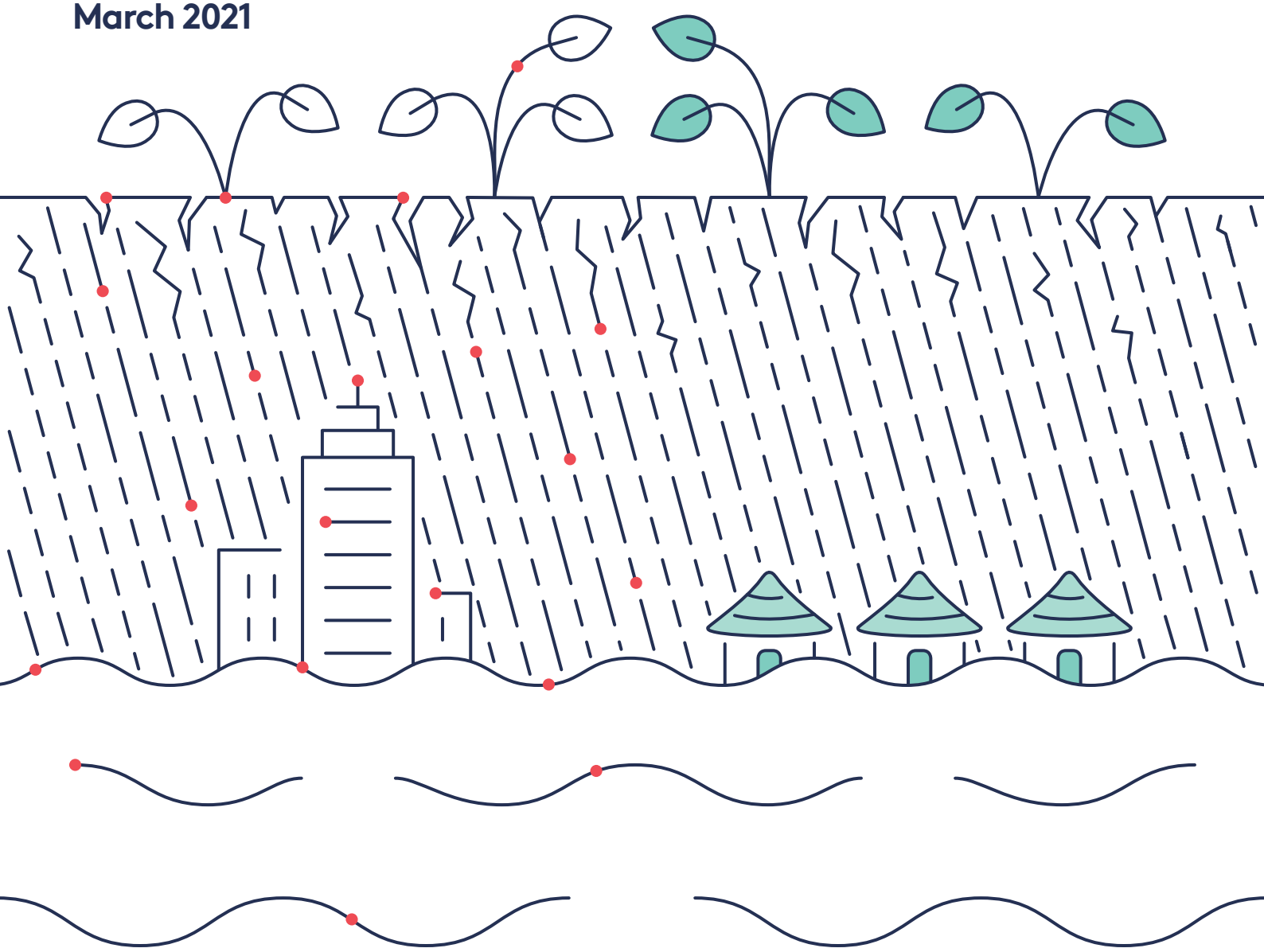
Saving lives and livelihoods: The benefits of investments in climate change adaptation and resilience

Sophie Dicker, Sam Unsworth, Rebecca Byrnes and Bob Ward

March 2021



LSE

Grantham Research Institute on Climate Change and the Environment

Centre for Climate Change Economics and Policy

The Centre for Climate Change Economics and Policy (CCCEP) was established in 2008 to advance public and private action on climate change through rigorous, innovative research. The Centre is hosted jointly by the University of Leeds and the London School of Economics and Political Science. It is funded by the UK Economic and Social Research Council.
www.cccep.ac.uk

The Grantham Research Institute on Climate Change and the Environment was established in 2008 at the London School of Economics and Political Science. The Institute brings together international expertise on economics, as well as finance, geography, the environment, international development and political economy to establish a world-leading centre for policy-relevant research, teaching and training in climate change and the environment. It is funded by the Grantham Foundation for the Protection of the Environment, which also funds the Grantham Institute – Climate Change and Environment at Imperial College London.
www.lse.ac.uk/grantham/

About the authors

Sophie Dicker is a Policy Analyst at the Grantham Research Institute on Climate Change and the Environment.

Sam Unsworth and Rebecca Byrnes are former Policy Analysts at the Grantham Research Institute on Climate Change and the Environment.

Bob Ward is Policy and Communications Director of the Grantham Research Institute on Climate Change and the Environment.

Acknowledgements

The authors thank the following for their useful comments on an earlier draft of this report: Mihir Bhatt, Aditi Paul, Florence Crick, Tim Reeder, Laura Littleton, Alvina Erman, Bontje Marie Zangerling, Phong Tran, Architesh Panda, Nicola Ranger, Martin Prowse, Swenja Surminski. Georgina Kyriacou copy-edited the report. Funding from the Grantham Foundation for the Protection of the Environment and the ESRC through the Centre for Climate Change Economics and Policy is gratefully acknowledged.

The authors declare no conflict of interest in the preparation of this report. The views in the report remain those of the authors and do not necessarily represent those of the host or funding institutions. Any errors and omissions remain the authors' own.

This paper was first published in March 2021 by the Grantham Research Institute on Climate Change and the Environment and the Centre for Climate Change Economics and Policy.

Suggested citation: Dicker S, Unsworth S, Byrnes R and Ward B (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.

Contents

Summary 1

1. Introduction: climate change adaptation in context 4

2. Making the case for financing climate change adaptation 8

3. Our approach 12

4. Case studies 13

Case study 1. Heat Action Plan in Ahmedabad, India 13

Case study 2. Devolved climate finance in arid and semi-arid counties of Kenya 18

Case study 3. Microcredit and technical assistance for typhoon resilient housing in Da Nang, Vietnam 24

Case study 4. Adaptation Pathways planning in the Thames Estuary 2100 Programme, UK 28

Case study 5. 'Grey and green' responses to urban flood risk in Beira, Mozambique 31

Case study 6. Cyclone risk mitigation in Odisha, India 37

5. Conclusions and recommmendations 44

Appendix: Defining climate change adaptation 48

References 49

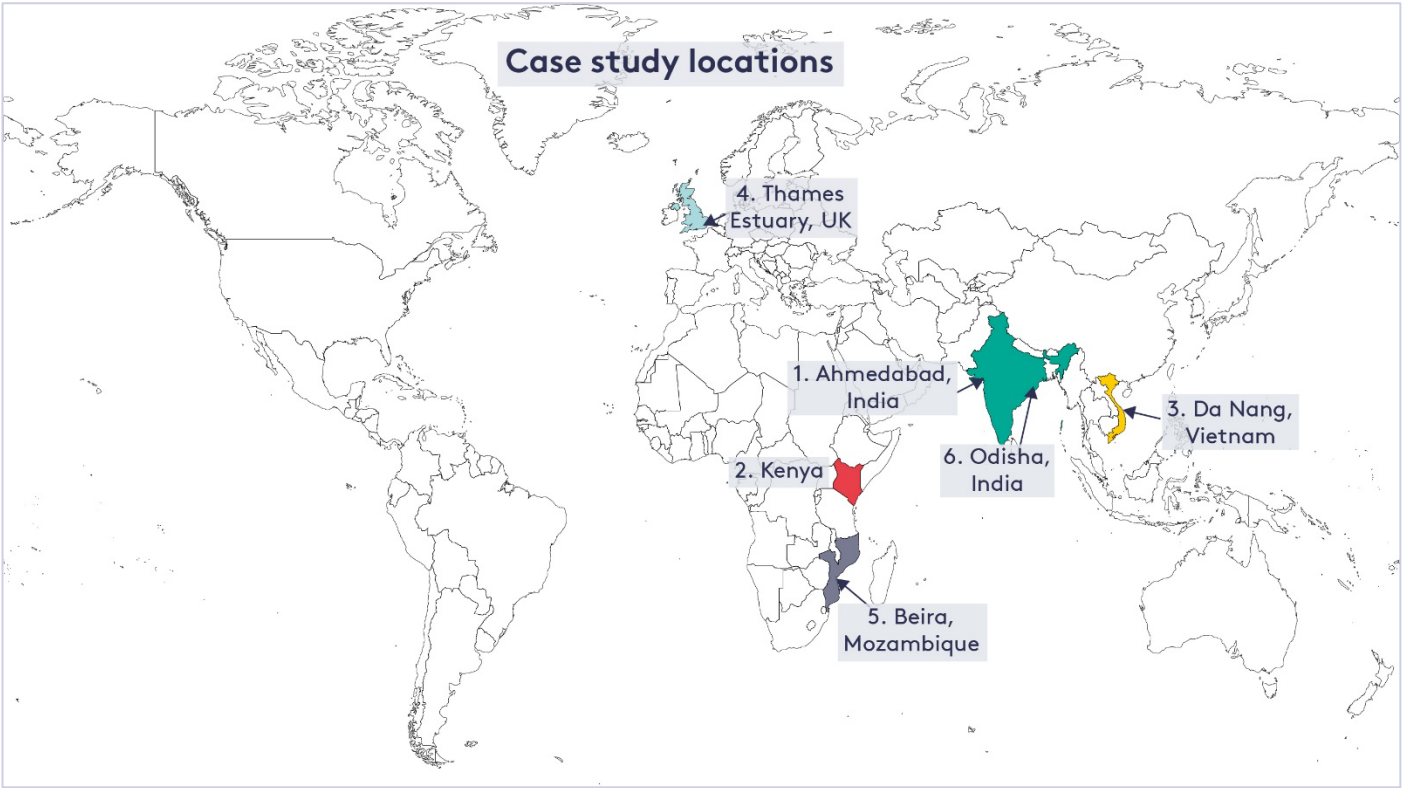
Summary

Adaptation to and resilience against the impacts of climate change are urgent and growing priorities around the world as levels of greenhouse gases in the atmosphere continue to increase. Impacts such as sea level rise and changes in the frequency and intensity of extreme weather events, including heavy rainfall, tropical storms and heatwaves, are a threat to lives and livelihoods around the world. These impacts undermine economic development and efforts to eliminate poverty and raise living standards. Indeed, efforts to achieve the Sustainable Development Goals are being harmed by climate change impacts that are already occurring. It is the poorest people in every country who are usually most vulnerable and exposed to these impacts. And these impacts will continue to grow until global emissions of greenhouse gases are reduced effectively to [net] zero.

Investing in climate change adaptation and resilience can be an extremely cost-effective way of protecting communities, livelihoods and businesses, and promoting economic development and growth.

Case study findings

This report highlights six case studies of successful climate change adaptation and resilience, mostly in developing countries. We assess the impacts of specific adaptation and resilience processes, the benefits gained and the lessons learned.



Some highlights from the six case studies include:

- **In Ahmedabad, India, a city-led Heat Action Plan has significantly reduced heat-related mortality and morbidity**, with an estimated 1,190 average deaths avoided per year. The Plan has helped businesses avoid significant negative impacts on productivity, as well as indirectly creating employment opportunities, including for women and small businesses. The Plan also led to a focus on other health risks, such as poor air quality, with the development of a similar programme to combat air pollution, building on the capacity and networks developed by the Heat Action Plan. The Plan has now been used as a model for

more than 100 other heat-vulnerable cities and districts in India, and lessons have been taken up at the national level, as well as applied in other heat-vulnerable countries.

- **In arid and semi-arid regions of Kenya, devolved climate financing has helped to increase water availability**, leading to increased food security, cleaner water supplies and fewer livestock deaths, as well as strengthening and diversifying livelihoods. It has reduced reliance on migration as a coping mechanism, strengthened education opportunities, and has encouraged co-investments at the local level. The design of the funding mechanism has enhanced community-driven planning, local ownership and inclusion, including ensuring greater engagement from women and young people in planning processes. It has helped to integrate climate action into other planning and budgetary processes, and to support transparency and accountability in governance processes. The financing mechanism is now being scaled up nationwide.
- **In Da Nang, Vietnam, a micro-credit and technical assistance programme has developed typhoon-resilient housing** in vulnerable areas of the city. The houses engaged in the programme were able to withstand Typhoon Nari in 2013 without damage, while houses in other areas collapsed, had their roofs torn off and were flooded. The protected households reported feeling safer and more secure, meaning they were more able to be involved in income-generation activities. The intervention attracted further investment to encourage households to take up more resilient housing and was built on by the city government to develop a financial resilience strategy for Da Nang. The Government also adopted a new regulation requiring storm-resilient techniques in construction. The Da Nang Women's Union, a key delivery partner, has developed its capacity through the programme and is now a significant agent of change in climate change resilience for poor and vulnerable households in the city.
- **In the Thames Estuary, UK, long-term planning for flood risk management, including protection from surge tides, has averted serious flooding** in London and the estuary area. Assessment of the value of future avoided losses also indicates substantial benefits, including avoided fatalities and maintaining investor confidence, with indirect impacts on business of between £53bn and £58bn. The Plan – innovative at the time of development – has been replicated in other world cities such as New York, and has provided an important example of how to ensure long-term political support for adaptation measures. The adaptive pathways approach taken has ensured the effective and efficient use of public funds, and the inbuilt review process has supported collaboration with a range of key stakeholders, including businesses, councils, communities and non-governmental organisations.
- **In Beira, Mozambique, a holistic approach to urban flood risk, including combining engineering and nature-based interventions, has prevented the occurrence of previously frequent flooding.** It has created direct and indirect employment opportunities, including establishing the area as more conducive for businesses, and has improved housing conditions and decreased health risks related to flood water, like cholera. The creation of an urban park aims to create environmental benefits by lowering temperatures, supporting biodiversity, and promoting cleaner air, while also retaining water and providing a public space for social and cultural activities. The networks and capacity built by the adaptation process have supported the development of a comprehensive disaster response plan following Cyclone Idai, and lessons are being shared with other cities with similar risk profiles in the region.
- **In the state of Odisha, India, decades of action to reduce the vulnerability of coastal communities to cyclones has seen drastic decreases in death tolls.** In 2019 Cyclone Fani brought 64 fatalities whereas a cyclone of comparable strength in 1999 caused more than 8,900 deaths. 16,737 hectares of agricultural land were protected during Cyclone Fani, including against the salinisation of soils and water sources, with a greater proportion of livestock and property also protected. Multi-purpose cyclone shelters form a variety of roles

for communities when not being used as shelters, including for education and health purposes, and have contributed to local capacity-building and social cohesion. Improvements in roads and bridges to increase connectivity to shelters has also improved access to markets, schools and medical centres.

All six of these examples demonstrate the value of adaptation and resilience to prevent loss, damage and suffering. Yet it is widely acknowledged that not enough is being invested in these ex-ante measures to prevent and limit climate- and weather-related disasters now and in the future, despite clear evidence that they are more cost-effective than ex-post, emergency responses.

Recommendations

Based on the analysis of these six case studies, we identify eight key recommendations for both developed and developing countries:

1. All countries should give higher priority to investments in adaptation and resilience, and integrate them with policies and decisions to promote the transition to an inclusive zero-carbon economy.
2. Scale up the quantity of well-targeted finance available for climate change adaptation and resilience.
3. Increase the effectiveness of multilateral and bilateral funding by working with recipients to ensure it is targeted on both established and innovative climate change adaptation processes.
4. Decision-making frameworks for financing adaptation should recognise and value a diverse range of possible benefits that may result.
5. Target investment towards adaptation processes that include a focus on natural, knowledge, human and social capital and seek to scale up successful models, such as those that enhance existing institutions or result in legislative change.
6. Prioritise financing for adaptation for the most vulnerable people and ensure investments are embedded within the broader sustainable development and growth agenda.
7. Create and support platforms and networks for South–South, South–North and North–South learning and knowledge-sharing about adaptation processes.
8. Donors should increase support for robust, long-term, bottom-up and open-ended M&E for adaptation processes in order to strengthen and diversify the evidence base.

1. Introduction: climate change adaptation in context

Adaptation to climate change[1] is a crucial pillar of the sustainable growth and development story of the 21st century. Investing in resilient infrastructure, institutions, systems and natural capital has immediate benefits, while failing to do so can incur immediate and future locked-in costs, endanger lives and hinder entrepreneurship and economic activity. Improved resilience to climate change impacts achieved as a result of adaptation action is not only a protective measure to manage acute shocks and slow-onset hazards: it is also a driver of social and economic development.

This report uses six case studies, mostly from developing countries, to highlight examples of successful adaptation and resilience. It analyses specific adaptation and resilience processes, the benefits gained and the lessons learned, before making broader recommendations for all countries.

Adaptation and resilience in the Paris Agreement

The Paris Agreement seeks to reduce the impacts of climate change through its Article 7, which established "the global goal on adaptation of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development and ensuring an adequate adaptation response in the context of the temperature goal" (United Nations Framework Convention on Climate Change, 2015). It also recognises, in Article 8, "the importance of averting, minimizing and addressing loss and damage associated with the adverse effects of climate change, including extreme weather events and slow onset events, and the role of sustainable development in reducing the risk of loss and damage".

Further, Article 9 of the Agreement states: "Developed country Parties shall provide financial resources to assist developing country Parties with respect to both mitigation and adaptation", and "The provision of scaled-up financial resources should aim to achieve a balance between adaptation and mitigation, taking into account country-driven strategies, and the priorities and needs of developing country Parties, especially those that are particularly vulnerable to the adverse effects of climate change and have significant capacity constraints, such as the least developed countries and small island developing States, considering the need for public and grant-based resources for adaptation."

Climate impacts are undermining social and economic development

Nothwithstanding the Paris Agreement's stipulations, with the impacts of climate change already occurring and growing, a failure to adapt adequately is already costing lives and livelihoods around the world through weather- and climate-related disasters. A recent analysis published by the Centre for Research on the Epidemiology of Disasters and UN Office for Disaster Risk Reduction (2020) concluded that disasters of this nature are increasing in frequency, killing more than 500,000 people worldwide and affecting almost 4 billion between 2000 and 2019. The most recent Global Assessment Report on Disaster Risk Reduction (GAR19) concluded: "Climate change is increasing the risk of disaster – amplifying existing risk and creating new risks including the direct consequences of a warming planet – with cascading consequences in the short, medium and long term" (UN Office for Disaster Risk Reduction, 2019).

GAR19 also pointed out that the poorest people, in both developed and developing countries, often suffer the most from weather- and climate-related disasters because they are the most vulnerable. These people are also the least able to adapt to the impacts of climate change. While wealthy countries often suffer the highest absolute amounts of economic damage, it is lives and livelihoods in poor countries that are most likely to be destroyed by weather- and climate-related disasters, now and in the future.

[1] A note on how climate change adaptation is defined is included in the Appendix.

Indeed, these impacts undermine economic development and the achievement of the Sustainable Development Goals (SDGs) around the world, particularly in poor countries. The most recent assessment by the United Nations (2020) pointed out that "climate change continues to exacerbate the frequency and severity of natural disasters". It noted: "Biological hazards such as COVID-19, along with other hazards such as hurricanes, floods, earthquakes and wildfires, cause disasters and worsen poverty" and that the Least Developed Countries have been "disproportionately affected" by these disasters.

The COVID-19 pandemic has highlighted the extent to which human populations around the world are exposed and vulnerable to global threats such as infectious diseases, biodiversity loss and climate change. An obvious response should be to prioritise efforts to reduce the risks by maximising resilience against the potential future impacts of such global hazards. All countries should be seeking to accelerate their transition to economic development and growth that is both zero-carbon and climate-resilient. Yet, climate change adaptation is not sufficiently prioritised or financed – in developing or developed countries. This is shown, for instance, by the fact that the economic recovery packages from the COVID-19 pandemic put forward by countries have largely omitted investments in climate change adaptation and resilience.

Increasing the visibility of the benefits of adaptation investment

As investments in climate change adaptation are intended to reduce and prevent damage and harm from impacts, the returns can often be hidden. Indeed, it often seems that some politicians find it easier to respond to disasters than to minimise their adverse consequences in advance, even though there is abundant evidence that it is more cost-effective to limit and cut the risks. Investments in disaster risk reduction and management and climate change adaptation can shrink, but not completely eliminate, the consequences of current and future weather- and climate-related events, and so significantly decrease the costs of disaster emergency responses. However, as GAR19 pointed out, "the reduction of risk rarely features high on national political agendas" (UN Office for Disaster Risk Reduction, 2019).

Indeed, even before the pandemic, the required increases in the breadth and depth of investment for adaptation had not followed from the growing body of technical analysis of the benefits of existing adaptation processes. In addition to technical analysis, a new approach is required to generate sufficient funding for adaptation and resilience, particularly within existing financial flows – an approach that more clearly takes account of the value of investment in adaptation and resilience.

This report contributes to this new approach by making the benefits of such investments more visible. In the case studies that it highlights, adaptation has led to significant successes in minimising damage and harm, protecting revenue and developing economic, social, environmental and governance benefits. We focus on examples in developing countries and draw attention to the importance of investments by both donor and recipient countries. Our chosen case studies are based on robust evidence that shows harm and damage have been avoided in these locations due to effective adaptation and resilience.

Adaptation: an integral part of the sustainable development agenda

There is growing recognition of the value of transformative climate change adaptation and resilience. This approach emphasises the importance of taking a whole-systems approach to adaptation, highlighting that fundamental changes to these systems may be required to address root causes of vulnerability, as opposed to incremental adaptation measures or coping strategies (Fedele et al., 2019). For instance, this includes evaluating the resilience of global food systems in light of climate change, identifying vulnerabilities and employing a suite of transformative measures across linked areas such as global farming practices, value chains, diets and behaviours, policies and finance provision.

