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Cost-effectiveness of disaster risk reduction and adaptation to climate change

Roz Price
Institute of Development Studies
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Question

How cost-effective are different interventions for disaster risk reduction and adaptation to climate change?

- *Which interventions offer the best cost-effectiveness/value-for-money?*
- *For the interventions identified, how location/context specific are the cost-effectiveness/value-for-money metrics?*
- *What is the strength of the evidence behind the cost-effectiveness/value-for-money measurements for different types of interventions?*

Contents

1. Overview

Climate change adaptation (CCA) and disaster risk reduction (DRR) have similar aims and mutual benefits. Strengthening CCA through effective DRR is a new research interest in the fields of climate change and disaster risk science. This review presents estimates of the cost-effectiveness of CCA interventions and DRR interventions through the conventional economic measurement of cost-benefit analysis (CBA).[1] It focuses on CBA as there is significant literature on this in relation to DRR and CCA, and little could be found on values from other economic measures (as is highlighted by Mechler, 2016).

Watkiss (2015) highlights that there is now a reasonably large literature of relevance for the costs and benefits of adaptation, identifying over 500 papers; however, these are primarily grey literature from non-governmental organisations (NGOs), donors and governments. There is also a rich literature on economic assessments of DRR, however this too is dominated by grey literature. Methods for identifying options and assessing costs and benefits of CCA have changed over time, with more recent studies using iterative climate risk management (which puts more emphasis on current climate variability for the short-term, as well as future risks and uncertainty for the long-term) (ECONADAPT, 2015). A number of authors have carried out in-depth literature reviews of the cost-effectiveness of CCA and DRR interventions through CBA and benefit-cost ratio (BCR) values (in particular see Savage, 2015 and Shreve & Kelman, 2014), these were the main sources used in this review.

Main findings:

- Economic returns associated with climate resilient development are reported in the literature as positive for the overwhelming majority of sources reviewed (i.e. BCRs in excess of 3:1 and in some cases as high as 50:1) (Savage, 2015). Projects across all sectors report positive returns, including in disaster risk reduction, social protection and livelihoods, resilient infrastructure and public goods, and climate smart agriculture. The evidence base is weaker for investments in capacity building (Savage, 2015).
- Climate smart agriculture generally has high BCRs in studies, often derived from agricultural productivity benefits with the potential for additional revenue streams (Savage, 2015). Although costs are likely to be higher than those reported.
- Venton et al (2013) in their review of 23 studies conclude that CBA has helped to show value for money of community-based DRR and early response activities. They argue that donors should refocus from ‘what’ types of interventions can be scaled up to ‘how’ to design and implement a programme of work so that it delivers good value for money.
- A recent evaluation of early response and resilience building in Kenya, Ethiopia and Somalia, found that for every US$1 spent on safety net/resilience programming results in net benefits of between US$2.3 and US$3.3 aggregated across the three countries (Venton, 2018). Investing in resilience to drought is significantly more cost effective than providing ongoing humanitarian assistance.
- Ecosystem-based adaptation (EbA) and DRR can deliver multiple benefits beyond adaptation and reducing disaster risk. However, costings are rarely available for Eco-DRR and EbA interventions although this is improving (see Emerton, 2017). Mangrove restoration generally has high BCRs but is very context specific, with many of the studies based in Vietnam (see Shreve & Kelman, 2014).
- Although there is a lot of rhetoric suggesting that DRR is cost-effective, surprisingly there is little in the way of robust evidence (Mechler, 2016: 1). However, reviews of CBA for DRR find that there are sizeable returns to DRR (see Shreve & Kelman, 2014; Mechler,

[1] There are a number of CBA case studies presented in Table 1 and Table 2 in this review.

2016). Mechler estimates average global DRR benefits of about 4 times the costs in terms of avoided and reduced losses (2016: 3). Venton (2018) argues the evidence is strong that investing in DRR and resilience yields economic benefits greater than costs.

- Risk insurance has been advocated as a practice that has high potential to provide CCA and DRR benefits, and has been proposed as a cost-effective way of coping with financial shocks. However, there is a lack of robust evidence to support this argument and further research is needed (Prabhakar et al, 2017; Schaeffer and Waters, 2016).
- Criticisms and limitations of CBA for CCA and DRR include (Shreve and Kelman, 2014): technical limitations for the valuation of non-market goods, such as wildlife or landscapes; lack of methods for incorporating uncertainty and irreversibility; lack of quantification of the distributional impacts (e.g. who benefits and who pays?); ethical concerns over associating a monetary value to life; difficulties with quantifying other intangibles (including benefits); need to make too many assumptions regarding hazard and vulnerability; lack of historical data to predict loss in a probabilistic manner; discretionary discounting of future costs to present values.
- Despite its limitations and criticisms, CBA continues to be an important tool for prioritising efficient CCA and DRM measures. But with a shifting emphasis from infrastructure-based options (hard resilience) to preparedness and systemic interventions (soft resilience), other tools such as cost-effectiveness analysis, multi-criteria analysis and robust decision-making approaches deserve more attention (Mechler, 2016: 1).
- Importance of considerations of vulnerability (at different levels, groups etc) and resilience in CCA and DRR assessments. The role of social systems and power in vulnerability.

The literature is diverse and cautions against simple reporting of the costs of adaptation because costs depend on the method, objectives and assumptions used (ECONADAPT, 2015: 6). The wide range of methods and approaches (including assumptions, discount rates and sensitivity analysis) now in use suggests that economic analysis of DRR and CCA is highly context specific and makes direct comparability between studies challenging. There is therefore an increasing recognition that the transferability of existing estimates is difficult, and care should be taken in reporting and compiling estimates.

A number of gaps in the CCA research and economic assessments have emerged including ecosystems and business/services, and the evidence base is concentrated in some sectors, notably water management, floods, agriculture and the built environment (Watkiss, 2015). Furthermore, the brunt of the reported DRR evidence exists for flood risk prevention, sometimes coupled with water management and preparedness. Less is known about drought and hurricane risk management, disaster preparedness and risk financing (Mechler, 2016: 22).

