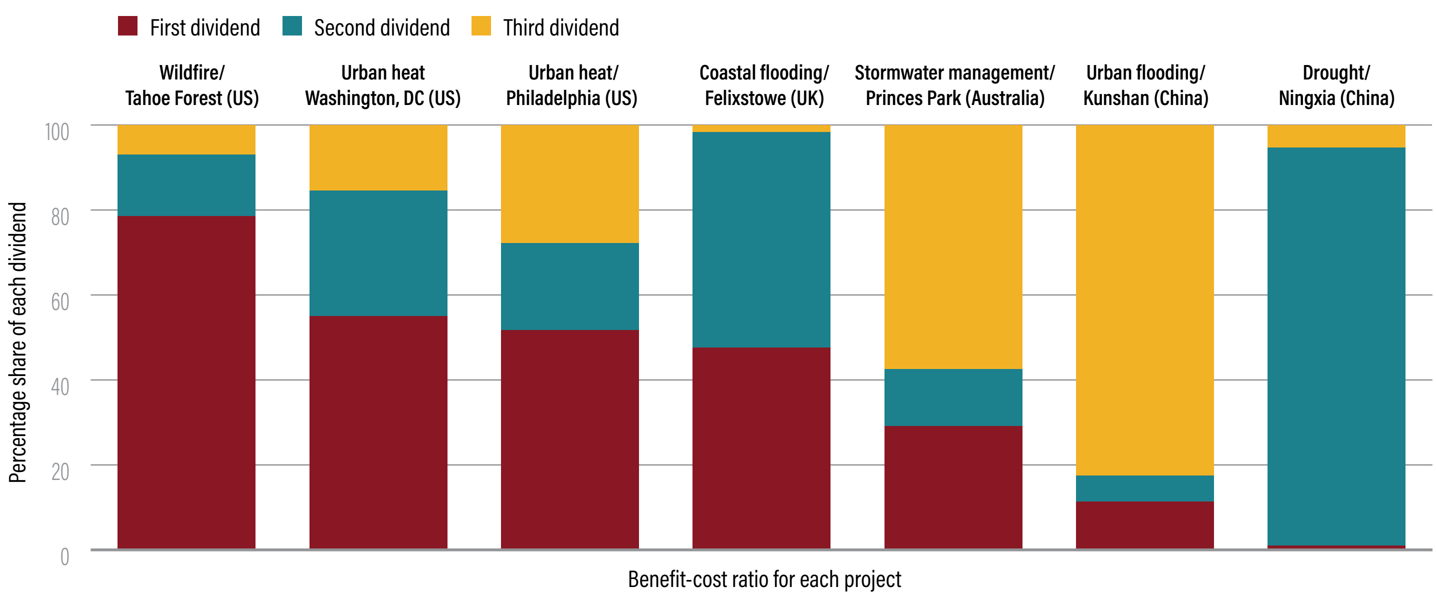
Sources: See individual project descriptions.

The size of each dividend type as a share of total benefits varies greatly across all projects. As shown in Figure 1, avoided losses make up over half of total benefits in only two of the seven projects. While avoided losses were the single-largest dividend for three projects (improved management of forest wildfires and urban heat), second and third dividend benefits play a significantly greater role in the remaining four. For two projects—coastal flooding and agricultural drought management—the induced development benefits were the largest category, accounting for 52–94 percent of the benefits. For two other projects—stormwater management and urban drainage and flooding—the environmental and social benefits were the largest category, accounting for 55–82 percent of total benefits.

While not statistically representative of all adaptation investments, this sample shows that the second and third dividends combined are often larger than the first. While a larger number of projects needs to be assessed to establish more generalizable patterns, a number of insights emerge from the sample:

- Avoided losses are the largest category of benefits for wildfire and urban heat, where projected damages are acute, localized, and often associated with loss of life. Preventing such loss of life brings high economic benefits to the first dividend.
- All projects involving water, such as drainage and stormwater management, urban and coastal flooding, and drought management in agricultural areas, have induced development and nonmarket dividends that exceed the avoided losses.
- Investments to improve drainage, flood control, and drought-related water shortages are typically geographically extensive and often involve "green" infrastructure that builds resilience through large-scale restoration of watersheds, wetlands, and coastal areas. They have lower levels of avoided deaths in the first dividend and high second and third dividend values for two main reasons: first, by reducing systemic water-related risks in urban areas they reduce costs and induce new development; second, they are often at a scale that produces high environmental benefits in the form of ecosystem services.

Figure 1 | **Each triple dividend as a share of total project benefits**



Note: Projects sorted in order of declining share of benefits for avoided losses [first dividend].

Source: Table 5.