Reflecting these complex intersections within adaptation, the direct benefits of scaled-up climate change adaptation and resilience span across the areas covered by the Sustainable

Development Goals (SDGs). These benefits are created by reducing direct and indirect harm and damage from climate change impacts, stimulating economic activity by reducing risk, adapting agricultural systems to warming temperatures, limiting and addressing the spread of disease, managing water infrastructure, empowering local development through decentralised community energy, investing in sustainable and lasting infrastructure, reducing inequality within and between countries, and promoting better planning of urban environments.

Transformation of systems is required to achieve adequate climate change adaptation and resilience in many areas. For example, if food systems are to support current and future populations in a sustainable way and withstand the current and future impacts of climate change, transformation of the agricultural system is necessary (Steiner et al., 2020). Yet, to date there has been limited empirical research on transformational adaptation and the barriers it faces (Panda, 2018).

The need for more ex-ante investment

Climate change adaptation more widely has suffered from a lack of investment. According to the UN Environment Programme (2016a), in developing countries alone, adapting to climate change will require US$140–300bn per year by 2030, and US$280–500bn per year by 2050. However, an annual average of just US$22bn was invested worldwide in adaptation in 2015 and 2016, according to estimates by the Climate Policy Initiative (Richmond et al., 2020). A recent analysis by the Organisation for Economic Co-operation and Development found that of US$78.9bn of climate finance provided and mobilised in 2018 by developed countries for developing countries in the context of processes of the United Nations Framework Convention on Climate Change (UNFCCC), 70 per cent was earmarked exclusively for mitigation and only US$16.8bn was aimed solely at adaptation (OECD, 2020).

Speaking in January 2021, the United Nations Secretary-General, António Guterres, highlighted the lack of investment and stated that "donor countries and multilateral, regional and national development banks need to significantly increase the volume and predictability of their finance for adaptation and resilience". He called for "50 per cent of the total share of climate finance provided by all developed countries and multilateral development banks to be allocated to adaptation and resilience in developing countries" (Guterres, 2021).

It should be noted that the lack of investment in adaptation and resilience mirrors the lack of investment in disaster risk reduction (DRR). The Sendai Framework for Disaster Risk Reduction 2015–2030 (United Nations, 2015) set the following goal: "Prevent new and reduce existing disaster risk through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience." It set four priorities, including "investing in disaster risk reduction for resilience".

However, four years on from this goal being set, GAR19 found: "Financing for DRR has been highly volatile, ex post and marginal" (UNDRR, 2019). It pointed out that US$5.2bn was spent on DRR between 2005 and 2017, which represents only 3.8 per cent of total humanitarian financing, highlighting how neglected ex-ante investment is. While disaster relief finance is of critical importance from a development and humanitarian perspective, and can sometimes play a role in facilitating post-disaster adaptation and resilience-building, this is not always the case. Both ex-ante and ex-post finance must be recognised as necessary and complementary to effectively respond to risk. More ex-ante investment is therefore needed to limit and reduce the risks associated with climate change impacts now and in the future. This is the broad challenge that this report seeks to highlight by drawing together some case studies that show the wide-ranging benefits of strategic investments in climate change adaptation. Highlighting the positive impacts in this way should help to make the benefits from investments in adaptation more visible, enabling adaptation spending to be valued politically and institutionally on the same level as spending on disaster relief.

Structure of the report

The report begins with an overview of the importance of climate change adaptation, including how it can be financed and by whom, and a summary of the research approach and methodology. Six case studies then follow, describing different adaptation processes:

- Heat Action Plan in Ahmedabad, India
- Devolved climate finance in arid and semi-arid counties in Kenya
- Microcredit and technical assistance for typhoon-resilient housing in Da Nang, Vietnam
- 'Adaptation pathways' planning in the Thames Estuary 2100 Programme, UK
- 'Grey and green' responses to urban flood risk in Beira, Mozambique
- Cyclone risk mitigation in Odisha, India.

While the geographies, hazards, stakeholders, governance processes and sources of finance differ between the cases, each tells a story that illustrates the value that climate change adaptation and resilience can deliver.

The report concludes by identifying and summarising common themes that relate to best practice that should be shared, gaps in the current investment landscape and approaches to financing and adaptation practice that warrant rethinking. These themes inform a series of recommendations designed to help economies and communities around the world to realise the benefits offered by climate change adaptation.

2. Making the case for financing climate change adaptation

Investments are required urgently in making human, social, physical and natural capital climate-resilient, given that the impacts of climate change are already occurring. These include changes in the frequency and intensity of extreme weather events as well as slow-onset events such as sea level rise and desertification.

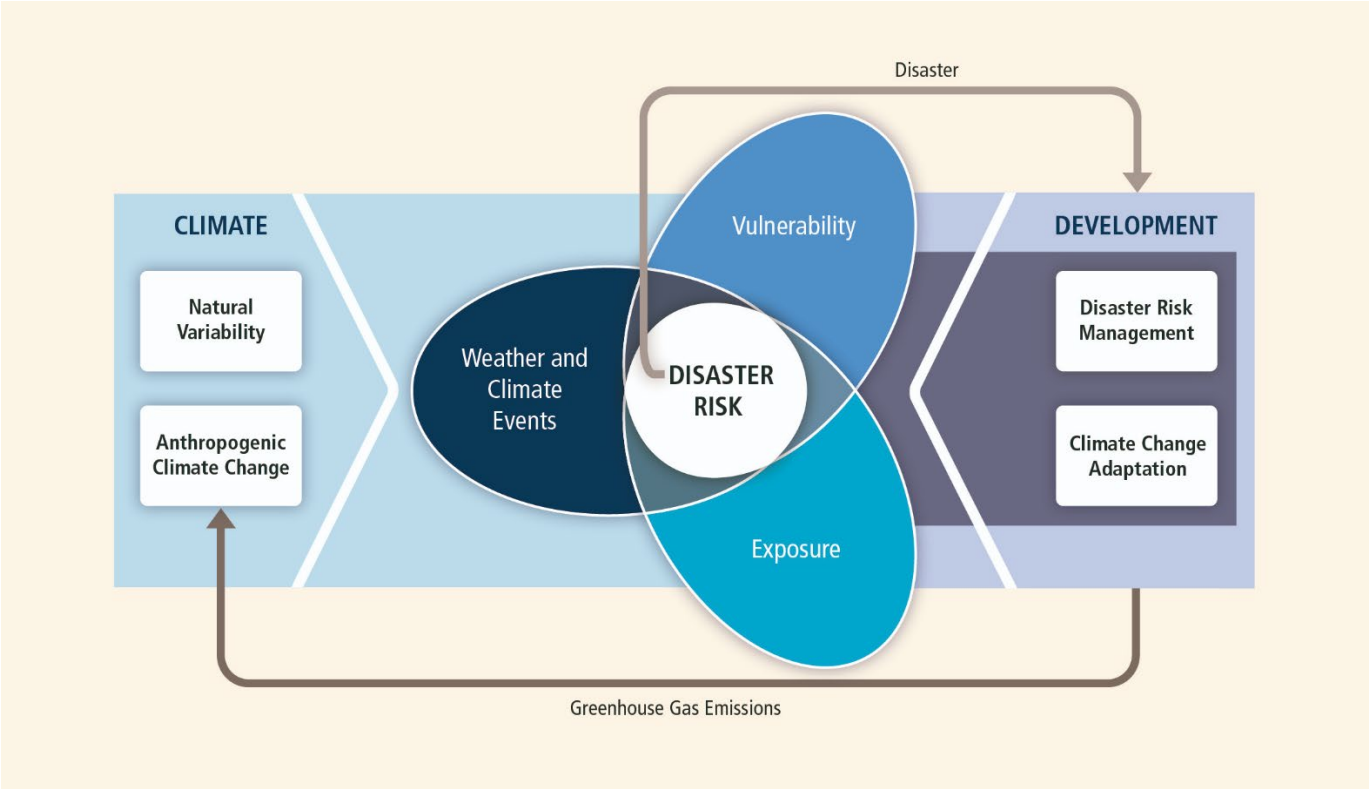
In this section we address three key questions regarding the investment case for adaptation: what constitutes climate change adaptation, where can investments in adaptation be targeted, and what returns can be expected from investments in climate change adaptation? We then outline potential sources of adaptation financing and identify some of the most significant political economy and institutional barriers to investment in adaptation to date.

What constitutes climate change adaptation?

Adaptation is understood as "changes in processes, practices and structures" to limit damages associated with the impacts of climate change already locked into the system, or to benefit from any opportunities associated with climate change where possible (UNFCCC, n.d.). Adaptation is rooted in principles of resilience, and relates to accounting and preparing for *future risks* that might be created by climate change, as well as today's risks. Climate change adaptation measures thus seek to respond to levels of risk that are altered by a changing climate. There can be differences between disaster risk reduction and management and climate change adaptation because climate- and weather-related hazards in the future could change.

Figure 2.1 sets out the key concepts related to adaptation which are used in this paper, while the Appendix provides a more detailed explanation of what constitutes adaptation.

Figure 2.1. Illustration of key concepts used in this paper



Source: Figure SPM.1 (IPCC, 2012)

Where can investments in adaptation be targeted?

Adaptation investment in physical capital

Infrastructure investment decisions today should be informed by an assessment of current and future risks. If long-term climate change is not accounted for appropriately, it could mean locking-in exposure and vulnerability to growing impacts, leading to higher costs, greater losses or wasted investments in the future (Ranger et al., 2013). Many major infrastructure developments have both long lead times and long lifetimes; for instance, bridges typically have lifetimes of at least 50 years, and drainage and sewerage systems typically last 60 to 100-plus years (see Rogers Gibson, 2017).

Due to the longevity of the built environment, there is a clear value in integrating considerations of adaptation and resilience into investment and decision-making processes to ensure that infrastructure is able to withstand the impacts of climate change in the future. In addition, existing infrastructure may need to be retrofitted, or managed differently, to account for climate change impacts. Climate change can undermine the critical infrastructure that enables many forms of economic activity. Many of these impacts are expected to occur at the same time and amplify each other, so could have immense implications for the functioning of economies, societies and ecosystems (IPCC, 2018).

Adaptation investments in natural capital

This form of adaptation investment involves the preservation or restoration of ecosystems and other forms of natural capital that can deliver adaptation benefits for both human societies and the natural world. It includes the improvement of soil fertility, landscaping for fire management, and the conservation and restoration of forest and riparian corridors, wetlands and mangroves. For example, mangrove forests can act as natural defences, protecting communities and other ecosystems from sea swells and tropical cyclones, while also providing ecosystems services (e.g. food and resources) to surrounding communities (Macintosh et al., 2012).

It may not be possible to define ecosystems-based adaptation as being clearly separate from disaster risk reduction and management, or broader ecosystems-focused measures. This is because ecosystems-based adaptation often consists of many of the same strategies and measures adopted in processes targeting ecological protection and restoration. Nonetheless, investments in natural capital, particularly when planned and implemented at a scale and breadth that recognise the challenges of future climate change, can play a key part in adaptation strategies.

Adaptation investments in human, social and knowledge capital

These investments allow societies to develop the capacity, capabilities and collective willingness and cohesion to respond to the hazards and risks created by climate change – both now and in the future – recognising the high degree of uncertainty facing societies today over future outcomes. The ability of societies to adapt is determined, in part, by their ability to act collectively, with climate change adaptation being a dynamic social process (Adger, 2003). Investment in human, social and knowledge capital is particularly valuable in models of community-based adaptation (Ensor et al., 2015), in which 'soft' adaptation investments (as opposed to 'hard' infrastructure projects) seek to build the adaptive capacity (and thus climate resilience) of communities for a range of possible future scenarios.

Examples of adaptation investments in these forms of capital include capacity-building activities for government officials to consider future climate scenarios in planning processes, and the production of new, bespoke climate information that can continually inform planning processes and response measures into the future. They may also include sharing of indigenous knowledge on climate variability and traditional adaptation measures such as drought-resistant farming practices.

What returns can be expected from investments in climate change adaptation?

Many studies have attempted to quantify the financial value of adaptation. Evidence suggests that every US$1 spent on DRR can save between $4 and $11 in losses from a range of disaster events, including flooding, wildfires and storm surges (Multihazard Mitigation Council, 2018). The 2015 Global Assessment Report on Disaster Risk Reduction (GAR15) found that "annual global investment of US$6bn in appropriate disaster risk management strategies would generate total benefits in terms of risk reduction of US$360 billion", indicating a leveraging ratio of 1:60. These total values draw on a range of different forms of benefit that are identified to result from effective adaptation processes. The three principal categories of benefit, described in more detail below, are: saved lives and avoided damages; economic benefits; and broader social, environmental and governance benefits. Taken together, these benefits, are known as the triple dividend of resilience (Surminski and Tanner, 2016) and this concept underpins the 2019 report of the Global Commission on Adaptation.

Saved lives and avoided damages

The simplest and most compelling argument for investing in adaptation to increase climate resilience is that it saves lives and prevents loss across all of the dimensions of capital: human, social, physical, natural and financial. For example, investments in cyclone shelters and an early warning system limited deaths in the Indian state of Odisha during Cyclone Fani, a category four cyclone in 2019, to 64, when 20 years earlier a similarly strong cyclone killed 10,000 people (see case study 6 in Section 4).

Economic benefits

Adaptation and resilience can also help to reduce the severity of economic downturns following a climate-related shock, and to stimulate sustainable development. For example, a key barrier to investment in adaptation is that businesses and households typically try to avoid long-term investments, and are often reluctant to take entrepreneurial risks. However, evidence shows that risk-taking is further depressed in more vulnerable communities facing the ever-present risk of climate change impacts, where businesses and households are also likely to adopt shorter planning horizons. This has a dampening effect on development and therefore reducing this risk can stimulate economic activity (Surminski and Tanner, 2016).

Broader social, environmental and governance benefits

Climate-resilient communities, infrastructure, ecosystems and governance processes can also offer broader co-benefits. For example, new health and education infrastructure in Papua New Guinea, Bangladesh and Odisha has been designed to provide spaces for community gatherings in addition to acting as cyclone shelters (ibid.). Dams, flood levies and storm water tunnels have been used to support transport infrastructure in St Petersburg, throughout Bangladesh and in Kuala Lumpur respectively (ibid.). As our case studies highlight, adaptation projects can also lead to improved social outcomes and resilience in other areas, including against financial shocks.

Who pays for adaptation?

With different types of monetary and non-monetary returns from investments, a range of different finance providers can contribute to adaptation processes. Donor finance tends to be central in those examples of adaptation processes that began sufficiently long ago to yield evidence of benefits already, such as those highlighted in this report – particularly avoided damages. However, this does not preclude private finance providers from involvement in adaptation, and there are growing calls and opportunities for the private sector to finance adaptation (UNFCCC, 2019). Furthermore, there is a risk of placing too much emphasis on the agency and role played by donors in delivering adaptation, conceived as discreet, time-bound 'projects' that align with donor funding cycles. Instead, this report recognises 'adaptation processes'. The case studies are each focused on a specific location, and a range of different actors that provide different inputs; the role of donors is highlighted as contributing towards the adaptation process, as opposed to embodying it. In this context, donors may play a variety of roles in adaptation processes, including

strategic, demand-led interventions accompanied by a clear exit strategy. There are a variety of different roles for actors who might be involved in financing, championing or delivering adaptation processes, such as local government, national government, technical experts, donors, the private sector and civil society.

Political economy and institutional barriers to investing in adaptation

Despite the wide range of benefits that can be derived from investments in adaptation, a number of barriers continue to stymie investment flows. Many of these are political and institutional. The lengthy periods typically required for adaptation investments to yield results are often well outside of the timeframes of political decisions and electoral cycles. In addition, the period over which the benefits might be realised, and the magnitude of those benefits, may be uncertain. As a result, there is little incentive to spend money on measures to mitigate risks related to hazards that may not happen, or that may yield only longer-term benefits.

In contrast, spending on emergency disaster responses is often more visible and the perceived benefits more immediate. This implies that at a political level there is a greater incentive to invest in disaster relief than disaster reduction measures. This is compounded by the current lack of visibility of the value of climate change adaptation among many policymakers and voters in donor countries. In both cases, political constituencies lobbying for adaptation measures are under-developed. However, recent social movements that have highlighted the risks of climate change, such as Fridays for the Future and the Extinction Rebellion protests in the UK, together with the green parties that were successful in the most recent European Parliamentary elections, could have a key role to play in demanding greater adaptation investment from donor governments.

Barnett et al. (2015) argue that path dependency is a major barrier to adaptation, manifesting in "resistance to changing the way things have always been done, even if business as usual seems to be increasingly maladaptive [… and] resistance to doing things that have never been done or to improving deficient practices". In Australia, management of the Murray-Darling river basin exemplifies this kind of path dependency. The catchment area provides water to rural and farming communities across five states and territories and its management has focused on improving the existing water trading scheme to allow water to be allocated 'efficiently'. However, attempting to increase the value of output from the use of water in the basin has the potential to divert even more water away from downstream, lower value and non-market uses, with the potential for negative environmental and social impacts that are not adequately priced into the trading scheme (ibid; Murray-Darling Basin Authority, 2020).

In the humanitarian and development sectors, current institutional structures and incentives often undermine efforts to direct financial flows towards resilience. For example, the way the humanitarian system is financed does not incentivise the understanding of risk or prioritisation of ex-ante action (Poole et al., 2020). In spite of some innovative emerging approaches, it tends to be easier to access finance after a disaster than before, with significant flows from a range of sources and funding mechanisms only being made available for emergency responses. Of total humanitarian financing between 2005 and 2017, US$5.2bn, or 3.8 per cent, was directed to DRR (UNDRR, 2019). In an already under-resourced system, humanitarian action prioritises response to existing basic needs such as the provision of food, water, sanitation and hygiene (WASH), shelter and social protection.

However, a shift in mindset can be achieved with sufficient political and institutional will to prioritise climate change adaptation and to alter perverse incentives within governance and financing systems. This shift will likely require increased acknowledgement of the broad benefits accrued by investing in adaptation (as highlighted by our case studies), e.g. through the protection and enhancement of lives, property, livelihoods and governance institutions. Acknowledging the role of adaptation investment in supporting other outcomes to which governments and communities are already committed, such as the SDGs, may also help to overcome disincentives for investing in climate change adaptation. A push to increase the visibility of the benefits of investing in adaptation processes would promote such outcomes.

3. Our approach

Identification of case studies

The primary method used for this report has been a literature review, drawing on existing evidence. In addition we held a small number of interviews with key stakeholders. The case selection was made to gain a broad perspective on the compelling investment case presented by adaptation, with an attempt to include:

- **Examples where it was possible to measure the number of lives or properties saved** as a result of the adaptation intervention, to demonstrate how investments can save lives, homes and businesses that would otherwise have been lost and would not have been recovered as part of post-disaster relief.
- **Examples where the broader economic, physical and social benefits** have been captured, for example through project evaluation reports or discussions with key stakeholders, so it is possible to illustrate the wider benefits that adaptation projects have, regardless of the frequency of climate-related events.
- **Examples of a range of different hazards and measures,** to demonstrate that these benefits hold across all types of adaptation projects.
- **Examples of a range of different types of adaptation process, from a governance perspective**. Some adaptation processes have been driven primarily by recipient countries and others by donors. However, in all instances, the involvement of a diverse range of stakeholders has been essential to an effective adaptation process, including academic institutions, businesses, local communities and non-governmental organisations (NGOs).
- **Examples of a range of geographical locations**, reflecting the diverse local contexts within which adaptation is required.

Given limitations in publicly available documentation, adaptation case studies from the Least Developed Countries and Small Island Developing State groups are under-represented in this collection.

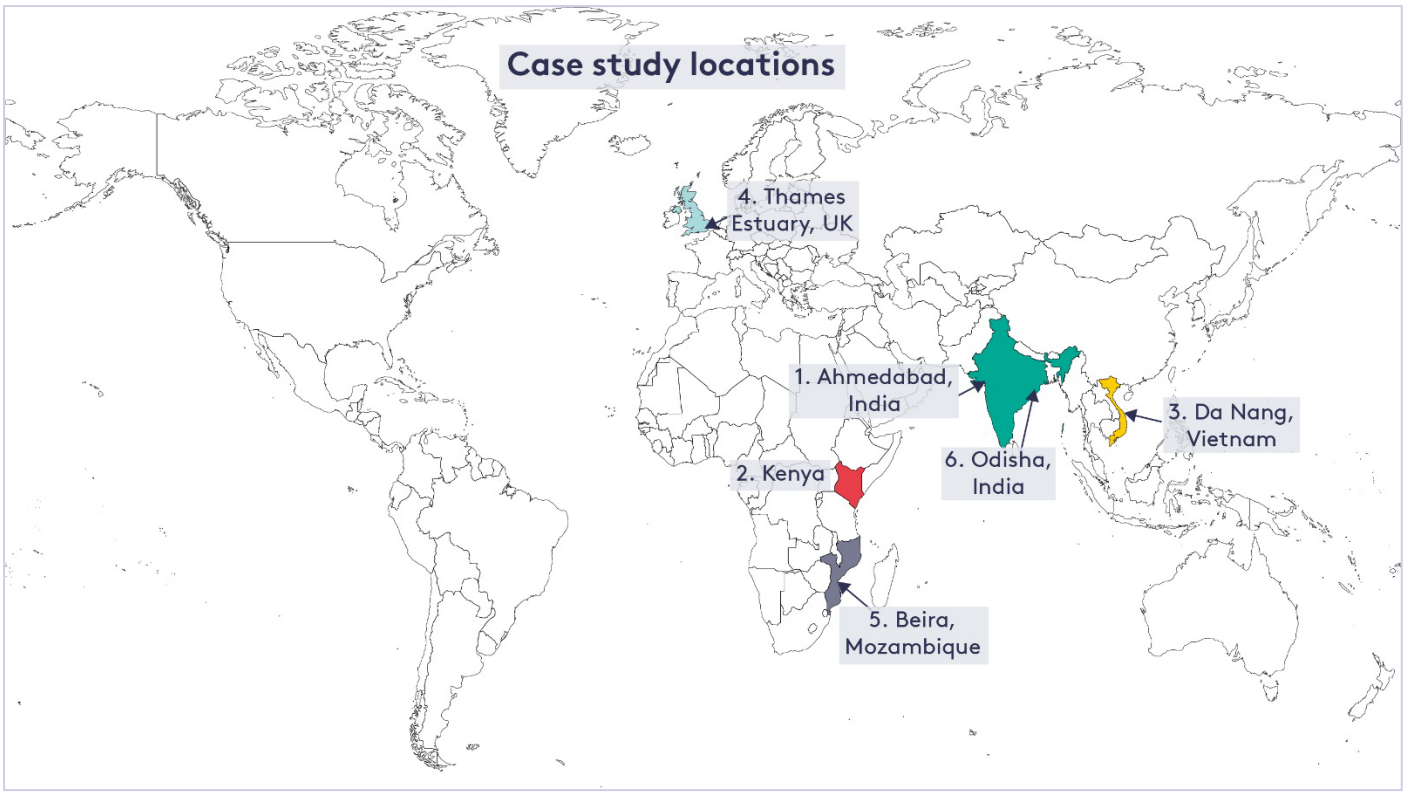
Research methodology

We have explored six case studies using a combination of desk-based research and expert interviews. Where possible, we have drawn on existing evaluation reports that assess the impacts and successes of projects, supplemented by other available information, including academic analysis, media reports and government documentation, to understand each project, including associated activities, outcomes and impacts. We have supplemented this information with interviews from experts and practitioners involved in each adaptation process, who were able to provide further insights about successes and challenges. Where possible, we have sought quantitative metrics, such as the number of deaths prevented or houses protected, but supplemented with qualitative information about social and economic benefits within target households and communities, in line with the different categories of benefit highlighted by the triple dividend narrative.