Given the limited time available for this review and its nature, it has not been possible to comment comprehensively on the strength of the evidence presented, especially given the subjective nature of CBA. This review is not exhaustive, and it is recommended to refer to other key sources of information for further reading and in-depth knowledge on cost-effectiveness of CCA measures, including Emerton (2017), Savage (2015) and Watkiss et al (2014). Shreve and Kelman (2014) and Mechler (2016) are key pieces of literature on the use of CBA in DRR. Although DRR and CCA have important gender and disability considerations, the literature reviewed in this report was largely gender blind and did not reflect issues of disability.

2. Disaster risk reduction (DRR) and climate change adaptation (CCA)

The United Nations Framework Convention on Climate Change (UNFCCC) defines CCA as "adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change".[2] The United Nations Office for Disaster Risk Reduction (UNISDR) defines DRR as "the concept and practice of reducing disaster risks through systematic efforts to analyse and reduce the causal factors of disasters. Reducing exposure to hazards, lessening vulnerability of people and property, wise management of land and the environment, and improving preparedness and early warning for adverse events are all examples of disaster risk reduction".[3]

Strengthening CCA through effective DRR is a new research interest in the fields of climate change and disaster risk science (Lei and Wang, 2014: 1590). The Intergovernmental Panel on Climate Change's (IPCC) Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX) (IPCC, 2012: 35) advices that to enable climate-resilient development, effective DRR (i.e. through disaster risk management (DRM)) should involve a portfolio of actions. This portfolio should aim to improve the understanding of disaster risks, to reduce and transfer risk and to respond to events and disasters, as well as include measures to continually improve disaster preparedness, response and recovery. Kelman et al (2017) highlight a number of existing approaches to DRR that may also have simultaneous applications in CCA through their contribution to reducing vulnerability and exposure and enhancing coping capacity. These approaches include community-based DRR (CBDRR) and ecosystem-based DRR (Eco-DRR)/ecosystem-based adaptation (EbA).

In 2015 and 2016, governments agreed the Sendai Framework for Disaster Risk Reduction (Sendai Framework), the United Nations Sustainable Development Goals, the Paris Agreement on Climate Change and the World Humanitarian Summit framework. Peters and Tanner (2016: 2) highlight that 'resilience' features in all four of these major post-2015 frameworks and agreements. They argue that resilience provides a useful umbrella under which to address the range of hazards and risks that a country or community might face (Peters and Tanner, 2016: 1).

The emphasis in the Sendai Framework on anticipatory action in building resilience reflects a broader shift within the disasters community away from the idea of managing disasters and towards the idea of managing risk (Peters and Tanner, 2016: 2). Venton et al (2012: 22) highlights that resilience is not an end-point, no community is immune to the impacts of shocks, and those factors that affect vulnerability and resilience are constantly changing. Rather, the aim is to engage in a process that is building the resilience of people to cope with shocks, and that allows for flexibility and choice so that people can adapt. Watkiss (2015: i), in his review of the current state-of-knowledge and emerging thinking on the economics of CCA, highlights that the framing of adaptation has changed in recent years, from a more assessment-based focus to a more practical and early implementation-based focus. He finds that there is now a greater emphasis on capacity building, non-technical adaptation and early low-regret options. Alongside

[2] http://unfccc.int/focus/adaptation/items/6999.php

[3] https://www.unisdr.org/who-we-are/what-is-drr

this, there is more awareness of the process of adaptation and the need to address socio-institutional issues and barriers (market, governance and policy failures and behavioural barriers). Importantly, these issues and barriers lead to some challenges for the appraisal of climate resilient development, notably for analysing the costs and benefits of capacity building, technical assistance and institutional strengthening (Watkiss, 2015: i).

3. Common economic measurements

DRR policy scenario assessment (evaluating welfare and disaster risk implications with and without DRR interventions) may be incorporated into national risk assessment to assist selection among alternative DRR policy and investment options. The common methodologies for evaluating DRR policy scenarios include cost-benefit analysis (CBA), cost-effectiveness analysis[4], multi-criteria analysis[5] and robust decision-making approaches[6], with each having distinct applicability in a variety of decision contexts (Mechler, 2016; UNISDR, 2017: 66). The knowledge base on the costs and benefits of adaptation has evolved significantly in recent years, and there are now many more studies at national, regional and local scale, with coverage in both developed and developing countries (ECONADAPT, 2015: 3). A recent EU-funded study ECONADAPT (2015) identified more than 500 relevant sources with cost and benefit data. Hence, this review focuses on CBA as there is significant literature on this in relation to DRR and CCA, and little could be found on other economic measures (as was highlighted by Mechler, 2016).

Watkiss et al (2014) highlight a number of alternative potentially suitable methods for economic assessment of CCA, including real options analysis, robust decision-making, portfolio analysis as well as iterative risk management and rule-based criteria. As highlighted in Watkiss (2015), while there is an increasing evidence base of such applications, these are predominantly stand-alone assessments. There are also no hard or fast rules on when to use a specific approach and none of them provides a single 'best' method for all adaptation appraisal. A key finding by Watkiss (2015) is that these new methods are resource-intensive and technically complex. There has been some effort to develop these into light-touch applications.

[4] Cost-effectiveness analysis (CEA): identifies least-cost options to meet a certain, predefined target or policy objective (which, in effect, represents the project benefit measured in monetary terms). CEA does not require the quantification of benefits, as the project costs are the key variable of consideration to be minimised (Mechler, 2016; UNISDR, 2017: 67).

[5] Multi-criteria analysis (MCA): assesses how well DRR investments achieve multiple objectives such as economic, social, environmental and fiscal goals, as well as co-benefits. Using selected criteria and indicators as verifiable measures for monitoring across time and space, MCA observes and evaluates DRR investment performance in quantitative or qualitative terms. Because MCA does not require the monetisation of all values, it is seen as potentially more palatable and flexible than CBA and CEA. A major challenge, however, is assigning weights to the criteria (UNISDR, 2017: 67).

