Catalyzing Climate and Disaster Resilience

Processes for Identifying Tangible and Economically Robust Strategies

INDIA: NEPAL: PAKISTAN

FINAL REPORT OF THE RISK TO RESILIENCE STUDY

The Risk to Resilience Study Team

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Cover: Temporary bamboo bridge south of Gaur in Nepal Tarai used during non-rainy season. The Bairgania embankment with a dysfunctional sluice is seen in background.
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Publications from the Risk to Resilience Study

A number of different publications have been produced for the Risk to Resilience project. The first report, a qualitative analysis of the case study areas, is the book *Working with the Winds of Change: Toward Strategies for Responding to the Risks Associated with Climate Change and other Hazards* published in 2007. Following that, the series of nine working papers listed below and titled *From Risk to Resilience,* was published in 2008. This publication is the final report for the project. All these publications are available for download at www.i-s-e-t.org or www.climate-transitions.org.

From Risk to Resilience 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

Acknowledgements

This report 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 fieldwork undertaken in the Nepal Tarai; Eastern Uttar Pradesh, India; and Rawalpindi, Pakistan. The study as a whole was financed by DFID. Related activities financed by IDRC on adaptation to climate change, NOAA on the use of climate information products and ProVention on disaster risk reduction have also been undertaken in conjunction with the study and have contributed in a substantive manner to the results presented here. The support of all these organizations is gratefully acknowledged.

The Risk to Resilience project was highly collaborative. All partner organizations played central field, analytical and conceptual roles. This said, specific organizations did lead different components. Research in each location was conducted by core project partners: ISET-Nepal and Nepal Water Conservation Foundation led activities in Nepal; Winrock International India led all activities in India, working in close coordination with the Gorakhpur Environmental Action Group and the ISET Associates in India; and PIEDAR and ISET Associates worked closely together in Pakistan. The 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.

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CHAPTER 1

Rethinking the Costs and Benefits of Disaster Risk Reduction under Changing Climate Conditions

Marcus Moench (ISET) &
The Risk to Resilience Study Team

Key Messages

The economic benefits to society of investing in disaster risk management substantially exceed the costs. Appropriately designed risk reduction strategies represent a sound investment that is central both to alleviating poverty and to responding to the expected impacts of climate change on lives and livelihood systems. This core finding emerges from detailed analysis of avenues for reducing flood and, to a lesser extent, drought risks in India, Nepal and Pakistan. As the sample benefit cost ratios contained in Table 1 indicate, in most cases investigated, benefit/cost ratios are positive and in some instances well above those achieved through other common development investments. This finding holds true for an array of interventions that include insurance, early warning systems, local village-level responses, and large-scale infrastructure. Return rates are often higher when the impacts of climate change are considered, particularly for strategies that are resilient in the face of uncertainty. Return rates appear particularly robust for the often lower-cost so called people centred interventions that reduce the risks associated with high frequency, low magnitude events rather than those associated with large disasters. Such events, which can occur annually, result in chronic losses that can erode the wealth of the affected populations. In contrast, the economic benefits that result from interventions that require high initial investments and are targeted at less frequent but more extreme events are less robust. These 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. Indeed, investing in low-cost forms of risk reduction that are designed to increase the resiliency of livelihoods, housing and other infrastructure at the household and community levels may be among the most cost-effective avenues for reducing risks and thereby for supporting adaptation to climate change. This does not, however, imply that investments should be directed away from 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 small disasters that receive little public or policy attention in addition to extreme events with a large-scale, higher-profile impact.

There are three major exceptions to our core finding that risk reduction pays. First, risk reduction may not pay where strategies have major externalities and/or depend heavily on precise knowledge regarding the magnitude and probability of specific events. In the case of embankments for flood control, for example, accurate evaluation of externalities related to drainage, land use and disease may reduce or offset any benefits from risk reduction. Second, risk reduction also may not pay in high cost specialized systems that are designed to respond to individual rather than multiple hazards. This is particularly true if such systems are over-designed or depend on institutions or technical maintenance that are difficult to sustain in the interval between hazard events. Third, unless the value of life is monetized, risk reduction may not generate economic returns in cases where the main benefit is in terms of lives, rather than assets, saved. In this case, however, rather than undertaking an economic cost-benefit analysis it is probably more appropriate to compare investments on the basis of cost per life saved rather than attempt to monetize the value of life. Aside from these three exceptions, in most cases appropriately designed risk reduction strategies do represent a sound investment that, as already noted above, is central both to alleviating poverty and to responding to the expected impacts of climate change on lives and livelihood systems.

Table 1 | **Sample results from cost-benefit analysis of risk management measures in specific case contexts***

Sample interventions	Estimated B/C Ratio**	Change in B/C ratio with Climate Change
UTTAR PRADESH FLOOD MANAGEMENT		
Construction of embankments for flood control (existing programme). Ratio shown reflects indirect costs and benefits. A strict engineering analysis that excludes indirect costs and benefits would, under current climatic conditions, give a B/C ratio of 4.6.	1	Likely to decline
Maintenance of existing embankments	2	Stable
Distributed mix of community based interventions	2.5	Increases
UTTAR PRADESH DROUGHT MANAGEMENT		
Groundwater irrigation (risk reduction alone)	1.6	Increases to 2
Index based insurance programme	2	Declines to 1.2
Combination of insurance and irrigation	2.2	Stable
RAWALPINDI URBAN FLOOD MANAGEMENT		
Expressway/Channel	1.88	Not analyzed
Community pond	8.55	Likely to be robust
River improvement by removing blockages at key choke points	25	Likely to be robust or increase
Early warning system as currently installed. This is a dedicated early warning system that was installed following a major flood event in 2002. The benefit-cost ratio is not representative of other early warning systems.	0.96 Cost per life saved approximately USD 44,000	Benefits would increase with anticipated increases in flooding - but the greatest increases would come with improvements in design
Relocation of population and restoration of the flood plain	1.34	Likely to increase
NEPAL QUALITATIVE COST BENEFIT ANALYSIS		
Flood control embankments along Bagmati River: Evaluation included indirect benefits and costs as well as their distribution	Costs appear to exceed benefits	Appears likely to decline
Distributed mix of community level interventions: Note benefit and cost characteristics are qualitatively different from those associated with embankments and in many cases can't be directly compared.	Benefits appear to exceed costs	Appears likely to increase

* All B/C ratios shown are for 10% discount rates. Assumptions and details underlying all ratios are discussed extensively in the relevant chapters below.
** A note for non-economists: a B/C ratio above 1.0 indicates benefits outweighing costs. The higher the number, the higher the benefit.

The above said it is essential to recognize that returns from investment in risk management depend both on the specific details or design of a given intervention and on the resilience of the underlying strategy. While risk management does in a generic sense pay, the returns and effectiveness of many guiding strategies and specific interventions depend heavily on projections regarding future conditions and on other factors where uncertainty is high. Some strategies and interventions deliver robust returns under a wide range of conditions while others depend heavily on the specific nature of hazards. The range in the resilience of different strategies and interventions also has implications for our ability to evaluate their returns in contexts where limited amounts of data are available and numerous assumptions must be made. Specifically:

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. The former types of investment 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 and where hazards are influenced by changing climatic conditions. 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. It is particularly inappropriate to treat projections of future climate conditions as providing an accurate representation of future event probabilities.* Techniques such as those developed in this project to down-scale the results of global circulation models to local areas can provide key insights but it is essential to acknowledge their limitations. They provide indications of potential future climate conditions but cannot be relied on as accurate projections. 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 changes required for local impact evaluation.

3. *In virtually all of the cases we investigated, we discovered that approaches to risk reduction that combine a mix of "hard" infrastructure and "soft" institutional or financial measures are more robust than approaches that focus on one or the other alone.* In addition, many of the most resilient avenues for risk reduction may involve strengthening of underlying communication, transport, economic, banking and other systems rather than on targeted responses to specific hazards (Moench and Dixit, 2007).