From the data, it is clear that a wide range of adaptation investments can have much higher returns than simply avoided losses, and that fully valuing their benefits increases their attractiveness in determining investment priorities. With the increasing demand for adaptation investments, and the greater supply of climate adaptation finance, it will become more important to demonstrate the second and third dividends in CBA. As the data and methodologies generally exist to conduct full valuation of adaptation investment benefits, not doing so represents a flaw in project appraisal that severely underrepresents the full value of adaptation investments, especially when anticipated risk never materializes at all.

3. PRACTITIONER VIEWS ON THE TRIPLE DIVIDEND OF RESILIENCE

We circulated a survey among 70 adaptation and resilience researchers from academia and NGOs, as well as among donors, in order to better understand the state of play of triple dividend concepts and practice. Of the 30 respondents, 90 percent reported that either they or their organization analyzed climate adaptation interventions, and 87 percent were aware of the triple dividend concept. When asked "what kind of benefits of climate adaptation interventions have you assessed," two said "avoided losses," one said "environmental benefits," two said "other," but most (22) said "all of the above," including economic and social benefits. Further, 79 percent of the respondents could name an example of the triple dividend concept being used. Among these were a World Health Organization project, "Building Adaptation to Climate Change in Health in LDCs through Resilient Water, Sanitation and Hygiene (WASH)"; an Asian Development Bank project, "Road Network Upgrading Sector Project in Timor-Leste"; the Keep Safe Miami Affordable Housing Program; the European Investment Bank's Sustainable Ocean Fund; and the UK Government's COP26 Presidency narrative.

Most important, the survey supported the idea that improved awareness and application of the full benefits of climate adaptation interventions will help facilitate increased adaptation investment. Nearly all respondents (97 percent) agreed with the statement, "An improved understanding of the triple dividend would help governments or private firms scale up climate adaptation interventions."

The survey illustrates that researchers and practitioners are increasingly aware of the TDR approach, increasingly considering the full range of benefits in appraising projects, and believe that assessing triple dividends will build a useful and growing evidence base of the full benefits of adaptation interventions.

4. MOVING FORWARD: LESSONS LEARNED AND THE FUTURE OF TDR RESEARCH

This stocktake of the TDR literature to date and review of key examples of the triple dividend in practice have revealed a number of insights that, coupled with the survey results, hold important lessons for researchers and practitioners operating in a quickly evolving field. Since estimating and aggregating all three dividends dramatically increases the projected BCRs of adaptation investments, promoting ways to scale up an integrated TDR approach has merit.

Adequately accounting for the many varied benefits of resilience interventions is complex and challenging. Some dividends are not commonly quantified, while others lack sufficient data and analysis. Recent research has begun to fill existing gaps, drawing on a range of well-established methodologies, such as increased attention to valuing natural capital in CBA. But other topics, such as the technically difficult task of assessing the additionality of climate adaptation measures without a clearly defined baseline and in the face of long-term uncertainty, need collaborative research. As the cases presented in this working paper illustrate, current practice is evolving from defining and establishing the concept toward applying it to climate resilience interventions in practice. The ability of 79 percent of survey respondents to name one or more concrete examples of the TDR concept in use is an encouraging sign for the further refinement of triple dividend approaches, especially as regards the more difficult quantification of nonmarket social and environmental benefits.

TDR research needs to gather more evidence across sectors, scales, and regions. The cases presented in this working paper are only the start of what is needed. Our analysis points to a number of recommendations to help scale up the financing of effective climate adaptation interventions. CBAs of interventions ranging from small forest management to big city infrastructure projects are increasingly returning data for the second and third dividend of resilience-building in addition to the more commonly quantified first dividend of avoided losses. Yet such comprehensive analyses are more the exception than the rule and are still lacking for low- and middle-income country cases. More detailed ex ante analysis, as well as ex post assessment, is needed to enable better decision-making in both the Global North and South.

One topic that clearly merits additional work is the equity aspects of adaptation investments, particularly at the local level. The work should include both benefits to marginalized groups (e.g., through increased tree cover or reflective roofs and pavements that alleviate urban heat island effects) and potentially negative effects of such interventions (e.g., that greater tree cover increases real estate values, which might drive up the cost of living and push out marginal groups). While valuing these aspects of social impacts is part of CBA theory, such valuation is rarely done in practice. The climate adaptation research agenda offers an opportunity to build up an important evidence base.

TDR research needs to improve resilience indicators and converge on what benefits can and should be quantified, especially for the second and third dividends. The differences across the cases presented above illustrate a common problem of CBA, that is, that the selection of what is and is not included can seem somewhat arbitrary and may be used to justify a decision after it has already been taken. A better understanding of what can usefully be included in TDR-aligned assessments is important if different options are to be effectively compared. This includes robust and transparent methodologies, showing exactly how results have been calculated.