[6] Robust decision-making approaches (RDMA): has received increasing emphasis recently, particularly in the context of climate change adaptation. Comprising both quantitative and qualitative methodologies, RDMA draws the focus away from optimal decisions (such as those supported with CBA and CEA) and aim to identify options with minimum regret, that is, minimal losses in benefits of a chosen strategy under alternative scenarios where some parameters are highly uncertain and impacts are potentially devastating or irreversible (UNISDR, 2017: 67).

Cost-Benefit Analysis (CBA)

Cost-benefit analysis (CBA) supports decision-making based on efficiency criteria, maximising net benefits of investment over time, as measured in monetary terms. CBA has been the primary approach for prioritising among risk reduction investment options in developed countries (Mechler, 2016; UNISDR, 2017: 66). CBA prioritises three decision criteria: Net Present Value (NPV), the Benefit/Cost ratio (BCR), and the Economic rate of return (ERR). Mechler (2016: 5) highlights that the BCR arguably offers the highest intuitive appeal due to its relative metric (benefits per costs); it has also been used most frequently in the context of DRR (and CCA).

As yet there is no common or standard methodology for CBA, and a variety of approaches have been used (Twigg, 2015: 365). For climate change, there is not a strong methodology to assign deep uncertainties subjective probabilities. Kalra et al (2014: 8-9) highlight that CBA, as traditionally practiced, is an example of an Agree-on-Assumptions process since it can only be applied if stakeholders agree on how to quantify various impacts. In general, nearly all parameters in a CBA of long-term investments are deeply uncertain. CBAs are generally quantitative, using data from primary and secondary sources, but they can also incorporate qualitative aspects, especially when carried out at community level as part of a participatory process or to explore quantitative findings more extensively (Twigg, 2015: 366).

Shyam (2013: 7) suggests that despite its limitations, CBA is more useful as a process in itself than its outcomes (see Hallegate et al 2012; Kull et al 2013 in Shyam, 2013: 7). In a CBA process stakeholders, if enabled, can participate in sharing information and opinion, observing what constitutes benefits or costs and how the results are achieved. Mechler (2016: 2) argues that as disaster risk is characterised by low-probability, high-impact events, truly considering risk and capturing variability probabilistically is a very important design and assessment characteristic for CBAs. Ideally, such risk assessment requires probabilistic analysis to adequately represent the potential for impacts as well as the benefits in terms of reduced impacts.

4. Cost-effectiveness estimates

CCA and climate resilient development

Savage (2015: ii) in his evidence paper on value for money of investments in climate resilient development, found that the economic returns associated with climate resilient development are reported in the literature as positive for the overwhelming majority of sources reviewed. In most cases, benefits were identified as being significantly in excess of the costs (i.e. BCRs in excess of 3:1 and in some cases as high as 50:1). Projects across all sectors report positive returns, including in disaster risk reduction, social protection and livelihoods, resilient infrastructure and public goods, and climate smart agriculture (Savage, 2015: ii). However, many of the earlier studies with higher BCRs used classic impact assessment of technical options and did not take into account uncertainty associated with future climate change. He further found that there is some evidence that more recent studies may provide more realistic (although still positive) assessment (OECD 2015 in Savage, 2015). The evidence base is weaker for investments in capacity building. Savage (2015: iii) provides a summary of BCRs found in his review (Table 1), these are focused on CCA interventions but also include some DRR studies (additional BCRs for DRR can also be found in Table 2).

Table 1 Summary of BCR evidence base for CCA and DRR

Sector	Reported BCRs	Strength of CBA Evidence (based on number and quality of studies)	References (full references found in Savage, 2015)	Country/region of focus (where available)
DRR and preparedness:				
Enhanced hydrological and meteorological information	2-36	Good	• Flörke et al, 2011 • Hallegate, 2012 • Macauley, 2010 • MMC, 2005 • EASPE, 2002 • Watkiss et al, 2014 • World Bank, 2011 • World Bank, 2012 (see also Clements, 2013; Desbartes, 2012)	• US • US
Early Warning Systems	2-5	Moderate	• Watkiss et al, 2014 (see also Hallegate, 2012)	
Disaster risk management	4-5	Good	• Cartwright et al., 2013 • Hawley et al., 2012 • Mechler, 2012	• Durban, South Africa
Building codes and set back zones	<1-6	Moderate	• Cartwright et al, 2013 • ECA, 2009 • IIASA et al, 2009	• Durban, South Africa • Guyana • India & Jakarta
Disaster risk finance instruments (drought)	2	Moderate	• Risk to Resilience Study Team, 2009 (see also CCRIF, 2010; Mechler, 2012)	• Nepal Tarai, India, Eastern Uttar Pradesh, & Pakistan, Rawalpindi
Livelihoods and social protection	1-13	Good	• DFID, 2011 • DFID, 2013	• Bangladesh, Colombia, Ethiopia, Ghana, Mexico, OPTs, & Uganda

			• Hunt, 2011 • ODI, 2014 • Schipper, 2011 • World Bank, 2011	• Mozambique, Bangladesh, Niger, Kenya & Ethiopia • Ethiopia • Ethiopia
Capacity building for response/recovery	13-28	Weak	• Cartwright et al, 2013 • Mullen et al, 2015 (See also IPCC, 2014; Wilby and Keenan, 2012)	• Durban, South Africa • India & Vietnam
Investment in resilient infrastructure and the built environment	>1	Weak	• Brown et al, 2009 • DFID, 2013 • Hinkel et al, 2014 • Mechler et al, 2014 • Mechler, 2012 • MMC, 2005 • Rojas et al, 2013 • World Bank, 2010	• Africa • Mozambique, Bangladesh, Niger, Kenya & Ethiopia • US • Europe
Public goods (eg flood defences)	2-50	Moderate	• CCRIF, 2010 • ECA, 2009 • Watkiss et al, 2014	• Caribbean
Climate smart agriculture	>1	Good	• Branca 2011 • Branca et al, 2012 • ECA, 2009 • Kato et al, 2009 • Lunduka 2013 • McCarthy et al. 2011 • Ranger and Garbett-Shiels 2012 • Tenge et al. 2007 • Watkiss et al, 2014	• Malawi • Malawi • Mali • Ethiopia • Malawi

Source: Adapted from Savage, 2015: iii. For full details of the methodologies used (including assumptions and discount rates) refer directly to studies.

