# From Risk to Resilience

Working Paper 9

*Understanding the Costs and Benefits of Disaster Risk Reduction under Changing Climatic Conditions*

India • Nepal • Pakistan

Marcus Moench &
The Risk to Resilience Study Team

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Cover: On 18th August 2008 the Kosi embankment north of Kosi Barrage breached causing widespread devastation in Nepal and North Bihar. Photo of breached east-west highway near Laukhi, Nepal. Photo courtesy of Keshab Ghimire.

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# Contents

# Key Messages

The benefits of investing in disaster risk management substantially exceed the costs. This is the core finding that emerges from a series of detailed probabilistic analyses of avenues for flood and, to a lesser extent, drought risk reduction in India, Nepal and Pakistan. In most cases investigated, benefit/cost ratios are positive and in some instances may be well above those achieved through other common development investments. This finding holds true for an array of interventions that range across a spectrum from insurance to early warning and from distributed responses at the village level to large-scale infrastructure. Return rates are often higher when the impacts of climate change are considered, particularly for strategies that are resilient under uncertainty. Return rates appear particularly robust for the often lower-cost "people-centered" interventions that reduce risks associated with high frequency but low magnitude events rather than large disasters. Such events are a source of chronic, in some cases annual, losses that can erode the wealth of affected populations. The economic benefits from interventions that require high initial investments and are targeted at less frequent "extreme events" are particularly vulnerable to assumptions regarding the appropriate discount rate to use and to uncertainties regarding the frequency and magnitude of extreme events as climate conditions change. Investing in lower cost forms of risk reduction that are designed to increase the resiliency of livelihoods, housing and other infrastructure at the household and community level may be among the most economically effective avenues for reducing risks and thereby supporting adaptation to climate change. This does not, however, imply that investments should be directed away from the lower frequency-higher magnitude disasters that can set individuals, households and regions back for many years. Instead, it implies the need for a balanced approach that combines sustained attention to the small disasters that receive little public or policy attention as well as the large-scale, high-profile impact of extreme events.

There are two major exceptions to our core finding that "risk reduction pays." Risk reduction often doesn't pay where strategies have major externalities and/or depend heavily on specific knowledge concerning the magnitude and probability of specific event types. In the case of embankments for flood control, for example, accurate evaluation of externalities related to drainage, land use and disease may offset any benefits from risk reduction. Risk reduction also may not pay in the case of high cost "over-built" specialized systems. Specialized early warning systems designed to reduce risks from low-frequency events, for example, may have poor rates of return unless the value of life is monetized or unless the cost effectiveness of different approaches to saving lives is compared with other investments where the objective is similar. In most cases evaluated, however, appropriately designed risk reduction strategies represent a sound investment that is central both to poverty alleviation and for responding to the impacts on lives and livelihood systems anticipated as a consequence of climate change.

The question of appropriate design is important to recognize. While risk reduction does pay, returns and the effectiveness of some strategies depend heavily on future climate projections and other factors where uncertainty is high. Other strategies, however, deliver robust returns under a wide range of conditions. These differences in the resilience of approaches also have implications for our ability to evaluate their returns in contexts where limited amounts of data are available and numerous assumptions must be made in order to evaluate returns. In specific:

1. The rates of return between different types of investments in risk reduction vary greatly in how robust they are under different sets of assumptions and different projections of climate change. In many cases, lower levels of investment can generate rates of return that are both greater and much more robust than higher cost investments. This appears to be particularly true of investments that provide annual benefits by improving the ability of populations to "live with" frequent floods and droughts rather than investments focused on larger but less frequent "extreme events." For basic human behavioural reasons, such investments may also be more socially and institutionally sustainable than ones directed at infrequent larger events (Gunderson and Holling, 2002; Holling, Gunderson et al., 2002).

2. Even with the best scientific information the ability to project future event probabilities will be highly uncertain. Nowhere is this more evident than in the data limited environments that characterize much of the developing world. As a result, *any attempt to project the future costs and benefits of climate related disaster risk reduction investments using probabilistic approaches is subject to high levels of uncertainty.*

3. In virtually all cases investigated, approaches to risk reduction that combine a mix of "hard" infrastructure and "softer" institutional or financial measures are more robust than approaches that focus on one or the other alone. Many of the most robust avenues for risk reduction address underlying systems such as those documented in earlier research (Moench and Dixit, 2007).

4. Large-scale infrastructure investments, while they may generate positive rates of return, are particularly vulnerable to assumptions regarding discount rates, investment costs, event frequencies and, most importantly, the negative consequences ("disbenefits" or externalities) that tend not to be counted in project evaluation. *In the case of embankments, inclusion of realistic land values,*

*crop and other losses associated with water logging and increases in disease fundamentally reduce the benefit/cost ratio*. Returns from such large investments are, furthermore, highly vulnerable to climate change projections.

5. Approaches to evaluating the costs and benefits of disaster risk reduction *and* to interpreting the results of such analyses need to be assessed carefully. In many analyses, the real data required to accurately evaluate costs and benefits aren't available and are difficult to generate. As a result, such analyses depend very heavily on assumptions and estimates made by project members or experts. These are often deeply hidden in models and in the technical portions of the analysis and are as a result unlikely to be evident to any but the most engaged users.

6. Where technical evaluations of climate change are concerned, innovative techniques for downscaling the results of global circulation models to local areas have been developed under the project and used in the estimation of future event probabilities to evaluate the costs and benefits of risk reduction interventions. While such methods do provide key insights, their limitations are essential to recognize. In specific, it is inappropriate to treat the projections as providing an accurate representation of future event probabilities. Furthermore, in many cases the absence of basic location-specific historical data limits the ability to translate downscaled results from circulation models into streamflows or the other types of projections required for local impact evaluation.

7. Given the high levels of data required for accurate estimation of the costs and benefits of disaster risk reduction under climate change and the inherent uncertainties in such processes, *more limited forms of financial and project analysis are likely to be more appropriate than full CBAs in most project and evaluation contexts.* Simplified methodologies that enable identification of key cost and benefit areas along with their general magnitude coupled with methods for comparing the cost effectiveness of different strategies for reaching similar risk reduction outcomes are an essential complement to more rarely applicable full CBA methodologies. In many cases, the costs of a full CBA will exceed the benefits.

Overall, the case studies on which this report is based demonstrate both the high economic returns that can be achieved by investing in risk reduction *and* the importance of methodologies for analyzing the viability of different approaches under often highly uncertain future conditions. Cost-benefit analysis is one such methodology. In many cases, however, more simplified approaches that identify, but do not fully quantify, major costs and benefits and also highlight key externalities, uncertainties and assumptions may generate as much information as a full CBA.

# Introduction

At a global level, evidence regarding the economic impacts of climate change and disasters is accumulating rapidly. It is now widely recognized that recurrent disasters represent a major factor undermining the ability of regions, nations and the global community to meet basic development goals. Roughly 75% of disasters are related to storms, floods, droughts and other climate-related causes (Hoyois and Guha-Sapir, 2004). The intensity and possibly the frequency of such events are likely to be exacerbated by climate change (IPCC, 2007). As a result, disaster risk reduction (DRR) is central both to meeting global development objectives and, equally fundamentally, as a core component in any attempt to adapt to climate change. This is recognized globally in key agreements for action such as the Hyogo Framework for Action (ISDR, 2005).

While broad consensus exists on the need for disaster risk reduction, a wide variety of avenues that range across the spectrum from the design of physical structures to the growth of social networks and institutions exist that could potentially reduce or alter the nature of risks. Often little information is available on the economic basis for investment in alternative avenues for risk reduction, making investments in specific DRR activities difficult to justify relative to both the alternatives available and to other social investments that contribute toward similar development objectives. National and local governments, international financing agencies and NGOs have limited resources. Investments in DRR either in relation to existing conditions or those likely to emerge as a consequence of climate change take resources away from other areas where investment may be equally important. As a result, there is both a need and a demand for analytical frameworks such as cost-benefit analysis that can support decision-making with regard to investments in climate and other disaster risk reduction investments. This need and the pressure to provide solid justification for investments is likely to grow as global investment in addressing the impacts of climate change increases. While constraints on the absolute availability of financing will decline if innovative mechanisms for funding climate adaptation are implemented, global scrutiny and, in some cases, opposition to such funds will increase as well. Consequently, solid evaluation of the economic costs and benefits of alternative strategies will be increasingly essential to counter the opposition and concern that will inevitably grow as the scale of investments increases.

The challenge is not, however, just to demonstrate the economic returns from investments. In many cases, perceptions regarding both disaster risks and avenues for addressing them vary greatly between individuals and groups. This is particularly true in the context of climate change where historical experience may have limited relevance for future conditions. It is also the case where the impact of disaster events is differentiated on the basis of social or economic grouping. Women, for example, often face fundamentally different types of impacts than men during disasters due to the nature and location of their day-to-day activities and the different types of social networks and economic opportunities they have access to. As a result, approaches that reduce or alter the nature of risk for one group may not address the needs of other groups.

In this context, simply documenting the economic justification for investments in risk reduction will be insufficient. Analytical frameworks and approaches that help to identify who gains, who loses and whether or not the costs of disasters, particularly those associated with climate change, are equitably addressed will be essential. Global efforts to address climate change are heavily influenced by the recognition that those benefiting from high carbon lifestyles aren't the large poor populations in developing countries who will bear much of the cost of climate change. As a result, questions of equity are central to virtually all efforts to respond to the impacts of climate change. Analytical frameworks that help to identify the distribution of impacts from climate related disasters and the distribution of benefits associated with strategies to address those impacts are essential.

Beyond analytical frameworks, on an applied, pragmatic level, the great diversity of approaches that could reduce risk from disasters necessitates processes for identifying specifically what should be done to reduce risks and for whom in different contexts. Terms such as "disaster risk reduction" or "climate adaptation and resilience" only acquire real meaning when they can be translated into specific courses of action that have an impact at the ground level. At present, systematic processes for identifying courses of action to reduce risk for vulnerable communities are rare. In many cases, actions to reduce disaster risk focus on proximate causes – such as poor building construction or the lack of protective infrastructure and points of refuge – rather than the deeper systemic factors that create or ameliorate risk within society. These are discussed further in the array of publications produced by the Risk to Resilience project (www.climate-transitions.org & www.i-s-e-t.org). This summary report, however, focuses primarily on the costs and benefits of specific strategies for reducing flood and drought related disaster risk both currently and under scenarios designed to illustrate the effects of climate change.