In bringing all of these materials together, we have drawn on 'contribution analysis' methods. These are based on an approach through which evaluators draw on existing evidence to understand a project, its intended 'theory of change', and its actual outcomes and impacts, in the context of the broader landscape of stakeholders and external events. This allows an understanding of the extent to which a project was responsible for relevant changes in the level of resilience in the target area.

Given the desk-based nature of the research, it was not possible to independently verify the impacts described, nor to identify impacts of the interventions on the most vulnerable people, beyond those documented in the available materials.

4. Case studies



Case study 1

Heat Action Plan in Ahmedabad, India

Background

Ahmedabad in Gujarat state is the fifth most populous city in India, with a current estimated population of 6.6 million in the city and 8.3 million across the metropolitan area (Bharti and Mehrota, 2020). It is projected to become one of seven Indian megacities by 2030 (UNDESA, 2019). As a city that is rapidly growing, and with a significant migrant population, it has sizeable areas of unplanned, low-income housing. Migrant slums make up a significant proportion of households (Knowlton et al., 2014).

Ahmedabad is a major industrial centre, situated within one of India's fastest growing state economies. The city's economy is heavily reliant on manufacturing (including in the textiles, chemicals, metal works and pharmaceuticals industries), as well as rapidly developing urban infrastructure for the services economy in recent years. In addition to the formal sector, high levels of informal work are undertaken in Ahmedabad, including in home-based manufacturing and in retail (Bharti and Mehrota, 2020).

Climate risks and their impacts

Heatwaves are common in India throughout the hot months of April to June, before the monsoon season. According to figures published by the Government of India's National Statistical Office in 2020, 3,365 deaths in the country were caused by heatwaves in the five years from 2015 to 2019. Heatwaves are projected to grow in frequency, duration and intensity in India and across South Asia (Im et al., 2017), significantly increasing levels of risk to health and livelihoods (Knowlton et al. 2014). In India, there has been a steep increase in the number of high temperature days in north and western regions, including Gujarat, since the 1990s (Jaswal et al., 2015). Analysis suggests that both heat wave frequency and heat wave duration could increase significantly over the coming decades in central and northwest India under a scenario of moderate increases in greenhouse

gas concentrations, with four to seven days added per decade (Rohini et al., 2019). In cities, extreme heat is intensified by factors such as heat-absorbent buildings, high building density and higher air pollution. In Ahmedabad, rapid urbanisation has led to many natural land surfaces being replaced by manmade materials more likely to retain heat, contributing to the urban heat island effect (Mathew et al., 2016).

Extreme heat is an often underestimated and under-reported threat, yet sustained exposure can increase mortality and illness, including heat exhaustion, severe dehydration, heat stroke, and the exacerbation of pre-existing respiratory and cardiovascular diseases (Kovats and Hajat, 2008). Vulnerability to extreme heat is not equal across the population – it is exacerbated by often intersecting factors, including poor-quality housing, high population density, lack of access to water and electricity, limited mobility and social isolation, old age and underlying health issues, restrictive gender norms, and physical exertion in the heat, including as a result of occupation (ibid). Young children are also at higher risk than other age groups.

Beyond increased mortality, extreme heat and heatwaves can have significant social and economic impacts. Without sufficient adaptive measures, heatwaves are likely to limit labour capacity and to reduce productivity. The McKinsey Global Institute has warned that India could lose 2.5–4.5 per cent of GDP by 2030 to loss of productivity during periods of extreme heat (Woetzel et al., 2020).

Workers – especially those most exposed to heat, such as construction workers, taxi drivers, traffic police, and those in the informal sector – are more likely to become unwell and need to take more frequent breaks. Outdoor construction workers in India have reported increased exhaustion, dizziness, fainting, blurred vision, impaired judgement and higher likelihood of making mistakes in high temperatures, making the sector extremely vulnerable to extreme heat (Dutta et al., 2015). A range of workplaces and schools in areas susceptible to extreme heat have also been forced to close temporarily during previous heatwaves (Kirbyshire and Paul, 2017). Given that those reliant on heat-exposed work are often lower-income earners, loss of earnings due to heatwaves could exacerbate existing economic inequalities.

In Ahmedabad, the heat season extends from March to July. In May 2010, a heatwave with peak temperatures of 46.8˚C resulted in a rise in heat-related illness and death in the city. An excess of 1,344 all-cause deaths occurred compared with previous years (Azhar et al., 2014; IIPHG et al., 2015). There was no national or local policy on extreme heat, and heatwaves were not explicitly included in India's *National Action Plan on Climate Change*, published in 2008. The lack of adaptation measures in place was compounded by the lack of public awareness of both the threshold for, and the risks posed by, extreme heat, especially among the most vulnerable people. For example, rural–urban migrants may be used to living in traditionally-built, heat-resilient housing in their places of origin but when they reach the city (where they often settle in low-income or slum areas) they are unlikely to have access to housing of this kind.

The adaptation process

As predictable hazards, many of the detrimental impacts of heatwaves are preventable. In Ahmedabad, a coalition of academic, municipal, health and environmental groups partnered to address heat induced health impacts, led by the Indian Institute of Public Health – Gandhinagar, the Natural Resources Defence Council and Ahmedabad Municipal Corporation (AMC).

The coalition developed a Heat Action Plan (HAP) based on scientific research, including establishing the true number of deaths caused by the heat wave in Ahmedabad in 2010, collecting examples of global best practice on early warning and heat adaptation, and conducting heat vulnerability studies. A framework for the implementation, coordination and evaluation of a strategy, the HAP outlined immediate and longer-term activities to increase preparedness, information sharing and response coordination.

The Heat Action Plan initially focused on activities in three key areas:

- Community outreach to build awareness, preparedness and prevention of heat-related illness – focused on vulnerable groups, particularly slum communities and outdoor workers.
- An intra-agency early warning system, including the development of a seven-day weather forecast.
- Building the capacity of Ahmedabad's health care professionals.

An aim to reduce urban-exacerbated heat through longer-term adaptation measures was later added.

Activities were undertaken prior to, during and after the heat season. The coalition focused as much as possible on measures that could be implemented with relative ease and cost-effectiveness. A 'nodal officer' was appointed by the AMC within the municipal health department to direct and coordinate the HAP, including notifying all relevant stakeholders once a temperature forecast triggers a heat alert. By embedding this role within local government, existing programming and infrastructure could be leveraged in implementing the HAP.

Capacity-building for health professionals included training in identifying and recording heat-related illness and mortality, in part in anticipation of future extreme heat events and the need for accurate data. Anticipation of future heatwaves also drove efforts to develop public awareness about the risks of extreme heat and the actions that should be taken to limit risk. Public outreach was undertaken through media engagement (TV, radio, print outlets), public signage (billboards, rickshaw banners, temperature displays), leaflet distribution, and community engagement.

The HAP was adopted by the city in April 2013 and has been updated annually by the AMC since, as a dynamic and iterative process. The built-in evaluation process allowed for further adaptations to occur in response to identified gaps and future needs. Cool roofs that are painted with reflective white paint, for example, have been promoted in later iterations of the Plan (from 2017) – pictured below. Increased public outreach activities and greater targeting of at-risk groups also featured centrally in later iterations – for example, with a focus each on traffic police, on gender-related protection activities and on protecting young children.

The AMC developed a dedicated budget line to cover the Plan's inaugural activities with an initial investment of approximately US$60,000 (Kirbyshire and Paul, 2017). Activities were supported by a range of international organisations, including the Climate and Development Knowledge Network.

The Ahmedabad Mayor and Members of the Standing Committee painting a roof white to launch the city's cool roofs initiative in April 2017.
This is a cheap and effective way to protect people inside these buildings from extreme heat, being able to reduce indoor temperatures by 2–5˚C.

Photo: Nehmat Kaur, NRDC, reproduced with permission.

In what ways do these actions constitute adaptation to climate change?

The HAP states: "Rising to this challenge of climate change and increasing heat waves, the Ahmedabad Municipal Corporation (AMC) is working to prepare health systems and residents against dangerous heat waves" (AMC, 2019). The development of early warnings for extreme heat is a key climate change adaptation action under the HAP, using new processes to gather and process local climate data. Prior to the introduction of the HAP, the local office of the Indian Metrological Department issued forecasts of extreme heat two days in advance, and the only local data collection point was located outside of the hot core of the city. The project team, working in partnership with a university based in the United States, developed a pilot for seven-day forecasts through an innovative temperature forecast system (IIPHG et al., 2015), resulting in accurate and reliable longer-term local forecasting. This provides accurate heat data several days in advance to initiate coordinated action to alert the local government, health care centres and the public of the forecast heatwave through channels pre-established by the HAP. This process is based on locally determined thresholds to trigger warnings. Before the introduction of the HAP, the Meteorological Department did not share temperature data with the city's health department.

In addition to the capacity built to provide more accurate forecasting, relevant actors in local government have also developed their technical knowledge and understanding of how to use climate data (Kirbyshire and Paul, 2017).

The painting of the roofs of low-income housing with reflective white paint was also an adaptation in recognition of the increased threat of heatwaves, and the higher risk this poses to those in poor housing. It is a cheap and effective way to protect those inside from extreme heat, being able to reduce indoor temperatures by 2–5˚C (AMC, 2018).

More broadly, the flexibility built into the planning and governance approach – including the significant emphasis placed on evaluation and learning, which feeds into an update of the HAP on an annual basis – will allow the modification of the HAP on the basis of emerging data and alterations in context in future years, including in relation to risks resulting from a changing climate.

The success story

Direct avoided losses

The HAP has significantly reduced heat-related mortality and illness with an estimated 1,190 average deaths per year avoided following its implementation in 2013 (Hess et al., 2018).

As an indirect indicator of avoided deaths and illness, evaluations of the HAP have also concluded that awareness about extreme heat and the appropriate precautions and actions to reduce risk have improved (IIPHG et al., 2015). For example, they have highlighted that the community engagement strategy developed as part of the HAP resulted in significant behaviour change, such as the alteration of routines and the increased intake of hydrating fluids, most notably in vulnerable communities. Engagement activity in some communities – for example slum communities – remains active today.

Other economic benefits

No comprehensive study has been conducted into the economic benefits created by the HAP, either broad or industry-specific, but many economy-related benefits have been reported.

An HAP project partner reported that the awareness-raising aspect of the HAP elicited a positive response from many employers, helping to reduce risk and avoid negative impacts on productivity during periods of extreme heat. Actions included scheduling shifts at non-peak temperatures and ensuring sufficient access to water, shade and breaks. Within the police, notable improvements included falls in the amount of casual leave taken and in the amount of money spent on healthcare.

It has been reported that increased employment opportunities were created by improved public awareness of the occurrence and related risks of extreme heat. For example, it has been

estimated that 3,000–5,000 more street vendors, in addition to existing stores, now sell cooling drinks in the summer months since the introduction of the HAP. This illustrates a likely boost to small businesses and, as a significant number of street vendors are women (Mahadevia, 2014), to women's employment.

Painting the roofs of low-income housing with white reflective paint has enabled women, who are more likely than men to work from home (in activities such as sewing), to remain indoors and continue their activities when the heat would previously have stopped them. The painting of roofs may also help to save energy and bring down the costs of cooling in other ways (AMC, 2018) when compared with, for example, the use of air conditioning.

The HAP has allowed schools to continue to provide uninterrupted access to education during some periods of extreme heat, with a "remarkable reduction" in those missing school during heatwaves. However, this is limited and the 2019 iteration of the HAP advises school closures on days when temperatures reach 45˚C or higher (AMC, 2019).

Wider benefits

The HAP has created greater awareness of the impacts of extreme heat and climate change, with acknowledgement and action from a range of actors who previously did not recognise the risk. Drawing attention to the role of climate change in the occurrence of extreme heat has raised its profile more broadly within the population and also encouraged greater focus on greenhouse gas emissions and mitigation measures. The AMC is planning to install solar panels on its buildings, and to plant 500,000 trees annually between 2020 and 2025 (NRDC, 2020).

The HAP has also highlighted other existing vulnerabilities in Ahmedabad. The focus on protecting slum communities from heat waves, for example, has further highlighted specific vulnerabilities of those living in poor quality housing without access to water or electricity.

Research to inform iterations of the HAP, and the relationships it has developed, have also led to work to protect health in new areas. For example, a study undertaken with traffic police in 2016 as part of the HAP highlighted the risk to workers' health of traffic pollutants (Kirbyshire and Paul, 2017). The city now has an Air Information and Response Plan.

One evaluation credited the design of the HAP for the "the breadth and depth of the partnership across the city working on the issue [which] has helped to keep and build momentum" (Kirbyshire and Paul, 2017). The capacity built through the HAP in a range of areas has also contributed to its sustainability and to the development of related projects. For example, the success of the HAP has led city officials to develop a similar programme to fight air pollution, modelled on the same process. The Air Information and Response Plan promotes interagency coordination, public awareness and capacity-building among medical professionals. This provides a clear example of the capacity built in local government institutions through the HAP, including in planning and evaluation. One evaluation found that the HAP "built interest in the evaluation and feedback process within several government agencies" (IIPHG, 2015).

The city-led approach taken by the HAP has become a model for other heat-vulnerable cities and states in India. By May 2020, 23 states and more than 100 cities and districts were developing their own heat action plans (NRDC, 2020), with leadership, and resulting changes in policy, on extreme heat now having been exercised at the national level. The city resilience toolkit produced by the coalition to support the development of heat action plans elsewhere has been enhanced by the National Disaster Management Authority in its *National Guidelines for Preparation for an Action Plan – Prevention and Management of Heat Wave* (NDMA, 2019). Project partners have also applied lessons from the HAP in tackling extreme heat in other countries, as well as promoting it as a model for responses to other extreme weather events in rapidly urbanising cities. With Ahmedabad considered to be the first city in South Asia to have comprehensively responded to the threat of extreme heat, it has been noted that the city and the organisations involved have developed significant political capital from the HAP and as a result have been able to leverage resources, such as volunteer time, from interested institutions.

Lessons learned

- **The use of data has been a key factor in Ahmedabad in changing perceptions** and ensuring that local government bodies recognised the true threat posed by extreme heat as a disaster that required advance preparation. This has included sharing international experience and best practice, establishing the true death toll of the 2010 heatwave, and conducting heat vulnerability studies. These activities helped to foster the political will and leadership that has underpinned long-term engagement on the issue, and there has been continued and sustained progress.
- **Quick action following the adoption of the HAP, and a focus on cost-effective and time-efficient activities** while working through existing structures, ensured initial measures – and demonstrated outputs – were in place quickly, and in time for the highest temperatures of 2013. One evaluation found that "rapid and visible benefits helped to galvanise political will to take heat action further" (Kirbyshire and Paul, 2017). This provided the momentum to deepen implementation and broaden the reach of the HAP in subsequent years, including action against longer term and more challenging aspects of the heat threat (ibid).
- **A rigorous built-in evaluation process has been vital in the annual revision of the HAP** to focus on specific vulnerabilities and to engage with emerging issues. It is important that this adaptive process is also built into the local heat action plans being developed in other cities and regions. Ahmedabad has recognised that other adaptation measures in cities, such as afforestation and greening, and policies to reduce pollution, also improve health outcomes.

Following the benefits realised by the HAP, a key challenge now is to move from the implementation of adaptation programming to embed climate change adaptation into urban design processes. Despite the awareness raised by the HAP, a project partner has pointed out that there continues to be 'business as usual' in urban planning processes. For example, the design of Ahmedabad's metro system has not accounted for the growing threat from extreme heat (or any other climate change adaptation needs).

Case study 2

Devolved climate finance in arid and semi-arid counties of Kenya

Background

Over 80 per cent of Kenya's area is classified as arid or semi-arid land (ASAL). These areas are home to one-third of the country's population – approximately 16 million people (UNDP, 2018). Livelihoods in ASAL regions are derived predominantly from pastoralism, smallholder agriculture and livestock rearing. These livelihoods are highly dependent on land and natural resource management, as well as on water availability – yet reliable access to clean water is a major challenge, as arid and semi-arid lands are highly susceptible to drought.

Climate change is projected to lead to a rise in average temperature by 1.2–2.2˚C in Kenya by 2050, as well as an increase in the severity of dry spells and duration of heat waves, and increased water scarcity (USAID, 2018). The drought of 2016, for example, began when the rains failed and temperatures were unusually high – hotter than they would have been without the influence of climate change (Uhe et al., 2017).

Climate change impacts pose a serious threat to achieving the Sustainable Development Goals in Kenya (USAID, 2018). For example, droughts have increased food insecurity and levels of poverty, and have had a negative impact on household and community vulnerability to future droughts; and the occurrence of droughts in quick succession has weakened abilities to respond to the next event (Wekesa et al., 2006). Development deficits are in turn a core driver of vulnerability to climate risk in arid and semi-arid areas. As such, building resilience in arid regions is a slow and complex process, and a focus on closing gaps in development between different populations or areas is essential (Crick et al., 2019).

Losses to Kenya's agricultural sector as a result of climate change are projected to result from reduced grain yields and quality, heat stress to livestock, and damage to crops and land (USAID, 2018), with severe consequences for livelihoods. The drought of 2008 to 2011 resulted in US$12.1bn in damage, including US$10.2bn in losses from livestock and crops (ibid.).

Those worst hit by drought often move in search of water and pasture lands, with women, children and the elderly often the most vulnerable to the impacts, in part owing to a range of barriers to their movement. Drought has also led to significant conflict within and between communities, predominantly over access to limited resources.

Kenya's arid and semi-arid lands have been disproportionately vulnerable to climate risk, in part because of a legacy of political, social and economic marginalisation, as well as government planning systems that are poorly adapted to the contexts and specific needs of these areas (Crick et al., 2019; Republic of Kenya, 2012a and 2012b; Msangi et al., 2014).

Kenya launched a National Climate Change Response Strategy in 2010, and a National Climate Change Action Plan (2013–2017) in 2012. In addition, two policies specific to arid and semi-arid lands were adopted in 2012.[2] A new constitution, introduced in 2010, and devolution instituted in 2013, established county governments with the policy and legal frameworks to both plan for and finance local development.

The adaptation process

In 2010, the Ministry of State for Development of Northern Kenya and other Arid Lands requested technical assistance from the International Institute for Environment and Development (IIED) to improve planning in Kenya's arid and semi-arid lands. This was prompted by the then-upcoming creation of county governments under plans for devolution in 2013. The Ministry aimed to strengthen institutional capacity for good governance and adaptive planning at the county level, a vital step to building sustainable development in arid and semi-arid lands in the face of climate change (Crick et al., 2019).

Collecting water at Masue rock catchment, Makueni County, Kenya, benefiting from investment made under the CCCF mechanism. *Photos: Courtesy of Jane Kiiru, Ada Secretariat*

An initial pilot, from 2011 to 2013, was introduced in three districts of an arid county, Isiolo. It used a participatory action-research process to co-generate information on the limitations of the planning system,[3] in order to build the future county government's capacity to respond to climate change (ibid.). The pilot designed and tested a devolved mechanism – the County Adaptation Fund – to enable the future county government to access climate finance. It also strengthened institutions and planning mechanisms and developed a monitoring and evaluation (M&E) system.

[2] A National Policy for the Sustainable Development of Northern Kenya and other Arid Lands, and the Vision 2030 Development Strategy for Northern Kenya and other Arid Lands.

[3] Among the limitations found were a disconnect with traditional community-based institutions, a lack of integration of climate information into government planning, centrally set budgeting, and a lack of community capacity to engage effectively with government systems (Crick et al., 2019).

Following the first round of funding for the pilot (£500,000 for 23 public goods investments[4]), tangible benefits included improved water availability, pasture management and livestock health (ibid.). In arid and semi-arid lands these are all important factors in reducing vulnerability and strengthening adaptive capacity to future climate events (ibid.; Müller and Pizer, 2014; NDMA, 2014). The pilot also demonstrated the level of local capacity (what would become ward level under the future county government) when sufficient support for the development of financial, human and knowledge capital was in place – a key outcome in ensuring the newly-established local governments would not be reluctant to devolve power further[5] (Crick et al., 2019; Bagré et al., 2003; IIED, 2006; Faye, 2008).

A second phase between 2013 and 2018 extended this pilot to four more arid and semi-arid counties – Garissa, Kitui, Makueni and Wajir – and consolidated the work in Isiolo. Collectively, these counties comprise 29 per cent of Kenya's area and are home to a population of approximately 3.3 million people (Crick et al., 2019). The second phase aimed to build the resilience of households to climate risks in poor and vulnerable communities, putting them in control of their adaptation priorities, while also encouraging greater social inclusion and accountability.

The work was led by the newly-established National Drought Management Authority, with funding from the UK's Department for International Development (DfID) (£6.5m) and later the Swedish International Development Cooperation Agency (SIDA) (£484,000) awarded to the Adaptation ('Ada') Consortium (made up of the Kenya Meteorological Department, the UK Met Office, Christian Aid, IIED and in-country partners).