The ECONADAPT (2015: 6) review of 500 studies found that more recent policy-orientated studies estimate higher adaptation costs than the earlier, technical literature. This is because these policy studies work with existing objectives and standards, and factor in multiple risks and wider non-climatic drivers, uncertainty, and the opportunity and transaction costs associated with policy implementation. Watkiss et al (2014: 109) highlight that CBA values are useful for the purposes of benchmarking in the context of an appraisal. However, unlike mitigation costs, CCA costs and benefits tend to be heavily influenced by local geographic, environmental and economic factors, i.e. they are site and location specific. They also highlight that in undertaking an assessment of the economic benefits of adaptation, it is important to consider whether the activities are additional to those likely to be undertaken in the absence of the programme. This can involve quite complex decisions, and the attribution rules may depend on the application/context and the boundary of the analysis.

Emerton (2017: vii) argues that an important guiding principle in CCA valuation is that one method is rarely enough. Focusing on only a single aspect of values (for example biophysical, economic or social) is unlikely to provide an accurate picture. Adaptation typically has multiple goals (which require different methods to assess them), and involves a diverse range of beneficiaries, costs-bearers and other stakeholders (who have different needs, priorities and perceptions of value). Watkiss (2015: 5) highlights that there has been a shift towards frameworks that follow the concepts of adaptive management and encourage a focus on immediate low-regret actions, combined with an evaluation and learning process to improve future strategies and decisions. Common decisions for early adaptation include: immediate actions that address the current adaptation deficit and also build resilience for the future; the integration of adaptation into immediate decisions or activities with long life-times, such as infrastructure or planning; and the immediate need to start planning for the future impacts of climate change, noting the high uncertainty (Watkiss, 2015; 5).

DRR

Tanner and Rentschler (2015: 5) argue that investing in disaster resilience can yield a ‘triple dividend’ by: (1) avoiding losses when disasters strike; (2) unlocking development potential by stimulating innovation and bolstering economic activity in a context of reduced disaster-related background risk for investment; and (3) through the synergies of the social, environment and economic co-benefits of disaster risk management investments even if a disaster does not happen for many years.

Shreve and Kelman (2014: 213) compile and compare original CBA case studies reporting DRR BCRs, without restrictions as to hazard type, location, scale, or other parameters. Many of the results support the economic effectiveness of DRR, however, key limitations include a lack of: sensitivity analyses; meta-analyses that critique the literature; consideration of climate change; evaluation of the duration of benefits; and broader consideration of the process of vulnerability, and potential dis-benefits of DRR measures. The studies demonstrate the importance of context for each BCR result. Table 2 is taken from Shreve and Kelman (2014: 215-226), with some more recent additional literature.

Shreve and Kelman (2014: 227) found that most studies had elements of both ‘structural’ (e.g. measures such as installing dykes, or levees) and ‘non-structural’ (e.g. measures such as developing an evacuation plan, training, and establishing community funds) DRR activities. They found that the majority of studies reported difficulty with valuing certain components of non-structural activities, which often require valuing social and environmental aspects that do not have a market value (e.g. sense of security, avoided property damage). This reflects the findings of Watkiss et al (2014) above. Shreve and Keelman (2014) also found that indirect costs (such as from livelihood disruption) and benefits were rarely included. The wide variation found in the methodologies, assumptions, discount rates and sensitivity analysis suggest that economic analysis of DRR measures is highly context sensitive (Shyam, 2013: 7).

Table 2 Descriptions of DRR activities, BCR, adapted from Shreve and Kelman, 2014, 215-226

Sector	Reported BCRs	References (full references found in Shreve & Kelman, 2014)	Country/region /target benefactors
Drought DRM non-structural (including alternative crop types and seed varieties; training in soil water conservation; contingency planning)	24-35	Venton (2010)	Malawi, agricultural–pastoralists in Mzimba District
Drought DRM non-structural ((1) micro-crop insurance; (2) groundwater irrigation; (3) combination)	1-3.5	Mechler et al & The Risk to Resilience Study Team, 2008	India, Uttar Pradesh
Drought DRM mix ((1) Construction of terraces; (2) construction of earth embankments; (3) Communal Vegetable Garden (irrigated); (4) hafir construction)	(1) 61 (2) 2.4 (3) 1800 (4) 2.7	Khogali and Zewdu, 2009	Sudan, pastoralists, agricultural-pastoralists & households
Drought DRM mix ((1) Livestock Resilience Measures; (2) water interventions a. shallow well, b. drilled well 500 people, c. drilled well 1000 people; (3) education)	(1) 5.5 (2) a. 26 b. 6 c. 1.1 (3) 0.4	*Venton et al, 2012[7]	Kenya
Drought DRM mix ((1) Livestock Resilience Measures; (2) water interventions a. underground cistern/tank, b. Water Sector Development Programme)	(1) 3.8 (2) a. 27 b. 5.5	*Venton et al, 2012	Ethiopia
Crop insurance ((1) insured farmers; (2) uninsured farmers)	(1) 1.49 (2) 1.31	*Prabhakar et al, 2017[8]	Philippines
Early warning system for Flood	1-7	Holland, 2008	Fiji, Navua
Early warning system for Flood	2.6–9	EWASE, 2008	Austria