Further progress is also needed to better define the precise scope and time frame of each dividend and the parameters required to effectively measure the "with" and "without" impacts of many different types of projects. For example, creating such internationally aligned parameters could be taken up within the physical risks remit of the Task Force on Climate-Related Financial Disclosure (Swann and Miller 2019). To fill data gaps, additional work is required to ensure adequate baseline data collection for each defined parameter, and to allow systematic tracking of those parameters during project implementation. Such improvements will also make the economic and financial analysis more directly useful to private investors and commercial banks, who will be increasingly interested in the quantification of induced development benefits that may provide business opportunities.

Research findings need to be easily accessible and effectively communicated, perhaps through a donor-led community of practice, if they are to guide future research and influence decision-making. The narrative power of the TDR concept derives from its ability to raise awareness about many so-far-unrecognized and underresearched benefits of investments in adaptation and resilience-building. Yet decisions on which interventions to pursue require more than identifying the presence of multiple dividends or, indeed, quantifying them. Policymaking is rarely purely evidence-based, but economic and financial analysis is a critical element. Evidence of the multiple dividends of resilience interventions can inform policy and investment decisions if advocated effectively. Doing so requires a more informed understanding by researchers of how such evidence is used and in which contexts, recognizing that the political economy underpinning them matters (Tanner et al. 2019). A more comprehensive methodological TDR guidance note would be a valuable follow-up to this working paper. In addition, greater capacity-building will be required to improve standard practice.

The public and private sectors both stand to benefit from increased use of the triple dividend approach. Both sectors need more detailed information to help guide their choices, a point backed up by both the cases and the survey: all but 1 of the 30 respondents agreed that resilience interventions will be scaled up if their benefits are more fully quantified and the triple dividend is better understood. The public sector will need to redress the persistent imbalance between climate mitigation and adaptation investments, understanding the societal dividends that accrue from increased climate resilience, and using limited resources smartly to catalyze private sector funding flows. The private sector will need a better understanding of how climate change–related risk and return calculations can illustrate the financial benefits to be gained through the second dividend, in addition to improving knowledge of the various induced economic benefits that flow from resilience investments.

Donors and governments should commit to implementing the TDR approach in project appraisals. Agreement on a comprehensive assessment framework would enable more consistent project analysis, thereby fostering improved comparative analysis of adaptation options and prioritizing those found to have the largest impact. The cases analyzed here reveal that different assessment frameworks may return substantially different benefit-cost ratios, complicating an effective comparative analysis of adaptation options. A more standardized framework to assess the triple dividends could help avoid both bias in selecting individual benefits to consider and an under- or overvaluation of those benefits. It would also simplify data collection by making core indicators clear and standardized by project type.

CONCLUSION

As this working paper has shown, the evolving theoretical discussion of the TDR concept is increasingly supported by empirical evidence. Results from the case studies presented above reveal that full accounting of all three dividends shows vastly increased potential benefits for several different adaptation investment types. Importantly, estimating the full triple dividend captures benefits that accrue even when climate disasters do not occur. Neglecting the second and third dividends means neglecting benefits associated with economic regeneration, job creation, increased tourism, improved air and water quality, better health outcomes, more recreational opportunities, greater species diversity and plant cover, better educational opportunities, energy savings, reduced GHG emissions, and improved social equity. These benefits often match or even exceed the value of avoided losses.

A shift in thinking is needed for both the public and private sectors to mobilize sufficient funds and catalyze greater investment in resilience interventions. This working paper lays out several strategies to help achieve this. More consistent and transparent research and informed advocacy are needed. Only then can solutions be effectively catalyzed and scaled, enabling both the Global North and South to build sufficient adaptive capacity and resilience in the face of a changing climate.

APPENDIX A. AN EXAMPLE OF A FULL TRIPLE DIVIDEND ASSESSMENT: THE CASE OF URBAN HEAT ISLANDS IN PHILADELPHIA

Table A1 summarizes Kats and Glassbrook's (2018) main findings on the cost-effectiveness of citywide adoption of five key climate adaptation measures (cool roofs, green roofs, solar photovoltaic, reflective pavements, and urban trees) to address urban heat island effects in Philadelphia over a 40-year period, based on 2015 data. The overall cost is split into initial cost and running costs. Benefits valued include avoided tourism losses and emergency health impacts through avoided heat mortality (first dividend); energy cost savings, reduced stormwater runoff, and increased employment opportunities (second dividend); improved air quality and climate change mitigation (third dividend). All costs and benefits quantified are in present value. The report details explicit assumptions underpinning each of the benefits identified, as well as term and discount rates.