The pilot was refined with insight from Consortium members and the County Climate Change Fund (CCCF) – a devolved climate finance mechanism – was developed. The mechanism comprises a fund to finance climate action, adaptation planning committees at county and ward level, climate information and resilience planning tools, and an M&E mechanism. It is designed both to channel climate financing to county-level governments and to empower local communities by strengthening their participation in the use and management of those funds. The CCCF was integrated in county-level planning and budget procedures by the Ada Consortium members working closely with local governments, conducting co-generated research, training and advocacy.

Key activities included:

- Incorporating climate change into County Integrated Development Plans
- Developing legislation to formalise the establishment and functioning of the CCCF, and county- and ward-level adaptation planning committees
- Developing county-level climate information service plans
- Testing the relevance and appropriateness of resilience planning tools (e.g. participatory resource mapping), ensuring greater social inclusion and targeting the needs of the vulnerable.

Community participation is driven and facilitated by ward-level adaptation committees, which take fully developed and costed proposals to the county-level adaptation committees. Through the participatory process, communities have focused initial investments mostly on water infrastructure, such as water pans, earth and sand dams, boreholes, shallow wells and rock catchments. These locally-led public investments are expected to offer a "cascade of additional direct and indirect benefits" (Crick et al., 2019) across economic and social metrics – all contributing to increased resilience.

[4] Funding predominantly from DfID and the Catholic Organisation for Relief and Development Aid.
[5] As had happened following reforms that introduced decentralisation in a number of countries in the Sahel over recent decades.

In what ways do these actions constitute adaptation to climate change?

Climate information from the Kenya Meteorological Department is integrated into the participatory resilience assessments and resource mapping undertaken by the Ward Climate Change Planning Committees (Crick et al., 2019). This ensures consideration of current and future climate data in the decision-making process for investment at the local level. The use of participatory tools further facilitates informed discussion between communities and the county government on the factors that affect the ability of local livelihood systems to withstand climate change impacts (and accounts for factors such as gender, age and production systems). Findings feed into annual development plans and county-level integrated development plans, as well as supporting community members to explain their adaptation strategies to county planners and NGOs. It is an opportunity for planners to better understand how livelihoods function and interact at a local level, as well as the factors that constrain adaptative capacity and ways to overcome them.

County Directors of Meteorology are employed by the Kenya Meteorological Department to oversee integration of climate information services into county institutions, and to develop county climate information plans. They are also involved in relevant decision-making bodies to ensure proposals sufficiently address climate change and uncertainty, as well as facilitating conversations about climate information between the Kenya Meteorological Department and county and community actors.

The strengthening of M&E systems at local, county and national-government levels will provide support for the evaluation of mechanisms for building local adaptive capacity and climate-resilient development for the most vulnerable. For example, a pilot under the CCCF mechanism supported ward climate change planning committees to develop aims, plans and appropriate indicators for the use of funding. The pilot also tested different channels for the effective communication of climate information, including radio, SMS and designated intermediaries (Ada Consortium, 2018b). The Kenya Meteorological Department also piloted a training of trainers course to support participants (including relevant county government officials, as well as religious and community leaders) to effectively communicate climate information, and to provide insights about its uses and benefits.

The resilience planning tools piloted under the CCCF mechanism have also enabled counties and communities to prioritise investment in the most appropriate public goods that contribute to their resilience (Crick et al., 2019) – with the flexibility to adapt to future changes in a way that is informed by locally-specific information.

The success story

Direct avoided losses

Building resilience to drought is a complex and gradual process, and the majority of wards have so far only had access to one round of funding. However, a number of initial large-scale household surveys and case studies indicate significant positive initial benefits for individuals, households and communities as a result of locally-led interventions to secure water supplies, including through the installation of sand dams, water pans and water kiosks (Ada Consortium, 2018a; Bonaya and Rugano, 2018; Crick et al., 2019; Tari et al., 2015). Reported benefits include reduced livestock deaths, increased food security, strengthened and diversified livelihoods, and cleaner water for domestic use (Crick et al., 2019). Decreased use of coping mechanisms such as migration, which exposed herders to more losses because of disease, conflict over water and pasture, and stress from being away from home, has also been noted (ibid.).

Community surveys in Isiolo, Makueni and Wajir found a 100 per cent increase in reported access to water for households and livestock, with an average two hours saved per household per day in water collection – equivalent to 700 hours per year (ibid.).

Other economic benefits

Improved access to water for domestic, agricultural and livestock use has created a range of reported economic benefits to date. Beyond reduced outgoings to purchase water during dry periods, improved livestock health and better quality meat have been reported, resulting in improved incomes from the sale of milk, meat and other animal produce. One project beneficiary stated: "The project provided water for livestock use lasting the entire dry period of 2017. This translated to substantial saving for most households that keep livestock, because in similar situations before the earth dam was established families were forced to buy borehole water […] for their livestock" (Crick et al., 2019). As a result of water becoming available all year round, farmers have been able to produce both in and out of season, increasing income levels and expanding livelihood opportunities. The use of climate information has also benefited farmers by helping them to plan better, leading to improved yields (ibid.).

New economic opportunities and livelihood diversification have also been reported, for example in the cultivation of new vegetable gardens, small-scale irrigation and tree nurseries – enabled by both improved water supply and time freed up by not needing to travel to collect water. Women have set up small businesses such as food kiosks at water points, and elsewhere are using increased water supplies to grow vegetables for their own use or for sale.

In a survey of three of the counties, improved access to water was reported as providing an average net benefit per household of £109 (KES 14,170) per year – an 8 per cent increase in annual household income (Crick et al., 2019; Ada Consortium, 2018a). Taking the amount invested over the life of the CCCF mechanism, direct benefits per household as a result of the intervention exceed overall investment costs by a factor of three per year (ibid.).

Several co-investments from within the community have resulted from participation in decision-making, accountability and governance of CCCF investments. Although this has been predominantly through in-kind labour (MacGregor, 2018), there have also been examples where financing has come from within the community to fill the gaps in investments (Ada Consortium 2018a; Crick et al., 2019b). For example, additional water tanks were purchased by one community to extend CCCF investment in a rock catchment capable of holding more water than the capacity of tanks installed by the CCCF initially allowed. This inspired a neighbouring school to acquire additional water storage tanks for use by pupils in the dry season (ibid.).

Capacity-building of ward committees has reportedly resulted in enhanced job prospects and active support for participation in decision-making, which has increased human and knowledge capital. For example, one survey respondent stated, "the training added value to my CV" and "because of [it], I applied for a job and got employed as an early childhood development teacher" (Ada Consortium, 2018a). Another participant noted that his engagement with the committee opened him up to livelihood possibilities beyond herding and prompted him to start sending his children to school (ibid.).

County funding which guarantees 1–2 per cent of development budgets to adaptation projects is now enshrined in legislation as a result of the CCCF mechanism (DCF Alliance, 2019). Implementation of this commitment by Makueni and Wajir counties resulted in KES 8m (£62,000) being allocated by each county government in 2018–19.

Wider benefits

Institutional reforms under the CCCF mechanism are allowing the voices of more vulnerable and marginalised people to be heard. The legal frameworks established under the CCCF – climate change regulations in some counties and climate change acts in others – formalised the county- and ward-level committees and institutionalised the process of ward-level identification, prioritisation and costing of investments, in partnership with the local community. The community is also empowered to monitor projects. This structure supports community-driven planning, ownership and inclusion with regards to CCCF financing (Ada Consortium, 2018a) and has

resulted in participation and inclusion measures being built into county development planning processes more broadly[6] (Crick et al., 2019).

At the community level, the CCCF mechanism has resulted in greater engagement among women and young people in planning processes. This has been supported by training and capacity-building through local committees, as well as inclusion criteria and processes to ensure the views of all community groups are appropriately represented. For example, where women's views are not reflected strongly enough in plans, women-only meetings are held to address this imbalance (Bonaya and Rugano, 2018). Anecdotal evidence suggests that the CCCF mechanism may be "helping change communities' attitudes towards women and supporting women and youth to become more visible and active within communities" (Crick et al., 2019) – with some women taking on leadership roles in their communities (both within local committees and more broadly) and discussing issues of community development with men where they were not previously (Bonaya and Rugano 2018; Crick et al., 2019).

It has also been reported that "community consultations have become more participatory and communities have strengthened their political voice, increasingly holding county planning departments to account" (Crick et al., 2019) – driving transparency and accountability in governance processes. This is supported by strengthened vertical links between community, ward and county levels, with greater interaction (including greater consultation of ward-level representatives), improved relations, and learning supported between different levels. Findings from household surveys suggest that standards in the way investments had been implemented had been improved as a result of increased public participation and scrutiny (ibid.). Moreover, the CCCF mechanism has been cited by county officials to highlight the "value of participatory planning in generating effective and efficient public goods investments that represent value for money" (ibid).

The CCCF mechanism has also resulted in the integration or mainstreaming of climate change action into other planning and budgetary processes, such as annual development plans (Ada Consortium, 2018), and has strengthened traditional institutions for natural resource management. The success of the CCCF mechanism in supporting the development of county-level climate information plans has led the Kenya Meteorological Department to develop similar plans for other counties, accompanied by training of County Directors of Meteorology. The Consortium is also working with the Kenya School of Government to deliver county-level training on climate information services and the integration of climate change in budgeting and planning. In addition, the monitoring system piloted under the CCCF mechanism – the Tracking Adaptation and Monitoring Development Framework – tracks the linkages between adaptation, resilience and economic development. These factors support the improved linking of adaptation and sustainable development planning and implementation at the local level.

The reduction in time spent collecting water is acknowledged to be supporting children in their schoolwork, with anecdotal evidence of increased time at school for both girls and boys, and higher levels of support at home – which has brought marked educational benefits. It has been noted that girls in particular have more time to spend on their schoolwork as a result of reduced time spent collecting water (Bonaya and Rugano, 2018). Other reported benefits include greater social cohesion and fewer conflicts within households (with decreases in domestic violence) and communities, as well as between neighbouring villages.

The expansion of the pilot is one of the priorities of the National Climate Change Action Plan, 2018–2022 (DCF Alliance, 2019) – with roll-out planned nationwide, from arid and semi-arid areas to the lake region, coastal areas and urban areas, including Nairobi. The scale-up is being led by the Ministry of Devolution and Arid and Semi-Arid Lands, through the National Drought Management Authority, working with a range of national and local partners, and supported by the World Bank, SIDA, DfID and IFAD. Learning from the CCCF mechanism pilots will inform

[6] For example, evidence suggests that the model of devolved decision-making under the mechanism – with its emphasis on participation and inclusion – has had a positive impact by strengthening these aspects in County Integrated Development Plans.

modifications of the mechanism to apply to these new contexts. This approach has also been recognised in Kenya's National Adaptation Plan (ibid).

Lessons learned

- **An iterative design and implementation approach, informed by learning and community engagement**, and made possible by flexibility in financing from DfID and SIDA, facilitated problem-solving for complex issues likely to occur when dealing with institutional strengthening and climate change.
- **Locally-managed, participatory approaches to funding** can increase efficiency, effectiveness and value for money, compared with nationally-managed funding. These benefits have also been recognised in efforts to build resilience in rural communities in other contexts (Nyangena et al., 2017). They show how, with the right initiative, changes in governance structures, such as the introduction of devolution, offer a key opportunity to build stronger adaptive capacity into newly established systems. Governments and financiers should be alert to this opportunity.
- **The integration of climate information into participatory assessments** can be a key way to ensure investments enhance household and community resilience to climate risk. The maintenance and further development of a strong focus on community participation and inclusion will be critical to building on initial successes. This should include greater concentration on the most vulnerable. For example, improvements are required to ensure climate information is reaching and benefiting the poorest households, particularly those who fall outside of dominant livelihoods; to identify the most appropriate channels of information dissemination, to ensure the most vulnerable people are reached; and to improve understanding of the constraints to accessing and using climate information systems (Apagar et al., 2017; Crick et al., 2019).
- **Greater focus might now be placed on how to engage the private sector,** too, in community climate resilience as the mechanism is extended to other regions, including urban areas.

Case study 3

Microcredit and technical assistance for typhoon resilient housing in Da Nang, Vietnam

Background

Aerial view of flooding in Da Nang after Typhoon Ketsana in 2009
Photo: haithanh, CC BY 2.0 via Wikimedia Commons

Da Nang is a city of 1.1 million people, located in central Vietnam, and is one of the country's fastest growing urban areas (Da Nang Today, 2019; Tran et al., 2014). It is located on the south central coast of the country, within the tropical cyclone belt, and typically experiences three to five storms per year, impacting 80–90 per cent of the local population (Tran et al., 2014).

Following the Reform Policy of 1986, Vietnam transitioned from a centrally-planned economy to a market economy. In the process of this transition, many households were able to generate higher

levels of income, much of which was reinvested into the housing sector as families had access to better-quality building materials, such as cement blocks, steel bars, fired bricks and corrugating sheeting, instead of timber and bamboo (ibid.). However, this rapid urban growth and construction posed a major challenge: the use of higher-quality building materials was not often coupled with storm-resilient housing design or construction techniques, and increased vulnerability to damage in many instances (ibid.). Housing was the sector most affected during storm events, highlighting a need to improve the resilience of homes.

As is commonly the case, Vietnam's limited resources have often meant that disaster relief has been prioritised over disaster risk reduction (UNDRR, 2019). Therefore when storms hit, there is limited capacity to 'build back better' – homes typically have been rebuilt using the same non-resilient construction methods and materials as before (Tran, 2014). Climate projections indicate that typhoons impacting Da Nang are likely to increase the risk of flooding in the future due to rising sea levels and more intense rainfall (Opitz-Stapleton and Hawley, 2013).

Vietnam has established agencies within different regions and administrative levels to prevent and mitigate the impact of storms and floods. Nationally, the Central Committee for Flood and Storm Control assists with the development and implementation of annual flood and storm plans, while People's Committees establish local committees for flood and storm control in provinces, districts and communities (Tran et al., 2014).

Two policy documents govern disaster risk reduction and climate change at a national level in Vietnam: the *National Strategy for Natural Resource Prevention, Response and Mitigation to 2020* (2007) and the *National Target Program to Respond to Climate Change* (2008). These documents provide top-down direction to local governments, but the design of specific implementation strategies is left up to the regions (Tran et al., 2014). In Da Nang, disaster risk reduction is now incorporated into building codes, but only houses with a floor area above 250m^2 are required to obtain a building permit, thereby excluding most vulnerable housing from this requirement. There are also no policies or legal frameworks that require households to use construction practices that promote resilience (ibid.).

The adaptation process

In 2011, the city of Da Nang was in the process of developing a city-wide resilience plan. This formed part of the 100 Resilient Cities project funded by the Rockefeller Foundation.[7] As part of this broader effort, the Da Nang Women's Union, along with the Institute for Social and Environmental Transition (ISET), were funded by the Rockefeller Foundation and the Nordic Development Fund to establish an incentive scheme for poor, near-poor and middle-income households to construct more resilient housing.

While the funding provided by donors for adaptation was novel, the institutions were well-established, with clear social and knowledge capital, and had a demonstrable record of achieving positive societal outcomes. The Women's Union is a quasi-governmental organisation with strong local connections and was therefore well-placed to manage the provision of grants and loans and liaise with local households for resilience. There were two components to the incentive scheme: a financial incentive and free technical support in the design of the house. A microcredit and technical assistance programme was established, aimed at developing typhoon-resilient housing in vulnerable areas of Da Nang (Tran, 2014).

The financial incentive was made up of a combination of the existing city government subsidy programme and a low interest rate loan from the Women's Union. The proportion of grant versus subsidy depended on household income (the poorest of households were able to access a larger grant). The Women's Union also worked with the Da Nang Climate Change Coordination Office and the Central Vietnam Architecture Consultancy, a construction consultancy firm which they hired to provide free technical support and advice to households to help them decide whether to

[7] The final resilience plan from 2017 is available at https://www.100resilientcities.org/wp-content/uploads/2017/07/Da-Nang-Resilience-Strategy_2.pdf

refurbish or completely reconstruct their home, as well as how to do so in the most resilient manner (Shaw et al., 2016; Tran et al., 2014).

As a result of the Women's Union's existing community relationships and capacity developed through management of other community finance initiatives, the organisation was able to monitor recipients to ensure the loans and grants were being used for the purpose for which they were provided. The Women's Union was also able to offer flexibility for poor households to ensure households were able to meet basic needs. Thus the project invested both directly in physical capital (resilient infrastructure) and in enhancing the social, human and knowledge capital that already existed in the Women's Union. This meant the Women's Union was able to consider climate change resilience in the finance it provided.

Other aspects of the work included a research project to find examples of resilient housing design and measure the cost-benefit ratio of investing in a resilient house (CDKN, n.d.; Tran, 2014).

In what ways do these actions constitute adaptation to climate change?

The ISET project team worked with the National Centre for Atmospheric Research in Colorado to develop climate projections for the Da Nang region, and found that while typhoons may not necessarily become more frequent in Vietnam, they are likely to become stronger. An exercise was then undertaken to find a balance between resilience considerations and affordability for low-income households to reduce risk. Project partners recommended that houses should be resilient to wind speeds of around 12 on the Beaufort scale – the threshold speed for a tropical storm to be classified as a typhoon in the Pacific region. To cope with particularly strong typhoons, households' own resilience would need to be supplemented by government-funded community storm shelters and early warning systems.

Integration of the resilient housing project into a larger resilience strategy for the city also helped to build local capacity for adaptation planning which would enable the city to progressively prepare for more frequent and severe climate hazards in the future.

The success story

Direct avoided losses

All but one of the 245 houses that were part of the project had completed their reconstruction or refurbishment when Da Nang unfortunately had to put its resilient housing to the test. On 15 October 2013, Typhoon Nari struck the south central coast of Vietnam, with 122,000 people evacuated (Minh, 2013). Typhoon Nari caused significant flooding throughout Da Nang and the surrounding provinces, as a result of which at least 27 people died and 116 people were injured. In total 614 houses collapsed, 13,131 houses had their roofs fully or partially torn off, and 96,760 houses were flooded (UN Country Team in Vietnam, 2013). However, all 244 of the completed resilient households that were part of the project withstood the typhoon without damage (CDKN, n.d.; Shaw et al., 2016), representing a resounding early success for the adaptation process during this tragic event.

Other economic benefits

The project generated significant benefits in addition to the avoided losses during Typhoon Nari. Households that participated gained new skills and experience related to designing and reconstructing their homes. Shaw et al. (2016) argue that the project also generated greater awareness of the need for storm-resilient housing, which in turn increased the demand from poor households for access to the scheme, thus validating further investment in the programme by impact-motivated investors. In addition, Shaw et al. highlight the knowledge and human capital built through the project, identifying that the Women's Union itself was a beneficiary. The project enabled the Union to "develop skills for managing and scaling a fund for storm-resistant housing and emerge as a key agent of change in climate change resilience for poor and vulnerable households", thus enabling economic development (ibid.).

Wider benefits

Anecdotally, in addition to the immediate benefits of typhoon resilience, families involved in the programme reported feeling safer and more secure, which led to greater investment in income generation activities for their families and children. In delivering the financial mechanism to households, the Women's Union also provided informal support and monitoring of additional household resilience measures through nutrition and education. Having better quality housing also meant that households had an asset against which they could access further finance for other items.

The demonstrated success of the project through the buildings' resilience to Typhoon Nari led to increased interest in the project and follow-up funding from major donors. The Asian Development Bank funded a feasibility study examining how to scale up the project for more households in Da Nang. The Nordic Development Fund provided further funding to replicate the project's model and conduct further analysis on different incentive packages to encourage households to take up more resilient housing. The Da Nang city government also engaged in discussions with the World Bank to develop a financial resilience strategy for Da Nang, including promoting resilient housing through the mechanism used as part of the original project.

Following Typhoon Nari, the project partners along with the Women's Union advocated to the city government for improved regulation, and the government issued a decree requiring housing to be more resilient. In November 2013, the city of Da Nang adopted a new regulation requiring the Department of Construction to use storm-resistant techniques when considering housing construction permits (Wagnon, 2014). However, houses under 250m^2 in size still require minimal engineering detail in their permits, so it is unclear if this decree will filter down to the most vulnerable households. Further guidelines for housing construction have since been developed but these are not binding. Part of the challenge involves balancing bureaucracy and administrative costs. However, there has been a reported improvement in building standards adopted by businesses.

Lessons learned

- **It is important that ongoing resilient housing programmes do not happen in isolation**, as recommended by the project partners in interviews, recognising the challenges of increasing typhoon strength, with rising sea levels and climbing rainfall intensity. The trade-off between cost and resilience discussed above led to the decision to aim for resilience to the lowest strength category of typhoon. There is an ongoing need for government support for community-level shelters, early warning systems and more resilient housing, which is often beyond what households can afford by themselves.
- **The importance of building local capacity** has also been highlighted by the project. Because it was primarily driven by the Women's Union in partnership with ISET and the local government, there is now local capacity to implement improved planning processes and additional adaptation projects in Da Nang. This means future projects can continue to be locally-driven and guided by locally-determined needs, even if funded by external donors. It is important to have a local organisation like the Women's Union taking on the role of change agent and working to advocate and assist government with developing longer-term plans. This helps to overcome the challenges of relatively short political time horizons (e.g. four to five years), which can make it difficult to get political buy-in for preparedness to low frequency but high severity events.
- **It can be much easier to convince people to invest right after a disaster has occurred**, as the experience of Typhoon Nari showed.
- **Some poor households will struggle to afford more resilient housing**, no matter how great the benefits are, and will need financial support of the kind used in this project, despite the project's success.
- **Secure property rights are also important for poorer households**, to ensure they have the confidence to invest.

Case study 6

Adaptation Pathways planning in the Thames Estuary 2100 Programme, UK

Background

For almost two millennia, the Thames Estuary has formed the beating heart of London and its surrounding areas, with economic activity heavily concentrated on the banks of the river. The Thames Estuary consists of the stretch of the River Thames flowing through London, from Teddington Weir in West London out to the North Sea Coast. It is subject to a daily rise and fall in water levels of around 7m (Environment Agency, 2012). Through a combination of freshwater flow and tidal waters, large parts of London are exposed to flood risk from the estuary. The most acute risk of flooding comes from North Sea surge tides which occur in the Thames Estuary when a depression – a band of atmospheric low pressure – moves across the Atlantic Ocean towards the British Isles. The sea under the depression rises above the normal level, creating a mass of water that passes the north of Scotland and moves south into the North Sea. This mass can move down England's east coast and funnel up the Thames, and can be made even bigger if there are strong northerly winds. Surge tides can increase water levels substantially beyond the usual tidal variation and pose a significant threat, particularly at times when tide levels are already higher than usual.