[7] Full reference: Venton, C. C., Fitzgibbon, C., Shitarek, T., Coulter, L., & Dooley, O. (2012). The economics of early response and disaster resilience: lessons from Kenya and Ethiopia. London: DFID. https://www.gov.uk/government/publications/the-economics-of-early-response-and-disaster-resilience-lessons-from-kenya-and-ethiopia

[8] Full reference: Prabhakar, S.V.R.K., Solomon, S., Abu-Bakar, A., Cummins, J., Pereira, J.J. & Pulhin, J.M. (2017) Case studies in insurance effectiveness: Some insights into costs and benefits, Southeast Asia Disaster Prevention Research Initiative. https://pub.iges.or.jp/pub/case-studies-insurance-effectiveness-some

Flood DRM structural (Polder construction)	2.2–3.8	Mechler, 2005	Peru, Piura
Flood DRM structural (Integrated water management and flood protection scheme)	1.9–2.5	Mechler, 2005	Indonesia, Semerang
Flood DRM Structural (including (1) footbridge, (2) sea wall, (3) dyke)	(1) 24 (2) 4.9 (3) 0.7	Burton and Venton, 2009	Philippines
Flood DRM Structural (including (1) levees; (2) flood retention dams; (3) flood diversion)	(1) 0.29–1.03 (2) 0.7–1.34 (3) 1.1	Heidari, 2009	Iran, Dez and Karun river floodplains
Flood DRM structural (including (1) constructing one-meter high wall; (2) elevating homes against floods)	(1) 60 (2) 14.5	Kunreuther and Michel-Kerjan, 2012	Multiple countries (34)
Flood DRM mix (including capacity building, structural and early warning interventions)	3.49	White and Rorick, 2010	Nepal, Kailali
Flood DRM mix (including mitigation works, maintenance, preparedness plans, emergency fund etc.)	18.6 (sensitivity analysis 14.8)	Nepal Red Cross, 2008	Nepal, Ilam District
Flood DRM mix ((1) Expressway/channel, river improvements; (2) early warning system; (3) relocation of houses, wetland restoration)	(1) 8.55–9.25 (2) 0.96 (3) 1.34	Khan et al & The Risk to Resilience Study Team, 2008	Pakistan, Lai Basin
Flood DRM mix (including structural flood mitigation measures and early warning system)	2–2.5	Kull, 2008	Nepal and India, Gangetic Basin
Flood DRM mix (including community groups, community emergency funds, awareness rising, construction of tube wells etc.)	1.18–3.04	IFRC, 2012	Bangladesh
Flood DRM mix (including (1) rainforestation farming; (2) bamboo plantation; (3) river channel improvements)	(1) 30 (2) 14.74 (3) 3.5	Dedeurwaerdere, 1998	Philippines
Flood DRM mix (including (1) Riparian buffers; (2) Upland afforestation; (3) Floodplain	(1) 2.8-21.6 (2) 1.2-3.4 (3) 0.8-4.2	*Daigneault et al, 2016[9]	Fiji, two river catchments

[9] Full reference: Daigneault, A., Brown, P., & Gawith, D. (2016) 'Dredging versus hedging: Comparing hard infrastructure to ecosystem-based adaptation to flooding', Ecological Economics, 122, 25-35. https://doi.org/10.1016/j.ecolecon.2015.11.023

vegetation; (4) Reinforce riverbanks; (5) River dredging)	(4) 0.3-1.3 (5) 0.6-5.5		
Flood & Drought DRM non-structural (raised hand pump)	3.2	Venton & Venton, 2004	India, Bihar & Khammam
Hydro-meteorological DRR non-structural (coastal mangrove afforestation programs)	18.64–68.92	IFRC, 2011	Vietnam
Hydro-meteorological DRR non-structural (Installation of a boat-winch system)	3.5	Khan et al, 2012	Vietnam, Fishermen
Hydro-meteorological DRR non-structural ((1) mangrove restoration; (2) aquaculture development)	(1) 1.88-3.72 (2) 1.11-1.33	*Tuan & Tinh, 2013[10]	Vietnam, Thi Nai Lagoon, Quy Nhon City,
Hydro-meteorological DRM structural (improving roof protection against hurricane and cyclonic winds)	2.2–6.07	Kunreuther and Michel-Kerjan, 2012	Multiple countries (34)
Meteorological services non-structural (divided into public and for various economic sectors)	35-40	Guocai and Wang, 2003	China
Meteorological services (Proposed modernisation of the national meteorological services in (1) Belarus; (2) Georgia; (3) Kazakhstan)	(1) 3.3 (2) 5.7 (3) 3.1	World Bank, 2008	Belarus, Georgia and Kazakhstan
Cyclonic wind DRM structural (Retrofitting options for housing against cyclonic wind ((1) wood; (2) unreinforced masonry; (3) both))	(1) 1.01-3.37 (2) 0.52-1.73 (3) 0.63-2.10	*UNISDR, 2015[11]	Madagascar
Vulnerability to Resilience (V2R) programme (2013-2016) (DRR and sustainable livelihoods)	<1-2.86	*Ahmed et al, 2016[12]	Bangladesh

Source: Adapted from Shreve and Kelman, 2014: 215-226. Some additional BCRs have been added from more recent literature*. For full details of the methodologies used (including assumptions and discount rates) refer to Shreve & Kelman (2014) or directly to study references.