4. Evaluations of the rates of return of large-scale infrastructure may be misleadingly positive because of assumptions made about discount rates, investment costs, event frequencies and, very significantly, because negative consequences ("disbenefits" or externalities) tend not to be considered. *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. How the costs and benefits of disaster risk reduction are evaluated and how the results of such analyses are interpreted needs to be carefully assessed. In many

analyses, the data required to conduct an accurate evaluation are not available or are difficult to generate. *As a result, such analyses depend very heavily on the assumptions and estimates of project staff and other experts.* Because these assumptions often are hidden deeply in models and technical discussions they are unlikely to be evident to any but the most engaged of users.

6. Given the high levels of data required along with the uncertainties inherent in relation to climate change, *in most contexts limited financial and project analyses are likely to be more useful than attempts to conduct full cost-benefit analyses.* Simplified methodologies that enable analysts to identify key cost and benefit areas along with their general magnitudes, coupled with methods for comparing the cost effectiveness of different strategies for reaching similar risk reduction outcomes are essential complements to less frequently applicable full cost-benefit methodologies. In many cases, the costs of a full cost-benefit analysis will exceed the benefits.

Overall, the case studies in this volume 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 cost-benefit analysis.

In addition to the role of cost-benefit analysis in evaluating the economic returns from investments in risk management, *the cases in this volume also demonstrate the importance of process.* The process of conducting a cost-benefit analysis encourages individuals and organizations to move beyond rhetoric and identify very tangible sets of interventions. It also helps them to evaluate the relationship between perceived risks, vulnerable groups and proposed responses in ways that can highlight underlying assumptions and hidden social or other consequences. Where climate change is concerned, conducting a cost-benefit analysis of risk management measures also forces organizations to translate, as far as possible, global scientific information into local contexts. Finally, when conducted in an open, transparent and participatory manner, the process can serve as a major tool for bringing diverse groups of stakeholders and perspectives together, thus generating broad-based ownership and understanding of proposed strategies.

The processes outlined in this volume proceed from qualitative engagement and analysis through quantitative analysis and then back to qualitative. Risks are first identified through qualitative shared learning processes. These are then quantified and evaluated where possible in economic terms. The results of this evaluation are, however, recognized as inherently partial; they reflect the factors that can be quantified and not the numerous social or other considerations that cannot. As a result, the final step in the process, a return to qualitative evaluation, is central to its accuracy. This qualitative-quantitative-qualitative sequence enables stakeholders to understand not just the overall economic returns from a risk management intervention but also its distributional and other potential consequences. This, we believe, is central to understanding *who bears the costs and who benefits from* interventions to manage disaster and other risks. As a result, the process is of far more utility for both the identification of effective strategies for risk management and the targeting of such strategies in ways that address the needs of poor or particularly vulnerable communities than the formal results of the economic evaluation.

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 undermine 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 to 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 DRR, little information is available on the economics of investment in alternative risk reduction strategies and the spectrum of potential strategies ranges greatly from the design of physical structures to the growth of social networks and institutions. This makes directing investment to specific DRR activities difficult to justify relative both to 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 and, furthermore, investments in DRR draw resources away from other areas where investment may be equally important. Hence, there is both a need and a demand for analytical frameworks, such as cost-benefit analysis, that can support decision-making. This need and the pressure to provide solid justification for investments are likely to grow. While constraints on the absolute availability of financing to address the impacts of climate change may decline if innovative mechanisms for funding climate adaptation are implemented, the current global financial crisis suggests that scrutiny and, in some cases, opposition to such funds will increase. A solid evaluation of the economic costs and benefits of alternative strategies will be essential to address the opposition and concern that will inevitably grow if the scale of investments increases.

The challenge is not, however, just to demonstrate the economic returns from investments. Perceptions of 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 disasters affect social or economic groups differently. Women, for example, often face fundamentally different types of impacts than men do during disasters due to the nature and location of their day-to-day activities and the different types of social networks and economic opportunities to which they have access. 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 an economic justification for investment in risk reduction is insufficient. More wide-reaching 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 are also essential. Global efforts to address climate change recognize that those benefiting from high carbon lifestyles are not the large poor populations in developing countries who will bear much of the cost. Consequently, issues of equity and the ability to target resources for adaptation in ways that actually target the most vulnerable groups are central to all efforts to respond to the impacts of climate change. Analytical frameworks exploring the distribution of both impacts from climate related disasters and benefits from risk reduction strategies are, as a result, essential.

At a pragmatic level, the great diversity of approaches to managing disaster risk requires the identification of what specifically 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 tangible courses of action that have impacts at the ground level. At present, systematic processes for identifying courses of action to reduce risk for vulnerable communities are rare. Generally, 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 (Moench and Dixit, 2007). In contrast, this report 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 future effects of climate change.

The Project on Risk to Resilience

The purpose of the project on *Risk to Resilience* was to evaluate the costs and benefits of disaster risk reduction in case study areas in India, Nepal and Pakistan. We focused on water related disasters and the manner in which they may change as a consequence of climate change. Our objective was to develop a suite of methods and analytical cases that both illustrate methods and evaluate the costs and benefits of specific risk reduction strategies under different climate scenarios. Our approach consisted of the following key elements:

1. *Scoping*: An intensive scoping process to identify locations and risks that formed a representative basis for detailed cases.

2. *Vulnerability and capacity analysis*: A systematic process within case areas, including the development of quantitative vulnerability indices, to identify vulnerable groups and disaggregate different dimensions of vulnerability.

3. *Shared learning dialogues within identified case areas*: Iterative meetings with communities and key actors that enabled moving from the analysis of vulnerability to the clear identification of alternative strategies for disaster risk reduction that key actors in the government and affected communities believed will address risk under current and projected climate conditions.

4. *Systematic qualitative approaches for evaluating trade-offs (broad costs and benefits) between alternative strategies for risk reduction:* Who benefits? Who loses? and Why?

5. *Cost-benefit analysis using quantitative probabilistic techniques for evaluating different approaches to disaster risk reduction.* This economic and hazard-modelling component included techniques for down-scaling and evaluating the impacts of climate change in data limited contexts.

The above methods are discussed in detail in the following chapter. This summary focuses on core insights emerging from the application of this suite of methods to flood-related disaster risks in case study sites in the Nepal Tarai (the plains adjacent to India), Rawalpindi, Pakistan, and Eastern Uttar Pradesh, India. Examples of their application have also been discussed in a preliminary manner in W*orking With the Winds of Change*, an earlier ISET publication (Moench and Dixit, 2007). The sites and locations where research was conducted are shown in Figure 1.

| 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 evolve rapidly as emergent properties of development and settlement processes in different contexts. In conjunction with pre-existing patterns of social, economic and gender differentiation, such processes create a kaleidoscope in which patterns of vulnerability appear or disappear in ways that depend as much on interactions within livelihood systems (which 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 the national level, in highly dynamic political environments, institutional memories tend to be short. However well planned or conceived, the resolve to implement strategies to enforce building codes or land use plans or to maintain early warning systems tends to dissipate rapidly following disaster events. Unless the "demand" underpinning such strategies remains constant, the dynamic set of urgent issues facing government actors will drive disaster risk reduction activities into the background - at least until the next disaster.

Similar challenges exist at the community level unless risk reduction measures respond to frequently recurring events. The institutional memory within communities and the organizational foundations of many community based organizations depend heavily on the degree to which a community is a relatively stable and unified entity. If the types of events that cause disaster occur infrequently, then the institutional memory of and the organizational capacity to reduce risk will decrease. The ephemeral nature of institutional memories significantly undermines 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 the perceptions of hazard risks by various groups within hazard prone areas. In the case of the Lai Basin in Rawalpindi, Pakistan, for example, men focus on the direct flood risk to assets, structures and lives, while women emphasized the disease and health problems associated with increases in liquid and solid waste pollution during floods.

Given the complexity inherent in the cases, our analysis of the costs and benefits of disaster risk reduction focused on a range of risk response measures implemented by governments. Many of these interventions are structural: they involve the construction of water control structures, such as embankments, and other physical measures. In addition, we also identified alternative portfolios of realistic local-level interventions that could contribute to disaster risk reduction. These include a spectrum of activities, ranging from the establishment of protected locations (the raising of houses and schools above flood levels) to the establishment of grain banks, local warning systems, self help groups for micro-credit and more diversified livelihood systems. As far as possible, we evaluated the costs and benefits of these alternatives and contrasted them to those of larger structural interventions. The implications of climate change were considered in these analyses through a combination of published information on climate impacts and new techniques, partially developed by the ISET team, for down-scaling the outputs of general circulation models.