Table A1 | **Costs and benefits of citywide adoption of urban heat island adaptation measures in Philadelphia**

CATEGORY	PRESENT VALUE OVER 40-YEAR ANALYSIS PERIOD (BILLION US$)	COSTS OR BENEFITS
Overall cost	**2.38**	
First cost	1.56	Costs
O & M	0.491	
Additional replacements	0.334	
Employment training	0.003	
Overall benefits	**10.78**	
Avoided tourism loss	4.81	First dividend
Emergency health impacts	0.758	
Employment	0.471	Second dividend
Energy (generation from PV, peak energy load reduction, cost savings)	1.33	
Financial incentives (financial support schemes offered for solar PV installation)	0.225	
Stormwater retention/runoff reduction	0.185	
Health improvements (ozone reduction, PM2.5 reduction)	1.53	Third dividend
Climate change (GHG emissions reduction)	1.47	

Note: GHG = greenhouse gas; O&M = operation and management; PM = particulate matter; PV = photovoltaic.

Source: Authors based on Kats and Glassbrook (2018).

APPENDIX B. SURVEY DETAILS

The survey instrument below was sent in the spring of 2021 to about 70 adaptation and resilience researchers from academia and nongovernmental organizations, as well as to donors.

The World Resources Institute, SOAS University of London, and the LSE Grantham Research Institute on Climate Change are currently working on a project assessing the current state of research and practice on the triple dividend of climate adaptation and resilience interventions.

We would greatly value your participation in a very brief survey to help us establish the thinking of leading experts in this space. The survey will only take two minutes to complete and responses are anonymized.

The triple dividend of building climate resilience

Introduction

The triple dividend concept is simple. It holds that climate adaptation projects have benefits that go beyond "avoided losses" (i.e., the damages that would otherwise occur from climate change). The cost-benefit analysis of adaptation projects, therefore, should also value the additional economic, social, and environmental benefits that may accrue regardless of whether the climate threat occurs or not.

1. Are you aware of the triple dividend concept?

☐ Yes

☐ No

2. Do you or your organization analyze climate adaptation interventions?

☐ Yes

☐ No

3. If yes, what kind of benefits of climate adaptation interventions have you assessed?

☐ Avoided loss/damage

☐ Economic development

☐ Social development

☐ Environmental protection

☐ All of the above

☐ Other (please specify)

4. In your experience, would an improved understanding of the triple dividend help governments or private firms scale up climate adaptation interventions?

☐ Yes

☐ No

5. Can you name a specific example of the triple dividend concept being used?

☐ Yes

☐ No

☐ Please specify example

Thank you for completing the survey.

REFERENCES

Aon. 2020. *Weather, Climate and Catastrophe Insight: 2019 Annual Report*. London: Aon.

Apergi, M., E. Wilkinson, and M. Calderone. 2020. *The "Triple Dividend" of Early Warning Systems: Evidence from Tanzania's Coastal Areas*. London: Overseas Development Institute. http://cdn-odi-production.s3-website-eu-west-1.amazonaws.com/media/documents/202006_odi_triple_dividend_wp_final.pdf.

Arfanuzzaman, S.M. Hassan, and M.A. Syed. 2021. "Cost-Benefit of Promising Adaptations for Resilient Development in Climate Hotspots: Evidence from Lower Teesta Basin in Bangladesh." *Journal of Water and Climate Change* 21 (1): 44–59.

Balting, D.F., A. AghaKouchak, G. Lohmann, and M. Ionita. 2021. "Northern Hemisphere Drought Risk in a Warming Climate." *npj Climate and Atmospheric Science* 4 (61): 1–13.

Bertilsson, L., K. Wiklund, I. de Moura Tebaldi, O.M. Rezende, A.P. Veról, and M.G. Miguez. 2019. "Urban Flood Resilience: A Multi-criteria Index to Integrate Flood Resilience into Urban Planning." *Journal of Hydrology* 573: 970–82.

Botzen, W.J.W., O. Deschenes, and M. Sanders. 2019. "The Economic Impacts of Natural Disasters: A Review of Models and Empirical Studies." *Review of Environmental Economics and Policy* 13 (3): 167–88.

Boudreaux, C.J., M.P. Escaleras, and M. Skidmore. 2019. "Natural Disasters and Entrepreneurship Activity." *Economics Letters* 182: 82–85.

Braese, J., J. Rentschler, and S. Hallegatte. 2019. "Resilient Infrastructure for Thriving Firms: A Review of the Evidence." World Bank Policy Research Working Paper 8895. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/31915.

Burke, M., A. Driscoll, S. Heft-Neal, and M. Wara. 2021. "The Changing Risk and Burden of Wildfire in the United States." *Proceedings of the National Academy of Sciences* 118 (2): 1–6.

Campos Arce, J.J. 2019. "Forests, Inclusive and Sustainable Economic Growth and Employment." Background study prepared for the 14th session of the United Nations Forum on Forests. https://www.un.org/esa/forests/wp-content/uploads/2019/04/UNFF14-BkgdStudy-SDG8-March2019.pdf.