# The Project on Risk to Resilience

The purpose of the project on *Risk to Resilience* is to evaluate the costs and benefits of disaster risk reduction across a series of case areas in India, Nepal and Pakistan. We focus on water related disasters and the manner in which they may change as a consequence of climate change. Our objective has been to develop a suite of methods and analytical cases that both illustrate how the costs and benefits of different risk reduction strategies can be evaluated under different climate scenarios and also generate analytical results for the risk reduction strategies evaluated. Methodologically, our approach consists of the following key elements:

1. *Scoping*: An intensive scoping process to identify locations and risks that can form a representative basis for detailed cases.
2. *Vulnerability and capacity analysis*: A systematic process within case areas, including development of semi-quantitative vulnerability indices, to identify vulnerable groups and disaggregate the different dimensions of vulnerability.
3. *Shared learning dialogues within identified case areas*: Iterative meetings with communities and key actors that sequentially allow us to move from the analysis of vulnerability to clear identification of the alternative strategies for disaster risk reduction that key actors in government and affected communities believe will address risk under current and projected climate conditions.
4. *Systematic qualitative approaches for evaluating tradeoffs (broad costs and benefits) between alternative strategies for risk reduction:* Who benefits, who loses and why?
5. *CBA using quantitative probabilistic techniques for evaluating the costs and benefits of different approaches to disaster risk reduction.* This is a core economic and hazard-modelling element and includes techniques for downscaling and evaluating the impacts of climate change in data limited contexts.

The above techniques are also discussed in detail in a separate detailed methodology report to be produced by ISET.[1] This report will focus on the core insights that have been generated through application of the techniques to flood related disaster risks in case study sites respectively in the Nepal Tarai, Rawalpindi (Pakistan) and Eastern Uttar Pradesh (India). Examples of their application have

[1] When completed these will be available on the publications tab on the ISET website: www.i-s-e-t.org

also been discussed in a preliminary manner in *Working With the Winds of Change*, an earlier ISET publication from the project (Moench and Dixit, 2007). A separate report to be produced by the project will also address drought hazards and insurance in the Eastern Uttar Pradesh context. The sites and locations where research under the project was conducted are shown in Figure 1. The Eastern Uttar Pradesh case presents full quantitative results while the Pakistan and Nepal cases are more qualitative in nature.

The programme on which this report is based was structured in a highly collaborative manner with all involved organizations playing core field, analytical and conceptual roles. This said, individual organizations played a lead role in specific component activities. Research in each of the case locations was conducted by core partners in the project: ISET-Nepal and Nepal Water Conservation Foundation led activities in the Nepal case site, Winrock International India led all activities in India and worked in close coordination with the Gorakhpur Environmental Action Group, Janvikas and the lead ISET associate in India. In Pakistan, PIEDAR and ISET associates worked closely together on the Rawalpindi case. International Institute of Applied Systems Analysis (IIASA) and King's College London led respectively on the technical cost-benefit and vulnerability components of the project. All activities were coordinated and supported by ISET and ISET's regional associates.

| Figure 1 | Research locations

# Critical Issues

Research on the costs and benefits of disaster risk reduction in the context of climate change is, in many ways, a window into complexity. The political and social context of South Asia is dynamic and fluid. Risks appear as rapidly evolving emergent properties of development and settlement processes in different contexts. In conjunction with often pre-existing patterns of social, economic and gender differentiation such processes create a kaleidoscope in which patterns of vulnerability appear or dissipate in ways that depend as much on interactions within livelihood systems that span the spectrum from local to global as they do on exposure to location specific hazards. As some of our earlier research has clearly documented, changes in vulnerability to disaster often depend as much, if not more, on systemic factors that may have little to do with actions taken under the rubric of "disaster risk reduction" *per se* (Moench and Dixit, 2007). Changing access to communications, financial systems, transport, utilities, health services and local to global social networks heavily influence where people live, their overall mobility and the vulnerability of their livelihood systems to disruption during floods, droughts or other climate related events. They also influence the viability of targeted strategies for risk reduction. At a national level, in highly dynamic political environments, institutional memories tend to be short. However well planned or conceived, strategies to enforce building codes, enforce land use plans or maintain early warning systems tend to dissipate rapidly following disaster events. Unless the "demand" underpinning such strategies remains constant, the constantly emerging kaleidoscope of urgent issues facing government actors will drive disaster risk reduction activities into the background – at least until the next disaster. This may also be the case with many strategies based on action at the community level unless risk reduction measures respond to events that recur with a high level of frequency. In addition, the institutional memory within communities and the organizational foundations of many community based organizations depend heavily on the degree to which a community actually represents a relatively stable and unified entity. If the types of events that cause disaster occur infrequently, then institutional memory and organizational capacity to reduce risk will dissipate. This has been documented in other research as a major factor undermining the ability of societies to organize in response to long-term challenges (Gunderson and Holling, 2002). The situation is further complicated by fundamental differences in perception regarding hazard risks between groups within hazard prone areas. In the case of the Lai Basin in Rawalpindi, Pakistan, for example, men focused on the direct flood risk to assets, structures and lives while women emphasized the perpetual hazard of disease from the ubiquitous liquid and solid waste pollution in the stream.

Given the complexity inherent in the case contexts, our analysis of the costs and benefits of disaster risk reduction has focused first on the actions government and individuals are actually implementing in response to specific hazard risks in case areas. Many of these interventions are structural. They involve the construction of water control structures, such as embankments, and other physical measures. In addition, through the scoping processes we have identified what we believe is a realistic alternative portfolio of local-level interventions that could contribute to disaster risk reduction. Components in this portfolio include a spectrum of interventions that range from establishment of protected locations (the raising of houses and schools above flood levels) to establishment of grain banks, local warning systems, self-help groups for micro-credit and more diversified livelihood systems. As far as possible the costs and benefits of these have been evaluated as a contrast to the approaches actually being implemented by governments and individual actors. Inserting the implications of climate change into each of these analyses has been done using a combination of published information on climate impacts and some new techniques, partially developed by the ISET team, for downscaling the outputs from general circulation models.

The above approach is realistic but also highlights, once again, the complexity inherent in evaluating the costs and benefits of disaster risk reduction in applied contexts. Often the only real “data” that shed light on the costs and benefits of disaster risk reduction relate to large-scale structural interventions that have been implemented by governments. In many, if not most cases, these data are partial and biased. Costs are often underestimated and externalities are often excluded. Evaluation of other strategies depends on projections and assumptions that may or may not be fully justified or accurately represent future conditions. The use of climate projections illustrates this well. Accurately evaluating the benefits from disaster risk reduction activities requires information regarding the probability of future events. Unless probabilistic information is available, losses cannot be estimated and, as a result, neither can the benefits of loss reduction. While existing information on climate change may provide information on broad trends, the current resolution of climate models provides little real information on the conditions that may be experienced in specific local areas. Techniques for downscaling information to these areas involve, in essence, generating scenarios of future climatic conditions. There is very little ability to evaluate or test how accurate representations of future conditions such scenarios actually are. Uncertainty is equally high regarding many other factors or courses of action that could contribute to disaster risk reduction. As the case studies presented later in this report clearly illustrate, data on assets at risk, hazard characteristics, losses for differing hazard intensities, externalities and the sustainability of interventions are often unavailable or inaccessible. Such data are of fundamental importance for any systematic evaluation of the costs and benefits of DRR measures. Addressing such gaps is often possible but the necessity implies that any scientifically defensible cost-benefit analysis will require substantial investment in basic data collection and, even if this is undertaken, substantial uncertainties will remain.

The challenge, however, goes well beyond that just mentioned. As noted above, the political and social context of South Asia is highly dynamic and there are substantial reasons for questioning whether or not any interventions that require long-term institutional support can be sustained, particularly where the events that catalyze disaster are widely spaced. This is, of course, a critical question for evaluation of costs and benefits. Unless measures actually are in place and functional when events occur, any investment in them will be wasted. While the costs and benefits of, for example, improvements in house design may be high, the costs and benefits of a programme designed to achieve that through building regulations depend on whether or not those regulations can be enforced over the long term. Prior experience on this is less than encouraging as documented in the history of policy responses to prior earthquakes in Pakistan (see Risk to Resilience Working Paper No.12). Relatively little information or data currently exist that can be used to evaluate such questions in a systematic way within a cost-benefit framework.

Finally, questions regarding any strategy for risk reduction often exist that aren't well addressed within a cost-benefit framework. As discussed earlier, vulnerability to disasters often varies greatly between groups. In many cases, distributional issues exist in relation to risk reduction interventions. The distributional consequences of different strategies heavily influence whether or not risk reduction contributes to larger goals such as poverty alleviation.

Overall, the broad array of challenges inherent in conducting scientifically defensible analyses of the costs and benefits of disaster risk reduction highlight both the strengths and limitations of the approach. On one hand, systematic exploration of factors that contribute to the costs and benefits of different strategies represents a powerful process for identifying and evaluating key issues. On the other, the final numbers generated through a full economic analysis depend heavily on numerous assumptions and, as a result, can be very misleading as a basis for decision-making. *In many cases, as a result, the process of conducting the systematic set of evaluations required for a cost-benefit analysis is more important than the ultimate ratios produced.* The process can serve as a transparent framework for identification and analysis of tradeoffs between approaches. Finally, benefit/cost ratios, however attractive they may seem for decision-makers or those advocating specific strategies, require intimate knowledge of the data and assumptions on which they are based in order to be interpreted accurately. Consequently, the potential for misleading interpretations is high unless decision-makers are intimately involved in the analytical process.

# The Case Studies

As previously noted, analyses of the costs and benefits of disaster risk reduction were undertaken for this study in case areas in Rawalpindi (Pakistan), Eastern Uttar Pradesh (India) and the Nepal Tarai. In each of these case studies, alternative strategies for risk reduction were identified that focused respectively on existing risk management interventions implemented by the government and alternative strategies developed on the basis of detailed dialogue with local communities, NGOs, risk management experts and local government entities. In the Nepal case, strategies were evaluated using qualitative approaches to identifying the major costs and benefits associated with each set of strategies. In Pakistan and India more quantitative analyses were undertaken with the India case involving a full quantitative CBA coupled with extensive analysis to downscale results from climate change projections and incorporate them in the analysis. Except in the detailed case in India where, in addition to flood, drought risks were also analyzed, all of the analyses focused on evaluation of flood risks. Full details on the methodologies used and the cases themselves are available in the other publications in this series (Risk to Resilience Working Papers Nos. 1 through 8) and in full reports on the same themes that are being produced separately. The main focus of each of the different working papers is summarized in Annex II.

## Flooding in the Nepal Tarai

The Tarai region of Nepal, the narrow belt of plains between India and the Himalayan foothills, is subject to regular flooding. In order to ameliorate the impacts of this flooding, embankments have been constructed both within Nepal and across the border in India. In addition, local groups, NGOs and government entities have been supporting communities to take a variety of actions (including the construction of flood resilient housing, building secure water supply sources and sanitation facilities and reducing flood exposure through forest buffers) that reduce the impact of regular flooding on local populations.