[10] Full reference: Tuan, T.H. & Tinh, B.D. (2013) *Cost–benefit analysis of mangrove restoration in Thi Nai Lagoon, Quy Nhon City, Vietnam*, London: IIED. http://pubs.iied.org/10644IIED/?a=T+Tuan

[11] Full reference: UNISDR (2015a). *Review of Madagascar*. UNISDR working papers on public investment planning and financing strategy for disaster risk reduction. http://www.unisdr.org/we/inform/publications/43522

[12] Full reference: Ahmed, B., Kelman, I., Fehr, H.K., & Saha, M. (2016) Community Resilience to Cyclone Disasters in Coastal Bangladesh. *Sustainability*, *8*, 805. http://www.mdpi.com/2071-1050/8/8/805

Mechler (2016: 3) discusses the use of CBA for assessing the efficiency of certain DRR interventions. He highlights that although there is a lot of rhetoric suggesting that DRR is cost-effective, surprisingly there is little in the way of robust evidence (2016: 1). Overall, his assessment of CBA for DRR finds that “the available evidence indeed suggests sizeable returns to DRR and as a global estimate across interventions and hazards on average DRR can be said to render benefits about four times the costs in terms of avoided and reduced losses” (2016: 3). He concludes that CBA continues to be an important tool for prioritising efficient DRM measures but with a shifting emphasis from infrastructure-based options (hard resilience) to preparedness and systemic interventions (soft resilience), other tools such as cost-effectiveness analysis, multi-criteria analysis and robust decision-making approaches deserve more attention (Mechler, 2016: 1).

Venton (2018) argues that the evidence is strong that investing in risk reduction and resilience yields economic benefits greater than costs. However, the evidence on the extent to which investments in resilience reduce the impact of a drought on humanitarian liabilities is, to date, less clear. Measuring the effectiveness of resilience requires long time horizons to truly capture its cost-effectiveness (Venton, 2018: 7). Venton recently evaluated the economic case for early response and resilience building in Kenya, Ethiopia and Somalia, building on a study commissioned by DFID in 2013 that evaluated the Economics of Early Response and Resilience in five countries. This analysis used the Household Economy Analysis (HEA) to model the potential impact of different response scenarios over 15 years. Her findings aggregated across the three countries included that for every US$1 spent on safety net/resilience programming results in net benefits of between US$2.3 and US$3.3 (Venton, 2018: 12). Investing in resilience to drought is significantly more cost effective than providing ongoing humanitarian assistance, generating net savings of approximately US$287 million per year over a 15-year period. She concludes that investment in shock responsive and adaptive management approaches that can respond to the particular context and changing circumstances of households should help to realise outcomes most effectively.

CBDRR interventions

CBDRR is defined as a process in which affected communities are at the centre of any risk reduction strategy (or adaptation intervention) (Kelman et al, 2017). This is often referred to as a participatory and bottom-up process that is initiated, led and/or managed by the community itself. This approach has been adopted in many countries within the last decade.

Venton et al (2013) explore how CBA is increasingly being used to provide a more robust analysis of the costs of CBDRR and community-based adaptation. It can be used *before* a programme is implemented to decide on the most appropriate package of interventions, or *after* a programme has been implemented to evaluate the effectiveness of activities. CBA for CBDRR is challenging in that the main benefit of CBDRR is a reduction of disaster losses, which can be very difficult to measure and which often accrue over long-term periods further complicating the issue of distribution of costs and benefits (Kelman, Mercer, and Gaillard, 2017). More recently, there has been a convergence of CBA with social return on investment (SROI) methodologies, as CBAs increasingly incorporate community participation and broaden their scope to account for social and environmental issues (Venton et al, 2013).

Venton et al (2013) reviewed 23 studies that have field-tested CBA to either inform or evaluate CBDRR and climate risk management initiatives. They argue that “CBA plays a valuable role and has added to the evidence base demonstrating ‘value for money’ of community-based disaster risk reduction, climate change adaptation and more recently early response activities" (Venton et al, 2013: 5). They conclude that if donors want to deliver value for money at scale, they need to refocus from 'what' types of interventions can be scaled up to 'how' to design and implement a programme of work so that it delivers good value for money.

Eco-DRR/EbA interventions

EbA and Eco-DRR can deliver multiple benefits beyond adaptation and reducing disaster risk. Examples include the restoration and conservation of coastal vegetated ecosystems such as mangroves for protection from storm surges, which also enhances carbon sequestration as well as community engagement and livelihood opportunities (Shreve and Kelman, 2014: 228). However, costings are rarely available for Eco-DRR and EbA interventions. Shreve and Kelman (2014: 230) only found two examples of using CBA to analyse mangroves for DRR (see Table 2) and highlight that it has limited coverage in the literature. In a report for the Secretariat of the Convention on Biological Diversity, Lo (2016) highlights that quantifying the economic benefits of EbA and Eco-DRR may be difficult given the nascent implementation stage of programmes and activities, and given that non-monetary benefits, such as cultural or educational benefits, can be difficult to quantify. Lo (2016: 50) also notes that costs and benefits may not be distributed equally among stakeholders or sectors of society, creating incentives for some to implement EbA, but not for others.

Emerton (2017) has produced a sourcebook for the German Corporation for International Cooperation (GIZ) on the topic of EbA valuation. It offers a resource to guide the design, delivery and use of EbA valuation studies to inform and influence decision-making. One of the defining characteristics of EbA is that it positions people at the centre of the adaptation process, and involves community-based and participatory approaches (IIED 2016, SCBD 2009, 2010 in Emerton, 2017). For this reason, the concept of value pluralism or multiple values has emerged as a key issue in EbA valuation, and wherever possible, efforts at EbA assessment and valuation should attempt to adopt the concept of multiple values (Emerton, 2017: 15). Emerton (2017: 26) deals with five main categories of valuation methods: biophysical effects, risk exposure and vulnerability, economic costs and benefits, livelihoods and wellbeing impacts, social and institutional outcomes. Emerton explores the use of these methods through 40 case studies. For example, Golub and Golub (2016 cited in Emerton, 2017: 120) carried out a study to assess the costs and benefits of climate adaptation in Bangladesh. They found that almost all of the adaptation options considered (foreshore afforestation and mangrove protection, construction of cyclone-resistant shelters/ housing and early warning systems) had a BCR greater than one. Only polder reconstruction and setback of less than 3 metre inundation area were demonstrated to not have a positive return. The two long-term strategies, aiming to increase agricultural productivity and relocation vulnerable populations, showed the highest returns, followed by mangrove restoration protection (all with BCRs greater than two). In contrast to the other options, mangrove based adaptation generates a sizeable share of external benefits, as well as offering opportunities to leverage additional financial flows and income.