While the above approach is realistic, it 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. These data are often partial and biased. In most situations, costs are underestimated and data on externalities are unavailable. As a result, 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 such probabilistic information is available, losses likely within a specific time frame cannot be estimated and, as a result, neither can the benefits of loss reduction. While existing data on climate change does provide information on broad trends, current climate models are unable to generate information on conditions likely to be experienced in specific local areas. Techniques for down-scaling information to these areas involve, in essence, generating scenarios of future climatic conditions. However, our ability to evaluate or test the accuracy of future scenarios is very limited. Uncertainty is equally high regarding other factors or courses of action that could contribute to disaster risk reduction. As the case studies presented in this volume 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, yet such data are of fundamental importance for any systematic evaluation of the costs and benefits of DRR measures. While addressing such gaps is possible, any scientifically defensible cost-benefit analysis will require substantial investment in basic data collection. Even if this investment is undertaken, however, considerable uncertainties will remain.

The challenge goes well beyond that just mentioned. The dynamic political and social context of South Asia generates questions about the sustainability of interventions requiring long-term institutional support, particularly where there are long time lags between disaster events. This is, of course, a critical question for the evaluation of costs and benefits. Unless measures are in place and functional when events occur, any investment will be wasted. While the costs and benefits of, for example, improving house design may be high, the costs and benefits of a programme designed to achieve this through building regulations depend on whether or not those regulations can be enforced over the long term. Prior experience, as documented in the history of policy responses to prior earthquakes in Pakistan, is less than encouraging (Chapter 6 in this volume). Relatively little data currently exist to evaluate such questions in a systematic way within a cost-benefit framework.

Finally, questions regarding strategies for risk reduction often exist that are not well addressed within the framework of cost-benefit analysis. Vulnerability to disasters often varies greatly between groups, and 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 societal 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 highlights both the strengths and the limitations of the approach. On one hand, the 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 mislead decision-making. *Consequently, in many cases, the process of conducting the systematic set of evaluations required for a cost-benefit analysis is more important than the ratios ultimately produced.* The *process* can serve as a transparent framework for the identification and analysis of trade-offs among approaches, particularly if it starts with qualitative evaluation, utilizes quantitative techniques where possible but then returns and evaluates quantitative results through a wider qualitative lens. Benefit-cost ratios, however attractive they may seem to 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. The potential for misleading interpretations is high unless decision-makers are intimately involved in the qualitative-quantitative-qualitative analytical process.

The Case Studies

Analyses of the costs and benefits of disaster risk reduction were undertaken in case study areas in Rawalpindi, Pakistan; Eastern Uttar Pradesh, India; and the Nepal Tarai. In each case, the avenues for risk reduction identified included existing risk management interventions implemented by the respective governments and the alternative strategies identified during intensive dialogues with local communities, NGOs, risk management experts and local government entities. In the Nepal case, strategies were evaluated using qualitative approaches to identify major costs and benefits. In Pakistan and India the research combined qualitative and varying degrees of quantitative analysis. The cases in India involved a full quantitative cost-benefit analysis coupled with extensive modelling to down-scale results from climate change projections. All cases focused on flood risks, except in India, where drought risks were also analyzed. The methodologies used and the cases investigated are detailed in the chapters that follow.

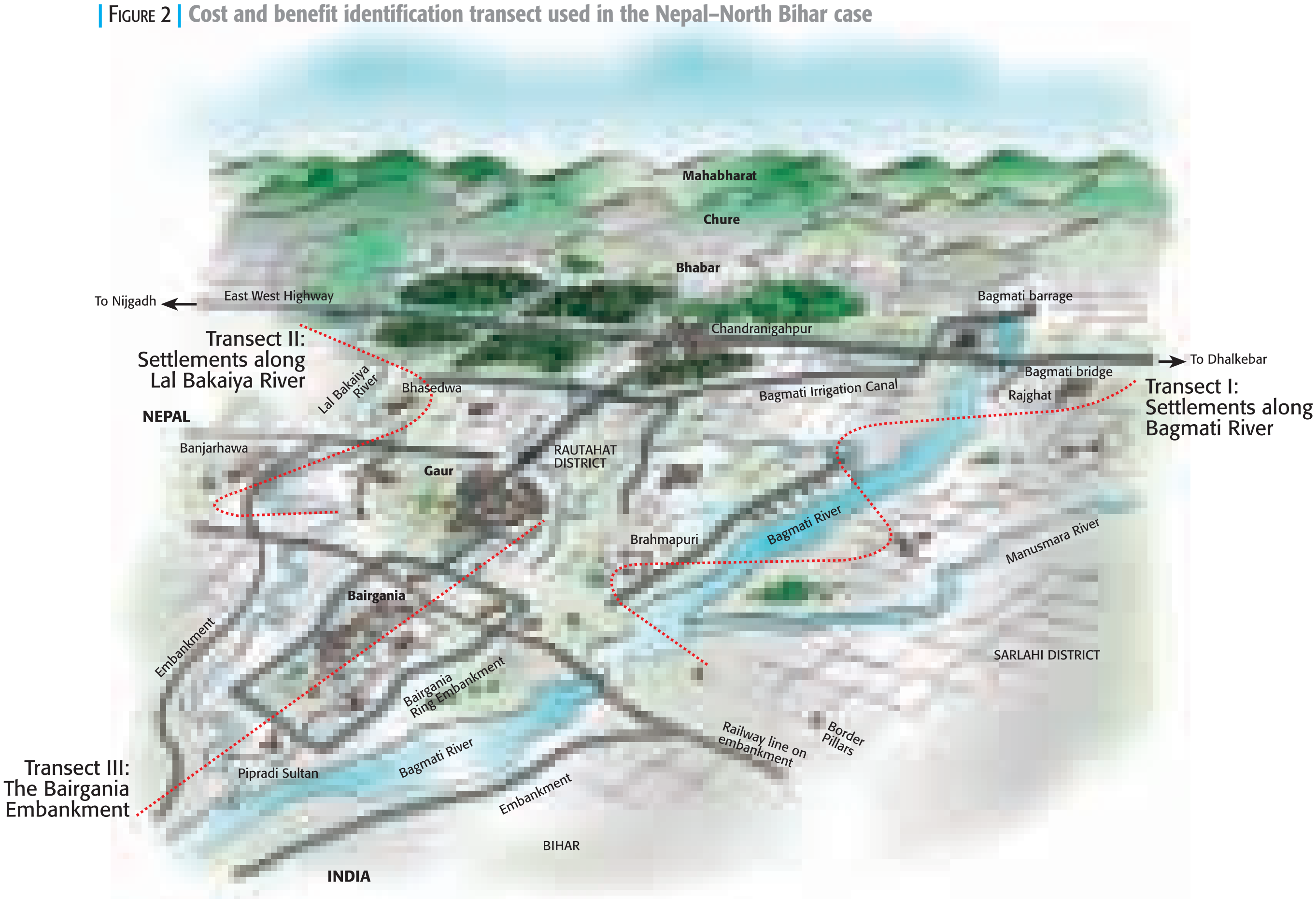
Flooding in the Nepal Tarai

The Tarai region of Nepal, the narrow belt of plains between India and the Himalayan foothills, is subject to regular flooding. In order to limit the negative impacts of flooding, embankments have been constructed both within Nepal and across the border in India. In addition, local groups, NGOs and government entities have supported communities to take a variety of actions to limit flood impacts at the local level. This has included construction of small spurs and embankments to stabilize riverbanks, establishment of raised locations and buildings that provide refuge from floods, building secure water supply systems and sanitation facilities, and reducing flood exposure through forest buffers on stream banks.