The areas at risk of flooding are also key contributors to London's role as the economic, institutional and cultural centre of the UK; the flood zone is home to over 1.3 million residents, 40,000 commercial and industrial properties, government buildings, four world heritage sites and eight power stations. Important business districts, such as the Docklands, lie wholly within the floodplain. London's continued prosperity is thus contingent on the effective management of flood risk, and this management must take future climate change into account. However, there is substantial uncertainty regarding how future flood risk might be exacerbated by climate change, with this uncertainty growing as the timeframe extends further into the future (Ranger et al., 2013). There is particular uncertainty around the impact of climate thresholds, such as the destabilisation of the polar land-based ice sheets, on sea level rise and the consequences for water levels in the Thames Estuary (ibid.). The quality and availability of climate data are improving with time, but actions to mitigate risk should not be delayed.

The Thames Barrier was opened in 1984 to protect against storm surges, but its design did not account for the possible impacts of climate change. The quality of protection the Barrier provides will diminish as sea levels, and the frequency and height of surge tides, rise with climate change. However, over the past decade, the Environment Agency has invested in maintenance and refurbishment works to ensure the Barrier is able to withstand rising sea levels and more frequent storm surges. Thanks to this, and an improved understanding of flood modelling, it is now expected that the Barrier will be able to continue to protect London until 2070 (Environment Agency, 2020).

The adaptation process

Development of the Thames Estuary 2100 (TE2100) Plan started in 2002 and the Plan – a cross-government initiative led by the Environment Agency – was published in 2012. The aim of the project was to address the challenge of long-term planning of flood risk management for London and the Thames Estuary in the face of deep uncertainty over the level and nature of the risk. A key strategic aim from the outset for the TE2100 Plan was that it must be anchored firmly in risk assessment and management. Furthermore, it was stipulated that this risk needs to account for both existing and future assets, while also considering the possible changes in socioeconomic conditions and climate over the next 100 years. The Environment Agency set out to design a plan that was "adaptable to change and [would] remain fit for purpose throughout its 100 year lifetime" (Environment Agency, 2012).

The Plan has a set of interrelated objectives beyond flood risk management for the people and properties within the floodplain. It includes actions to enable adaptation to climate change, to facilitate sustainable and resilient development, to protect social, cultural and commercial value, and to enhance and restore ecosystems within the floodplain (Environment Agency, 2019).

The Thames Estuary 2100 Plan area

Photo: © Ordnance Survey and the Environment Agency, 2018. Reproduced with permission.

The Thames Barrier is expected to continue to protect London to a sufficient standard until 2070. The Plan identifies different options for improving or replacing the Thames Barrier beyond that date. Because it is an adaptive plan, the final choice is unlikely to be made until 2050. A critical mechanism of the Plan is a 10-year review period, which evaluates how the situation has changed since the previous review period and therefore how response measures should be designed.[8]

Having a plan covering such a lengthy time period raises institutional challenges, from the perspective of both politics (recognising that it will span many different governments) and funding. Once the office of London Mayor, Ken Livingstone, understood the approach during the planning stages, it was strongly supportive, and this backing has remained in place through successive Mayoral changes. Central government has also been supportive, although no new legislation was required to derive the Plan.[9]

The Thames Estuary 2100 Plan is divided into three phases, spanning nearly 100 years (Environment Agency, 2020):

Phase 1: 2012 until 2035:

- Maintain and improve current flood risk management assets including walls gates, embankments and pumps
- Protect land needed for future improvements to flood defences
- Monitor how the estuary is changing

Phase 2: 2035 to 2050:

- Raise existing flood walls, embankments and smaller barriers
- Reshape the riverside through development, to improve flood defences, create habitat and improve access to the river

Phase 3: 2050 to 2100:

- Decide and construct the best option for the future of the Thames Barrier
- Adapt other flood risk management assets to work alongside this to protect the estuary

In terms of funding, the Plan relies on £10bn being available from government when it is needed in the future and this has been incorporated into the long-term England and Wales Investment Strategy. Furthermore, the 10-year review mechanism provides an opportunity to revisit and allocate funding as it is required. Nonetheless, it will be critical to the success of the Plan that the UK government remains committed to it and makes funding available as required.

In what ways does the TE2100 Plan constitute adaptation to climate change?

The Plan is based on an approach known as Adaptation Pathways planning, which was unique at the time in a number of ways. From the outset, the TE2100 Plan has had planning for future climate change at the core of its approach. However, this does not mean that it makes plans based on a

[8] The first full review and update is currently underway, with a revised Plan expect to be published in late 2022.
[9] The adoption of the Climate Change Act in 2008 provided an overarching framework for adaptation which may have lent support indirectly.

fixed perception of future risk levels exacerbated by climate change. Instead, the Adaptation Pathways approach focuses on adaptive capacity over a long period, and can be modified to take account of different projections for climate change and sea level rise. Hence, it can be refined on a continuous basis as knowledge of climate change and understanding of future risk improves.

When the Plan was developed it made use of the latest climate change guidance available at the time, including the Fourth Assessment Report by the Intergovernmental Panel on Climate Change, as well as independent, bespoke research on possible changes to fluvial flows, tidal storm surges and sea-level rise. This helped to inform a clear vision of a 'worst case' future scenario that might be encountered. However, the Plan does not make infrastructure decisions based on expectation of this scenario; rather, it ensures that the decision-making process takes a systems approach and seeks to understand the thresholds over which these systems would fail, taking into account a range of scenarios that are broad enough to include the 'worst case' scenario.

The success story

Direct avoided losses

The Thames Barrier was built to a technical specification that provides a very high level of protection today, while not originally intended to be a climate change adaptation measure. The Barrier has been called into active service most years since it started to operate in 1982, with, for example, 24 closures in 2000/2001 to deal with a combination of tidal and river flooding events. This frequent usage led Penning-Rowsell et al. (2013) to conclude that "without this intervention, London would have experienced serious flooding on several occasions since its completion in 1982". For instance, a 2014 tide, which did not cause any damage, was of a comparable level to the major tide of 31 January/1 February 1953, the greatest surge on record, which combined with a high spring tide to flood 1,000 London homes and drown 300 people along the East coast of England. It is noteworthy that usage of the barrier has increased over time, from four closures in the 1980s to 75 closures in the 2000s to protect against both tidal and combined tidal/fluvial flooding (Environment Agency, n.d.).

Through the TE2100 Plan, the Thames Barrier and the associated flood defence mechanisms in place are now expected to be robust against climate change and associated surge tide severity up to around the year 2070. Processes are now in place to ensure this level of protection is maintained up to 2100 and beyond. This can ensure that the benefits of avoided losses can continue to be felt into the future. Assessments of the value of future avoided losses by maintaining protection from flood risk indicate substantial benefits. Benefits related to fatality prevention are estimated to be about £11bn (Penning-Rowsell et al., 2013).

Other economic benefits

There is more than £275bn worth of property and infrastructure in the tidal flood zone in the Thames Estuary. London is a globally important city and is responsible for generating around 23 per cent of the UK's GDP. If concerns over exposure to increased flood risk were to jeopardise investor confidence in London, it would have disastrous economic impacts. An academic evaluation indicates that, while there are uncertainties over the exact nature of risks in the future, ensuring continued protection from the sea is highly cost-beneficial from an economic perspective (Penning-Rowsell et al., 2013). The evaluation estimates that indirect impacts on business could be between £53bn and £58bn, based on levels of disinvestment (and associated gross value added 'leakage' away from London) by the financial services sector in response to different flood risk scenarios. This provides additional assurance to London's businesses that the risk that London is being exposed to is being managed and mitigated, ensuring a healthy investment landscape.

A significant benefit of the TE2100 plan is its cost-effectiveness. The academic literature on adaptation warns that there are substantial risks in adaptation planning beyond taking insufficient action to account for climate risk. Taking too much action, or the wrong type of action, also presents substantial risks, which can lock in greater risk by wasting investments or leading to

additional retrofit costs later (Ranger and Niehorster, 2012). The adaptive pathways approach has identified the point in the future when the existing flood defences, primarily the Thames Barrier, will start to become ineffective, given the lifespan of the infrastructure (coming to the end of its useful life by 2070) and the likely impacts of climate change (for example, the standard of protection will fall as sea levels rise) (Ranger et al., 2013). It has led to the right forms of investment being targeted, in light of the latest climate information, at the time when it is needed. The approach has therefore meant more effective and efficient use of public funds.

Wider benefits

The Plan's innovative governance process, characterised by long-term, flexible planning to manage uncertainty, has significantly strengthened the case for other cities and localities, and their political leaders and communities, to implement adaptation measures. This success is reflected in the Plan being replicated in other world cities such as New York. Furthermore, the 10-year review process provides an important chance to build engagement and an ongoing sense of involvement in the adaptation process for local businesses and communities. Government collaboration with councils, communities, businesses and NGOs is vital to the process, as is the opportunity to explore where the environment can be improved for local communities by supporting local and national regeneration ambitions for the Thames Estuary (Environment Agency, 2020). Furthermore, through the decision-making process, a monetary value was associated with avoided environmental damage by not investing in hard engineering solutions – which can have negative impacts on wetland habitats, for instance – unless absolutely necessary.

Lessons learned

- **The critical innovations within the TE2100 Plan include the 'decision-centred' planning process**, which is common in project appraisal. This transformative adaptation approach focuses on the vulnerability of the whole system, and identifies options for action. Ranger et al. (2013) provide a detailed evaluation of these innovations, which came about through a long and active process of learning, collaboration and development during the project. Ranger et al. also highlight the use of 'narrative scenarios' which extended beyond scientific modelling to also consider anecdotal knowledge, and Adaptation Pathways which enable flexibility and sequencing, while still empirically monitoring points in time when decisions – and response measures – will be needed.
- **More broadly, the Adaptation Pathways approach has provided an example of how to ensure long-term political support for adaptation measures** – a key challenge in many countries – by keeping long-term options open. This motivates decision-makers across successive governments to modify their plans to better accommodate future knowledge of climate change and conditions (Bloemen et al., 2018).

Case study 5

'Grey and green' responses to urban flood risk in Beira, Mozambique

Background

Mozambique is one of Africa's most exposed countries to extreme weather events, including floods, cyclones and droughts. Climate projections indicate that Mozambique's exposure to these hazards will increase into the future (KFW Development Bank, 2015) – with the World Bank suggesting that "without changes to climate and disaster risk management and financing policy, climate change is expected to cause economic damages of between US$2.3 billion and US$7.4 billion during the period 2003–50 in Mozambique (discounted and in 2003 prices)" (World Bank, 2019b).

Beira is Mozambique's fifth largest city, with more than 600,000 inhabitants in 2020, and the population is expected to reach 830,000 to 1.4 million by 2035 (Initiative on Financing for Resilient and Green Urban Global Solutions, 2020). Approximately 300,000 people in Beira live in poorly planned or informal settlements, which are particularly vulnerable to the impacts of extreme

weather events, including coastal and river flooding. Many of these informal areas have a high population density, high poverty rate and poor residential, water and wastewater infrastructure – limiting residents' capacity to adapt to climate risks. Rapid population growth in Mozambique's urban coastal areas over recent decades has not been accompanied by the necessary corresponding investment in basic infrastructure and services (World Bank, 2018b), including those required to protect against extreme weather.

Beira is one of Mozambique's largest and most important ports, second only in size to the capital Maputo for international cargo transportation. The port functions as a gateway to several significant transport corridors, allowing access to the rest of the country and to neighbouring landlocked countries including Zambia, Zimbabwe and Malawi, for trade. Beira also has a significant fishing industry.

Sitting just above sea-level, Beira has long been exposed to frequent flooding from heavy rainfall and storm surges, especially when these factors coincide with a high tide (World Bank, 2014). The Indian Ocean in this area has a large tidal range of up to 7 metres, increasing the city's vulnerability to flooding (KFW Development Bank, 2015; Spekker and Heskamp, 2017). This vulnerability is likely to be exacerbated with climate change, due to extreme weather, rising sea levels, and coastal erosion (CES, 2020).

The River Chiveve, a tidal river that runs through the central business district and low- and medium-income residential neighbourhoods, has also been prone to become filled with silt and residential waste, and as a result does not act as a functional drainage channel for the city. These factors, along with rapid urbanisation,[10] have damaged the natural ecosystem of the river.

Over recent decades, flooding has frequently forced people out of their homes – predominantly those located in the informal settlements along the banks of the Chiveve (Spekker and Heskamp, 2017). It has caused acute health problems, including cholera and malaria, as water supplies are contaminated and mosquitos breed in the stagnant floodwaters. Severe flooding has also caused significant damage to the city's economy.

Mozambique has a substantial set of national policies and structures in place for flood management, having sought to shift the focus of its disaster management approach from reaction to preparedness in 1999. This has included close collaboration with the National Institute of Meteorology on flooding preparedness measures, such as an early warning system, supported by good quality climate and hydrological data. These data are linked to disaster response, with mechanisms to involve district governments, local authorities and NGOs. However, competing financial and developmental needs limit the resources available for preparedness and response. Combined with high levels of poverty among the population, this lack of resources means the majority of Mozambicans remain highly exposed to flooding and other climate-related risks (Hellmuth et al., 2007).

The adaptation process

Working with a variety of national and local governmental actors, including the National Directorate for Local Government Development, the Agency for Water and Sanitation Infrastructure, and the Municipality of Beira, the World Bank and the German KFW Development Bank financed a number of interventions to support an improvement in flood resilience in the city through a coordinated, staggered approach.

Firstly, the stormwater drainage system was strengthened and extended, with the rehabilitation and construction of 11km of drainage canals, the installation of six flood control stations, and the construction of a retention basin with the capacity to hold 170,000m^3 (see photo below). The system drains rainwater during low tide and stores rainwater at high tide, with flood gates controlling the level of water held in different parts of the system as required. Solar-powered lamps were installed along the canals and 5km of roads were also repaired or resurfaced.

[10] Significantly, a low bridge with a narrow underground conduit for river water had been built in the estuary, blocking tidal water from entering the river, and becoming blocked itself as an outlet by sediment and waste.

A stormwater drainage system has helped build resilience in Beira.

Photo © World Bank/ Sarah Farhat, reproduced with permission.

Completed in July 2018, the improvements were financed through US$60m in credit from the World Bank.[11] Covering central areas of the city, the interventions formed the first phase of stormwater drainage improvements under Beira's Masterplan 2015–2035.

Secondly, with financing provided in two main phases, the Green Urban Infrastructure Project and its forerunner, the Chiveve River Rehabilitation Project, have sought to reduce urban flood risk in the River Chiveve catchment, by restoring and protecting the natural drainage capacity of the river and wetland ecosystems. The first stage of financing (€13m) was provided by KFW,[12] which commissioned German engineering firm Inros Lackner to carry out feasibility and design work from 2013, with construction starting on the Chiveve Rehabilitation in 2015. During the extensive feasibility phase, it became clear that there was a need for a hybrid 'grey-green' solution: that is, with a focus on nature-based solutions alongside 'hard' physical defences such as a flood barrier. As such, the restoration of the natural ecosystem, such as the mangroves and wetlands threatened by ongoing urbanisation, was integrated into infrastructure planning.

Inros Lackner designed a controllable tidal outlet structure and flood barrier at the fishing port to protect the city from spring tides, storm surges, and excessive rainfall (KFW Development Bank, 2015; Spekker and Heskamp, 2017). Gates on the flood barrier were designed to control the water level along the river course, and to hold water in a purpose-built retention basin until it can be released via the tidal outlet at low tide, preventing it from flooding the city's settlements (Spekker and Heskamp, 2017). The measures also included dredging, enlarging and rehabilitating the river to re-establish its natural drainage function.

The first phase was completed at the end of 2016. A second stage of the project, the so-called Green Urban Infrastructure Project, aimed to rehabilitate the space around the river. This included creating a green landscape park to protect the river course from encroaching urbanisation and to protect the natural drainage capacity of the river and its floodplains (KFW Development Bank, 2015; Spekker and Heskamp, 2017). In addition to flood protection, the park is designed to realise several community co-benefits, such as a playground, sports facilities, a botanical garden, an open air theatre, an event centre, a restaurant, kiosks, sanitation facilities and lighting (KFW Development Bank, 2015). The redevelopment will also include new pedestrian bridges, cycle lanes and the rehabilitation of a local market. The restoration of mangroves and other natural habitats on the riverbanks has also been a key focus. The second phase was completed in late 2020, and was financed by the World Bank jointly with KFW.[13]

[11] Through the International Development Association branch.
[12] Energy and climate fund of German Federal Ministry of Economic Cooperation and Development, provided through KfW.
[13] The Mozambique Cities and Climate Change Project was funded by US$120m IDA credit. This financing includes areas/objectives outside of Beira. Additional funding came from the Pilot Program for Climate Resilience and US$15.75m from the Strategic Climate Fund. KFW provided €14m.

Both the World Bank and KFW also focused on building human and knowledge capital by financing the provision of technical assistance and capacity-building at the municipal level, to give particular support to the operation and maintenance of the new systems. A broader awareness-raising campaign was also conducted, including the establishment of an information centre about the project in a central area of the city, and the distribution of comic-style leaflets in schools about the importance of the river and keeping it clean.

Adaptive planning was key, with changes to goals and target groups required following the first feasibility study – for example, an added focus was placed on ecological components – and coordinated working between donors to enable integrated programming and increased impact. The initial scope of the feasibility study for the second phase of the rehabilitation of the Chiveve was shaped by key stakeholders, including interactions between local government, civil society and academia in stakeholder workshops, as well as through public hearings (CES, 2020). This resulted in changes, such as the addition of economic infrastructure to the project to generate funds for the operation and management of the park.

In what ways do these actions constitute adaptation to climate change?

Data on future climate risk were used in the modelling carried out during the feasibility study for the stormwater drainage system, and informed the detailed design of the drainage infrastructure. This analysis included studies conducted by the National Institute for Disaster Management (INGC), which estimated an average 18.5 per cent increase in rainfall and a rise of 13.5cm in sea level over the given project horizon of 25 years.[14]

The feasibility study on which the rehabilitation of the Chiveve was based also included a climate change assessment, run-off and flood modelling, a coastal assessment, and other environmental data. Rain gauges and water level recorders were added during the second phase, which was completed in 2020. When combined with evaluation of the tidal logbooks, this was expected to make it possible to "better understand the characteristics of the rehabilitated Rio Chiveve and to improve operation and adapt to changing boundary conditions" (CES, 2020).

The success story

Direct avoided losses

The drainage system and reservoir have been working well in preventing the city from flooding and there has been no major flooding in the project areas since the construction works were completed (CES, 2020).

The flood resilience measures were put to the test for the first time in February 2017, when a one-in-ten-year rainfall event occurred, with 225mm of rain falling over a 24-hour period. No major flooding occurred in the project areas (Spekker and Heskamp, 2017).

In January 2019, the city experienced what a project partner labelled a "one in 50-year flood" and a "significant test for the system" – with 277mm of rain reported in Beira in 24 hours, more than the 250mm expected in the entire month of January (Al Jazeera, 2019). The drainage system and basin worked well under significant pressure and there was no major flooding in the project area. A faster recovery was reported for those impacted by flooding of the old canal system outside the project area. A project partner asserted that under previous circumstances floodwaters would have remained for weeks.

When Cyclone Idai struck the coastline of Mozambique in March 2019, Beira experienced less flooding than other parts of the country (International Development Association, 2019), although some parts of the city were badly hit. Satellite information showed that 36.2 per cent of the city was flooded, affecting 217,000 people. The drainage channel remained intact and discharged large amounts of storm water released by the cyclone and the heavy rainfall that followed (Dutch Water Sector, 2019). The more limited damage, however, was restricted to the areas served by the new drainage system: a substantial part of the city was flooded, highlighting the need for

[14] Information from feasibility study shared in conversation with project informant from the World Bank.

additional drainage outside of the project area. It demonstrated the potential of the system and the advantages that could result from scaling it up.

Although the flood defences played a significant role in the reduction of damage, this was greatly helped by the fact that the cyclone made landfall during low tide. However, the flood defences did not prevent catastrophic damage from being wreaked in Beira by Cyclone Idai's strong winds of more than 175 kilometres per hour.

This is therefore an example of an intervention with demonstrated success within its limited capacity that could have prevented significantly more damage had it both received greater financing and been more integrated with city planning processes across multiple hazards.

Other economic benefits

Direct and indirect employment opportunities have been created as a result of the interventions, although these opportunities have not yet been formally quantified[15] (KFW Development Bank, 2015).

A project partner described the transformation of land use along sections of the drainage canals, from empty space to "prime real estate". This has included a significant increase in businesses locating there, especially kiosks, in part owing to the much-increased movement of people along the canal. Both local people and those from other parts of the city now use the basin and canal area for leisure activities, including exercise. This has been facilitated by the improved access to the area by car and motorbike.

There has also been a dramatic improvement in security in the area, with a reported "sharp decline of robberies, rape and thefts" (CES, 2020). The installation of lighting as part of the project infrastructure was reported to be significant in facilitating this change, as people were said to feel safer to visit the area and to handle money. This was noted as being significant in supporting business and job opportunities for women especially, who had expressed feeling more comfortable in transporting goods and holding money in the area following the changes. While clearly this does not tackle the root causes of violence and theft, including towards women, it at least facilitates a safer, and thereby more business-conducive, environment.

The intervention has led to improved housing stock in the area, according to anecdotal evidence. It was noted that a significant number of people have been investing in upgrading their housing, which is more worthwhile now that the risk of frequent flooding has been drastically reduced. According to the Municipality of Beira, structural damages to buildings induced by changes in groundwater levels are also reducing as a result of the intervention (CES, 2020).

It was also noted that the use of coping mechanisms is no longer necessary, such as someone from the household, usually a woman, being required to stay at home to take action in cases of flooding with little warning. This is likely to have a positive impact on the work opportunities available to women in the area, who may no longer be confined by the limited options of home-based work.

The dredging of the fishing port at the mouth of the river to improve water flow also had the benefit of creating additional mobility for fishing boats (CES, 2020).