Dicker, S., S. Unsworth, R. Byrnes, and B. Ward. 2021. *Saving Lives and Livelihoods: The Benefits of Investments in Climate Change Adaptation and Resilience*. London: Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics and Policy, London School of Economics and Political Science. https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2021/03/Saving-lives-and-livelihoods_the-benefits-of-investments-in-climate-change-adaptation-and-resilience.pdf.

Ding, H., T. Yu, W. Xi, L., Lu, W.K. Fong, Y. Cao, S. Kuang, et al. 2021. "Accelerating Climate-Resilient Infrastructure Investment in China." Washington, DC: World Resources Institute. https://wri.org.cn/sites/default/files/2021-12/accelerating-climate-resilient-infrastructure-investment-in-china-summary-report-EN.pdf.

EPA (U.S. Environmental Protection Agency). 2022. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2020." https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2020.

Estrada, F., W.J.W. Botzen, and R.S.J. Tol. 2017. "A Global Economic Assessment of City Policies to Reduce Climate Change Impacts." *Nature Climate Change* 7: 403–6.

Fung, J.F., J. Helgeson, D. Webb, C. O'Fallon, and H. Cutler. 2020. "Does Resilience Yield Dividends? Co-benefits of Investing in Increased Resilience in Cedar Rapids." *Economic Systems Research* 33 (3): 336–62.

Global Commission on Adaptation. 2019. *Adapt Now: A Global Call for Leadership on Climate Resilience*. Global Center on Adaptation and World Resources Institute. https://files.wri.org/s3fs-public/uploads/GlobalCommission_Report_FINAL.pdf.

Guo, J., D. Kubli, and P. Saner. 2021. *The Economics of Climate Change: No Action Not an Option*. Zurich: Swiss Re Institute. https://www.swissre.com/institute/research/topics-and-risk-dialogues/climate-and-natural-catastrophe-risk/expertise-publication-economics-of-climate-change.html.

Hallegatte, S., J. Rentschler, and J. Rozenberg. 2019. *Lifelines: The Resilient Infrastructure Opportunity*. Sustainable Infrastructure series. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/31805.

Kats, G., and K. Glassbrook. 2018. *Delivering Urban Resilience*. Washington, DC: Capital-E. https://smartsurfacescoalition.org/analysis/delivering-urban-resilience-full-report.

McCormick, K., and S. Marshall. 2015. *Returns on Resilience: The Business Case*. Washington, DC: Urban Land Institute.

McNamara, K.E., R. Westoby, and A. Chandra. 2021. "Exploring Climate-Driven Non-economic Loss and Damage in the Pacific Islands." *Current Opinion in Environmental Sustainability* 50: 1–11.

Mechler, R., and S. Hochrainer-Stigler. 2019. "Generating Multiple Resilience Dividends from Managing Unnatural Disasters in Asia: Opportunities for Measurement and Policy." ADB Economics Working Paper Series 601. Manila: Asian Development Bank. https://www.adb.org/sites/default/files/publication/545766/ewp-601-resilience-dividends-unnatural-disasters-asia.pdf.

Menéndez, P., I.J. Losada, S. Torres-Ortega, S. Narayan, and M.W. Beck. 2020. "The Global Flood Protection Benefits of Mangroves." *Scientific Reports* 10 (4404): 1–11.

Mensah, J.T. 2018. "Jobs! Electricity Shortages and Unemployment in Africa." Policy Research Working Paper 8415. Washington, DC: World Bank. https://openknowle dge.worldbank.org/handle/10986/29717.

Met Office. 2022. *UK Climate Projections: Headline Findings*. Exeter, UK: Met Office. https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18_headline_findings_v4_aug22.pdf.

Morgan, C. 2021. *INFFEWS Worked Example: Princes Park Stormwater Harvesting*. Melbourne, Australia: Cooperative Research Centre for Water Sensitive Cities. https://watersensitivecities.org.au/wp-content/uploads/2021/05/PC1881-INFFEWS-worked-example-Princes-Park-final.pdf.

Multi-hazard Mitigation Council. 2019. *Natural Hazard Mitigation Saves: 2019 Report*. Washington, DC: National Institute of Building Sciences. https://www.nibs.org/files/pdfs/NIBS_MMC_MitigationSaves_2019.pdf.

Oberholzer, B., A. Knep, and M. Vögeli 2017. *Valuing the Resilience Dividend*. Basel, Switzerland: Global Infrastructure Basel Foundation.

Olazabal, M., I. Galarraga, J. Ford, E.S. de Murieta, and A. Lesnikowski. 2019. "Are Local Climate Adaptation Policies Credible? A Conceptual and Operational Assessment Framework." *International Journal of Urban Sustainable Development* 11 (3): 277–96.