A qualitative systematic "cost-benefit" assessment of the main avenues for flood risk reduction was undertaken by the Risk to Resilience team in the Lower Bagmati Basin. This location is close to the base of the Himalayan foothills in contrast to the more central Ganga Basin location of the India case study areas. The costs and benefits identified by local populations for specific risk mitigation measures were systematically documented along a series of transects across flood-affected areas (Figure 2). At regular points along transects, shared learning dialogues (SLDs) were held to identify the major costs and benefits associated with each risk reduction measure. Local groups weighted each of the costs and benefits using plus and minus symbols to indicate their views. This enabled the development of a systematic qualitative picture of the costs and benefits of each set of interventions for the region as a whole. The approach also established a foundation that could be used for a quantitative evaluation of costs and benefits in the future if desired.

The picture emerging from the analysis is of clear tradeoffs. According to local populations, when embankments and other major structural measures are used as the primary mechanisms for flood control the negative impacts outweigh many of the benefits. Embankments, while protecting some areas, shift flooding to other areas and block drainage. In addition, the failure of an embankment can cause a major disaster, a fact clearly illustrated by the breach of the Kosi embankment in eastern Nepal in August 2008 (see Box 1). The failure was not related to an extreme flood event after prolonged rainfall in the upper basin as in the past; it failed when river flows were below the average for August. The Kosi River broke through a poorly maintained embankment section and flowed across the Nepal-India border in channels that it had abandoned decades ago. Over 50,000 people in Nepal and over 3,500,000 in India were affected. In contrast to the large structural measures, the same communities perceive smaller-scale more "people centred" interventions—ranging from the provision of

| FIGURE 2 | **Cost and benefit identification transect used in the Nepal–North Bihar case**



BOX 1

The Kosi Embankment Breach

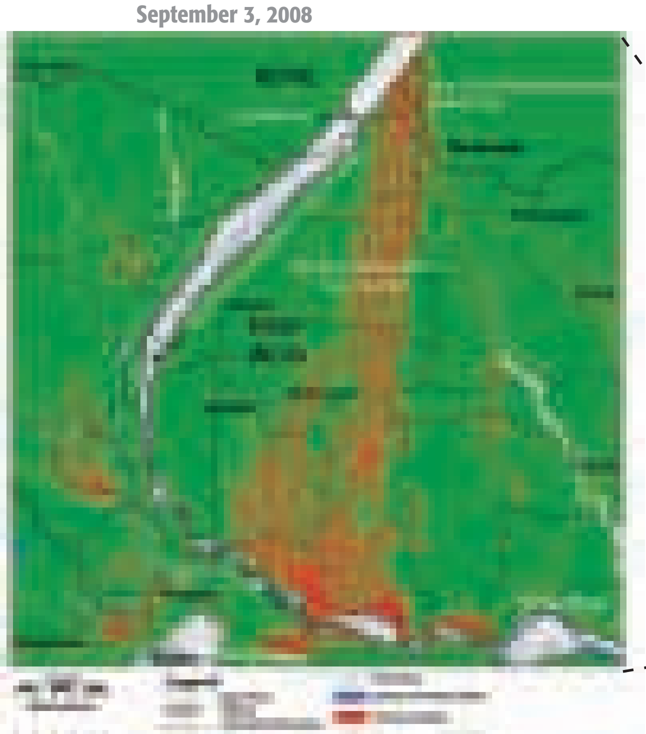
On August 18, 2008 a flood control embankment along the Kosi River in Nepal Tarai breached. The failure occurred when flow in that river was below the long-term average flow for the month of August. Over the following weeks a disaster slowly unfolded as the Kosi River began flowing along one of its old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

The Kosi drains an area of 60,000 km^2 in Tibet, Nepal and North Bihar (India). 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. In the past, as its main channel 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 level of the riverbed above the surrounding land, a factor that contributed to the 2008 breach. 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. Other factors leading to the breach include 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.

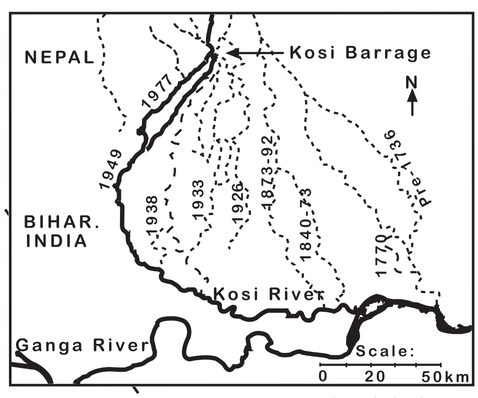
Once the embankments were completed in 1959, the area to the east of the river was largely protected from major flooding and in the subsequent four decades roads, irrigation channels, railways and other features were constructed. These developments blocked the natural drainage and divided the region 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 of 30-40 kilometres seeking the path of least resistance and filling the enclosed basins, low-lying lands and ponds. Low points were scoured and transformed into new main channels for the river, and sand and sediment were 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 were displaced and lives were lost.

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

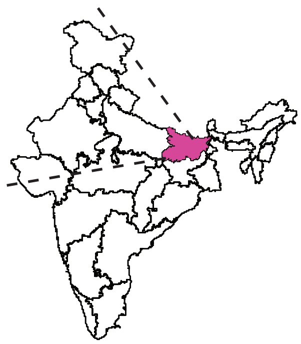


Adapted from: NRSA, Dept. of Space, Govt. of India
(Based on the analysis of Radarsat-2 data of September 3, 2008)

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 high sediment load. Topographic maps indicate that the riverbed within the embankment is now about four metres higher than the adjoining land; in other words the elevation of the bed has increased approximately 1 metre per decade since the embankments were put in place. This August 2008 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. However, protection has encouraged forms of development that are poorly adapted to flooding. As illustrated in the Nepal Tarai and Eastern Uttar Pradesh (India) flood case studies (Chapters 4 and 6 in this volume), while flood protection does generate clear benefits, it also entails major costs. In the Eastern Uttar Pradesh case study, the combined costs associated with land loss, poor drainage and water logging brought the benefit/cost ratio close to 1 suggesting that the economics of investment in embankments is highly questionable. This calculation does not even consider the potential for breaches.

What are the costs of the Kosi breach? The true costs may never be known. The most evident costs include the loss of land, assets and livelihoods–and of course the loss of lives. They also include losses associated with current and future agricultural production. 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 now submerged land. 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**

© A. Pokhrel

boats to the construction of raised areas—as having relatively large benefits in relation to their costs. They also are not subject to the types of catastrophic failure that large-scale structural measures are. These types of catastrophic failure can, as described in the accompanying box on the breach in the Kosi embankment, cause major disasters.

The risk reduction interventions that were identified and evaluated included large structural measures such as embankments as well as local interventions such as boats, bamboo bridges, raised community plinths and houses, sanitation facilities and early warning systems. The SLDs and plus-minus system gave a general overview of major cost and benefit streams (See Chapters 2 and 4 for detailed examples). Many of the people centred approaches involved far fewer trade-offs than did the large structural measures. The costs involved were primarily initial capital investments and there were few, if any, major externalities to take into consideration. Such measures 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 "people centred" interventions will increase.

Qualitative cost-benefit analyses, such as the one conducted in Nepal, provide many of the same insights that are generated by a quantitative approach in that they highlight both the direct and indirect costs and benefits associated with different types of risk reduction intervention. They do not, however, accurately pinpoint the magnitude of those costs and benefits identified remain difficult to compare. As a result, the qualitative analysis lay the groundwork for quantitative evaluations but do not replace them.