Wider benefits

The urban park is expected to build natural and social capital, creating environmental benefits by lowering temperatures, supporting biodiversity, and promoting cleaner air and water retention. The park will also provide public space for leisure activities, including sports, arts and culture (World Bank, 2018b, 2020), which can be used by, for example, children from the nearby formal and informal settlements. KFW claims that "the quality of life of the residents is improving by gaining access to the recreational area as well as social and cultural events in the park" (KFW

[15] A forthcoming evaluation by the World Bank will be available after the close of the project, to provide further insight into the impacts of the intervention.

Development Bank, 2015). The cited health benefits of the park include space for exercise, as well as encouraging cycling and team sports. Installation of cycle lanes in the area is also expected to increase connectivity and to lead to safer and healthier transport options for citizens (ibid.).

Further health benefits, resulting from the removal of stagnant flood waters and improved waste practices, have been realised. A project partner stated that, during interviews with local stakeholders, reports of incidences of cholera and malaria have significantly reduced. Waste collection in an informal settlement on the banks of the Chiveve now occurs daily, funded by the Municipality.

Significant capacity has been built among local technical staff, including those who operate the flood gate at the port. A project participant noted that training and accumulated experience had increased the ability to deal with more volatile weather and sea level rise.

The implementation partnership also created strong, collaborative relationships between institutions, a factor cited as having helped pave the way for the development of a comprehensive disaster response plan in Beira following Cyclone Idai. This built on existing collaboration and learning, and allowed for significant focus on 'missing pieces of the puzzle' in disaster preparedness – such as increasing coastal protection, expanding drainage canals to other parts of the city, and focusing more on nature-based solutions – and a longer-term view than is usually achieved in disaster response planning. This is an example of how adaptation financing can spotlight other key areas.

The Chiveve rehabilitation is a pilot project for flood protection through grey-green infrastructure, one of the first nature-based urban flood management projects supported by the World Bank, and in Mozambique it has been unique in scale and approach. Significant opportunity exists, therefore, for transmitting learning, and strong interest has been reported from many other African cities that have similar exposures to coastal flood risk. Work is currently being undertaken by the World Bank and partners to facilitate and extend this learning, with potentially wide-ranging impacts for other coastal cities in Mozambique and the region (see CES, 2020; PROFOR, 2020).

Lessons learned

- **Potential for expansion:** Cyclone Idai put the flood resilience system in Beira to the test and demonstrated that it was an effective design that was able to protect the local area. However, the project was of too small a scale to defend the whole city, and only provided protection against flooding. As such, the project shows significant potential for further expansion, but also highlights the need for adaptation planning to account for multiple potential climate hazards which can compound risk. The World Bank agrees that more is needed in terms of investment, and ongoing maintenance of the system.
- **Nature-based solutions:** Consideration of nature-based solutions became an increasing focus during rehabilitation of the Chiveve river basin; however, this was not originally conceived as a grey-green intervention. This meant that a common understanding of the importance of nature-based solutions could have been a more important consideration alongside the traditional 'grey' solutions that dominate engineering approaches. Integrating nature-based solutions from the start would have allowed them to be embedded throughout the approach. Further, the evaluation by CES Consulting Engineers Salzgitter of the project suggests that "where ecosystems are part of the project solution or within the project area, clear guidelines and targets should be set by the financing institutions on protection and/or restoration measures" (CES, 2020).
- **To ensure sustainability**, a budget for the operation and management costs of urban park landscapes with leisure activities should be built in from an early planning stage, as with other elements of an intervention that will require financial and human resources after the planned financing period comes to a close.

For a wider range of lessons learnt, see the evaluation by CES Consulting Engineers Salzgitter, *Upscaling Nature-Based Flood Protection in Mozambique: Lessons Learnt from Beira* (2020).

Case study 6

Cyclone risk mitigation in Odisha, India

Background

Odisha is a low-lying state on India's east coast, on the Bay of Bengal. It is home to approximately 46 million people and is one of India's lowest income states, with a proportion of poor well above the national average at 43 per cent (Government of Odisha, Forests and Environment Department, 2018) and an average income of less than US$5 per day (Dora and Padhee, 2019; Kumar et al., 2019).

Odisha's economy has, however, seen high growth rates over recent years, with the state's GDP expanding at a compound annual growth rate of 12.7 per cent between 2015/16 and 2019/2020 (IBEF, 2020). Odisha's main economic sectors draw heavily on the natural wealth of the state, including its mineral and metal-based industries.[16] Agriculture is a key sector, especially for the rural poor – employing over 60 per cent of all workers according to the 2011 census, supporting food security, and feeding into other industrial and service sectors. Tourism is also an important sector, generating significant employment opportunities. In 2018–19, Odisha was visited by approximately 15.5 million domestic tourists and 114,000 foreign tourists (ibid.).

Although the population of Odisha is predominantly rural, the state has undergone significant urban growth (a 27 per cent increase approximately) over the past decade, with rapid growth in slum populations living in poorly constructed buildings in environmentally vulnerable areas (Government of Odisha, Forests and Environment Department, 2018).

Climate risks and their impacts

Natural disasters frequently disrupt the economic growth of the state (Government of Odisha, 2019), with its high poverty levels and high dependency on natural resources increasing the state's vulnerability (ibid.). Odisha has approximately 480km of coastline stretching from West Bengal to Andhra Pradesh, and often experiences extreme weather events, including cyclones and flooding.

India is exposed to approximately 10 per cent of the world's tropical cyclones (NCRMP, 2019). They cause a high number of deaths, loss of livelihood opportunities, damage and destruction of much property and infrastructure – and as a result can severely reverse development gains at frequent intervals (given their recurrent nature). Sea-level rise resulting from climate change is likely to increase the vulnerability of coastal areas to cyclone-induced storm surges and related flooding (Bahinipati, 2014).

A large portion of the agricultural land is cultivated during the *kharif* cropping season, which in Odisha traditionally lasts from May to November. Yet with the occurrence of cyclonic storms during the period of August to October, agricultural crops can be significantly impacted. For example, in 2010 unseasonal cyclonic rainfall led to major crop losses in 24 districts in Odisha, with a lost value of approximately Rs 60,000m (Bahinipati, 2014) – approximately US$1.35bn in 2010 US dollar terms. This trend is likely to continue for the foreseeable future, with cyclones in the Bay of Bengal projected to increase in number during the late monsoon season (August and September) by the years 2071–2100 (Unnikrishnan et al., 2011). The 2013–14 downturn in the state economy has been attributed to Cyclone Phalin, including the 9.78 per cent contraction experienced by the state's agriculture sector (Government of Odisha, Forests and Environment Department, 2018).

In late October 1999, Odisha was hit by two cyclones. The second was termed a 'super-cyclone' because of its high wind speeds of 260km/h (160mph/h) and it generated a storm surge that travelled up to 20km from the coast, destroying villages in its path. About 8,900 people were killed in the most heavily impacted district of Jagatsinghpur. Poor structural quality of infrastructure (including mud houses that were built to withstand regular low-intensity storms but not cyclonic winds) along with coordination and communication challenges contributed to this vast damage

[16] In 2018, Odisha contributed the largest share of value from mineral production in India (at 40.7 per cent). (IBEF, 2020)

and loss of life (Chhotray and Few, 2012). Significant outbreaks of several waterborne diseases also followed (Jha et al, 2016), as well as high incidences of mental health disorders, with one study finding over 80 per cent of subjects had probable psychiatric disorders, including post-traumatic stress disorder (PTSD) (44.3 per cent), anxiety disorder (57.5 per cent) and depression (52.7 per cent) (Kar et al., 2004). A study conducted a year after the super-cyclone found a majority of children in affected areas had post-traumatic symptoms, with 30 per cent suffering from PTSD (Kar et al., 2007).

The 1999 super-cyclone left a lasting impact on the region, with economic devastation, high levels of poverty, and added challenges such as increased salinity of agricultural lands due to the storm surge. These were among the factors that hampered the adaptive capacities of households and communities to recover economically, and to protect their homes and livelihoods from future cyclones (Chhotray and Few, 2012).

Before the super-cyclone of 1999 the Indian Red Cross Society had constructed 23 cyclone shelters in coastal districts, which were reported to have saved 42,000 lives (OSDMA, 2014). However, until the early 2000s, India's disaster management policy centred on relief and rescue operations rather than preparedness (Jha et al., 2016). The scale of death and destruction caused by the super-cyclone served as a catalyst for a focus on preparedness.

The adaptation process

Following the super-cyclone, a permanent disaster management authority – now named the Odisha State Disaster Mitigation Authority (OSDMA) – was set up in 1999 by the Government of Odisha with a focus on disaster preparedness, functioning at the state, district and local level. This preceded the establishment of the National Disaster Management Authority in 2005, and the national Disaster Management Act of the same year, which requires each of India's states to develop a disaster management plan. A raft of government- and donor-funded projects to promote resilient infrastructure, improved early warning and preparedness systems, and community engagement followed the establishment of OSDMA.

Odisha developed its first State Action Plan on Climate Change in 2010. This included a significant focus on climate change adaptation measures, including with regards to cyclones: multipurpose cyclone shelter construction, community capacity-building, streamlining early warning procedures, and construction and restoration of climate-resilient public infrastructure. The Government of Odisha also has a 'zero casualty' from cyclones aim. In addition to government finance, donor finance has been used to deliver projects in support of these aims.

Evacuees at a cyclone shelter at Basudevpur Bhadrak, Odisha

Photo: Government of Odisha, CC BY 4.0, via Wikimedia Commons

The National Cyclone Risk Mitigation Project (NCRMP) has played a key part in this adaptation process, with the aim of reducing the vulnerability of the coastal communities of Odisha (and Andhra Pradesh) to cyclone and other hydro-meteorological hazards. The World Bank provided US$284.8m[17] as an Adaptable Programme Loan with International Development Association credit (between 2010 and 2018), in addition to governmental funding of US$85.2m. The NCRMP was managed by the National Disaster Management Authority, in coordination with OSDMA, Odisha's Rural Development Department and the Department of Water Resources, among others. Key outcomes were to ensure: targeted communities were included in an Early Warning Dissemination System; that coastal communities had access to emergency shelters; the protection of agricultural land; and increasing local awareness of preparedness measures and responses to cyclones. Action focused on constructing and improving access to emergency shelters, including building or upgrading roads and bridges, and other cyclone risk mitigation infrastructure, such as embankments to protect agricultural land (with 58km of existing embankments rehabilitated across four districts [World Bank, 2019a]).

The Government of Odisha has long focused on building on the success of the shelters in saving lives during the 1999 super-cyclone by constructing a network of shelters, including 'multi-purpose cyclone shelters', across the state. The state partnered with the Indian Institute of Technology Kharagpur, which conducted a needs assessment and developed a blueprint for the design of the multi-purpose cyclone shelters. Location criteria were developed taking account of both the physical and socio-economic vulnerability of the locality, as well as the availability of space. The buildings are designed to withstand cyclonic winds and with plinths above the high flood line. Stilted floors ensure the buildings are unaffected by a storm surge, up to the first floor (Srivastav, 2019). The shelters are built with considerations of the specific needs of women and of people with disabilities, in line with national and state building codes. This has resulted in the inclusion of ramps and separate toilet facilities in the design of the multi-purpose shelters. The ground floor of some shelters is also designed to protect livestock.

The Government explicitly acknowledges in its cyclone shelter handbook that it would be ideal for individual houses to be reinforced and reconstructed to withstand cyclones. However, considerations of the cost, complexities involved in relocating communities, technical challenges and the scale of community participation needed in such an endeavour make this challenging. The Government therefore focused its immediate efforts on shelters that would protect people, if not their properties. As of 2019, Odisha had almost 900 cyclone shelters, funded by a combination of the World Bank, Red Cross, State Government and National Government (Dora and Padhee, 2019; Odisha State Disaster Management Authority, 2012; World Bank, 2019a).

In addition to the physical infrastructure, the NCRMP focused on the installation and operation of an early warning system, including capacity-building of state and district-level emergency operation centres, and education and training of coastal communities to maintain and operate the system. This was completed in 2018, with 122 siren towers covering 480km of coastline. It resulted in the creation of India's first-of-its-kind Early Warning Dissemination System (World Bank, 2019a), which provides connectivity to all vulnerable coastal villages through alert sirens. This included building towers for mounting sirens that are designed to withstand a wind speed of up to 250km/h. In addition, a location-based alert system was installed, and integrated with the equipment of India's state-owned telecommunications company. This allows subscribers to receive alerts through SMS, which as of March 2019 included approximately 5.75 million people in Odisha, and approximately 80 per cent (almost 928,700) of residents in coastal areas (ibid.). The Odisha State Disaster Management Agency plans to replicate this with two further telecoms providers. Prior to the update in approach, the Government of Odisha was using conventional communication methods[18] to disseminate warnings to coastal communities, with no early warning

[17] This is the amount committed through the International Development Association for both Odisha and Andhra Pradesh. The amount specific to Odisha is unclear – see https://projects.worldbank.org/en/projects-operations/project-detail/P092217?lang=en. The funding was agreed in two tranches – the original amount and then additional financing.

[18] During the cyclones of 2013 and 2014 (before the early warning system was functional) the Government used radio, TV, print media and handheld megaphones to alert communities. This took a significant amount of resource that could have otherwise been directed at other coordination and preparedness activities.

system in place. Without such alerts, many were unable to evacuate to safe shelters in sufficient time.

In addition, the NCRMP focused on national and state-level technical capacity-building and knowledge creation, including improved understanding of natural disaster risks, strengthened institutional capacity, and support for pilot activities. There have been state-run Odisha-wide mock cyclone drills annually since 2014, and approximately 15,800 people have been trained in early warning, evacuation, search and rescue, and first aid, in partnership with the Red Cross. A network of more than 300 disaster management taskforces was established, with women making up about 50 per cent. These taskforces, intended to consist of at least 50 volunteers, took part in the mock drills, and received search and rescue and first aid training (World Bank, 2019a). Outside of the NCRMP, the Odisha Disaster Rapid Action Force was established by state police for search and rescue purposes.

The demographic data for each of the villages near a cyclone shelter were mapped (and are regularly updated), including information on gender, age and additional mobility needs, to inform dedicated emergency support. Governance structures were also established with the aim of ensuring the ongoing maintenance, management and structural soundness of the shelters and embankments, and consisting of members of the local community.

In what ways do these actions constitute adaptation to climate change?

Although the approach adopted by the NCRMP was framed as disaster risk reduction, it contained key aspects to support a process of climate change adaptation. For example, it went beyond the construction of physical infrastructure and the development of an early warning system to include the training of thousands of community volunteers, and the establishment of governance structures such as Disaster Management Teams, with the effect of enhancing the capacity of officials, volunteers and the wider community across Odisha to plan, coordinate and mobilise rapidly in response to climate-related extreme events.

The early warning system built on the Indian Meteorological Department's programme to modernise its forecasting system – thus ensuring weather forecasts would inform the early warning system over time.

Physical infrastructure was built in line with national design standards, taking into account the estimated intensity and frequency of cyclones based on historical occurrences. For example, embankments protecting agricultural land were built to withstand wave heights of a similar magnitude to the super-cyclone of 1999. The World Bank has pointed out: "Due to climate change, the increased frequency and intensity of hydrometeorological hazards may pose a risk to the structural integrity of infrastructure" (World Bank, 2019a). The NCRMP supported the development of community-based management and maintenance of infrastructure, but major upgrade works will need to be budgeted for and implemented by the relevant state government departments with the appropriate technical expertise. With the right processes and funding, the project's physical infrastructure could be sufficient, or sufficiently upgraded, to combat future climate threats.

Understanding of cyclone risk was also improved through institutional strengthening. The Composite Risk Atlas – a web-based cyclone hazard and risk atlas, and risk management framework – was developed through the project to support decision-making. Training on the use of the atlas was provided to state government officials, in addition to the development of a manual. The Government of Odisha has since used the atlas to update its disaster management planning.

As such, although the investment has been described as disaster risk reduction, it has built a range of physical, human, knowledge and social capacity that can respond to more frequent and severe climate threats in the future – or which can be developed to do so. The NCRMP fits within a wider approach to adaptation by the state, outlined in the Odisha Climate Change Action Plan (2018–2023).

The success story

Direct avoided losses

When Cyclone Phailin hit Odisha in 2013, the death toll was contained at 44, following what was then the largest-ever evacuation for a storm in India's history, of about 1 million people (Government of Odisha et al., 2013; Walch, 2018). Approximately 30,000 domestic livestock were also successfully relocated (Jha, 2016).

On 3 May 2019, Cyclone Fani hit Odisha as a high-end category 4 cyclone, with windspeeds of 175–180km/h. Cyclone Fani was the 10th most severe cyclone to hit the Indian subcontinent since 1967 (Kumar et al., 2020). The storm was of comparable strength to the super-cyclone that devastated Odisha 20 years earlier, but rather than over 8,900 lives lost, the death toll was significantly lower at 64 (Dora and Padhee, 2019).

Preparation for Cyclone Fani involved the evacuation of 1.55 million coastal residents, with remote operation of alert sirens 36–48 hours before the cyclone made landfall, and the sending of 18 million SMS messages by the Odisha State Disaster Management Authority (World Bank, 2019a).

Fishing activities were suspended, and there were no casualties among the 200,000 fishermen evacuated from coastal areas. Approximately 25,000 tourists were also evacuated (ibid.).

The World Bank's evaluation suggests that the alert system now reaches 100 per cent of the targeted coastal population, with 82 per cent having access to emergency shelters. A survey conducted after a cyclone in 2017 confirmed that all households interviewed had received advance warning through alert sirens. The construction and restoration of access roads to the shelters were found to have improved accessibility significantly (ibid.).

In addition to the benefits from strengthened physical capital, much of the success can be attributed to the state government's actions in the lead-up to the storm. With several days' warning of the storm's approach, officials developed a comprehensive action plan, honed by experience and regular training of state emergency officers on evacuation procedures (Kumar et al., 2019). Measures implemented in the lead-up to the storm included deploying emergency personnel to district operation centres to provide assistance with preparations and during the storm, and the use of target lists of people in vulnerable houses, including the elderly and children.

This appears to be clear evidence that the measures taken strengthened the capacity of the Government of Odisha and communities for preparedness and early warning implementation. The accuracy of the Indian Meteorological Department's projections about Cyclone Fani's track, landfall and intensity also played a key role in enabling the Odisha state government to take these early and lifesaving actions (Nandi, 2019; World Bank, 2019a).

In the aftermath of the super-cyclone in 1999 it took weeks to clear a pathway for relief (cutting through fallen trees), months to restore critical infrastructure such as the electricity supply, and years for communities to recover livelihoods and from the psychological impacts. In contrast, following Cyclone Phailin in 2013, relief access was established within 24 hours and main roads were functional with 72 hours (OSDMA, 2014).

Odisha's preparedness and response is a major success story in terms of saving lives, but many still lost their homes and livelihoods, with 16.5 million people affected and US$3.4bn in damages as a result of Cyclone Fani (Government of Odisha, 2019).

Other economic benefits

According to the World Bank, 84 per cent of the targeted population in a survey reported a minimisation in loss of agricultural land during recent cyclones. In spite of storm surges of up to 4.6m during Cyclone Fani, there was no significant inundation of agricultural land, although crops were damaged by the high winds. Strengthening of the existing embankments in the preceding years ensured 16,737 hectares of agricultural land was protected, including against the salinisation of soils and its long-term impacts on agricultural livelihoods. A greater proportion of livestock was also reported to have been protected than during previous cyclones. The embankments also

protected houses and other property, and prevented the contamination of water sources by saline intrusion.

The World Bank (2019a) concluded that the NCRMP investments in improvements to embankments, and related protection of livelihoods, had an economic rate of return of 13 per cent, with a benefit-cost ratio of 2:1. The multi-purpose cyclone shelters and the early warning system were calculated to generate a 53 per cent economic rate of return, with a benefit-cost ratio of 4:1 (ibid.).

Wider benefits

Due to the multi-purpose design of the cyclone shelters, they also provide wider community co-benefits. They are also used as venues for a variety of social, cultural and political activities by local communities. For example, they are used as schools and training centres and public health centres, as well as by village councils and women's groups. They are used for social occasions such as weddings and ceremonies, and as polling stations during elections. Most recently, some of the shelters have also been used as COVID-19 quarantine centres (Barik, 2020). A focus group discussion highlighted that "the multipurpose nature of the shelters is effectively functioning as a hub for community mobilization and cohesion, enhancing social capital" (World Bank, 2019a).

Community-based committees were established to oversee the operation and management of the multi-purpose cyclone shelters. The Government developed a community-based fund of approximately US$7,000 per shelter to provide financial support to the committees. Interest earned on these funds and the hiring out of the shelters for private, commercial or public uses is designed to generate a sustainable income for the committees. They received training in shelter maintenance and book-keeping through the project, as well as in search and rescue and first aid. The committees also played a key role in the management of emergency supplies (food, water, medicines) and the evacuation of people during Cyclone Fani. This local capacity-building through committees was cited as building a sense of mutual support, which may have contributed to community resilience through the development of social capital (World Bank, 2019a).

The construction of roads and bridges as part of the intervention not only improved access to the shelters but also enhanced connectivity for remote villages, including with core road networks. This has improved access to markets, schools, medical centres and emergency services. The tops of embankments also improve connectivity, with some serving as roads.

The capacity-building strategy developed under the NCRMP has now been integrated into the National Action Plan on Capacity Building (2013–2022) developed by the National Institute of Disaster Management. At the close of the project, the Institute had instructed 475 master trainers (trainers of trainers) in several state governments (World Bank, 2019a). These modules will also be integrated into the capacity-building programmes on disaster risk management that are operated by Odisha State Disaster Management Agency (World Bank, 2019a).

The experience and knowledge gained through the project have been shared with other states with similar risk profiles. The lessons learned have informed a second National Cyclone Risk Mitigation Project, which covers six other coastal states (Goa, Gujarat, Karnataka, Kerala, Maharashtra and West Bengal). A collaboration with the Global Facility for Disaster Reduction and Recovery has allowed further, wider dissemination of lessons learned through three online publications.

Lessons learned

- **Long-term preparation:** Government officials attributed the efficiency and success of evacuation plans during recent cyclone events to 20 years of preparations (Kumar et al., 2019).
- **More capacity needed:** The huge success in terms of lives saved as a result of the Odisha State's efforts should not be minimised in any way, but it still suffered major economic and infrastructure losses. According to Deepak Singh, Lead Disaster Risk Management Specialist

at the World Bank, "The next step is for the state to build capacity to be able to minimize the loss of assets and livelihood" (World Bank, 2019c).