In order to assess the impacts of existing strategy on flood risks, a qualitative but systematic "cost-benefit" assessment of the main avenues for flood risk reduction in the Nepal case area was undertaken by ISET-Nepal in the Lower Bagmati Basin (Figure 2). This location is close to the base of the Himalayan range in contrast to the more central Ganga Basin location of the Eastern Uttar Pradesh case study areas that are discussed further below. The details of the Nepal case assessment are documented in more detail in other products from this project (Risk to Resilience Working Paper No. 6). The basic approach, however, involved systematic identification of the costs and benefits local populations identify for specific risk mitigation measures along a series of transects across flood-affected areas. These transects are shown in the diagram below. At regular points along the transect, shared learning dialogues were held to identify the major costs and benefits associated with each risk reduction measure. Local groups then weighted each of the costs and each of the benefits using +/- symbols to indicate their view regarding relative magnitudes. This enabled development of a systematic, although qualitative, picture of the costs and benefits of each set of interventions for the region as a whole. The approach also provides a foundation that could be used for more quantitative evaluation of the costs and benefits should that be desired.

The picture that emerges from the analysis is of clear tradeoffs. At the local level, when embankments and similar major structural measures are used as primary mechanisms for flood control, the negative impacts identified by local groups are perceived by them as overwhelming many of the benefits. Many of the negative impacts perceived by local groups relate to the manner in which embankments, while protecting some areas, shift flooding to other areas and block drainage. In

| FIGURE 2 | Cost and benefit identification transect

addition to such impacts, the failure of embankments can cause major disasters. This is clearly illustrated by the failure of the Kosi embankment in eastern Nepal that occurred at the time of writing this summary (see Box 1). This embankment failed at a time when river flows were below the average for August – it was not related to an extreme event. The Kosi broke through a poorly maintained embankment and flowed down across the Nepal-India border into channels that had been abandoned decades ago. At the time of writing, newspaper and relief agency accounts indicate that over 55,000 people are affected in Nepal and over 3,000,000 in India. In contrast, smaller-scale more "people-centered" interventions that range from the provision of boats to construction of raised areas are perceived by communities as having relatively large benefits in relation to their costs. They are also not subject to the types of catastrophic failure that is now occurring along the Kosi.

As noted above, the major costs and benefits associated with the risk reduction measures along each of the above transects were identified through shared learning dialogues and weighed by participants using a +/- system to obtain a first cut impression of major benefit and cost areas. Because the resulting tables are large, it is difficult to include them in the text here. Instead, an example along Transect 3 in Figure 2 is presented in Annex I. As this example illustrates, many of the distributed approaches appear to involve far fewer tradeoffs than the large structural measures. The costs involved relate to initial capital investments and there are few, if any, major externalities to take into consideration. They also appear to be relatively resilient under a wide variety of climate change scenarios. Unlike the embankments, where the negative consequences appear likely to increase more rapidly than the benefits as climate change proceeds, the benefits of distributed interventions will increase.

The information generated through the qualitative cost-benefit analysis conducted by ISET-Nepal provides many of the same insights that would be generated by a more quantitative approach. It highlights both the direct and indirect costs and benefits associated with each type of risk reduction intervention. This said, the magnitude of the costs and benefits identified remain difficult to compare. In many ways, as a result, the qualitative analysis lays the groundwork for a more quantitative evaluation but does not replace it.

## Rawalpindi, Pakistan

The Pakistan case focuses on flood risk reduction options along the Lai River (also called Lai Nullah) in urban Rawalpindi (see Figure 6, pg. 18). The Lai is a short river basin that, as in many similar urban areas, creates a high risk of flooding in a very densely populated area where physical assets, from housing to businesses, are concentrated.

The striking conclusion of the Lai study is that, given the high value of assets in urban areas, *almost any initiative to reduce risks will be cost effective.* This said, the benefit/cost ratio varies greatly between different approaches. In addition, the viability of different approaches in relation to the likely impacts of climate change does as well. The methodologies used to estimate costs and benefits are discussed in

BOX 1

**The August 18, 2008 Kosi Embankment Breach**

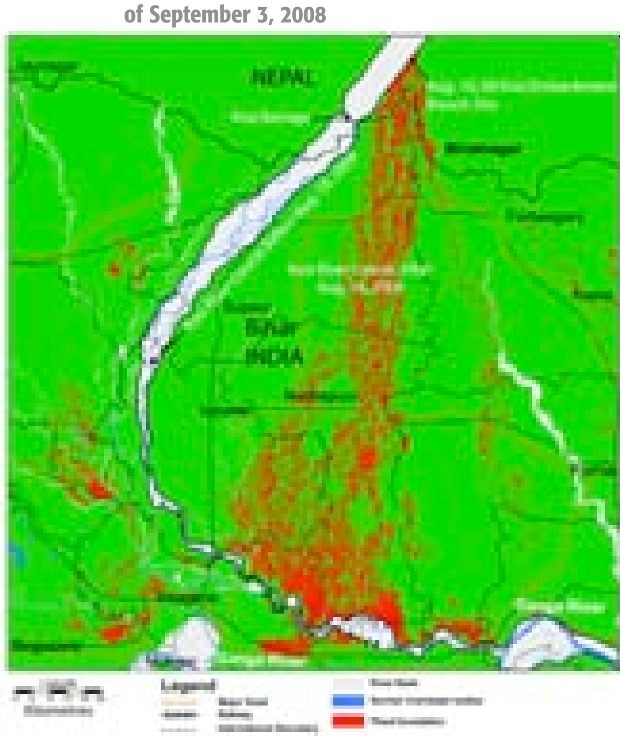
On August 18, 2008 a flood control embankment along the Kosi River in Nepal Tarai breached. The failure occurred when flow in that river was below the long-term average flow for the month of August. Over the following weeks a disaster slowly unfolded as the Kosi River began flowing along one of its old courses east of its present one.

The Kosi drains an area of 60,000 $km^2$ in Tibet, Nepal and North Bihar. In one year the river transfers an estimated 95 million $m^3$ of sediment derived from landslides and mass wasting to the Ganga. Much of the sediment is deposited in a huge fan where the river exits from the mountains to the plains. This exceptionally high load of sediment is brought down to Chatara in the Tarai and is dumped on the riverbed as the river slope levels off. Over time, as its main channel has aggraded, the Kosi had naturally shifted its course. In the preceding 220 years the river had oscillated over a stretch of 115 kilometres. In 1959 this natural process was interrupted when the river was jacketed between two embankments following an agreement between the governments of Nepal and India that had taken place in 1954.

Following completion of the Kosi barrage in 1964 the river gradient changed and sediment deposition in the river section upstream of the barrage increased rapidly. Over time, this raised the bed level of the river above the surrounding land, a factor that contributed to the breach of August 18, 2008. When that occurred, the main river discharge began flowing along a course that had been blocked by the eastern embankment. Instead of permanently protecting the surrounding area from floods, the embankments had changed the morphology of the river, raising the jacketed channel above the level of the surrounding land. This is one of several factors that led to the breach. Other factors included poor maintenance and institutional corruption and dysfunction in the aftermath of Nepal-India treaty on the river. The resulting flood caused widespread inundation and concomitant adverse effects on the social and economic systems dependent on the river.

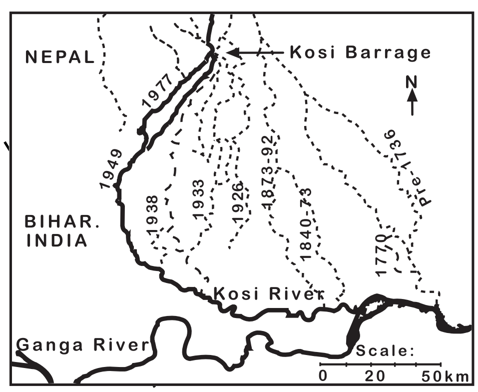
Once the embankments were completed in 1959, the area to the east of the river was largely protected from major flooding and in the subsequent four decades roads, irrigation channels, railways and other features were constructed. These developments blocked the natural drainage and divided the region into a series of enclosed basins. When the Kosi embankment breached, the waters no longer flowed in one or a few clearly-defined channels, but instead spread out across a width 30-40 km seeking the path of least resistance and filling the enclosed basins, low lying lands and ponds. As this piece is being written, somewhere in that vast flooded area low points are being scoured and transformed into new main channels for the river, and sand and sediment are being deposited across fields and in irrigation channels, drainage ditches and other structures. In addition, approximately 50,000 people in Nepal and more than three million in India have been displaced and lives have been lost.

FIGURE 3 | **Flood inundation map of part of North Bihar state and part of Nepal Tarai, satellite image of September 3, 2008**

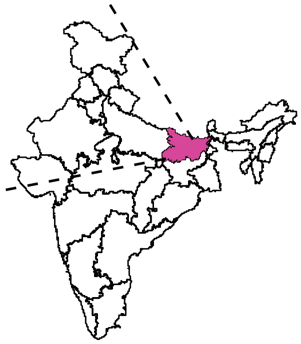



Adapted from: NRSA, Dept. of Space, Govt. of India
(Based on the analysis of Radarsat-2 data of September 3, 2008)

FIGURE 4 | **Changes in the course of the Kosi, 1700 - 2000**




Source: Gole and Chitale, 1966



Breaches are an inherent risk of any flood-control embankment but even more so in a river such as the Kosi where the riverbed aggrades rapidly because of the high sediment load. Topographic maps indicate that the river bed within the embankment is now about four meters higher than the adjoining land: in other words the elevation of the bed has increased approximately 1 meter per decade since the embankments were put in place. The August breach was the eighth major one since the embankment was constructed. No matter how well embankments are maintained, whether the breach occurs during a high flow or, as in this case, a normal one, breaches are inevitable. Furthermore, when such breaches occur it is next to impossible to permanently return the river to a bed that is, in many cases, well above the adjacent land without substantial input of resources and technology.

An embankment can provide relatively high levels of flood protection immediately following construction but its ability to protect declines at rates that depend primarily on sedimentation and, to a lesser extent, on how well it is constructed and maintained. Unless some way of addressing the massive amount of sediment deposition can be found, the river channel will breach and new channels will be established across lands that have been settled for decades.

What are the costs and benefits of an embankment? In the Kosi case, a large section of land in East Bihar was protected from recurrent flooding for about 50 years. The associated balance of benefits and costs is debatable. Protection has encouraged forms of development that are poorly adapted to flooding. Furthermore, as illustrated in the Eastern Uttar Pradesh and Nepal flood case studies (see From Risk to Resilience Working Papers Nos. 4 and 7), while flood protection does generate clear benefits, it also entails major costs. In the Eastern Uttar Pradesh case study, the costs associated with land loss, poor drainage and water logging coupled brought the benefit/cost ratio close to 1 suggesting that the economics of investment in embankments is highly questionable: And this reservation does not even consider the potential for breaches.