Rawalpindi, Pakistan

The Pakistani case study focuses on flood risk reduction options along the Lai River (also called the Lai Nullah) in urban Rawalpindi (see Figure 6). The Lai is a short river basin that, as is the case in many similar urban areas, creates a high risk of flooding in a very densely populated area where many physical assets, from houses 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 it also became clear that the benefit-cost ratio varies greatly from approach to approach, as does the viability of different approaches in relation to the likely impacts of climate change. Table 2 presents 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 being considered in the basin. The early warning system was implemented following a major flood in 2001 that took 74 lives and caused damage exceeding 1 billion USD. In response to this flood, the Japanese

TABLE 2 | Benefits and costs of interventions in the Lai Basin

Strategy/ Intervention	Net Present Value of Investment*	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

* Pakistan Rupees in Million

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

International Cooperation Agency (JICA) 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 establishing the early warning system that was later completed with their assistance. The urban expressway option was promoted by sections of 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. They propose eliminating 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 the environmental community whose members dominated the case study team, favoured the restoration option, analysis revealed that it had the highest up-front capital costs and the lowest benefit-cost ratio because the costs of relocating existing settlements and controlling waste and sewage are very high, a common challenge in urban areas. Equally interestingly, the early warning system-the only option actually implemented-also had a low benefit-cost ratio relative to some of the other options. This is due to two factors; the system is high cost and "over-built" and the advance warning time is limited to only 15 minutes because the river is so short. This short a warning does save lives, but not assets. Projections suggest that the cost of the early warning system works out to three million Pakistani rupees ($44,000) per life saved. Since no attempt was made to value lives, however, this figure 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 detailed advance work done 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 urban populations that permitted 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.

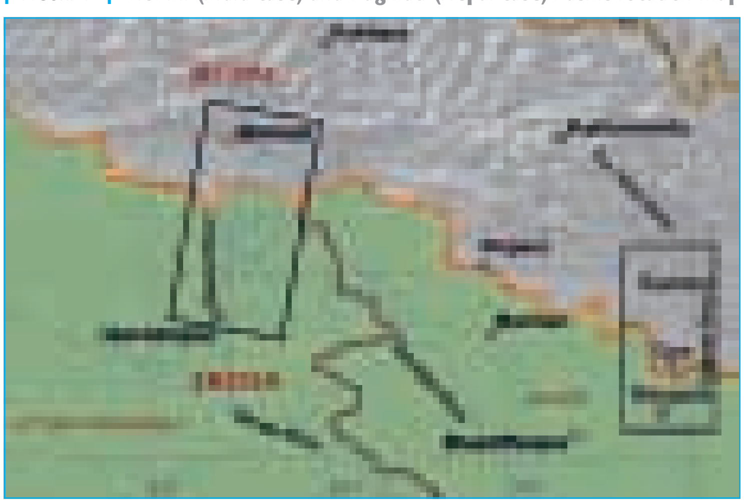
Overall, the Lai Basin study highlights the cost-effectiveness of most risk reduction projects in urban areas and the critical role a systematic cost-benefit analysis can play in their evaluation. Although it was impossible to generate direct estimates of changes in magnitudes of flood events likely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

The case of the Lai illustrates the substantial impact the availability and accessibility of data has on the ability to evaluate the costs and benefits of different options. It also highlights the fact that in some cases low-cost approaches can generate the same benefits as high-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, if they are poorly or over-designed, interventions that tend to be effective in most cases (early warning in this instance) can have very low return rates and may have a relatively high cost in relation to non-market objectives such as lives saved.

Eastern Uttar Pradesh, India

The Eastern Uttar Pradesh case studies (Chapters 6 and 7 in this volume) focused on measures to respond to both floods and droughts. Both cases were located in the Rohini Basin, as shown on the map below. They involved conducting 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. 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 uncertain. The final cost-benefit ratios must therefore be viewed as order-of-magnitude indicators, especially when climate change projections are considered. Nonetheless, the process of

FIGURE 7 | Rohini (India case) and Bagmati (Nepal case) basins location map



conducting the quantitative analysis highlighted an array of costs and benefits and their relative magnitudes that would not have been identified in a less systematic approach. 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.

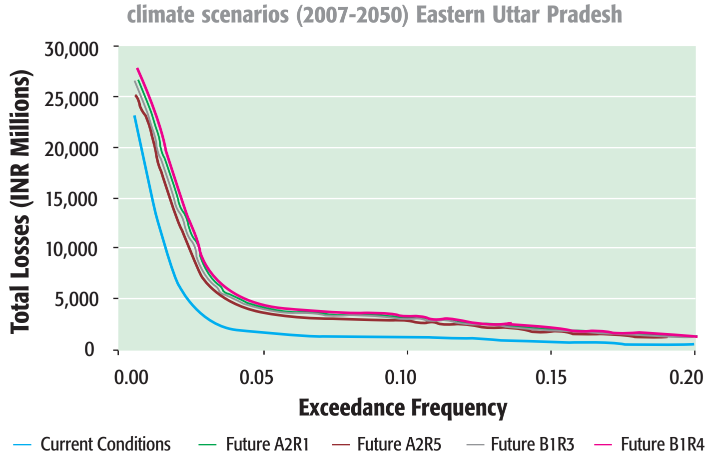
Flood Risk Reduction

As was the case in Nepal, analyses of flood mitigation strategies in Eastern Uttar Pradesh contrasted a diverse package of people centred, resilience-driven interventions with the conventional embankment-focused infrastructure strategy that has characterized government initiatives in the recent past. The "people centred approach" involved actions at the household level (raising house plinths, raising fodder storage units, and introducing a clean a water and sanitation package); actions at the community level (establishing an early warning system, raising community handpumps and toilets, building village flood shelters, developing community grain banks, developing community seed banks, locally maintaining of key drainage points, developing self help groups, and purchasing community boats); and societal-level interventions (promoting of flood-adapted agriculture and strengthening the overall health care system). These local-level, people centred interventions tended to have low up-front capital costs and to generate good returns both for the low-magnitude, high-frequency flood events that characterize life in the plains of the Ganga Basin, as well as for the larger events that cause "disaster." These characteristics, as discussed further below, made these interventions far more resilient than those involving high levels of investment and designed to respond to less frequent extreme events.

The analysis on which the above conclusions were based involved the use of innovative statistical techniques to down-scale results from the Canadian Third-Generation Coupled Climate Model (CGCM3). The scenarios analyzed (the A2 and B1 scenarios) contrast continued growth in carbon emissions levels (A2) with stabilization at around 550 ppm (B1). Outputs from down-scaling were coupled with rainfall-runoff and hydraulic river modelling to produce flooded area estimates with and without embankments for use in loss estimation. The modelled changes in flooded areas for the climate change scenarios were then used to adapt the current condition loss-frequency curves developed during the backwards-looking analysis to projected future climate conditions. Figure 8 shows the resulting 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, small events than on infrequent, large events. In other words, what is now a 10-year flood loss will, in the future, be a 5-year loss, while a current 100-year flood loss will become a 60-year loss.

Results from the modelling suggest that losses from small but more frequent events will increase considerably as climate change proceeds. As this occurs, the annual average loss burden will increase to the point where

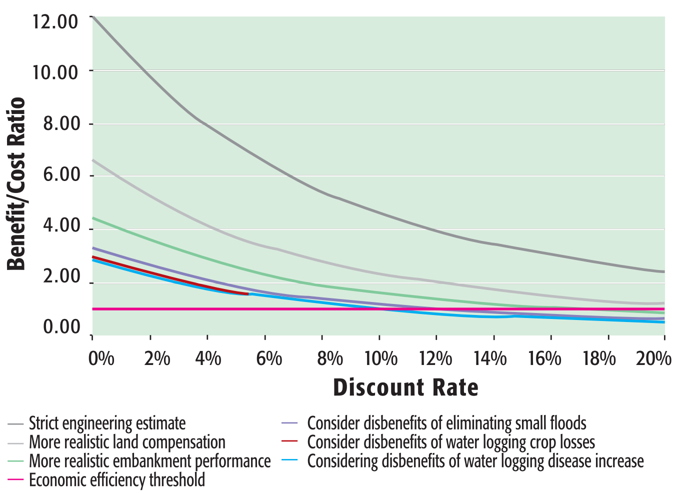
| FIGURE 8 | Flood loss-frequency curves for current conditions and future climate scenarios (2007-2050) Eastern Uttar Pradesh



such “small” floods become more important than large extreme events in terms of long-term economic impacts. The loss data available, however, were only for the large floods of in 1998 and 2007. The lack of data on losses for smaller events represents a major limitation for the analysis of risk reduction measures. The above caveats aside, results of the cost-benefit analysis indicates that there are fundamental differences in the performances of structural measures on the one hand and a package people centred interventions on the other.