- **More focus on development and resilience:** Future efforts should also address the broader areas of economic disadvantage that are hampering the ability to adapt at the household and community level. In addition to tackling development challenges, future government investment could focus on the resilience of housing and also on electrical systems, for instance by introducing underground power lines, to prevent major electricity outages having cascading impacts on health systems, water supply, communication and transport (World Bank, 2019a). The Government of Odisha has started to increase its focus on creating cyclone-resilient infrastructure. For example, the state aims to convert nearly 7 million non-concrete homes to pakka (concrete) houses (Srivastav, 2019).

5. Conclusions and recommmendations

Taken together, the case studies in this report provide clear evidence of the value of making investments in climate change adaptation. While the geographies, hazards, stakeholders, governance processes and sources of finance differ between the case studies, each tells a story that articulates the overwhelming benefits that adaptation to climate change can deliver. Across these studies, it is possible to identify common themes that relate to best practice that should be shared, gaps in the current investment landscape and approaches to financing and adaptation practice that warrant rethinking. These themes are summarised in this section, informing a series of recommendations that are designed to help economies and communities around the world to realise the benefits offered by climate change adaptation. These recommendations apply particularly to the financing decisions of donors and developing countries.

Theme 1: Climate change adaptation and resilience are critical to promoting prosperity and wellbeing, and should be integrated with zero-carbon economic development and growth.

The impacts of climate change are already occurring and growing. The increasing risks posed by, for instance, sea level rise and changes in extreme weather are a threat to lives and livelihoods around the world. These impacts undermine economic development and growth, particularly in poor countries. These impacts will continue to worsen until global emissions of greenhouse gases from human activities are reduced to net-zero. As women and girls in many places are often more exposed and vulnerable to climate change impacts than men and boys, adaptation and resilience can make an important contribution to promoting gender equality and inclusive growth.

> ***Recommendation 1: All countries should give higher priority to investments in adaptation and resilience, and integrate them with policies and decisions to promote the transition to an inclusive zero-carbon economy.***

Theme 2: Adaptation and resilience are pivotal to saving lives and limiting loss and damage, and produce a range of co-benefits, yet suffer from significant under-investment.

Adaptation and resilience processes can provide cost-effective ways of protecting lives and avoiding damage across the world. They play a key role in the avoidance or minimisation of loss and damage to property, public infrastructure, businesses and livelihoods. Moreover, investment in adaptation can support sustainable growth and development across a broad range of areas, including health and education. On the other hand, insufficient financing for adaptation is placing at risk the significant progress made over recent decades on other aspects of development.

Those populations and areas that are most at risk from climate change impacts are usually acutely aware of the need for greater focus on adaptation and resilience, and may have significant policy and governance structures in place. However, a lack of resources is often a key barrier to adaptation processes. A substantial increase in financing for adaptation, therefore, is required to prepare for, and where possible prevent, the high and increasing economic and social costs created by climate change impacts. The private sector should also recognise the benefits from futureproofing investments via adaptation measures, particularly in sectors such as real estate and telecommunications, and should be financing adaptation as well.

> ***Recommendation 2: Scale up the quantity of well-targeted finance available for climate change adaptation and resilience.***

Theme 3: Financing for adaptation can be better utilised to create greater impact, with multilateral and bilateral donors well placed to play a key supporting role.

Support for adaptation and resilience represents a very small part of the total financial flows within and between countries. Sources of potential private sector finance for adaptation remain largely untapped. Existing finance for adaptation should be used innovatively to ensure wider financial flows take account of resilience.

Different types of donors have distinct, complementary roles to play in this respect. For example, multilateral donors, such as the international financial institutions, are mostly limited to the provision of finance to governments, and may therefore have less flexibility to fund innovative approaches to adaptation and resilience beyond these flows. Bilateral funding, however, is often more flexible and so individual donors can play a unique role in directing adaptation financing to innovative approaches focused on increasing effectiveness. For example, bilateral financing can be tailored to help stakeholders overcome local barriers to adaptation. Bilateral finance can also be targeted at ex-ante actions at a local level. The funding provided by the UK Foreign, Commonwealth and Development Office and the Swedish International Development Cooperation Agency to support the development of innovative financing mechanisms for local climate change adaptation in Kenya provides a good example. Bilateral funding can also be used to leverage private sector finance for adaptation, including through public-private partnerships.

Better support for climate change adaptation processes means not only increasing the amount of financing, but also ensuring it is used in the most effective way to overcome barriers.

> ***Recommendation 3: Increase the effectiveness of multilateral and bilateral funding by working with recipients to ensure it is targeted on both established and innovative climate change adaptation processes.***

Theme 4: A range of economic benefits result from adaptation processes, both direct and indirect.

Different types of economic benefits result from adaptation processes. There is evidence from several of our case studies that investments in adaptation, including those funded by donors, can leverage private finance by building investor confidence in areas with improved resilience. The example provided by the Thames Estuary 2100 project in London illustrates the potential for attracting private sector investment by reducing risk, which also exists in developing countries. In other cases, such as the Kenya County Climate Change Fund, economic benefits are more direct, such as time savings, and are enabled by adaptation activities. These benefits, along with environmental and social co-benefits, may be regarded as ancillary to the aims of avoiding damage and loss of life. However, these benefits may be realised even if the climate-related hazards which the adaptation process is intended to address do not occur within financing horizons (e.g. loan repayments over five to 10 years). As more adaptation processes are financed, familiarity with the range of possible benefits, and the circumstances in which they are likely to occur, will increase, such as resilience-building activities that catalyse private investment.

> ***Recommendation 4: Decision-making frameworks for financing adaptation should recognise and value a diverse range of possible benefits that may result.***

Theme 5: While physical capital may be the easiest to conceptualise and the most visible form of adaptation, success also results from investments in other forms of capital, including natural and social.

Investments in adaptation processes have often focused on physical capital, but other forms of capital can be just as important in developing adaptive capacity and building resilience. Developing human and social capital in a range of governance institutions and at the community level, for example, has been key to many successful adaptation processes. As the case studies in both Kenya and Ahmedabad have illustrated, the development of institutional capacity, as well as relevant tools, can also be critical to the adaptation process. Building social and human

capital may even be the most effective way of managing multiple climate risks, as they create significant flexibility.

Many of the adaptation processes highlighted in this report have involved strengthening existing institutions, and in some cases have meant significant legislative and policy changes. This has allowed some self-financing sources to be created, removing the need for continued financier engagement and support. Similarly, social capital, such as the development of community cooperation and networks, like those developed in Kenya through community adaptation planning committees and in Odisha through community disaster management taskforces, has been shown to be an important aspect of developing local adaptive capacity and resilience. Natural capital also has a key role to play in adaptation processes, as well as providing other social and economic benefits.

Recommendation 5: Target investment towards adaptation processes that include a focus on natural, knowledge, human and social capital and seek to scale up successful models, such as those that enhance existing institutions or result in legislative change.

Theme 6: Gaps remain in adaptation financing targeted at those people who are most vulnerable to climate risk, undermining efforts to 'leave no one behind'.

Adaptation processes can trigger strong social benefits, such as greater political inclusion and meaningful community participation in decision-making. Nonetheless, targeting the people who are most vulnerable and exposed to climate-related risks is challenging, and they have often been overlooked or insufficiently reached by adaptation financing. Vulnerability to climate change is clearly linked to other intersecting social, economic and cultural factors, and the inequalities they cause. For example, many of our case studies show how poorly-planned and often rapid urbanisation puts residents in low-income urban areas at significantly higher risk of climate-related impacts. Climate-blind urban development and planning processes can lock in exposure and vulnerability to future risks. As such, adaptive capacity is likely to be a significant determinant of development outcomes in low-income urban areas, and vice versa.

If there is to be a chance of achieving the Sustainable Development Goals, including their aims to 'leave no one behind' and 'reach first those who are furthest behind', financing for climate change adaptation will be crucial. Innovative participatory methods to ensure social inclusion, such as those involved in the CCCF mechanism in Kenya, will also be central to ensuring funding is used in locally-appropriate ways that align with the needs of the most vulnerable people.

Recommendation 6: Prioritise financing for adaptation for the most vulnerable people and ensure investments are embedded within the broader sustainable development and growth agenda.

Theme 7: Adaptation is a challenge facing both developed and developing countries, and there are successful adaptation processes across the Global South and North, from which countries around the world can learn.

The case studies in this paper demonstrate that there is a rich body of experience across geographies, types of hazard and in the nature of the adaptation process and investments, including physical capital such as flood defences, nature-based solutions and human and knowledge capital. Comparisons can be drawn, and lessons learned, from across different geographies. For instance, the innovative and life-saving Heat Action Plan developed in Ahmedabad has already been emulated in other cities across India and could prove valuable to countries that are increasingly aware of the risks associated with extreme heat.

Similarly, comparisons can be made between the processes in Beira and the Thames Estuary, which led to physical infrastructure that exceeds current disaster risk reduction and considers possible future risk levels under climate change. It is possible to understand how the investments documented in Beira might be expanded into a broader, long-term governance process rooted in 'adaptation pathways', as demonstrated in the Thames Estuary 2100 programme. The critical components of the TE2100 programme needed for this type of governance process to be

effective included very long-term, non-partisan governmental commitments to addressing climate change and financing adaptation activities.

While not exhaustive, these case studies illustrate the wide range of opportunities for learning and collaboration between countries.

Recommendation 7: Create and support platforms and networks for South–South, South–North and North–South learning and knowledge-sharing about adaptation processes.

Theme 8: There remain limitations to the evidence base about the benefits that accrue from adaptation processes.

There are clear limitations to the evidence this report draws on to identify 'successful' cases of adaptation.

Firstly, these limitations relate to the evidence on which our case studies are based – this is a mixture of academic studies and monitoring and evaluation (M&E) reports, as well as discussions with stakeholders involved in adaptation processes. The evidence is patchy in places, both in terms of its coverage across different categories of benefit (e.g. environmental benefits) but also in the robustness of the evidence, with much of the evidence gathered about economic benefits being anecdotal. This reflects the fact that generating evidence may not have been a key consideration when the adaptation process was initiated, due possibly to the availability (or lack) of funding for holistic M&E activities, how these activities were framed, or the types of benefits that were being measured.

Secondly, there are challenges in collecting evidence of benefits from adaptation processes, particularly in Least Developed Countries and Small Island Developing States. In order to identify 'successful' instances of adaptation, the selection process for case studies for this report was limited to adaptation processes that happened sufficiently long ago for the results to have accrued and been documented. The selection of case studies reflects the current understanding of adaptation activity, in which the voices of the communities that are poorest and most vulnerable to climate change are often under-represented, even if they are successfully undertaking extensive and innovative adaptation activity.

Finally, the case studies are still relatively early and emerging examples of adaptation successes. The full returns from the investment in these adaptation projects will only become evident in the long term. As such, it will be critical to continue to invest in ongoing M&E activities into the future for pioneering adaptation processes such as those highlighted in this report.

Recommendation 8: Donors should increase support for robust, long-term, bottom-up and open-ended M&E for adaptation processes in order to strengthen and diversify the evidence base.

Appendix: Defining climate change adaptation

In defining climate change adaptation, terminology matters. Risk, and the risk of a possible event or damage occurring, are concepts that are key to understanding climate change adaptation. However, the relationship between climate change, levels of risk and subsequent resilience is complex, and risk and resilience are influenced by a range of drivers alongside climate change. Different disciplines apply different concepts when assessing resilience – from 'robustness' to 'bouncing back' and 'bouncing forward' in the face of shocks. A commonly used definition of resilience is the one provided by the United Nations Office for Disaster Risk Reduction: "The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management."[19]

Perceived levels of risk and resilience are an outcome of a series of interlinked drivers and hazards, which may or may not take climate change into account. A range of drivers inform levels of risk and resilience for different forms of capital (e.g. infrastructure), such as proximity to a potential hazard and regularity of maintenance. Climate change is an additional underlying driver. Climate change can ultimately increase the risk of damages or missed opportunities by exacerbating threats and hazards.

Adaptation is understood as "changes in processes, practices and structures" to limit damages associated with the impacts of climate change already locked into the system, or to benefit from any opportunities associated with climate change where possible (UNFCCC, n.d.). Adaptation is rooted in principles of resilience, but relates to accounting and preparing for *future risks,* which might be invoked by climate change as well as today's risks. Climate change adaptation is thus a measure that seeks to respond to a changing climate, in addition to other drivers that inform risk and resilience.

This highlights the nuanced differences between disaster risk reduction (DRR) and climate change adaptation. Disaster risk reduction is closely related to adaptation, and could be policies, objectives or measures implemented to respond to risk. Crucially, these must be taken before any disaster risk is apparent (Pilli-Sihvola and Väätäinen-Chimpuku, 2016). However, DRR need not take into account how hazards and risks may change into the future as a result of drivers such as climate change. In contrast, climate change adaptation can be defined as a process in natural systems to adjust to the actual climate and its effects, and a process in human systems to adjust to the actual and expected changing climate and its effects, "in order to moderate harm or exploit beneficial opportunities" (ibid.). Climate change resilience is thus a variable outcome that is informed by climate change-informed hazards and levels of risk.

[19] See https://www.undrr.org/terminology/resilience

References

Ada Consortium (2018) *Adaptation and resilience. Assessing the effectiveness of the CCCF mechanism on rural livelihoods and institutions in Kenya.* NDMA & ADA Consortium. https://www.adaconsortium.org/index.php/component/k2/item/381-assessing-the-effectiveness-of-the-cccf-mechanism-on-rural-livelihoods-and-institutions-in-kenya

Apgar M, Kniveton D, Naess L, Orindi V, Abuya N and Bonaya M (2017) *Improving the impact of climate information services in Kenya's arid and semi-arid lands.* IDS policy briefing.

Adger W N (2003) Social Capital, Collective Action, and Adaptation to Climate Change. *Ecological Economics* 79(4): 384-404. DOI: 10.1007/978-3-531-92258-4_19

Ahmedabad Municipal Corporation (2018) *Ahmedabad Heat Action Plan 2018. Guide to extreme heat planning in Ahmedabad, India.*

Ahmedabad Municipal Corporation (2019) *Ahmedabad Heat Action Plan 2019. Guide to extreme heat planning in Ahmedabad, India.*

Al Jazeera (2019) Flooding in Mozambique as Tropical Cyclone Desmond makes landfall. *Al Jazeera.* 23 January. https://www.aljazeera.com/news/2019/01/flooding-mozambique-tropical-cyclone-desmond-landfall-190122093541944.html

Azhar GS, Mavalankar D, Nori-Sarma A, Rajiva A, Dutta P, et al. (2014) Heat-Related Mortality in India: Excess All-Cause Mortality Associated with the 2010 Ahmedabad Heat Wave. *PLOS ONE* 9(3): e91831. https://doi.org/10.1371/journal.pone.0091831

Bahinipati C S (2014) Assessment of vulnerability to cyclones and floods in Odisha, India: A District-level analysis. *Current Science* 107. https://www.researchgate.net/publication/265459164_Assessment_of_vulnerability_to_cyclones_and_floods_in_Odisha_India_A_District-level_analysis

Barik S (2020) Cyclone Amphan. Coronavirus quarantine centres back to being cyclone shelters in Odisha. *The Hindu*, 20 May. https://www.thehindu.com/news/national/other-states/cyclone-amphan-coronavirus-quarantine-centres-back-to-being-cyclone-shelters-in-odisha/article31635762.ece

Barnett J, Evans L S, Gross C, Kiem A S, Kingsford R T, et al. (2015) From barriers to limits to climate change adaptation: path dependency and the speed of change. *Ecology and Society* 20(3): 5. https://www.ecologyandsociety.org/vol20/iss3/art5/

Bedelian C (2019) *Wajir county opens GIS lab to support rangeland and water planning*. http://www.braced.org/news/i/Wajir-county-opens-GIS-lab-to-support-rangeland-and-water-planning/. London: BRACED, Overseas Development Institute.

Bharti M, Mehrotra S 2020. Metropolitan Ahmedabad: Scaling Up with Contiguous Replication of Town Planning Schemes. In: *Greater Than Parts: A Metropolitan Opportunity, Volume II* (eds Mehrotra S, Lewis L, Orloff M, Olberding B). Washington, DC: World Bank. https://openknowledge.worldbank.org/bitstream/handle/10986/34821/Metropolitan-Ahmedabad-Scaling-Up-with-Contiguous-Replication-of-Town-Planning-Schemes.pdf

Bloemen P, Reeder T, Zevenbergen C, Rijke J, Kingsborough A (2018) Lessons learned from applying adaptation pathways in flood risk management and challenges for the further development of this approach. *Mitigation and Adaptation Strategies for Global Change* 23: 1083–1108. https://doi.org/10.1007/s11027-017-9773-9

Bonaya M and Rugano P (2018) *Gender inclusion and the CCCF mechanism: increasing the voice and the benefits for women*. Ada Consortium Policy Brief Issue 2018/1.

Centre for Research on the Epidemiology of Disasters and UN Office for Disaster Risk Reduction (2020) *Human cost of disasters: An overview of the last 20 years: 2000-2019*. https://www.undrr.org/publication/human-cost-disasters-2000-2019

CES Consulting Engineers Salzgitter GmbH; Inros Lackner SE (2020) *Mozambique - Upscaling Nature-Based Flood Protection In Mozambique's Cities: Lessons Learnt from Beira (English)*. Washington, D.C. : World Bank Group. http://documents.worldbank.org/curated/en/969931585303089862/Lessons-Learnt-from-Beira

CDKN (n.d.) PROJECT: Sheltering from a gathering storm. Webpage. https://cdkn.org/project/sheltering-from-a-gathering-storm/

Centre for Research on the Epidemiology of Disasters and UN Office for Disaster Risk Reduction (2020) *Human cost of disasters: An overview of the last 20 years: 2000-2019.* https://www.undrr.org/publication/human-cost-disasters-2000-2019

Chhotray V, Few R (2012) Post-disaster recovery and ongoing vulnerability: Ten years after the super-cyclone of 1999 in Orissa, *India Glob. Environ. Change, Global transformations, social metabolism and the dynamics of socio-environmental conflicts* 22: 695–702. https://doi.org/10.1016/j.gloenvcha.2012.05.001

Crick F, Hesse C, Orindi V, Bonaya M and Kiiru J (2019a) *Delivering climate finance at local level to support adaptation: experiences of County Climate Change Funds in Kenya*. Ada Consortium, Nairobi

Crick F, Gargule A, Green S and Suji O (2019b) *Chapter 3: Kenya country case study. Early outcomes of climate finance in Kenya: experiences from the County Climate Change Funds*. London, Overseas Development Institute

Da Nang Today (2019) City's population reaches over 1.1 million. *Da Nang Today*, 12 July.

DCF Alliance (2019) *The Devolved Climate Finance mechanisms: Principles, implementations and lessons from four semi-arid countries.* Working paper. The DCF Alliance. https://pubs.iied.org/G04424/

Dora M, Padhee A K (2019) India's cyclone Fani recovery offers the world lessons in disaster preparedness. *The Conversation*. http://theconversation.com/indias-cyclone-fani-recovery-offers-the-world-lessons-in-disaster-preparedness-116870

Dutch Water Sector (2019) The best of 2019: 10 remarkable news stories. Web page. https://www.dutchwatersector.com/news/the-best-of-2019-10-remarkable-news-stories

Dutta P, Rajiva A, Andhare D, Azhar G, Tiwari A, Sheffield P (2015) Perceived heat stress and health effects on construction workers. *Indian Journal of Occupational and Environmental Medicine* 19(3): 151–158. https://www.researchgate.net/publication/290515602_Perceived_heat_stress_and_health_effects_on_construction_workers

Ensor J E, Park S E, Hoddy E T, Ratner B D (2015) A rights-based perspective on adaptive capacity. *Global Environmental Change* 31: 38-49. https://www.sciencedirect.com/science/article/pii/S0959378014002039

Environment Agency (n.d.) Thames Barrier closures – indicator two. https://webarchive.nationalarchives.gov.uk/20100513120847/http://www.environment-agency.gov.uk/research/library/publications/41065.aspx

Environment Agency (2012) Managing flood risk through London and the Thames estuary. Thames Estuary 2100 Plan. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/322061/LIT7540_43858f.pdf

Environment Agency (2019) Thames Estuary 2100 – 2020 Review, September 2019. https://www.london.gov.uk/about-us/londonassembly/meetings/documents/s79843/04a.3%20TE2100%20-%202020%20Review%20-%20Intro%20to%20the%20project%20Sept%202019.pdf

Environment Agency (2020) Thames Estuary TE2100 Plan (29 May 2020 update). https://www.gov.uk/government/publications/thames-estuary-2100-te2100/thames-estuary-2100-te2100

Fedele G, Donatti C I, Harvey C A, Hannah L, Hole D G (2019) Transformative adaptation to climate change for sustainable social-ecological systems. *Giacomo Environmental Science & Policy* 101: 116-125. https://www.sciencedirect.com/science/article/pii/S1462901119305337

Government of Odisha, Forests and Environment Department (2018) *Odisha Climate Change Action Plan (for the period 2018-2023)*. http://climatechangecellodisha.org/pdf/State%20Action%20Plan%20on%20Climate%20Change%202018-23.pdfGovernment of Odisha 2019. Cyclone Fani: Damage, Loss, and Needs Assessment. May, Government of Odisha, United Nations, World Bank and Asian Development Bank. Available at: https://www.ilo.org/wcmsp5/groups/public/---ed_emp/documents/publication/wcms_732468.pdf

Government of Odisha (2019) Odisha Economic Survey 2018-2019. http://www.indiaenvironmentportal.org.in/content/464760/odisha-economic-survey-2018-19/

Government of Odisha, Asian Development Bank, World Bank (2013) *Cyclone Phailin in Odisha, October 2013: Rapid Damage and Needs Assessment Report*. World Bank, Washington, DC. https://openknowledge.worldbank.org/handle/10986/17608

Guterres A (2021) Remarks to the Climate Adaptation Summit, 25 January. https://www.un.org/sg/en/content/sg/speeches/2021-01-25/remarks-climate-adaptation-summit

Hellmuth M E, Moorhead A, Thomson M C, Williams J (Eds.) (2007) *Climate Risk Management in Africa: Learning from Practice*. International Research Institute for Climate and Society (IRI), Columbia University, New York, USA. https://www.fanrpan.org/archive/documents/d00255/3-Climate-risk_Africa_2007a.pdf

Hess J, Sathish LM, Knowlton K, Saha S, Dutta P et al. (2018) Building Resilience to Climate Change: Pilot Evaluation of the Impact of India's First Heat Action Plan on All-Cause Mortality. *Journal of Environmental and Public Health*, vol. 2018, Article ID 7973519, 8 https://doi.org/10.1155/2018/7973519

HM Treasury (2003) *Appraisal and evaluation in central government—the "Green Book"*. HMSO, London

Hunger Safety Net Programme (2015) *Briefing Note: HSNP Emergency Payments for May 2015*. National Drought Management Authority; UKaid; Australian Department for Foreign Affairs and Trade

Im E-S, Pal JS, Eltahir EAB (2017) Deadly heat waves projected in the densely populated agricultural regions of South Asia. *Science Advances*, 3, e1603322 DOI: 10.1126/sciadv.1603322

India Brand Equity Foundation [IBEF] (2020) About Odisha: Tourism, Mining Industries, Agriculture, Economy & Geography. Web page. https://www.ibef.org/states/odisha.aspx

Indian Institute of Public Health – Gandhinagar, Natural Resources Defense Council, Rollins School of Public Health of Emory University, Icahn School of Medicine at Mount Sinai (2015) *Evaluation of Ahmedabad's Heat Action Plan: Assessing India's First Climate Adaptation and Early Warning System for Extreme Heat.* https://www.nrdc.org/sites/default/files/ahmedabad-hap-evaluation.pdf Intergovernmental Panel on Climate Change (IPCC) 2012. Summary for Policymakers. In: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 1-19

Intergovernmental Panel on Climate Change (IPCC) 2014: *Climate Change 2014: Synthesis Report.* Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf

Intergovernmental Panel on Climate Change (IPCC) (2018) *Special report: global warming of 1.5 °C*. https://www.ipcc.ch/sr15/

International Development Association (2019) *Project appraisal document on a proposed grant in the amount of SDR 95.1 million (US$130 million equivalent) from the crisis response window to the Republic of Mozambique for the Cyclone Idai and Kenneth emergency recovery and resilience project*. Report No: PAD3379. 17 September 2019. http://documents1.worldbank.org/curated/en/763461570154496796/pdf/Mozambique-Cyclone-Idai-and-Kenneth-Emergency-Recovery-and-Resilience-Project.pdf

International Institute for Environment and Development [IIED] (2006) *Making decentralisation work for sustainable natural resource management in the Sahel. Lessons from a programme of action-research, policy debate and citizen empowerment.* IIED, London. https://pubs.iied.org/12530IIED

Jaswal A, Rao C, Singh V (2015) Climatology and trends of summer high temperature days in India during 1969–2013. *Journal of Earth System Science* 124: 1-15. 10.1007/s12040-014-0535-8.