Climate smart agriculture

Savage (2015: 4) highlights that in the developing country context, there has been significant analysis of climate smart options due to their potential for addressing existing climate variability and the impact of rainfed agriculture. Studies generally produce high BCR, often derived from agricultural productivity benefits with the potential for additional revenue streams. Savage (2015) also notes that under conditions of future climate change, the economic benefits of resilience should increase. However, he also notes that BCRs are highly site-specific and are also dependent on the choice of discount rate. There may be also be associated opportunity or transaction costs that can act as a barrier to adoption and economic benefits may not accrue to local farmers. As a result, costs are likely to be higher than those cited.

Climate risk insurance

Risk insurance has been advocated as a practice that has high potential to provide CCA and DRR benefits, and has been proposed as a cost-effective way of coping with financial shocks. There have been a number of high profile schemes advocated in recent years, for example, the G7 InsuResilience Initiative (Schaefer and Waters, 2016). However, there is a lack of robust evidence to support the argument that insurance can be an effective tool (Prabhakar et al, 2017; Schaeffer and Waters, 2016).

The Asia-Pacific Network for Global Change Research (APN) has funded a project to assess community risk insurance initiatives. As part of this project, Prabhakar et al (2017) highlight a number of case studies from selected countries where the costs and benefits of a variety of available insurance products are quantified and presented using survey approaches. The project quantified the BCR of risk insurance in these project countries. High BCR results suggest that insurance can be beneficial to farmers in all the countries. The results also suggest that in cases where catastrophic events occur annually, crop production without crop insurance is still financially profitable. They recommend the need for a comprehensive insurance effectiveness assessment framework to differentiate various forms of insurance products, which looks beyond the immediate insurance payoffs to identify long-term and sustainable risk-reduction benefits (Prabhakar et al, 2017: x).

Schaefer and Waters (2016) argue that insurance can be a tool to help people manage risk more effectively, but that it is not readily available for poor and vulnerable people in developing countries. They interviewed experts and analysed 18 existing climate risk insurance schemes (see p.26 in Schaefer and Waters, 2016 for a full list), to see if and how insurance schemes contribute to increasing the resilience of poor and vulnerable people. They highlight that “Insurance tools like micro-insurance, national sovereign insurance funds and multi-country/regional insurance pools are important tools to transfer and pool risks, although they may not always be the most cost-efficient approach” (Schaefer and Waters, 2016: 50). They point to high transaction costs and high prices for premiums as major obstacles responsible for low insurance penetration in developing countries, finding that financial sustainability is a major challenge for climate risk insurance schemes. Concluding, “insurance may not be cost-efficient for the poorest of the poor” (Schaefer and Waters, 2016: 50). However, Schaefer and Waters’ (2016: 55) analysis suggests that – if embedded into a wider risk management approach – climate risk insurance can contribute to improving key capacities (including anticipatory, absorptive and adaptive) that are imperative for reducing poverty and making poor and vulnerable people more resilient (see Schaefer and Waters, 2016: 58, for full results and evidence gaps).

5. Limitations and criticisms

Limitations

There are many significant gaps in the literature on CBA for DRR and CCA interventions, including gaps in geographic coverage and the prevalence of studies evaluating physical and economic vulnerabilities, as opposed to social and environmental vulnerabilities (Shreve and Kelman, 2014: 228). There is also limited publically available, peer-reviewed literature on recent (last 4 years) CBAs for DRR and CCA interventions. This may relate to the shift in focus of CCA and the impact of this on economic assessment of adaptation (as discussed earlier, also see Watkiss, 2015 and ECONADAPT, 2015). The majority of case studies come from grey literature assessments from NGOs, donors and governments. Furthermore, the brunt of the reported evidence exists for flood risk prevention, sometimes coupled with water management and preparedness. Less is known about drought and hurricane risk management, disaster preparedness and risk financing (Mechler, 2016: 22). The robustness of these estimates also differ, with some sectors much more limited in the scope of their literature and CBA estimates than others.

Criticisms

There is some degree of indecision about the appropriateness of CBA to analyse costs and benefits of DRR and CCA (see Shyam, 2013: 7). A focus on economic costs and benefits addresses only one aspect of people's vulnerability to disasters. One of the main criticisms of CBA in DRR is that it values costs and benefits in purely monetary terms. In the case of physical structures (e.g. homes, infrastructure, public buildings) and economic aspects (e.g. employment, crops and livestock, savings) these calculations are relatively straightforward. It is much more difficult to quantify less tangible aspects (e.g. the natural environment, social and psychological issues) and many CBAs do not pay enough attention to them (Twigg, 2015: 367). Projects with clear monetary benefits may be selected over those which may be equally beneficial, but whose results are not so easily quantified: this is problematic for community DRR, which typically includes a mixture of 'hard' and 'soft' measures.

Mechler (2016: 7) identifies a number of challenges that are specific to DRR and inherent with CBA: (1) representing disaster risk, (2) assessing intangibles and indirect benefits from disaster risk reduction investments, (3) assessing portfolios of systemic interventions versus single interventions, (4) the role of spatial and temporal scales, (5) discounting and the choice of discount rate (see Mechler, 2016 for an in-depth discussion of these challenges). Further methodological limitations identified by Venton et al (2013: 5) include: a focus on single hazards; uncertainty in estimating hazard probability; complexity of climate change for probabilistic risk modelling; and difficulties in comparing results across CBAs. Calculating the probability and extent of a hazard's occurrence and impacts can be difficult, especially at the local level and where there are data gaps. CBA is better at assessing shorter-term outcomes than longer-term trends, where there is a much higher level of uncertainty. Climate change adds another level of complexity (Twigg, 2015). There are also ethical concerns, the main one being that many people object in principle to assigning a monetary value to human life. Another is that conventional CBA does not consider the distribution of costs and benefits within communities. Additional qualitative assessment may be needed to identify the impacts on different households, social groups, businesses and institutions (Twigg, 2015: 367). Twigg (2015: 366) highlights that there are several challenges and issues regarding the use of CBA in risk reduction and CCA, as it is difficult to assess the human and economic impact or cost of disasters. Data and methods have improved over the years but remain unreliable, especially in low-income countries. Estimates of economic impact generally focus on direct costs, and it is more difficult to assess indirect and secondary costs.