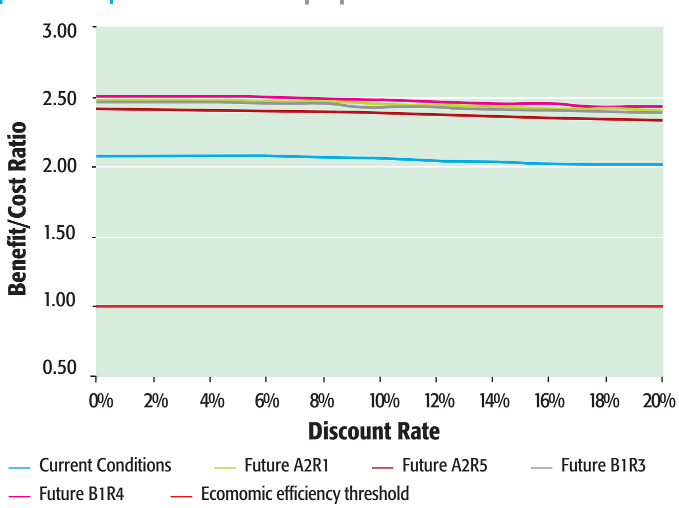
As Figure 9 indicates, while strict engineering analysis of structural measures suggests that structural measures should have a positive benefit/cost ratio of about 4.6, more realistic inclusion of “disbenefits” often ignored in economic analyses makes the economic efficiency of investing in such structures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

FIGURE 9 | Results of CBA for historical embankments performance



In contrast to the embankments, returns on the array of people centred risk reduction interventions proved to be both resilient under different climate change scenarios and relatively insensitive to discount rates. This is because although annual costs may be high, annual benefits are always greater making the weight given to current versus future benefit streams less important. Considering that most components in the people centred strategy are likely to generate an array of indirect benefits and that these were not incorporated in the analysis (the only non-flood related benefits explicitly considered were those resulting from adapted agricultural practices), the true economic efficiency of this strategy is likely to be higher than that shown in Figure 10.

FIGURE 10 | Results of CBA for people centred flood risk reduction



People centred, resilience-based flood risk reduction approaches tend to provide annual benefits (many of which were not captured in this study) regardless of whether a flood occurs or not. As costs are primarily annual (as opposed to one-time initial costs), it is safe to say that if annual benefits are greater than annual costs, then the project is “worth it.” This also holds true 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 their benefits do not depend on the occurrence of certain events. In terms of projected climate change, the people centred approach performs well even as flood risk increases and embankments lose efficiency.

Results of the above analyses have major policy implications. In particular, they suggest that *investments to reduce the impact of low-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 events.* This does not necessarily imply that investments should be directed away from the sort of low-frequency/high-magnitude disasters that can set individuals, households and regions back for many years. On the contrary, it implies that a balanced approach is needed, one that combines sustained attention to the small disasters that receive little public or policy attention as well as to extreme events and their large-scale, high-profile impact.

Drought Risk Reduction

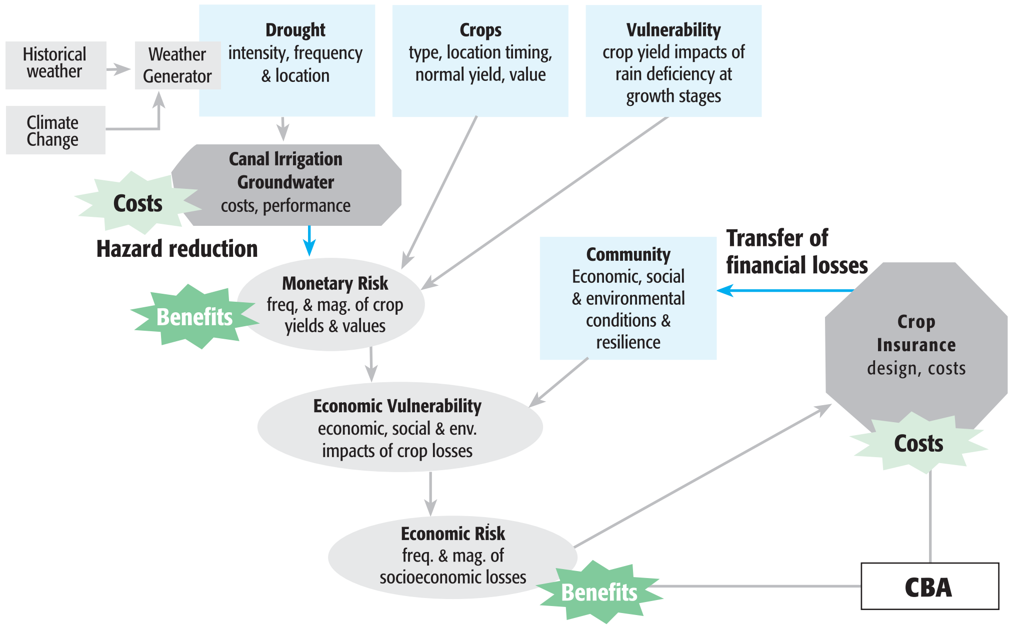
The Uttar Pradesh case site is highly vulnerable not just to floods but also to drought. The primary risk from drought relates to agricultural production in the rice-wheat system on which most rural livelihoods in the Ganga Basin are based. As a result, interventions are not as wide-ranging as they are in the case of floods. The Uttar Pradesh drought analysis focused on two strategies: using insurance mechanisms to spread drought risk and developing groundwater irrigation for reducing such risk. The approach to the case is summarized in Table 3.

In order to systematically assess the costs and benefits of these two risk reduction strategies (insurance and irrigation), we developed a risk-analytic modelling approach. This is illustrated in Figure 11 and discussed in more detail in Chapter 7. This stochastic model made use of Monte-Carlo simulation (the randomized simulation of an underlying statistical distribution) to

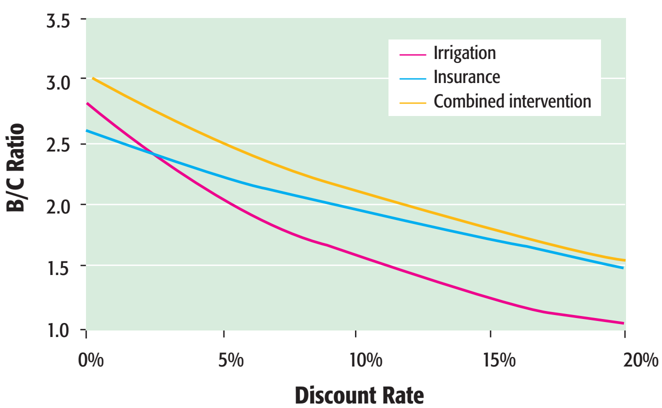
TABLE 3 | Key characteristics of the Uttar Pradesh drought CBA

Risks assessed	Drought risk affecting small-scale farmers in UP in terms of rice and wheat production and related income
Type of CBA	Forward looking, risk based methodology using projected climate and corresponding probabilistic outcomes
Utility	Pre-project appraisal or project appraisal for detailed evaluation of accepting, modifying or rejecting projects
Focus and options of analysis	Risk mitigation and sharing options considered: 1. Irrigation: Construction of boreholes for groundwater pumping - pumping to be paid for by household 2. Subsidized micro crop insurance 3. Integrated package of the options above
Benefits considered	Stabilization of income and consumption
Unit of analysis	Representative farmer household of 7 comprising 80% of the survey sample with income/person of up to INR 6,570 (national poverty line in 2008: INR 4,400).
Resource and time commitment for the analysis	Several man months of professional input due to statistical analysis, stochastic modelling, and explicit modelling of the household income generation process
Key findings	• All options seem economically efficient • Irrigation benefits increase with climate change as low intensity droughts increase • Insurance benefits reduced, as high intensity events becomes less frequent with climate change • Integrated package delivers similar benefits at lower costs • For harnessing the benefits of integrated packages, cross-sectoral cooperation between different public and private actors is essential.