What are the costs of this breach? The true costs may never be known. The most evident costs include the loss of land, assets and livelihoods. They also include losses associated with current and future agricultural production and in local ecosystems. In addition, the social cost associated with disruption of over three million people in one of the most politically unstable areas of India must be recognized. Some families may never be able to live on their land now that it has been submerged by the Kosi. Bihar is one of the poorest and least developed regions of India and is a focal point for insurgent activities. The loss of lives, livelihoods and, in many ways, hope for the future among its population may well exacerbate existing frustration and conflict, generating costs that spread across much of South Asian society, not just India. A systematic cost-benefit analysis that includes the potential for massive disruptions such as the one of August 2008 might assist in identifying strategies with lower levels of inherent risk.

| FIGURE 5 | **August 18, 2008 Kosi embankment breach site at Paschim Kusaha, Nepal**

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| TABLE 1 | Benefits and costs of interventions in the Lai Basin

| Strategy/ Intervention | Net Present Value of Investment (PKR mill.) | Benefit Cost Ratio |
|---|---|---|
| Expressway/channel | 24,800 | 1.88 |
| JICA options (both) | 3,593 | 9.25 |
| - Community pond | 2,234 | 8.55 |
| - River improvement | 1,359 | 25.00 |
| Early warning | 412 | 0.96 |
| Relocation/restoration | 15,321 | 1.34 |

Project's duration = 30 years
Social discount rate = 12%

detail along with other aspects of the case study in Risk to Resilience Working Paper No. 7. Table 1 gives the range of interventions considered and their respective benefit/cost ratios.

The options listed in this table reflect a cross-section of "realistic" interventions that have either been implemented or are actively under discussion in the area. The early warning system was implemented following a major flood in 2001 that took 74 lives and caused damages of over 1 billion USD. In response to this flood, JICA (the Japanese International Cooperation Agency) identified three options for reducing flood risks, specifically developing a large community pond as a buffering reservoir, improving (widening) the river in key bottleneck points and the early warning system that was later implemented with their assistance. The urban expressway option is one that was promoted by elements in the government in 2008. It essentially involved canalizing the river and using the corridor as an avenue for road construction to ease urban traffic congestion. Relocation and restoration of the river is the main avenue for reducing flood risks that has been identified by environmentalists. This would involve removing illegal settlements, controlling sewage and other waste disposal and creating an urban park that could also serve a flood control function.

| FIGURE 6 | Map of Lai Basin, Rawalpindi


Interestingly, although heavily advocated by the environmental community (members of which dominated the case study team), when the river restoration option was evaluated, it was found to have by far the highest up front capital costs and the lowest benefit/cost ratios. This is due to the very high cost of relocating existing settlements (always an issue in urban areas) and the need to control waste and sewage. Equally interestingly, the early warning system, the only option actually implemented, also had a low benefit/cost ratios relative to some of the other options. This is due to two factors – the high cost "overbuilt" nature of the system and the limited (15 minute) advance warning it is able to produce given the short nature of the stream. This short advance warning makes the early warning system valuable in relation to lives saved but does not give sufficient time to save assets. Projections suggest that the cost of the early warning system works out to 3 million Pakistani rupees ($44,000) per life saved. Since no attempt was made to value lives, this was not included in the cost-benefit analysis. It does, however, represent an appropriate metric for comparison to investments in other arenas, such as public health, where the cost of saving lives is relatively well documented.

Unlike the other case studies, substantial data were available for the Lai case. This was possible in large part because of the detailed work done in advance by JICA and by the large amounts of secondary data available through government agencies. It was also due to the high capacity of NGOs working with poor populations in the urban area which permitted much more extensive surveys and enabled greater use of external capacities for modelling and remote data collection. Despite this, however, it was not possible to accurately evaluate some hazard vectors or response options identified by local communities. In specific:

1. Although extensive work was done to downscale results from global climate models and produce future rainfall estimates for the Eastern Uttar Pradesh case that could, in theory, be used as inputs to rainfall-runoff models at the basin level for estimating changes in flood hazards under climate change, this proved to be impossible in the Lai Basin. Existing rainfall data showed essentially no correlation with flood flows in the basin. As a result, there was no basis for projecting future changes in flooding based on projected changes in rainfall.

2. Women in the basin identified dispersal of solid waste and sewage into residential areas along with the diseases this causes as the main concern associated with flooding. The Lai flood plain is a major site for the dumping of solid waste and many sewers also drain into it. The perspective of women contrasts distinctly with the focus of the government and most men on the physical damages associated with flooding. Unfortunately, due to lack of information on increases in disease and how this might change with control over waste disposal, it was not possible to evaluate the costs and benefits of improved solid waste and sewage management.

Overall, the Lai basin study highlights the economic efficiency of most risk reduction projects in urban areas and the critical role a systematic cost-benefit analysis can play in their evaluation. Although it proved impossible to generate direct estimates of flood changes that are likely to occur as a consequence of climate change, these are expected to increase and, as a result, the economic efficiency of all proposed measures to reduce such risks should as well.

The CBA process made it possible to compare similar approaches for cost effectiveness and gave a sense of proportion to softer approaches for risk reduction that tend to focus more on people rather than the hazard. The process also highlighted the shortcomings of CBA as a tool for assessing people-centered strategies to build resilience. Such strategies are often difficult to evaluate because many of the benefits are non-monetary or difficult to quantify. Furthermore, since CBA does not address the distributional aspects of different interventions, the impacts of flooding and the degree to which interventions addressed these for different groups were not incorporated in our analysis. If one were to incorporate resilience building and the implications for specific vulnerable groups, rather than just the impacts on assets and other financial goods, then the CBA would yield even better results. Qualitative techniques are essential in order to evaluate these types of implications and, as a result, it is extremely important to use more such qualitative tools in conjunction with the cost-benefit analysis.

The case of the Lai also illustrates the substantial impact data availability and accessibility has on the ability to evaluate the costs and benefits of different options. Finally, the Lai case highlights the fact that in some cases lower cost approaches can generate the same benefits as higher cost approaches and as a result have substantially better benefit/cost ratios – in this case, simple channel improvements would generate much the same benefits as major structural measures at a fraction of the cost. Similarly, some low cost interventions (the early warning example) can have very low return rates and may have a relatively high cost in relation to non-market objectives such as lives saved.



FIGURE 7 | Rohini and Bagmati Basins location map


## Eastern Uttar Pradesh, India

The Eastern Uttar Pradesh case studies (documented in more detail in Risk to Resilience Working Paper Nos. 4 & 5) focus on measures to respond to both floods and droughts. The locations for these cases are indicated in the map below. In contrast to the analysis in Nepal, both cases in Eastern Uttar Pradesh involved detailed quantitative analyses of the costs and benefits for different response measures and the implications of various climate change scenarios. Qualitative analysis was conducted to complement the results of quantitative analysis. In both cases, despite extensive data collection to support quantitative modelling, major uncertainties in data and driving assumptions mean that the results of cost-benefit analyses are themselves quite uncertain. Final outputs must therefore be viewed as order of magnitude indicators, especially when climate change projections are considered. This said, however, the analytical process involved in conducting the quantitative CBA highlighted an array of costs and benefits along with their relative magnitudes that would not have been identified in less systematic approaches to evaluation of risk management strategies. As a result, the process itself, rather than the final quantitative outputs, should be seen as having major advantages in support of informed decision-making.

### Flood Risk Reduction

As in the Nepal case, analyses of flood mitigation strategies in Eastern Uttar Pradesh contrasted a diverse package of "people-centered" resilience-driven interventions with the conventional embankment focused infrastructure strategy that has characterized government initiatives over recent history. The "people-centered" approach involved actions at the household level (raising of house plinths, raising of fodder storage units, and a water and sanitation package), actions at the community level (an early warning system, raising community handpumps and toilets, building of village flood shelters, development of community grain banks, development of community seed banks, local maintenance of key drainage points, development of self help groups, and purchasing of community boats) and societal level interventions (promotion of flood adapted agriculture and strengthening of the overall health care system). These types of local level "people-centered" interventions tend to involve low up-front capital costs and generate returns for the types of low magnitude, high frequency flood events that characterize life in the Ganga Basin as well as the larger events that cause "disaster." These characteristics, as discussed further below, make returns far more resilient than for courses of action that involve high levels of investment and are designed to respond to the less frequent extreme events that cause "disaster."

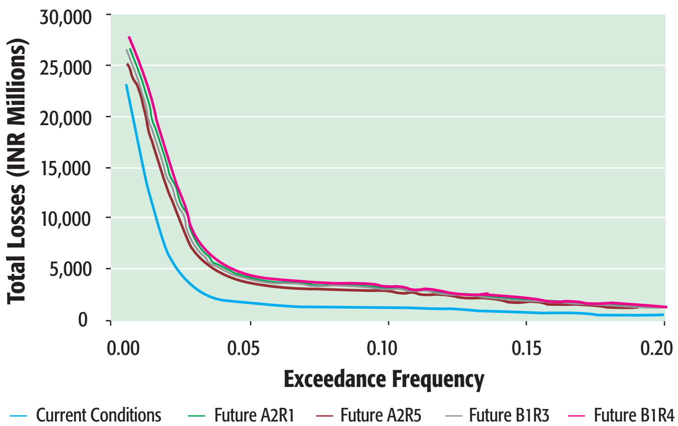
Results of the analyses showed a sharp contrast between the effectiveness of these different approaches. As detailed reports from these studies conclude:

"Historical analysis of embankments following a strict engineering cost-benefit analysis shows a high benefit/cost ratio, indicating economically efficient performance. However, incorporating conservative estimates of negative effects, more realistic costs, and actual structural performance, the ratio reduces substantially. Given the many involved uncertainties, it cannot be concluded that embankments have historically had an economically satisfactory performance. Future analysis of proper embankment maintenance indicates that under all climate change projections, it is economically efficient to maintain existing embankments. Projected climate changes will however reduce embankments' economic performance.

The benefit/cost ratio for the people-centered strategy indicates economic efficiency for all climate change scenarios. Moreover, the results are less dependent on the discount rate because benefits are greater than costs every year, even accruing in non-flood years. In contrast to embankments, the economic efficiency of the people-centered strategy does not reduce due to projected climate change impacts. The resilience-driven approach of the strategy means increased flood risk does not reduce benefits, whereas the threshold-driven embankments depend upon certain design floods to optimize benefits."