Oseni, M.O. 2019. "Costs of Unreliable Electricity to African Firms." Energy for Growth Hub, memo. https://www.energyforgrowth.org/memo/costs-of-unreliable-electricity-to-african-firms/.

Penning-Rowsell, E., N. Haigh, S. Lavery, and L. McFadden. 2013. "A Threatened World City: The Benefits of Protecting London from the Sea." *Natural Hazards* 66: 1383–404.

Ponzio, K.J., T. Osborne, G. Davies, B. LePage, P.V. Sundareshwar, S. Miller, A. Bochnak, et al. 2019. "Building Resiliency to Climate Change through Wetland Management and Restoration." In *Wetlands: Ecosystem Services, Restoration and Wise Use*, edited by S. An and J. Verhoeven, 255–309. Cham, Switzerland: Springer.

Reichstein, M., and N. Carvalhais. 2019. "Aspects of Forest Biomass in the Earth System: Its Role and Major Unknowns." *Surveys in Geophysics* 40 (4): 693–707.

Roezer, V., S. Surminski, F. Laurien, C. McQuistan, and R. Mechler. 2021. "Multiple Resilience Dividends at the Community Level: A Comparative Study on Disaster Risk Reduction Interventions in Different Countries." Centre for Climate Change Economics and Policy Working Paper 385 / Grantham Research Institute on Climate Change and the Environment Working Paper 357. London: London School of Economics and Political Science. https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2021/04/working-paper-385-Roezer-et-al-1.pdf.

Sayers, P., M. Horritt, E. Penning-Rowsell, and J. Fieth. 2017. *Present and Future Flood Vulnerability, Risk and Disadvantage: A UK Scale Assessment*. Report for the Joseph Rowntree Foundation. Watlington, UK: Sayers and Partners. http://www.sayersandpartners.co.uk/uploads/6/2/0/9/6209349/sayers_2017_-_present_and_future_flood_vulnerability_risk_and_disadvantage_-_final_report_-_uploaded_05june2017_printed_-_high_quality.pdf.

Serdeczny, O. 2019. "Non-economic Loss and Damage and the Warsaw International Mechanism." In *Loss and Damage from Climate Change*, edited by R. Mechler, L.M. Bouwer, T. Schinko, S. Surminski, and J. Linnerooth-Bayer, 205–20. Cham, Switzerland: Springer.

Su, B., J. Huang, T. Fischer, Y. Wang, Z.W. Kundzewicz, J. Zhai, H. Sund, et al. 2018. "Drought Losses in China Might Double between the 1.5°C and 2.0°C Warming." *Proceedings of the National Academy of Sciences* 115 (42): 10600–605.

Surminski, S., and T. Tanner, eds. 2016. *Realising the "Triple Dividend of Resilience": A New Business Case for Disaster Risk Management.* Cham, Switzerland: Springer.

Swann, S., and A. Miller. 2019. *Driving Finance Today for the Climate Resilient Society of Tomorrow*. Washington, DC: UNEP-FI and Global Commission on Adaptation. https://www.unepfi.org/wordpress/wp-content/uploads/2019/07/GCA-Adaptation-Finance.pdf.

Tanner, T., S. Surminski, E. Wilkinson, R. Reid, J. Rentschler, and S. Rajput. 2015. "The Triple Dividend of Resilience: Realising Development Goals through the Multiple Benefits of Disaster Risk Management." Washington, DC: World Bank. https://www.gfdrr.org/sites/default/files/publication/The_Triple_Dividend_of_Resilience.pdf.

Tanner, T., R.U. Zaman, S. Acharya, E. Gogoi, and A. Bahadur. 2019. "Influencing Resilience: The Role of Policy Entrepreneurs in Mainstreaming Climate Adaptation." *Disasters* 43: S388–S411.

Turner, K., T. Badura, and S. Ferrini. 2019. *Valuation, Natural Capital Accounting and Decision-Support Systems: Process, Tools and Methods*. Synthesis report. University of East Anglia Centre for Social and Economic Research on the Global Environment.

UK Environment Agency. 2021. "Thames Estuary 2100 (TE2100)." Policy paper. London: UK Government. https://www.gov.uk/government/publications/thames-estuary-2100-te2100.

United Nations. 2017. "Factsheet: People and Oceans." https://www.un.org/sustainabledevelopment/wp-content/uploads/2017/05/Ocean-fact-sheet-package.pdf.

UNEP (UN Environment Programme). 2021. *Adaptation Gap Report 2021*. Nairobi: United Nations. https://www.unep.org/resources/adaptation-gap-report-2021.