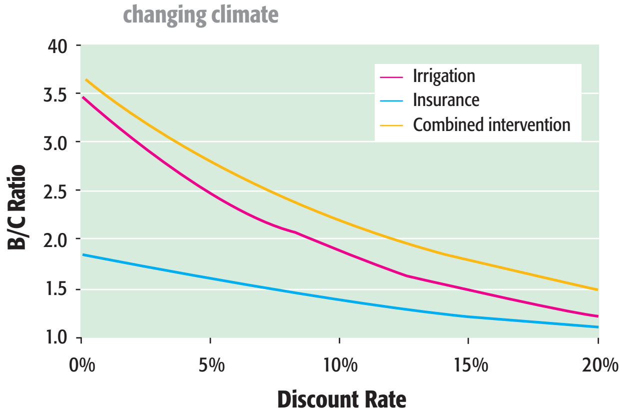
| FIGURE 11 | **Model algorithm**



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



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



generate probabilistic drought shocks to farmers. Climate changes were incorporated via statistical down-scaling for different climate change scenarios as well as for different models.

Based on the above modelling approach, the main benefits of identified disaster risk management interventions involved reduction in average losses and the variability of income. The detailed quantitative results indicated that investment in both insurance and irrigation are economically efficient and generate real benefits. As Figure 12 indicates, benefit/cost ratios are positive and robust under different discount rate assumptions.

As these strategies address different elements of the drought risk, they should be considered as complements rather than as alternatives to each other. This said, it is important to recognize that the relative effectiveness of both strategies is likely to change and climate conditions evolve. In specific, our analysis suggests that the benefits of insurance-based strategies are likely to decline in relation to their costs as chronic variability increases with climate change, while the economic efficiency of irrigation is likely to increase.

Our analysis indicates that a strategic combination of irrigation and insurance has higher return rates than either technique practiced individually, although all three approaches (irrigation, insurance or irrigation-insurance combined) are economically efficient. Insurance is not very dependent on discount rate assumptions, as it offers a secure, guaranteed payout, while irrigation and its benefits depend on the ability of a household to pay to pump water. A typical household as modelled in our case study is financially vulnerable. Multiple adverse shocks over time lead to accumulation of debt and to a declining ability to afford pumping in the future (leading to higher discount rates). With a changing climate, irrigation benefits increase as average rainfall and rainfall variability increase, while insurance benefits decline, as the incidence of high intensity events decreases. Integrated physical (irrigation) and financial (insurance) intervention packages yield greater benefits at similar costs than either strategy alone. This is a result of strategically targeting high frequency events with irrigation and low frequency events with insurance with a package approach to disaster risk management. Consequently, it seems important to explore the development of such integrated packages in a process involving different public and private actors.

Policy Issues

The policy context across South Asia highlights the importance of processes that foster the transparent evaluation of the costs and benefits of alternative approaches and their distributional implications.

Detailed analysis of the policy context in India, Nepal and Pakistan clearly shows that the policy environment where disasters and climate change are concerned is highly centralized. Substantial rhetoric exists regarding the need for community participation in reducing the risk of disasters but, in most cases, actual participation is limited. Initiatives to reduce disaster risk, particularly when implemented in response to specific disaster events, are often influenced by populist or other considerations rather than by their true role in risk reduction. In addition, the policy environment in all three countries limits learning. As discussed below, cost-benefit analysis could, if implemented in a transparent and participatory manner, play a major role in addressing some of the above limitations.

The Use and Abuse of Cost-Benefit Analysis

The case studies 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, cost-benefit analysis is more an organizing framework and process for understanding trade-offs than a fully "scientific" method for evaluating the economic returns from a specific investment. Even if they are produced through a comprehensive analysis, benefit-cost ratios depend heavily on the array of factors considered, the types and the accuracy of the data available, and the assumptions incorporated in the analysis. Furthermore, unless cost-benefit analysis is implemented 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 a full understanding of the factors on which they are based.

At present, most cost-benefit analyses are done on a one-off basis using approaches and frameworks tailored to specific local contexts. Although a number of guidelines exist (Handmer and Thompson, 1997; FEMA, 2001 for guidance on CBA for DRM and Navarro, 2005—the ILPES Manual for assessing the economic impacts of disasters), neither the manuals nor the results in the literature are fully consistent. As a result, in major areas such as drought risk reduction, there are no fully accepted and institutionalized methods for determining what a cost is, what a benefit is or how to discount the future. Furthermore, while many economists 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. The marked differences in the values of different groups are often difficult to show transparently in existing cost-benefit frameworks. Furthermore, as conventionally structured, cost-benefit analysis is intended to determine the overall returns to society of a given intervention, not how those costs and benefits are distributed. Distributional issues are, however, of central importance in many contexts, particularly where risk reduction interventions are justified on the basis of their implications for poverty alleviation or for the needs of specific vulnerable communities.

The above issues and their implications for the use of cost-benefit analysis 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 the availability of data and the ability to project returns over the lifetime of any given intervention. Two elements are central to this. The first concerns the availability of basic data on the costs of a project or intervention and the specific benefits it is likely to generate. The second concerns the ability to project the frequency of future events. Both issues are of particular concern in developing countries, where existing data tend to be limited or difficult to access and the collection of additional data is time consuming and often expensive.

In most situations, the costs of projects to reduce disaster risk are perceived as relatively easy to document with the important exception of any negative consequences ("disbenefits" or "externalities") they may generate. However, 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 the rate in the market. As illustrated in the flood case from Uttar Pradesh, the difference can be so huge as to fundamentally alter the results of the evaluation. Similar issues exist with other costs.

Issues related to the monetizing of benefits from investing in disaster risk reduction are even more complex. These benefits are, in essence, avoided costs; the costs that would have been incurred 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, requires a variety of data of types that are not generally 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. Such data is not generally available and it is even more difficult to accurately determine the degree to which a specific risk reduction intervention would reduce such losses. Furthermore, conceptually it would be important to assess the income and livelihood consequences (indirect risks) and their distributional consequences in addition to the loss of assets and structure (direct risks) of disasters. For example, a loss of INR 10,000 has very different implications for a poor labourer than for a large-scale farmer. Such a loss could result in severe malnutrition and deprivation for the labourer (a major societal cost), but the large-scale farmer would absorb the loss and avoid the indirect societal costs. Normally, indirect risks cannot be assessed easily, as this involves conducting surveys and statistical and economic analyses. As a result, analysts (even those in this study) tend to focus primarily on direct risks, which, in a development context, often understate the "real" impacts.

The limitations on data available also determine what strategies can be evaluated. In the Pakistan case, the lack of data on the indirect risks to health essentially eliminated our ability to estimate the costs and benefits of the main risk reduction intervention identified by women in the affected communities.

The lack of data needed to project event probabilities is particularly challenging in the case of climate related events. In many contexts, historical data regarding basic hydrologic parameters (rainfall, streamflows, flooded areas, etc.) are extremely limited or their access is restricted in the interests of national security. Such data, however, are required to down-scale results from general circulation models and translate them into future flood or drought event probabilities in specific localities. When limited historical data are coupled with the inherent uncertainties in data generated through down-scaling techniques, projections regarding the probability of future events are inherently highly uncertain. This uncertainty 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 payments of a similar magnitude must be made more frequently. Similarly, structures that are designed to withstand floods occurring every hundred years will fail if larger floods occur.

Assumptions

The limited availability of basic data forces analysts to rely heavily on assumptions in order to estimate the costs and benefits of different interventions. This is an arena where seasoned judgment is essential. It is also an arena where lack of transparency can seriously compromise the legitimacy of the results of cost-benefit analysis. As illustrated in the Uttar Pradesh flood case, differences in assumptions that seem relatively minor can often alter cost-benefit estimates in fundamental ways (Chapter 6). The benefit-cost ratios estimated depend significantly on the value of land assumed and the average width of the area affected by drainage problems behind embankments. Similarly in the Lai Basin case in Pakistan cost-benefit ratios depended on assumptions regarding the extent of assets that could be moved out of harm's way using the fifteen-minute warning provided by the early warning system.

Academic journals rely on peer review processes to validate both the assumptions and data on which analyses of all types are based. In applied cost-benefit analyses, a framework enabling 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 assumptions made tends to be buried in the technical details of analyses.