The analysis on which the above conclusions were based involved the use of innovative statistical techniques to downscale results from the Canadian Third Generation Coupled Climate Model (CGCM3). Scenarios analyzed (the A2 and B1 scenarios) assume respectively continued growth in carbon emissions levels (A2) and stabilization at around 550 ppm (B1). Outputs from downscaling were coupled with rainfall-runoff and hydraulic river modelling to produce flooded area estimates with and without embankments for use in loss estimation. Based on this, modelled changes in flooded areas for the climate change scenarios were used to adapt the current condition loss-frequency curves developed during the backwards-looking

| FIGURE 8 | Flood loss-frequency curves for current conditions and future climate scenarios (2007-2050) Eastern Uttar Pradesh



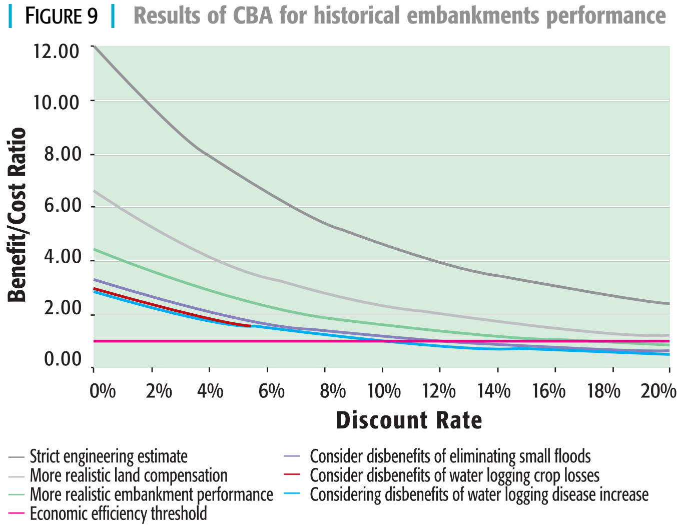

analysis to projected future climate conditions. Figure 8 shows the results, representing best estimates of current and future financial flood risk. It can be seen that climate change is projected to have a greater impact on frequent smaller events than rarer but larger events. In other words, while what is now a 10-year loss will in the future be about a 5-year event, while a current 100-year loss will in the future be about a 60-year loss.

Results from the modelling indicate that losses from smaller but more frequent events will increase greatly as climate change proceeds. As this occurs, the annual average loss burden will increase to the point where such "small" floods become more important than larger extreme events in terms of long-term economic impacts. Available loss data are, however, for the large floods that occurred in 1998 and 2007. The lack of real data on losses for smaller events represents a major limitation on the analysis of risk reduction measures. Estimates of small event losses based on statistical distributions could over- or under-estimate reality, greatly affecting the final results.

The above caveats aside, results of the cost-benefit analysis indicate fundamental differences in the performance of structural measures and the more "people-centered" package of interventions.

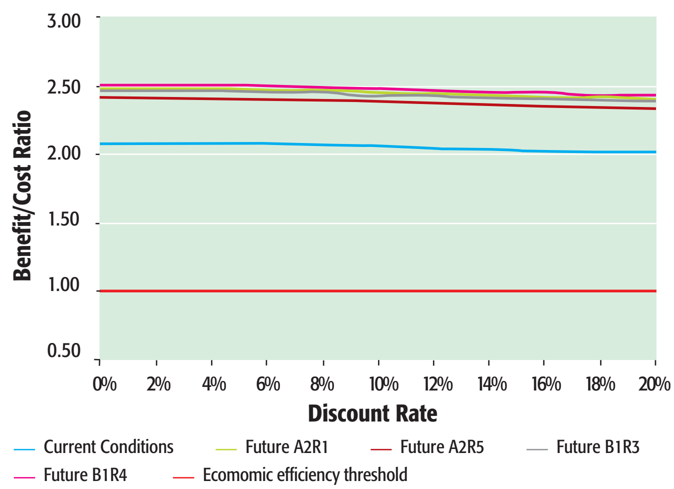
As Figure 9 indicates, while strict engineering analysis of structural measures suggests that structural measures would have a positive benefit/cost ratio of about 4.6, more realistic inclusion of externalities or the "disbenefits" that are often ignored in economic analyses makes the economic efficiency of investing in such structures highly questionable. Furthermore, because of the high up front capital cost of such investments, returns depend heavily on the choice of discount rates. Although this is not shown in the figure, when climate change is considered the economic efficiency of even maintaining existing embankments declines. This said, the benefit/cost ratios for maintenance does remain above 1 suggesting that maintenance of existing structures is economically efficient.

| FIGURE 9 | Results of CBA for historical embankments performance




In contrast to the embankments, the returns from a distributed array of "people-centered" risk reduction interventions deliver returns that are resilient under different climate change scenarios and relatively insensitive to discount rates. This is because although annual costs may be high, annual benefits are still always greater, such that the weight given to current versus future years is less important. Considering that the only non-flood related benefits explicitly considered were those resulting from adapted agricultural practices, it must be assumed that the true economic efficiency of the strategy, when considering other direct and indirect benefits, may well be higher than what is shown in Figure 10.

| FIGURE 10 | Results of CBA for people-centered flood risk reduction




People-centered resilience-based flood risk reduction approaches tend to provide benefits (many not even captured in this study) that occur every year, regardless of if a flood occurs or not. As costs are also primarily annual (as opposed to one-time initial), it is safe to say that if annual benefits are greater than costs, then the project is “worth it.” This holds true also for embankments, but such threshold-driven benefits are probabilistic (they may or may not be realized in any given year), while resilience-based approaches tend to yield at least some benefits every year.

Resilience-based approaches therefore reduce some of the cost-benefit uncertainty, or at least the dependence of the strategy’s performance on known risk, because they do not depend on certain events happening to be beneficial. This further manifests itself also in light of projected climate change: the people-centered approach continues to perform well even though flood risk increases, while embankments lose efficiency with increased flood risk.

Results of the analyses of flood mitigation options as part of a response to climate change have major policy implications. In specific, they suggest that *investments to reduce the impact of lower-magnitude but frequent events are likely to generate far more assured returns than investments in large infrastructure where up-front costs are high and returns depend on both discount rates and unknown future event probabilities.* As previously noted, however, this does not necessarily imply that investments should be directed away from the lower frequency-higher magnitude disasters that can set individuals, households and regions back for many years. Instead, it implies the need for a balanced approach that combines sustained attention to the small disasters that receive little public or policy attention as well as the large-scale, high-profile, impact of extreme events.

Although the above results appear to be robust under a variety of assumptions, the limitations of the current cost-benefit analysis are important to recognize. In specific, the types of data required to estimate the costs and benefits of different approaches are often not available, particularly for low magnitude events that don’t really qualify as “disasters” and, as a result, numerous assumptions must be made.

## Drought Risk Reduction

In addition to floods, the Uttar Pradesh case study site is highly vulnerable to drought. Unlike floods, however, the primary risk from drought relates to agricultural production in the rice-wheat system on which most rural livelihoods in the Ganga Basin are based. As a result, as opposed to the much wider set of interventions considered in the flood case, the Uttar Pradesh drought analysis focused on two strategies for reducing agricultural drought losses: irrigation and subsidized insurance schemes. The CBA approach is summarized in Table 2.

In order to systematically assess the costs and benefits of risk management using insurance and irrigation, we developed a risk-analytic modelling approach. This approach is discussed in detail in Risk to Resilience Working Paper No. 5. The following steps in line with the general methodology are taken in the model (Figure 11).

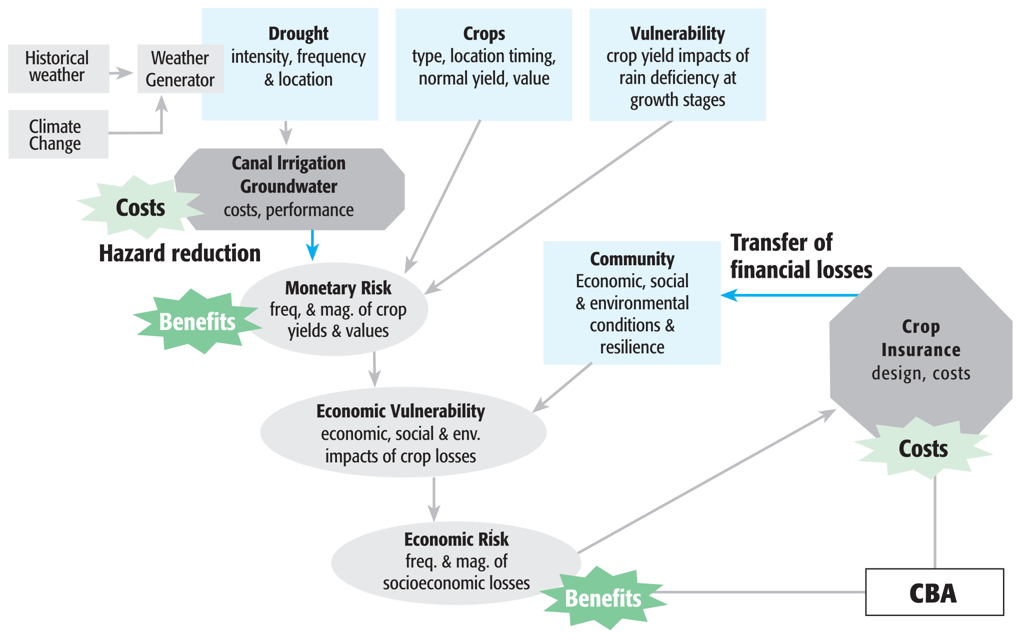
1. Assessing direct physical and monetary risk
2. Assessing economic risk to farmers' livelihoods
3. Studying the costs of risk management interventions
4. Benefits of interventions
5. Finally, the economic efficiency of options is calculated by comparing costs and benefits.

The model is stochastic in nature making use of Monte-Carlo simulation (randomized simulation of an underlying statistical distribution) to generate probabilistic drought shocks to farmers.