Jha A, Basu R, Basu A (2016) Studying Policy Changes in Disaster Management in India: A Tale of Two Cyclones. *Disaster Medicine and Public Health Preparedness, 10* (1), 42-46 https://www.cambridge.org/core/journals/disaster-medicine-and-public-health-preparedness/article/studying-policy-changes-in-disaster-management-in-india-a-tale-of-two-cyclones/CD07E3CA353E1AF2A3F0F1AA6A132B9F

Kar N, Thirthalli J, Sharma P, Murali N, Mehrotra S (2004) Mental Health Consequences of the Trauma of Super-Cyclone 1999 in Orissa. *Indian Journal of Psychiatry* 46: 228-37. https://www.researchgate.net/publication/49745733_Mental_Health_Consequences_of_the_Trauma_of_Super-Cyclone_1999_in_Orissa

Kar N, Mohapatra P K, Nayak K C, Pattanaik P, Swain S P, Kar H C (2007) Post-traumatic stress disorder in children and adolescents one year after a super-cyclone in Orissa, India: exploring cross-cultural validity and vulnerability factors. *BMC psychiatry*, *7*, 8. https://doi.org/10.1186/1471-244X-7-8

KFW Development Bank (2015) *Project Information: Adaptation – Mozambique*. Federal Ministry for Economic Cooperation and Development.

Kirbyshire A, Paul A (2017) *Heat action plans: Scaling up India's ambition to protect the climate-vulnerable*. CDKN Guide. Climate Development and Knowledge Network. https://cdkn.org/wp-content/uploads/2017/11/CDKN_Heatwave-Guide_FINAL-WEB.pdf

Knowlton K, Kulkarni S P, Azhar G S, Mavalankar D, Jaiswal A et al. (2014) Development and implementation of South Asia's first heat-health action plan in Ahmedabad (Gujarat, India). *International Journal of Environmental Research and Public Health*. 11(4): 3473–3492. https://doi.org/10.3390/ijerph110403473

Kovats RS, Hajat S (2008) Heat Stress and Public Health: A Critical Review. *Annual Review of Public Health*, 29(1): 41-55. https://doi.org/10.1146/annurev.publhealth.29.020907.090843

Kumar H, Gettleman J, Yasir S (2019) How Do You Save a Million People From a Cyclone? Ask a Poor State in India. *The New York Times*, 3 May.

Kumar S, Lal P, Kumar A (2020) Turbulence of tropical cyclone 'Fani' in the Bay of Bengal and Indian subcontinent. *Natural Hazards* 103: 1613–162. https://doi.org/10.1007/s11069-020-04033-5

MacGregor J (2018) *Effective innovation? Assessing the 'business case' for investing in the CCCF mechanism*. Ada Consortium Policy Brief issue 2018/3.

Macintosh D J, Mahindapala R, Markopoulos M (eds.) (2012) *Sharing Lessons on Mangrove Restoration*. Bangkok, Thailand: Mangroves for the Future and Gland, Switzerland: IUCN. http://www.mangrovesforthefuture.org/assets/Repository/Documents/Call-for-Action-and-Proceedings-from-2012-Colloquium-Mamallapuram-India.pdf#page=245

Mahadevia D, Suchita V, Aseem M (2014) *Informal Economy Monitoring Study: Street Vendors in Ahmedabad, India*. WIEGO, Manchester, UK. https://www.researchgate.net/publication/271844807_Street_Vendors_in_Ahmedabad

Mathew A, Sreekumar S, Khandelwal S, Kaul N, Kumar R (2016) Prediction of surface temperatures for the assessment of urban heat island effect over Ahmedabad city using linear time series model. *Energy and Buildings* 128: 605-616 https://www.sciencedirect.com/science/article/abs/pii/S0378778816306004#:~:text=Ahmedabad%20is%20one%20of%20the,heat%20island%20(UHI)%20effect

Merttens F (2018) *Evaluation of the Kenya Hunger Safety Net Programme Phase 2: Impact evaluation final report*. Oxford Policy Management.

Minh H B (2013) Typhoon Nari hits Vietnam, 122,000 people evacuated. *Reuters*, 15 October.

Msangi A, Rutabingwa J, Kaiza V, Allegretti A (2014) *Community and government planning together for climate-resilient growth: issues and opportunities from Longido, Monduli and Ngorongoro Districts, northern Tanzania*. IIED, London. http://pubs.iied.org/10075IIED/

Müller B, Pizer W (2014) *Devolved access modalities: lessons for the Green Climate Fund from existing practice*. European Capacity Building Initiative.

Multihazard Mitigation Council (2018) *Natural Hazard Mitigation Saves: 2018 Interim Report*. By Porter K et al. National Institute of Building Sciences, Washington, D.C. www.nibs.org

Murray-Darling Basin Authority (2020) Basin Plan water trading rules. https://www.mdba.gov.au/water-management/managing-water/water-markets-trade/basin-plan-water-trading-rules

National Cyclone Risk Mitigation Project [NCRMP] (n.d.) National cyclone mitigation project. Web page. NCRMP, Government of India. https://ncrmp.gov.in/cyclones-their-impact-in-india/

National Disaster Management Authority, Government of India [NDMA] (2014) Isiolo County Adaptation Fund. Activities, costs and impacts after the 1st investment round. NDMA and Ada Consortium, NDMA.

National Disaster Management Authority, Government of India [NDMA] (2019) *National Guidelines for Preparation for an Action Plan – Prevention and Management of Heat Wave*. NDMA, New Delhi

National Statistical Office (2020*) EnviStats-India 2020: Vol.I: Environment Statistics,* National Statistical Office, Ministry of Statistics & Programme Implementation, Government of India, New Delhi. http://mospi.nic.in/publication/envistats-india-2020-vol-1-environment-statistics

Nandi S (2019) Tracking Cyclone Fani & tackling the aftermath. *Sci. Report* 56(10): 43–44. NISCAIR-CSIR, India

Natural Resources Defense Council [NRDC] (2019) *Ahmedabad Heat Action Plan: 2019 Update*. https://www.nrdc.org/sites/default/files/ahmedabad-heat-action-plan-2018.pdf

Natural Resources Defense Council [NRDC] (2020) Expanding heat resilience across India: Heat Action Plan highlights. Factsheet. https://www.nrdc.org/sites/default/files/india-heat-resilient-cities-ib.pdf

Nyangena J, Scott C, Wario A (2017) *Finance for resilience building and ecosystem- based adaptation in Kenya. A comparative study of local and national managed funds.* Working paper, Ada Consortium. https://pubs.iied.org/G04189/

Odisha State Disaster Management Authority [OSDMA] (n.d.) *Early Warning Dissemination System (EWDS)* Government of Odisha, India. https://www.osdma.org/preparedness/early-warning-communications/ewds/

Odisha State Disaster Management Authority [OSDMA] (2012) *Multipurpose Cyclone Shelter Handbook*. Government of Odisha, India.

Odisha State Disaster Management Authority [OSDMA] (2014) Towards a Disaster Resilient Odisha A Journey from "Super Cyclone " 1999 to "Phailin" 2013 https://www.osdma.org/publication/towards-a-disaster-resilient-odisha/#gsc.tab=0

Opitz-Stapleton S, Hawley K (2013) *Extreme rainfall, climate change, and flooding* (Policy Brief). Boulder, CO: Institute for Social and Environmental Transition-International. https://www.i-s-e-t.org/publications-and-resources-1/da-nang%3A-extreme-rainfall%2C-climate-change%2C-and-flooding-%28policy-brief%29

Oxford Policy Management (2016) *Evaluation of the Kenya Hunger Safety Net Programme Phase 2: Drought Emergency Scale-up Payments Process Review - Final report.* National Drought Management Authority, UKAid, Australian Aid, Oxford Policy Management, Kenya.

Organisation for Economic Cooperation and Development [OECD] (2020) Climate Finance Provided and Mobilised by Developed Countries in 2013-18. https://www.oecd.org/environment/climate-finance-provided-and-mobilised-by-developed-countries-in-2013-18-f0773d55-en.htm

Panda A (2018) *Transformational adaptation of agricultural systems to climate change*. Wiley. https://doi.org/10.1002/wcc.520

Poole L, Clarke D, Swithern S (2020) *The future of crisis financing: a call to action*. Centre for Disaster Protection, London.

Penning-Rowsell E C, Haigh N, Lavery S, McFadden L (2013) A threatened world city: the benefits of protecting London from the sea. *Nat Hazards* 66: 1383–1404. https://doi.org/10.1007/s11069-011-0075-3

Pilli-Sihvola K, Senja Väätäinen-Chimpuku (2016) Defining climate change adaptation and disaster risk reduction policy integration: Evidence and recommendations from Zambia. *International Journal of Disaster Risk Reduction* 19. https://doi.org/10.1016/j.ijdrr.2016.07.010.

Program on Forests [PROFOR] (2020) Upscaling nature-based flood protection in Mozambique's coastal cities. Web page. https://www.profor.info/knowledge/upscaling-nature-based-flood-protection-mozambique%E2%80%99s-coastal-cities

Ranger N, Niehörster F (2012) Deep uncertainty in long-term hurricane risk: scenario generation and implications for future climate experiments. *Global Environmental Change* 22(3): 703-712. doi:10.1016/j.gloenvcha.2012.03.009

Ranger N, Reeder T, Lowe J (2013) Addressing 'deep' uncertainty over long-term climate in major infrastructure projects: four innovations of the Thames Estuary 2100 Project. *EURO Journal on Decision Processes* 1: 233-362

Republic of Kenya (2012a) *Sessional paper no. 8 of 2012 National Policy for the Sustainable Development of Northern Kenya and other Arid Lands: 'Releasing Our Full Potential'*. Office of the Prime Minister,

Ministry of State for Development of Northern Kenya and Other Arid Lands. https://tinyurl.com/y32ecnzy

Republic of Kenya (2012b) *Vision 2030. Development strategy for Northern Kenya and other Arid Lands*. Office of the Prime Minister, Ministry of State for Development of Northern Kenya and other Arid Lands.

Rohini P, Rajeevan M, Mukhopadhay P (2019) Future projections of heat waves over India from CMIP5 models. *Climate Dynamics* 53: 975–988 https://doi.org/10.1007/s00382-019-04700-9

Richmond M, Chavi Meattle, Valerio Micale, Padraig Oliver, Rajashree Padmanabhi (2020) *Climate Policy Initiative: A Snapshot of Global Adaptation Investment and Tracking Methods.* Climate Policy Initiative. https://cdn.gca.org/assets/2020-03/Adaptation_Finance_Tracking_Paper_Global_Commission_on_Adaptation_FINAL.pdf

Rogers Gibson J (2017) *Built to Last: Challenges and Opportunities for Climate-Smart Infrastructure in California.* Union of Concerned Scientists. https://www.ucsusa.org/sites/default/files/attach/2017/11/gw-whitepaper-smart-infrastructure.pdf

Shah T, Mavalankar D, Shah Azhar G, Jaiswal A, Connolly M (2014) *Addressing heat-related health risks in urban India: Ahmedabad's Heat Action Plan. Inside stories on climate compatible development.* Climate and Development Knowledge Network (CDKN)

Shaw R, Atta-ur-Rahman Surjan A, Parvin G A (Eds.) (2016) *Urban disasters and resilience in Asia.* Butterworth-Heinemann. https://doi.org/10.1016/C2014-0-01952-1

Spekker H, Heskamp J (2017) Flood protection for the City of Beira: An exemplary climate adaptation project in Mozambique. *Bautechnik* 94.

Steiner A, Aguilar G, Bomba K, Bonilla JP, Campbell A, et al. (2020) *Actions to transform food systems under climate change*. Wageningen, The Netherlands: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

Surminski S (2020) *A new mindset for resilience in the face of concurrent climate and health risks.* London: Grantham Research Institute on Climate Change and the Environment. https://www.lse.ac.uk/GranthamInstitute/news/a-new-mindset-for-resilience-in-the-face-of-concurrent-climate-and-health-risks/

Surminski S, Tanner T (Eds.) (2016) *Realising the 'Triple Dividend of Resilience' A New Business Case for Disaster Risk Management*. Decision Processes volume 1: 233–262. Springer.

Taruka S (2019) Lessons in disaster relief from the world's most cyclone-battered state. World Economic Forum, 20 December. https://www.weforum.org/agenda/2019/12/disaster-relief-lessons-cyclone-fani-odisha/

Initiative on Financing for Resilient and Green Urban Global Solutions (FRUGS) (2020) *Financing for Resilient and Green Urban Solutions in Beira, Mozambique*. United Nations Human Settlements Programme (UN-Habitat). https://unhabitat.org/sites/default/files/2020/02/the_frugs_city_study_report_on_beira_mozambique_1.pdf

The Hindu (2018) Odisha launches disaster alert system for its coast. *The Hindu*.

Tran P and Fox M (2014) *The Economics of Storm Resistant Shelters.* Institute for Social and Environmental Transition-International. https://isetinternational.wordpress.com/2014/01/27/the-economics-of-storm-resistant-shelters/

Tran P, Tran T H, Tran A T (2014) Sheltering from a Gathering Storm: Typhoon Resilience in Vietnam. Institute for Social and Environmental Transition International. https://www.i-s-e-t.org/sheltering-from-a-gathering-storm

Uhe P, Philip S, Kew S, Shah K, Kimutai J (2017) *The drought in Kenya 2016 -2017*. Climate and Development Knowledge Network and World Weather Attribution Initiative. https://reliefweb.int/sites/reliefweb.int/files/resources/The-drought-in-Kenya-2016-2017.pdf

United Nations Country Team in Vietnam (2013) *Vietnam: Typhoon NARI and update on Typhoon WUTIP. Situation Report No. 3 (as of 25 October 2013)*. https://reliefweb.int/report/viet-nam/vietnam-typhoon-nari-and-update-typhoon-wutip-situation-report-no-3-25-october-2013

United Nations Development Programme [UNDP] (2018) *Unlocking the potential of arid and semi-arid lands of Kenya.* https://www.ke.undp.org/content/kenya/en/home/presscenter/pressreleases/2018/unlocking-the-potential-of-arid-and-semi-arid-lands-of-kenya-.html

United Nations Environment Programme (2016a) *The Adaptation Finance Gap Report 2016*. UN Environment Programme (UNEP), Nairobi, Kenya. https://unepdtu.org/publications/the-adaptation-finance-gap-report/

United Nations Environment Programme (2016b) *Cost of adapting to climate change could hit $500B per year by 2050*. Press release 10 May. https://www.un.org/sustainabledevelopment/blog/2016/05/unep-report-cost-of-adapting-to-climate-change-could-hit-500b-per-year-by-2050/

United Nations Framework Convention on Climate Change (2015) *The Paris Agreement*. UNFCCC: Bonn, Germany: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

United Nations Framework Convention on Climate Change [UNFCCC] (2019) Opportunities and options for adaptation finance, including in relation to the private sector. https://unfccc.int/sites/default/files/resource/tp2019_03E.pdf

United Nations Framework Convention on Climate Change [UNFCCC] (n.d.) *What do adaptation to climate change and climate resilience mean?* https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/what-do-adaptation-to-climate-change-and-climate-resilience-mean

United Nations International Strategy for Disaster Reduction (UNISDR) (2009) *2009 UNISDR Terminology on Disaster Risk Reduction*. Available at: https://www.undrr.org/publication/2009-unisdr-terminology-disaster-risk-reduction

United Nations Office for Disaster Risk Reduction [UNDRR] (2015) *Global Assessment Report on Disaster Risk Reduction 2015 (GAR15): Making Development Sustainable: The Future of Disaster Risk Management*

United Nations Office for Disaster Risk Reduction [UNDRR] (2019) *Global Assessment Report on Disaster Risk Reduction 2019 (GAR19)*. https://www.undrr.org/publication/global-assessment-report-disaster-risk-reduction-2019

United Nations (2015) *Sendai Framework for Disaster Risk Reduction 2015-2030.* https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030

United Nations (2020) *The Sustainable Development Goals Report 2020*. https://unstats.un.org/sdgs/report/2020/The-Sustainable-Development-Goals-Report-2020.pdf

United Nations Vietnam (2019) *Results of the Population and Housing Census 01/4/2019.* https://vietnam.un.org/en/28931-results-population-and-housing-census-0142019

Unnikrishnan A, Ramesh K, Sindhu B (2011) Tropical Cyclones in the Bay of Bengal and extreme sea level projections along the east coast of India in a future climate scenario. *Current Science*. 101: 327-331. https://www.researchgate.net/publication/259279134_Tropical_Cyclones_in_the_Bay_of_Bengal_and_extreme_sea_level_projections_along_the_east_coast_of_India_in_a_future_climate_scenario

USAID (2018) *Climate risk profile: Kenya*. https://www.climatelinks.org/sites/default/files/asset/document/2018_USAID-ATLAS-Project_Climate-Risk-Profile-Kenya.pdf

Wagnon A (2014) *Success Story: City of Da Nang adopts new regulation that will implement resilience principles to all new housing construction.* Institute for Social and Environmental Transition-International. https://isetinternational.wordpress.com/2014/04/28/success-story-city-of-da-nang-adopts-new-regulation-that-will-implement-resilience-principles-to-all-new-housing-construction/

Walch C (2018) Evacuation ahead of natural disasters: Evidence from cyclone Phailin in India and typhoon Haiyan in the Philippines. *Geo: Geography and Environment*, 5(1): DOI: 10.1002/geo2.51

Wekesa M, Karani I, Waruhiu S, Acacia Consultants (2006) *Emergency interventions in the arid and semi-arid areas of northern Kenya*. Humanitarian Exchange (35), Humanitarian Practice Network ODI, London. https://odihpn.org/wp-content/uploads/2006/11/humanitarianexchange035.pdf

Woetzel J, Pinner D, Samandari H, Engel H, Krishnan M, et al. (2020) *Climate risk and response: Physical hazards and socioeconomic impacts*. McKinsey Global Institute https://www.mckinsey.com/business-functions/sustainability/our-insights/climate-risk-and-response-physical-hazards-and-socioeconomic-impacts#

World Bank (2010) India National Cyclone Risk Mitigation Project (1). https://projects.worldbank.org/en/projects-operations/project-detail/P092217

World Bank (2014) Odisha Disaster Recovery Project. https://projects.worldbank.org/en/projects-operations/project-detail/P148868

World Bank (2018a) *Project appraisal on a proposed credit in the amount of EUR 215.99 million to the Republic of Kenya for the Kenya social and economic inclusion project*. http://documents1.worldbank.org/curated/en/442271543719657009/pdf/KENYA-SOCIAL-PAD-11062018-6367929845058888118.pdf

World Bank (2018b) Helping Mozambique Cities Build Resilience to Climate Change. Web page. https://www.worldbank.org/en/news/feature/2018/06/05/helping-mozambique-cities-build-resilience-to-climate-change

World Bank (2019a) Implementation completion and results report http://documents1.worldbank.org/curated/ru/482381567532199583/pdf/India-First-National-Cyclone-Risk-Mitigation-Project.pdf

World Bank (2019b) Mozambique: Cyclone Idai & Kenneth Emergency Recovery and Resilience Project (P171040), Project Information Document. http://documents1.worldbank.org/curated/en/727131568020768626/pdf/Project-Information-Document-Mozambique-Cyclone-Idai-Kenneth-Emergency-Recovery-and-Resilience-Project-P171040.pdf

World Bank (2019c) *What states can learn from Odisha in disaster preparedness and mitigation.* https://www.worldbank.org/en/news/speech/2019/06/14/odisha-fani-disaster-preparedness