UNFCCC (UN Framework Convention on Climate Change). 2013. "Non-economic Losses in the Context of the Work Programme on Loss and Damage." Technical paper. Bonn, Germany: UNFCCC Secretariat. http://unfccc.int/resource/docs/2013/tp/02.pdf.

Vousdoukas, M.I., L. Mentaschi, J. Hinkel, P.J., Ward, I. Mongelli, J. Ciscar, and L. Feyen. 2020. "Economic Motivation for Raising Coastal Flood Defenses in Europe." *Nature Communications* 11 (2119): 1–11.

Wishart, M., T. Wong, B. Furmage, X. Liao, D. Pannell, and J. Wang. 2021. *The Gray, Green, Blue Continuum: Valuing the Benefits of Nature-Based Solutions for Integrated Urban Flood Management in China*. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/35687.

WMO (World Meteorological Association). 2022. *United in Science 2022*. Geneva: WMO.

Woetzel, J., D. Pinner, H. Samandari, H. Engel, M. Krishnan, B. Boland, and P. Cooper. 2020. "Can Coastal Cities Turn the Tide on Rising Flood Risk?" McKinsey Global Institute Case Study. https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Sustainability/Our%20Insights/Can%20coastal%20cities%20turn%20the%20tide%20on%20rising%20flood%20risk/MGI-Can-coastal-cities-turn-the-tide-on-rising-flood-risk.pdf.

World Bank. 2013. *Strong, Safe, and Resilient: A Strategic Policy Guide for Disaster Risk Management in East Asia and the Pacific*. Directions in Development series. Washington, DC: World Bank.

Yaron, G., and D. Wilson. 2020. "Estimating the Economic Returns to Community-Level Interventions That Build Resilience to Flooding." *Journal of Flood Risk Management*, 1–11.

Zhang, J., H. Chen, and Q. Zhang. 2019. "Extreme Drought in the Recent Two Decades in Northern China Resulting from Eurasian Warming." *Climate Dynamics* 52: 2885–902.

ADDITIONAL SOURCES

ADB (Asian Development Bank). 2019. *Asian Development Outlook 2019: Strengthening Disaster Resilience*. Manila: Asian Development Bank Institute. https://www.adb.org/sites/default/files/publication/492711/ado2019.pdf.

AfDB (African Development Bank). n.d. "Adaptation Benefits Mechanism (ABM)." Information note. https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/ABM_-_Giving_resilience_a_value_-_Pilot_phase_information_note.pdf.

Bain, P.G., T.L. Milfont, Y. Kashima, M. Bilewicz, G. Doron, R.B. Garôarsdóttir, V.V. Gouveia, et al. 2016. "Co-benefits of Addressing Climate Change Can Motivate Action around the World." *Nature Climate Change* 6 (2): 154–57.

Bond, C.A., A. Strong, N. Burger, and S. Weilant. 2017. *Guide to the Resilience Dividend Valuation Model*. Santa Monica, CA: RAND Corporation. https://www.rand.org/pubs/research_reports/RR2130.html.

de Murieta, E.S. 2020. "Ancillary Benefits of Adaptation: An Overview." In *Ancillary Benefits of Climate Policy: New Theoretical Developments and Empirical Findings*, edited by W. Buchholz et al., 181–96. Cham, Switzerland: Springer Nature.

Dottori, F., L. Mentaschi, A. Bianchi, L. Alfieri, and L. Feyen. 2020. *Adapting to Rising River Flood Risk in the EU under Climate Change*. JRC Technical Report. Brussels: European Commission. https://publications.jrc.ec.europa.eu/repository/handle/JRC118425.

Douris, J., and G. Kim. 2021. *WMO Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970–2019)*. Geneva: World Meteorological Organization. https://library.wmo.int/doc_num.php?explnum_id=10989.

Fung, J.F., and J.F. Helgeson. 2017. "Defining the Resilience Dividend: Accounting for Co-benefits of Resilience Planning." NIST Technical Note 1959. Washington, DC: U.S. Department of Commerce, National Institute of Standards and Technology. https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1959.pdf.

Helgeson, J., J. Fung, C. O'Fallon, D. Webb, and H. Cutler. 2018. "A Computable General Equilibrium Model of Cedar Rapids." Washington, DC: U.S. Department of Commerce, National Institute of Standards and Technology. https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.2029.pdf.

Hu, X., R. Pant, J.W. Hall, S. Surminski, and J. Huang. 2019. "Multi-scale Assessment of the Economic Impacts of Flooding: Evidence from Firm to Macro-level Analysis in the Chinese Manufacturing Sector." *Sustainability* 11: 1–18.

Karlsson, M., E. Alfredsson, and N. Westling. 2020. "Climate Policy Co-benefits: A Review." *Climate Policy* 20 (3): 292–316.

Levine, S. 2014. *Assessing Resilience: Why Quantification Misses the Point*. London: Overseas Development Institute. https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/9049.pdf.