TABLE 2 | Key characteristics of the Uttar Pradesh drought CBA

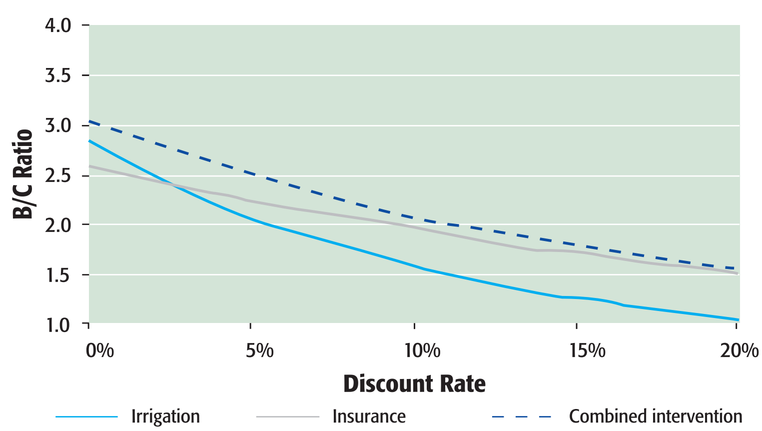
| | |
|---|---|
| Risks assessed | Drought risk affecting small-scale farmers in Uttar Pradesh in terms of rice and wheat production and related income |
| Type of CBA | Pre-project appraisal or project appraisal for detailed evaluation of accepting, modifying or rejecting project |
| Methodology | Forward looking, risk based methodology |
| Focus and options of analysis | Costs and benefits of donor DRM support for helping farmers better deal with drought risk to rice and wheat crops and subsequent income effects. Options considered<br>1. Irrigation: Implementation of a borehole for groundwater pumping, pumping to be paid by household<br>2. Subsidized micro crop insurance |
| Benefits | Reduction in variability of income due to DRM |
| Unit of analysis | Representative farmer household of 7 comprising 80% of the survey sample with income/person of up to 6,570 INR and median income of 4,380 INR (national poverty line in 2008: 4,433 INR). |
| Resource and time commitment for the analysis | Large due to statistical analysis, stochastic modelling, and explicit modelling of the household income generation process |
| Key findings | • All options seem economically efficient<br>• Irrigation benefits increase with climate change as rainfall means increased<br>• Insurance benefits reduced, as volatility becomes less important with climate change<br>• Integrated package delivers similar benefits at lower costs<br>• For harnessing the benefits of integrated packages, cross-sectoral cooperation between different public and private actors is essential. |

| FIGURE 11 | Model algorithm



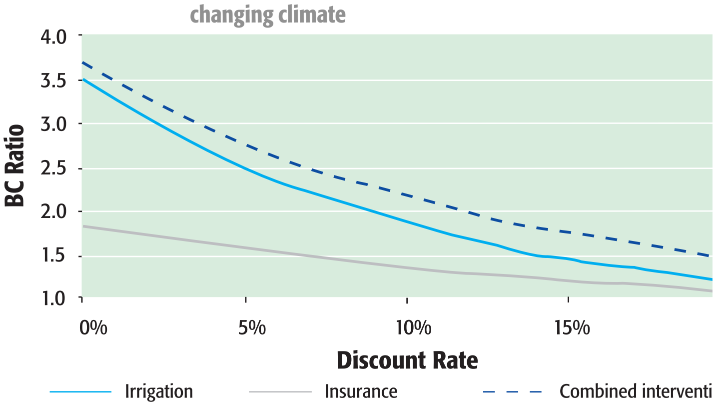

Monetary risk due to drought is modelled as a function of the hazard, the vulnerability and the exposure. Hazard is defined as the lack of rainfall over given time periods, vulnerability is determined through a statistical model which relates total rainfall amount over specific dates with average crop yields in tons per hectare, and exposure is determined through the average area over different households consumptions groups and different prices of crops due to drought events. Economic risk is income risk due to drought as amplified or mediated by the financial vulnerability of the household. Important changes in the future are explicitly modelled. Climate changes are incorporated via statistical downscaling for different climate change scenarios as well as different models. Also, changes in the variance of total rainfall over given time periods is explicitly modelled with the help of ensemble runs. This assists with estimating the uncertainty of climate related changes within this integrated modelling approach. In general, the uncertainties of this integrated modelling approach are substantial and need to be recognized when interpreting the quantitative results.

| FIGURE 12 | B/C ratios for interventions considered given a constant climate




Based on the above modelling approach, the main benefits generated by the disaster risk management interventions that were identified involve reduction in average losses and the variability of income. The detailed quantitative results indicate that investment in both insurance and irrigation are economically efficient and generate real benefits. As the Figure 12 indicates, benefit/cost ratios are positive and robust under different discount rate assumptions. These strategies address different portions of the drought risk. As a result, rather than representing alternatives they should be seen as complementing each other. This said, analytical results indicate that the efficiency of insurance-based strategies is likely to decline as chronic variability increases with climate change while the efficiency of irrigation is likely to increase. The detailed quantitative results indicate that investment in both insurance and irrigation are economically efficient and generate real benefits under constant and changing climates.

| FIGURE 13 | **B/C ratios for interventions considered given a changing climate**




As key findings of the CBA, we find the options and the integrated package economically efficient. Insurance seems less dependent on discount rate assumptions, which can be explained that it offers a *secure*, guaranteed payout, while irrigation and its benefits are dependent on the ex-post ability of the household to pay for pumping water. As the household is generally constrained in its financial ability, multiple events over the study period lead to accumulation of debt over time and inability to pursue pumping efforts in later periods (which are more heavily discounted than the present). With a changing climate, irrigation benefits are increasing as average rainfall and rainfall variability increases, while insurance benefits are reduced, as volatility is reduced. Again, a combined package, where the insurance contract is linked to the irrigation option and adapted to changing condition would reap highest benefits. Finally, integrated physical (irrigation) and financial (insurance) packages return higher benefits at similar costs, as interventions for higher (irrigation) and lower frequency events (insurance) are combined. As a consequence, it seems highly important to foster the exploration of such integrated packages in a process involving different public and private actors.

Results of the Uttar Pradesh drought CBA have important implications for both policy and the use of CBA in the identification of effective strategies for responding to drought and the impacts of climate change.

Where policy is concerned, the results highlight the complementary nature of institutional (insurance) and physical (groundwater) interventions. They also illustrate the potential limitations of risk spreading techniques such as insurance as opposed to risk reduction strategies as climate change proceeds. Risk spreading is most effective for larger magnitude lower frequency events where probabilities can be determined. It is less effective as a response to chronic variability of the type that many analyses suggest may increase as climate change proceeds.

As in the flood analysis, where the use of cost-benefit analysis is concerned, data limitations inherent in the drought case necessitated numerous assumptions and simplifications. Consequently, the resulting benefit/cost ratios themselves can only be viewed as indicative. The process and understanding of interactions and directions of change are, in many ways more important than the final numbers generated.

# The Use and Abuse of CBA

The case studies presented above illustrate both the importance of correctly evaluating the costs and benefits of different strategies for disaster risk reduction and the inherent limitations of existing methodologies for doing so. In many ways, CBA represents more an organizing framework and process for understanding tradeoffs than a fully "scientific" method for evaluating the economic returns from a specific investment. Benefit/cost ratios produced even through a comprehensive analysis depend heavily on the array of factors considered, the types and accuracy of available data and the assumptions incorporated in the analysis. Furthermore, unless CBA is done in a transparent manner, the results can easily be manipulated to produce any outcome the analyst desires. As a result, benefit/cost ratios are meaningless and subject to misinterpretation in the absence of full understanding of the factors on which they are based.

At present, most CBAs are generally done on a one-off basis using approaches and frameworks that are tailored to specific local contexts. Although a number of guidelines exist, such as Handmer and Thompson (1997) and FEMA (2001) for guidance on CBA for DRM, and the ILPES Manual for assessing the economic impacts of disasters (Navarro, 2005), neither the manuals nor results in the literature are fully consistent. As a result, in the DRR case there are no fully accepted and institutionalized methods for determining what is a cost, what is a benefit or how to discount the future. Furthermore, while many economists might agree on the value of a statistical life or where and how discounting should be applied, such calculations are often quite contentious in public policy and stakeholder environments. Values differ among groups and this variation is often difficult to show transparently in existing CBA frameworks. Furthermore, as conventionally structured, CBA is intended to determine the overall returns to society of a given intervention, not how the costs and benefits are distributed. Distributional issues are, however, of central importance in many contexts and particularly where risk reduction interventions are justified on the basis of their implications for poverty alleviation or the needs of specific vulnerable communities.

The above issues and their implications for the use of CBA are explored in more detail below. The methodology can provide key insights but the inherent limitations and subjective nature of many components are essential to understand.

## Data Dependence

Accurate estimation of the costs and benefits of disaster risk reduction in any context depends heavily on data availability and the ability to project returns over the lifetime of any given intervention. Two key elements are central to this. The first concerns the availability of basic data on costs of a project or intervention and the specific benefits it is likely to generate. The second concerns that ability to project future event frequencies. Both issues are particularly severe in developing country regions where existing data tend to be limited or difficult to access and additional data are expensive to collect.

In most situations, the costs of projects to reduce disaster risk are relatively easy to document with the important exception of any negative consequences ("disbenefits" or "externalities") it may generate. Issues related to negative consequences are discussed separately below – but it is important to recognize that even the relatively easily documented "costs" can be far from clear. In project evaluation, for example, governments often count the "cost" of land or other requirements at the rate they offer to displaced people when they exercise the principle of eminent domain rather than at current market rates. As illustrated in the flood case from Uttar Pradesh, the difference can be huge and can fundamentally alter the results of the evaluation. Similar issues relate to many cost elements. The issues are, however, far more severe in relation to benefits.

The benefits from investing in disaster risk reduction consist, in essence, of avoided costs. Avoided costs are the costs that would have occurred due to disasters in the absence of any investments in risk reduction. Actual data on the costs of disasters are, of course, only available for historical events. In many cases, these data consist only of what governments or insurance agencies actually paid out in compensation, not the real losses. Estimating the real losses, even from historical events, can require a variety of information on which data are generally not collected. In the case of floods, for example, important losses occur when people are unable to work either because of the flood itself or due to the increase in illness that generally accompanies flooding. Data documenting the number of days people were unable to work due to floods and the illnesses associated with them are, in most situations, not available and it is even more difficult to accurately determine the degree to which a specific risk reduction interventions would reduce such losses. Furthermore, conceptually it would be correct to assess the income and livelihood consequences (indirect risks) versus the loss of assets and structure (direct risks) of disasters. For example, a loss of 10,000 INR has very different implications for a poor labourer than for a large-scale farmer. Such as loss could, for example, cause severe follow-on consequences such as malnutrition and deprivation for the labourer, whereas the farmer would just be able to absorb this financial loss. Normally, the indirect risks cannot be easily assessed, as this involves conducting surveys and statistical and economic analyses, so analysts (also in this study) resort to the direct effects, which often in a development context actually understate the "real" impacts.

This type of data issue is an inherent problem in relation to most of the benefits from risk reduction. In the Pakistan case covering the Lai basin, lack of such data essentially eliminated the ability to estimate costs and benefits from the main risk reduction intervention identified by women in the affected communities.

The issue of data governing event probabilities is particularly challenging in the case of all climate related events. In many contexts, historical data regarding basic hydrologic parameters (rainfall, stream flows, flooded areas, etc.) are extremely limited or have restricted access in the interests of national security. Such historical data are, however, required in order to translate the results from GCM downscaling into future flood or drought event probabilities. When limited historical data are coupled with the inherent uncertainties in data generated through downscaling techniques, projections regarding the probability of future events are highly uncertain. This issue is of fundamental importance for everything from the structure of insurance programmes to the design of physical infrastructure. Insurance programmes that are designed, for example, to pay out once every twenty-five years will not be financially viable if similar magnitude payments must be made more frequently. Similarly, structures that are designed to withstand floods occurring every hundred years will fail if larger floods occur.