Shreve and Kelman (2014) identify important shortcomings in the use of CBA for DRR interventions, such as a lack of sensitivity testing of results, gaps regarding the inclusion of climate change, lack of consideration of dis-benefits and representations of vulnerability; yet, the review does not consider the role of probability and risk (Mechler, 2016: 2). Shreve and Kelman (2014: 232) conclude that the CBAs they studied demonstrate the importance of context for each BCR result, and further caution that it is "not clear that averaging BCRs across case studies produces a useable result for policy or decision makers, because the circumstances if the studies tend to be quite different – particularly with respect to vulnerability". They also highlight the influence of culture on hazard, vulnerability, risk and disaster. Values can differ depending on who is asked, with different perspectives assigning different values for property, land and infrastructure. Some studies have shown that vulnerability concerns can be addressed more robustly to some degree, as long as context is retained, for example through using shared learning dialogues (SLD), a participatory and multi-stakeholder approach to assessing vulnerability (Shreve and Kelman, 2014: 232). For example, Singh et al (2014) used a series of community SLDs in three villages in India to identify and analyse community perceptions of the costs and benefits of various options that households have adopted to mitigate losses from flood and waterlogging. They found that the location of the village affected how the communities valued different flood resilient measures for the house. They also noted that that the cheaper options like raised door, concrete shelf, etc. are perceived to be providing larger benefits than their perceived (or near to actual) costs, as compared to the costlier options like RCC or RBC roofs. The IPCC SREX report (IPCC, 2012: 268) concluded that the applicability of rigorous CBA for evaluations of managing extreme events is limited based on limited evidence and medium agreement.

Similar criticisms relate to CCA and the use of CBA. Watkiss (2015: 20) identifies a number of methodological challenges with the economic assessment of adaptation, including issues around adaptation objectives, baselines, discounting, equity, transferability and additionality. Most estimates of the costs and benefits of adaptation use some form of scenario-based impact assessment, assessing future projections of climate change, the subsequent impacts and then considering adaptation responses. ECONADAPT (2015: 4) highlights that these assessments face issues due to the difficulty in estimating the future impacts of climate change, and the costs and benefits of adaptation, especially given the high uncertainty. In response to these issues, the framing of adaptation has changed considerably over recent years with a shift to more practical and policy-orientated analysis. There has also been a move to recognise the timing and phasing of adaptation, taking account of future uncertainty, including the increasing use of iterative climate risk (adaptive management) and new decision support methods.

Vulnerability and resilience

Disasters are a complex mix of natural hazards and human action. Blaikie, Cannon, Davis and Wisner (2004) in their book on natural hazards, people's vulnerabilities and disasters, argue that disasters should not be segregated from everyday living, and that the risks involved in disasters must be connected with the vulnerability created for many people through their normal existence. To understand disasters you need to know not only about the types of hazards that might affect people, but also the different levels of vulnerability of different groups of people. This vulnerability is determined by social systems and power, not by natural forces, and hence needs to be understood in the context of political and economic systems that operate on national and even international scales.

Defining vulnerability is complex. The IPCC defines vulnerability to the impacts of climate change as “the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt” (IPCC, 2014d in Schaefer and Waters, 2016: 31). There are many factors that can lead to vulnerability, including economic; education; health and nutrition; housing and environment; social capital; and social inclusion. Furthermore, vulnerability itself is dynamic and related to exposure to climate risks as well as to assets and poverty (Schaefer and Waters, 2016: 31, 38).

Béné et al (2012: 10) emphasise the importance of distinguishing between the sensitivity of households to shocks (where wealthier groups in poor communities may not necessarily be less sensitive to the direct impacts of disasters than their poorer neighbours), and the capacity to recover (where this time wealthier households seem to be better equipped than poorer ones to recover from shocks). They further discuss the use of resilience in the DRR, CCA and social protection fields. They highlight that resilience thinking can help better incorporate the social-ecological linkages between the vulnerable groups and ecological services on which they depend, thus contributing to a more adequate targeting of (future) vulnerable groups. However, they caution against relying on the term ‘resilience’ too heavily, it needs to be considered more carefully, especially with the recognition of ‘good’ and ‘bad’ resilience. The politics of resilience (who are the winners who are the losers of ‘resilience interventions’) need to be recognised and integrated more clearly into the current discussion (Béné et al, 2012: 49).

Hallegatte et al (2017: 1) emphasise that although economic losses from disasters are useful in providing information on the trends and costs of disasters, they fail to detail how disasters affect people’s well-being. Hallegatte et al (2017: 1) argue that “[US]$1 in losses does not mean the same thing to a rich person and a poor person, and the severity of a $92 billion loss depends on who experiences it. […] By focusing on aggregate losses, the traditional approach examines how disasters affect people wealthy enough to have wealth to lose and so does not take into account most poor people”. They argue that poor people suffer disproportionately from natural hazards because of five main reasons: overexposure; higher vulnerability; less ability to cope and recover; permanent impacts on health and education; and effects of risk on saving and investment behaviour (Hallegatte et al, 2017: 4). Hallegatte et al (2017: 2) have developed a metric to measure natural disaster risk and losses are that can capture their overall effects on poor and non-poor people, even if the economic losses of poor people are small in absolute terms. This metric can be used in the analysis of DRM projects so that investments improve the well-being of all people and are not systematically driven toward wealthier areas and individuals. However, the socioeconomic resilience measure used by Hallegatte et al (2017: 10) does not cover all the areas discussed in research on resilience.

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