Markandya, A., and P. Watkiss. 2009. "Potential Costs and Benefits of Adaptation Options: A Review of Existing Literature." UNFCCC Technical Paper. F CDCeCce/mTPb/e2r0, 20090, 29. https://unfccc.int/resource/docs/2009/tp/02.pdf.

Pesaro, G., M.T. Mendoza, G. Minucci, and S. Menoni. 2018. "Cost-Benefit Analysis for Non-structural Flood Risk Mitigation Measures: Insights and Lessons Learnt from a Real Case Study." In *Safety and Reliability: Safe Societies in a Changing World*, edited by S. Haugen et al., 109–18. London: CRC Press.

Preston, C.J. 2017. "Challenges and Opportunities for Understanding Non-economic Loss and Damage." *Ethics, Policy & Environment* 20 (2): 143–55.

Singh, C., M. Madhavan, J. Arvind, and A. Bazaz. 2021. "Climate Change Adaptation in Indian Cities: A Review of Existing Actions and Spaces for Triple Wins." *Urban Climate* 36: 100783.

Sverdlik, A., D. Mitlin, and D. Dodman. 2019. "Realising the Multiple Benefits of Climate Resilience and Inclusive Development in Informal Settlements." New York: C40 Cities Climate Leadership Group. http://urbanresiliencehub.org/wp-content/uploads/2019/11/C40-Climate-Resilience-Inclusive-Housing.pdf.

Wang, K., Y.D. Aktas, J. Stocker, D. Carruthers, J. Hunt, and L. Malki-Epshtein. 2019. "Urban Heat Island Modelling of a Tropical City: Case of Kuala Lumpur." *Geoscience Letters* 6 (4): 1–11.

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

The authors would like to thank the following reviewers: Alvaro Rojas Ferreira, Emanuele Massetti, Helen Ding, Juan Carlos Altamirano, Ken Chomitz, Michael Toman, Valerie Laxton, and Vivek Venkatramani. We also thank Alex Martin, Emilia Suarez, Emily Matthews, Rebecca Carter, and Romain Warnault for help throughout WRI's review and editorial process. While our colleagues were very generous with their time and input, this working paper reflects the views of the authors alone.

ABOUT THE AUTHORS

Harald Heubaum is Associate Professor in Global Energy and Climate Policy, and Deputy Director of the Centre for Sustainable Finance, SOAS University of London.
Contact: hh15@soas.ac.uk.

Carter Brandon is Senior Fellow at World Resources Institute (WRI).
Contact: Carter.Brandon@wri.org.

Thomas Tanner is Director of the Centre for Development, Environment and Policy at SOAS University of London.
Contact: tt43@soas.ac.uk.

Swenja Surminski is Head of Adaptation Research at the Grantham Research Institute on Climate Change and the Environment at the London School of Economics and Political Science.
Contact: s.surminski@lse.ac.uk.

Viktor Roezer is a Research Fellow at the Grantham Research Institute on Climate Change and the Environment at the London School of Economics and Political Science.
Contact: v.roezer@lse.ac.uk.

ABOUT WRI

World Resources Institute is a global research organization that turns big ideas into action at the nexus of environment, economic opportunity, and human well-being.

Our Challenge

Natural resources are at the foundation of economic opportunity and human well-being. But today, we are depleting Earth's resources at rates that are not sustainable, endangering economies and people's lives. People depend on clean water, fertile land, healthy forests, and a stable climate. Livable cities and clean energy are essential for a sustainable planet. We must address these urgent, global challenges this decade.

Our Vision

We envision an equitable and prosperous planet driven by the wise management of natural resources. We aspire to create a world where the actions of government, business, and communities combine to eliminate poverty and sustain the natural environment for all people.

Our Approach

COUNT IT

We start with data. We conduct independent research and draw on the latest technology to develop new insights and recommendations. Our rigorous analysis identifies risks, unveils opportunities, and informs smart strategies. We focus our efforts on influential and emerging economies where the future of sustainability will be determined.

CHANGE IT

We use our research to influence government policies, business strategies, and civil society action. We test projects with communities, companies, and government agencies to build a strong evidence base. Then, we work with partners to deliver change on the ground that alleviates poverty and strengthens society. We hold ourselves accountable to ensure our outcomes will be bold and enduring.

SCALE IT

We don't think small. Once tested, we work with partners to adopt and expand our efforts regionally and globally. We engage with decision-makers to carry out our ideas and elevate our impact. We measure success through government and business actions that improve people's lives and sustain a healthy environment.

Copyright 2022 World Resources Institute. This work is licensed under the Creative Commons Attribution 4.0 International License.
To view a copy of the license, visit http://creativecommons.org/licenses/by/4.0/