## Assumptions

In most cases, the limited availability of basic data force analysts to rely heavily on assumptions in order to estimate the costs and benefits of different interventions. This is an arena where expert judgment is essential. It is also an arena where a lack of transparency can seriously compromise the legitimacy of CBA results. As illustrated in the flood case from India above, relatively minor seeming differences in assumptions can often alter cost-benefit estimates in fundamental ways (see also Risk to Resilience Working Paper No. 4). This is clearly illustrated by the impact on benefit/cost ratios estimated in the India case depending on the value of land assumed and the average width of the area affected by drainage problems behind embankments. It is also clearly illustrated by assumptions regarding the extent of assets that would be moved out of harm's way using the fifteen minute warning provided by the early warning system along the Lai Basin in Pakistan.

Academic journals rely on peer review processes to validate both the assumptions and data on which analyses of all types are based. In the CBA case, a framework that would enable stakeholders to see key assumptions and test their impact on the benefit/cost ratios generated would serve a similar purpose. At present, however, information on the assumptions being made tends to be buried in the technical analyses.

## Negative Consequences

The negative consequences ("externalities" or "disbenefits") associated with investments are often ignored in cost-benefit analyses. These often relate to environmental or other values that are difficult to identify and even more difficult to quantify. The Nepal case illustrates a clear mechanism for identifying the negative consequences of different investments and who they affect. Quantifying the negative consequences associated with risk reduction strategies can have a fundamental impact on the overall social cost-benefit assessment and, even where the activity still generates positive returns, may indicate the need for compensation of affected groups or areas. In the Uttar Pradesh flood case, for example, the negative consequences of embankments include: (1) loss of substantial agricultural land areas; (2) loss of the soil moisture and fertility benefits from small floods; (3) actual embankment performance that is substantially below design criteria; (4) losses in crop production due to water logging behind embankments; and (5) increases in disease vectors (Risk to Resilience Working Paper No. 5). Taken together these negative consequences shift the benefit/cost ratios calculated for embankments from above 4 for a purely engineering analysis to 1 or below at a 10% discount rate. That is to say, consideration of such elements changes the evaluation of the project from one with very high social rates of return to one where it is unlikely that the benefits substantially exceed the cost.

Overall, where interventions to address disaster risks have negative consequences, inclusion of them in the analysis is essential in order to identify real return rates. Interventions that do not have such negative consequences are likely to have far more robust returns.

## Discount Rates

As with any investment intended to generate benefits over an extended time period, the choice of discount rate has a major impact on the present value of an investment. This is particularly true where upfront investment costs are large and the costs avoided depend heavily on large magnitude but low frequency events rather than benefits that accrue each year. In this case, the choice of discount rates can heavily affect the economic efficiency of investments. In contrast, where benefits accrue from high-frequency, even if lower magnitude, events return rates tend to be more economically robust under different discount rate assumptions. Both of these issues are clearly illustrated in the contrasting returns for flood risk mitigation using embankments versus more distributed measures in the case from Eastern Uttar Pradesh.

Questions regarding the choice of discount rates are often socially sensitive since they inherently raise ethical questions regarding the tradeoff between current benefits (which benefit current populations) and future benefits (which may benefit future generations) and are a key area where transparency in the analysis is required.

## Distributional Questions

Conventional cost-benefit analysis is concerned primarily with the overall economic returns to society and not with their distribution. In situations such as the case areas where poverty is a major concern and justification for any intervention, distributional issues are of central importance. In many cases, the benefits from investments in risk reduction accrue to dominant sections of society and not to women, children, the poor or other socially excluded groups.

This issue is particularly evident in the examples of major infrastructure projects above but is likely to also be a concern for other interventions. In the case of embankments in Nepal and Uttar Pradesh, the largest beneficiaries tend to be wealthy individuals living in towns while the most vulnerable groups who live either between the river and embankment or just outside embankments or in locations where flow is concentrated tend to bear many of the negative consequences. Even with distributed forms of risk reduction, however, the most vulnerable groups are often the least likely to benefit. This is, however, not always the case. Interventions such as fodder and food banks through self-help groups that were identified in the Uttar Pradesh study are of particular benefit to the poor and can also have extremely high benefit/cost ratios.

Identifying opportunities for targeting benefits toward vulnerable groups highlights the importance of linking the CBA process with vulnerability analysis of the type discussed in Risk to Resilience Working Paper No. 2. The process of conducting the analysis conveys more "real" insights on the viability and desirability of DRR rather than the ultimate numbers estimated. While traditional cost-benefit techniques do not consider distributional issues, when used as part of a process in conjunction with the qualitative techniques described in the Nepal case key insights on distributional issues can be generated.

## Lack of Transparency

All of the above issues point toward the importance of transparency. In complex topic areas such as disaster risk reduction and climate change, the validity and accuracy of cost-benefit types of analyses depend heavily on a very wide range of factors that include data availability and quality, assumptions and model design. In most analyses, these factors are buried in the technical details of the analysis. As a result, decision-makers and other users of the results have little understanding regarding the numerous – and often heavily debatable – factors that determine the final numbers generated. The risks of this are clearly illustrated in the case of embankments in Uttar Pradesh where an economic analysis that draws on official figures and engineering standards alone would inaccurately suggest a high social return.

As a result, unless analytical frameworks and the processes used to collect data and make assumptions are transparent, the real meaning of any cost-benefit analysis are uncertain and the technique is heavily vulnerable to abuse when used to generate criteria for decision-making.

# Conclusions

The case studies on which this report is based clearly demonstrate that disaster risk reduction pays and can make a substantive contribution towards adapting to the impacts of climate change. This further confirms the results of numerous other studies on the costs and benefits of disaster risk reduction. *At the same time, however, the case studies also clearly demonstrate that not all forms of disaster risk reduction are good investments.* They also demonstrate that attention needs to be given to the manner in which cost-benefit analyses are framed and conducted. Unless correctly framed and conducted in a transparent and highly participatory manner, the results from CBA can be highly misleading.

Results of the qualitative and quantitative analyses and experience in the region combined with climatic projections indicating variability will increase suggest that much more attention needs to be paid to the consequences of inter-and intra-annual variability and strategies for reducing the risks related to it. At present, most attention is paid to high profile "extreme events" that generate large disasters. While responding to such events is important, recurrent smaller events have the potential to generate large aggregate economic impacts and may be of particular importance to the ability of populations to move out of poverty and adapt to climate change. As a result, low unit cost distributed approaches to risk reduction that respond to recurrent events may often be more economically and socially effective than large investments in embankments and major flood control measures which are targeted toward lower frequency but higher magnitude events. Results from the current project are insufficient to demonstrate this conclusively but do point toward areas where additional research could provide critical guidance to policy-making.

An additional critical area for evaluation is on the costs and benefits of integrated approaches where a mix of financial, small-scale distributed and carefully targeted larger scale interventions for risk sharing and risk reduction could generate substantially more benefits than any single approach could on its own. This is illustrated in the Uttar Pradesh drought case.

The case studies also illustrate the critical dependence of CBA on process and methods if it is to have any real relevance as a decision support tool. In some cases the results from CBA are not sensitive to assumptions concerning data or discount rates, in others the level of sensitivity is high. In Uttar Pradesh, for example, the CBA clearly demonstrates that distributed interventions that deliver benefits annually and have a low initial cost are less sensitive to discount rates or climate change scenarios. In more complicated cases, if CBA is to be used as a major decision support tool it cannot be used in isolation from more qualitative and open processes of analysis. In addition, the transparency and consistency of the methods used need to be substantially increased. In specific:

1. Consistent sets of methods are required for different types of interventions. Without this it is difficult to compare benefit and cost estimates between different analyses. Frameworks can evolve and be improved but internally consistent approaches are essential.

2. Consistent and transparent frameworks are required for identifying and displaying externalities and incorporating these in the analysis. Unless externalities are considered and incorporated effectively, the ratio of costs to benefits is essentially meaningless.

3. Consistent and transparent frameworks for identifying key data and their source are essential. Unless the source and reliability of data for cost-benefit analysis are transparent, stakeholders have essentially no basis for evaluating the validity of the results or of coming to their own conclusions.

4. Consistent and transparent framework for identifying assumptions and the basis on which they are made are as essential as knowing the validity and source of data inputs. Because data are lacking in most, if not all contexts, the assumptions made within the analysis often have a fundamental impact on the results generated. As with data, unless the basis for assumptions is transparent, stakeholders have essentially no basis for evaluating the validity of the results.

5. Finally, consistent approaches to sensitivity analysis and for displaying their implications for the resulting benefit/cost ratios are essential. This is required to identify the factors that have the largest impact on whether or not investments in risk reduction deliver robust returns under the wide array of possible conditions likely to occur in the future.

For CBA to evolve from a “special purpose” technique for one-off evaluation of DRR projects into a major tool supporting the identification and evaluation of strategies for responding to disasters and reducing the impact of climate change substantial improvements in methodologies and the processes through which they are applied are essential.

# Bibliography

FEMA (2001). "Guidance on Cost-Benefit Analysis of Hazard Mitigation Projects." Draft report, revision 2.0. Washington, D.C.

Gunderson, L. H. and C. S. Holling, Eds. (2002). Panarchy: Understanding Transformations in Human and Natural Systems. Washington, D.C., Island Press.

Handmer, J. and P. Thompson (1997). 'Economic Assessment of Disaster Mitigation: A Summary Guide'. Resource and Environmental Studies 13. Canberra: Centre for Resource and Environmental Studies, Australian National University.

Holling, C. S., L. H. Gunderson, et al. (2002). Sustainabiliity and Panarchies. Panarchy: Understanding Transformations in Human and Natural Systems. L. H. Gunderson and C. S. Holling. Washington, D.C., Island Press: 63-102.

Hoyois, P. and D. Guha-Sapir (2004). Disasters caused by flood : Preliminary data for a 30 year assessment of their occurrence and human impact. Health and Flood Risk Workshop; A Strategic Assessment of Adaptation Processes and Policies, University of East Anglia, Norwich, International workshop organized by the Tyndall Centre for Climate Change Research.

IPCC (2007). Climate Change 2007: The Physical Science Basis, Summary for Policymakers. Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva, Intergovernmental Panel on Climate Change: 18.

ISDR (2005). Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters. World Conference on Disaster Reduction, Kobe, Hyogo, Japan, International Strategy for Disaster Reduction.

Moench, M. and A. Dixit, Eds. (2007). Working with the Winds of Change: Toward Strategies for Responding to the Risks Associated with Climate Change and other Hazards. Kathmandu, ISET, ISET-Nepal and the ProVention Consortium.

Navarro, H. (2005). Manual para la evaluacion de impacto de proyectos y programas de lucha contra la pobreza. Manuales. Santiago de Chile, Instituto Latinoamericano y del Caribe de Planificacion Economica y Social (ILPES): Area de Proyectos y programacion de inversiones: 85.

# Annex I: Nepal Case Qualitative Cost-benefit Table Example

**Transect III** | Assessment of costs and benefits identified during SLDs along Gaur Municipality – Bairgania Ring Embankment–Pipradi Sultan

| Interventions | Plusses & minuses | Details (Regional terminology) | Basis through which value could be established (local units) |
|---|---|---|---|
| **EMBANKMENT** | | | |
| **Ring embankment, length 26.5 kilometres** | | | |
| Initial cost of embankment | | IRS 1,885, 552,941 for 26.5 kilometres of ring embankment. | Total cost for 85 kilometres of embankment from Dheng near the Indo-Nepal border to Runni Saidpur, including the 26.5 kilometres, was IRS 60.48 crores (1975-77) |
| Land lost | - - - | Around 125 hectares (26.5 kilometres of land of width 40.4 metres width plus 6 metres additional space both inside and outside of the embankment) | IRS 10,887,677 as per 1973/74 values. (The values used are based on the compensation received by some villagers. IRS 3,000 per kattha of land was provided in 1973/74) |
| Land protected | + + + | 1,000 hectares | IRS 2,954,501,618 @ IRS 10,000 per kattha |
| Crop protected | + + | 400 hectares is protected within the ring embankment. | IRS 9,444,960 per annum |
| Crop losses | - - - | *Kharif* crop not possible in 3,500 hectares due to inundation caused by the ring embankment. | IRS 82,643,401 per annum |
| Houses protected | + + + | 5,000 households of Bairgania municipality & twelve villages | |
| Houses inundated at least four months of the year | - - - | 2,700 households | IRS 1,350,000. Each household spends around IRS 500 to repair their house after every monsoon. |
| Land under permanent water logging | - - - | 50 hectares | IRS 14,760,000. Priced at IRS 10,000 per kattha of land. |
| Increase in malarial incidences | - - | *Kalazar*, malaria and japanese encephalitis are frequently mentioned by the villagers during SLDs | Numbers not available |
| Increased human diseases during inundation/flooding | - - - | People drink flood waters. | Numbers not available |
| Mobility restricted due to inundation | - - | People from about 2,700 households are unable to travel during monsoon. | IRS 6,075,000 as lost wages. Priced at IRS 50 a day for 90 days of a year for 50% of the houses affected. |
| Use of embankments as roads | + + | All dirt roads connecting Bairgania bazaar to the villages in the southern part of the ring embankment are inundated during monsoon season. The only way is walking on the embankment. | Numbers not available |
| Houses on embankments (includes railway embankments) | + | About 600 houses. Counting done using Google Earth map. People have built their houses, though illegal. | IRS 600,000. Valued at IRS 10,000 per household. |
| Human lives lost | - - - | Marpa villagers mention that at least 2 to 4 people die annually due to floods in Marpa alone. The embankment directs flows towards this village. | Numbers not available |

| | | | |
|---|---|---|---|
| Cattle lost | - - - | Marpa villagers mention that at least one dozen cattle die due to floods created by embankments in Marpa. The embankment directs flows towards this village. | Numbers not available. |
| Agricultural productivity losses | - - | 900 hectares. Despite use of chemical fertilizers the productivity is about half of areas not protected by embankments. | IRS 5,312,790/year. Productivity losses are estimated at 20 kilogrammes per kattha compared to areas not protected by embankments. And price of paddy is 10 per kilogramme. |
| Cattle productivity losses | - | Cattle do not get enough fodder during inundation and they are further prone to diseases. | Numbers not available. |
| **ALTERNATIVE INTERVENTIONS** | | | |
| **Boat serving 300 households of Pipradi Sultan** | | | |
| Initial cost of boat | - | Cost includes the cost of wooden log , cost of transporting log to the village and the skilled labour required to build. One wooden boat lasts for around five years. There is one boat serving 300 households. | IRS 20,000 |
| Cost of operation, repair & maintenance | - | Requires no operation cost as every person in the household can row it. | IRS 1,000 for annual repair & maintenance |
| Increased mobility | + + + | Males from all 300 households are able to commute for daily labour without having to swim long distances. The boat is used for commuting required for marketing and also for medical treatments. | IRS 48,000. Mobility is valued as 80 trips per family for 3 months for all 300 households. |
| **Flexible bamboo bridge** | | | |
| Initial cost of bridge | - | Connects Mahadev Patti village in Rautahat to Bairgania ring embankment | NPR 5,000 |
| Increased mobility | + + + | People from about 1,000 households use it for commuting. Motorcycles are charged NPR 5 per trip and bicycles NPR 2 per trip. | NPR 50,000 |
| **Raised community plinth** | | | |
| Initial cost | - - | The total cost also includes the cost of relocation and land provided 8 decimal or 1 kattha 12 dhur for relocation. | IRS 5,300,000 |
| Houses protected | + + + | 15 Musahar families of Marpa Village live permanently on the raised plinth. Another 30 households take shelter during 4 months of the monsoon. | IRS 186,000. Valued at IRS 10,000 per household permanently living on the platform and at IRS 1,200 per household for 30 households living 4 months of the year. |
| Land and crop loss | - - | Land was compensated @ IRS 6,000 per acre. Only the Rabi harvest is lost as the area is subjected to 8 feet of inundation in the monsoon. | IRS 102,000 |
| **Raised houses** | | | |
| Houses protected | + + + | 300 households of Piparadi Sultan are built on an average of 6 feet high earthen mounds. Some houses are built on 8 to 10 foot mounds. | IRS 1,500,000. Estimated as IRS 5,000 per household for 300 households. |
| **Sanitation facilities** | | | |
| Improved health | ++ | Most of the villages in the southern region of the embankment and in Laxmipur village of Rautahat had no sanitation units. | NPR 120,000,000. Community sanitation costs NPR 20,000 per unit (e.g the unit build by Oxfam). Assumed to build 6,000 sanitation units. |
| **Early warning systems (using cell phone, radio & telephones)** | | | |
| Life and assets saved | + + | Bairgania and 4 villages have access to cell phones and land line telephone connections. With additional input, the system can be made a multi-functional. | Tentative cost NPR 1,200,000 |
| **Inundation adapted water points** | | | |
| Savings from medical expenses, minimizing wages lost | + + + | Though only 5 raised water points have been observed in the villages, such water points would substantially reduce the occurrences of water borne diseases | IRS 24,000,000. Estimated as USD 10 per person to serve a population of 60,000. |

Note: The costs discussed here relate to the ring embankment around Bairgania block, not the other embankments along the Bagmati and Lal Bakaiya. These have not been included because these embankments have not been systematically studied.

# Annex II: Working Paper Series

| Working Paper Number | Title | Lead Authors | Focus |
|---|---|---|---|
| WP 1 | The Cost-Benefit Analysis Methodology | Reinhard Mechler (IIASA) | CBA methods |
| WP 2 | Pinning Down Vulnerability: From Narratives to Numbers | Daanish Mustafa (KCL); Sara Ahmed, Eva Saroch (ISET-India) | VCI methods |
| WP 3 | Downscaling: Potential Climate Change Impacts in the Rohini Basin, Nepal and India | Sarah Opitz-Stapleton (ISET); Subhrendu Gangopadhyay (University of Colorado, Boulder) | Climate downscaling methods |
| WP 4 | Evaluating Costs and Benefits of Flood Reduction Under Changing Climatic Conditions: Case of the Rohini River Basin, India | Daniel Kull (IIASA); Praveen Singh, Shashikant Chopde (WII); Shiraz A. Wajih (GEAG) | India floods |
| WP 5 | Uttar Pradesh Drought Cost-Benefit Analysis, India | Reinhard Mechler, Stefan Hochrainer, Daniel Kull (IIASA); Praveen Singh, Shashikant Chopde (WII); Shiraz A. Wajih (GEAG) | India drought |
| WP 6 | Costs and Benefits of Flood Mitigation in the Lower Bagmati Basin: Case of Nepal Tarai and North Bihar, India | Ajaya Dixit, Anil Pokhrel (ISET-Nepal); Marcus Moench (ISET) | Nepal Tarai and North Bihar floods |
| WP 7 | Pakistan Case Study: Evaluating the Costs and Benefits of Disaster Risk Reduction under Changing Climatic Conditions | Fawad Khan (ISET-Pakistan); Daanish Mustafa (KCL); Daniel Kull (IIASA) | Pakistan (urban) floods |
| WP 8 | Moving from Concepts to Practice: A Process and Methodology Summary for Identifying Effective Avenues for Risk Management Under Changing Climatic Conditions | Marcus Moench (ISET); Sara Ahmed (ISET-India); Reinhard Mechler (IIASA); Daanish Mustafa (KCL); Ajaya Dixit (ISET-Nepal); Sarah Opitz-Stapleton (ISET); Fawad Khan (ISET-Pakistan); Daniel Kull (IIASA) | Methodology summary |
| WP 9 | Understanding the Costs and Benefits of Disaster Risk Reduction under Changing Climatic Conditions | Marcus Moench (ISET) | Summary report |

# Annex III: Acknowledgements

This paper provides insights from an evaluation of the costs and benefits of disaster risk reduction and adaptation to climate change in South Asia. The report is based on a set of work undertaken in the Nepal Tarai, Eastern Uttar Pradesh, and Rawalpindi, Pakistan. The progamme as a whole is financed by DFID and has been undertaken in conjunction with related activities supported by IDRC, NOAA and ProVention. The support of all these organizations is gratefully acknowledged. Numerous organizations and individuals have contributed in a substantive way to the successful completion of this report. The core group of partners undertaking field work and analysis included: Reinhard Mechler, Daniel Kull, Stefan Hochrainer, Unmesh Patnaik and Joanne Bayer from IIASA in Austria; Sara Ahmed, ISET Associate, Eva Saroch; Shashikant Chopde, Praveen Singh, Sunandan Tiwari, Mamta Borgoyary and Sharmistha Bose of Winrock International India; Ajaya Dixit and Anil Pokhrel from ISET-Nepal; Marcus Moench and Sarah Opitz-Stapleton from ISET; Syed Ayub Qutub from PIEDAR, Pakistan; Shiraz A. Wajih, Abhilash Srivastav and Gyaneshwar Singh of Gorakhpur Environmental Action Group in Gorakhpur, Uttar Pradesh, India; Madhukar Upadhya and Kanchan Mani Dixit from Nepal Water Conservation Foundation in Kathmandu; Daanish Mustafa from King's College London; Fawad Khan, ISET Associate and Atta ur Rehman Sheikh; Subhrendu Gangopadhyay of Environmental Studies Program, University of Colorado, Boulder. Shashikant Chopde and Sonam Bennett-Vasseux from ISET made substantive editorial and other contributions to the project. Substantive inputs from field research were also contributed in India, Nepal and Pakistan by numerous dedicated field staff and individuals in government and non-government organizations as well as the local communities that they interacted with.

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