Negative Consequences

The negative consequences ("externalities" or "disbenefits") associated with investments are often ignored in cost-benefit analyses. These frequently 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 risk reduction strategies and whom they affect. Quantifying disbenefits can have a fundamental impact on the overall social cost-benefit assessment of an intervention and, even if the activity 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) the loss of substantial areas of agricultural land (2) the loss of the soil moisture and fertility benefits of small floods; (3) actual embankment performance that is substantially below design criteria; (4) losses in crop production caused by the water-logging behind embankments; and (5) increases in disease vectors. Taken together these negative consequences shift the benefit-cost ratios calculated at a 10% discount rate for embankments from above 4 in a purely engineering analysis to 1 or below. The consideration of externalities 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.

In general, where interventions to address disaster risks have negative consequences, they must be included 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 investments in disaster risk reduction. This is particularly true where up-front investment costs are large and the costs avoided depend heavily on large-magnitude, 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 an investment. In contrast, where benefits accrue from high-frequency low magnitude events, return rates tend to be more economically robust under a variety of discount rate assumptions. Both of these issues are clearly illustrated in the contrasting returns for flood risk mitigation using embankments versus more distributed "people centred" measures in the Eastern Uttar Pradesh case.

The choice of discount rates often is socially sensitive since it inherently raises ethical questions regarding the tradeoff between current benefits (which benefit current populations) and future benefits (which may benefit future generations). Hence, transparency in the analysis is critical.

Distributional Issues

Conventional cost-benefit analysis is concerned primarily with the overall economic returns to society and not with their distribution. In situations where poverty is a major concern such as is the case in studied the areas and where justification for any intervention depends heavily on the implications for vulnerable sections of society, 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 as discussed earlier, 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 between a river and its embankment, 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, the most vulnerable groups are often the least likely to benefit. This is not always the case, however. Interventions such as the fodder and food banks established by self help groups in Uttar Pradesh are of particular benefit to the poor and can also have extremely high benefit-cost ratios.

Targeting benefits toward vulnerable groups highlights the importance of linking cost-benefit analysis with vulnerability analysis. The process of conducting the analysis conveys more "real" insights on the viability and desirability of DRR measures than do the numbers estimated. While traditional cost-benefit techniques do not consider distribution, their use in conjunction with qualitative techniques (such as those described in the Nepal case) can generate key insights into distributional issues.

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 analyses depend heavily on a wide range of factors that include data availability and quality, assumptions and model design. In most analyses, these factors are buried in technical details. As a result, decision-makers and other users of the results have little understanding regarding the numerous - and often heavily debatable - assumptions that determine the 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 inaccurately suggest a high social return.

Unless the analytical frameworks and the processes used to collect data and make assumptions are transparent, the real meaning of any cost-benefit analysis will be uncertain and the technique will remain highly vulnerable to abuse when used to generate criteria for decision-making.

Conclusions

The case studies in this volume clearly demonstrate that disaster risk reduction pays and that it can make a substantive contribution towards helping people adapt to the impacts of climate change. Our conclusion 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 show 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 of cost-benefit analysis can be highly misleading.

Results of the qualitative and quantitative analyses, experiences in the region, along 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. These events 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 often may 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.

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

Cost-benefit analysis is extremely dependent on process and methods if it is to have any real relevance as a decision support tool. Open transparent processes that utilize both qualitative and quantitative methodologies are essential to produce results that are robust under different conditions and different sets of assumptions. In some cases, for example, the results of a cost-benefit analysis are not sensitive to assumptions concerning data or discount rates; in others the level of sensitivity is high. In Uttar Pradesh, for example, the cost-benefit analysis clearly demonstrated that distributed interventions delivering benefits annually with low initial costs are less sensitive to discount rates or climate change scenarios. In more complicated cases, if cost-benefit analysis is to be used as a major tool for supporting decision-making, it must be combined with qualitative and open processes of analysis.

Providing for transparency of data and data sources, assumptions, and externalities - including how these were identified - is critical in any cost-benefit analysis as these factors greatly influence the results. Transparency enables stakeholders to better evaluate the validity of the results and/or come to their own conclusions. In addition, consistent frameworks and methods for evaluating different types of interventions are required to better enable comparison of benefit and cost estimates. This is particularly important for sensitivity analysis and for displaying the implications for the resulting benefit-cost ratios. Transparency is also required in order 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 climate and other conditions likely to occur in the future.

Cost-benefit analysis has the potential to become a useful tool for decision-makers to evaluate strategies for responding to disasters and reducing the impact of climate change. Particularly in highly centralized policy environments such as those found in South Asia (see Chapter 8) participatory processes for conducting cost-benefit analysis could, by highlighting their often high returns relative to more centralized structural measures, enable much more serious focus on distributed community based approaches. However, for it to evolve from a "special purpose" technique for the one-off evaluation of DRR projects into a major decision-making support tool, substantial improvements in methodologies and the processes through which they are applied are essential.

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CHAPTER 2

Methods for Identifying Tangible Strategies for Risk Reduction

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Introduction

> "More effective prevention strategies would not only save tens of billions of dollars, but tens of thousands of lives. Funds currently spent on intervention and relief could be devoted to enhancing equitable and sustainable development instead, which would further reduce the risk of war and disaster. Building a culture of prevention is not easy. While the costs of prevention have to be paid in the present, their benefits lie in a distant future. Moreover, the benefits are not tangible; they are the disasters that did not happen,"
>
> (Kofi Annan, Annual Report on the Work of the Organisation of the United Nations, 1999).

The role of disasters in building and maintaining the cycle of poverty and undermining development progress is increasingly recognized as a major global challenge. While many recent disasters are related to geophysical events (earthquakes, tsunamis, etc.), approximately 70% are weather related and this proportion is likely to grow as climate change processes increase the variability and intensity of weather events (Hoyois and Guha-Sapir, 2004). As a result, cost-effective strategies for reducing disaster risk are central *both* to meeting development goals *and* responding to the challenges climate change will present all sectors of society, particularly the poor, women and other vulnerable groups.

The purpose of this chapter on methodologies is to present practical approaches for identifying, prioritizing and ultimately demonstrating the costs and benefits of tangible interventions to reduce disaster risks, particularly those likely to emerge as a consequence of climate change. Such practical approaches are essential if governments, humanitarian organizations, the private sector and local communities are going to invest substantial resources in reducing both current disaster risks and those anticipated as a consequence of climate change.

Cost-benefit analysis on its own is often a double-edge sword. Many of the costs and benefits associated with potential interventions to reduce risk are difficult to identify or quantify objectively. In many cases, perceptions regarding the nature of risks and the array of potential strategies for reducing them may differ greatly both within and between communities. As a result, while the concept of risk reduction may be understood, what it means in practical terms is often unclear in the absence of detailed analyses that address location specific conditions and the impacts of hazards on different groups. In addition, the overall economic returns from investments in risk reduction do not reflect their distribution across vulnerable groups in society. As a result, cost-benefit analysis needs to be part of a larger package of methodologies that include:

1. Clear and transparent processes with extensive stakeholder engagement that enable development of a common understanding regarding the nature of risk and the potential strategies for reducing it;
2. Detailed analysis of the factors contributing to vulnerability within exposed communities;
3. Quantitative and qualitative methods for evaluating the impacts of climate change; and
4. Processes for quantitative and qualitative data collection and cost-benefit analysis that are transparent, inclusive and clearly identify the assumptions on which the analysis is based.

This methodological summary outlines key elements and methodologies for understanding risk and vulnerability within communities, identifying potential response strategies and evaluating related qualitative and quantitative costs and benefits. The approach is based on a shared learning process that moves iteratively from initial scoping to systematic vulnerability analysis, to identification of potential risk reduction options, and to qualitative and quantitative evaluation of their costs and benefits as a basis for decision-making. In order to consider impacts of climate change on the economics of risk reduction strategies, the approach includes downscaling of results from global circulation models for incorporation in the quantitative evaluation of costs and benefits. Before detailing these methodologies, however, it is essential to understand the underlying reasons behind our emphasis on process rather than quantitative outcomes alone.

Processes & Qualitative Methodologies

The Importance of 'Soft' Process Approaches

Most investment decisions concerning disaster risk reduction (DRR) in South Asia have focused on hard prevention or structural measures for which data are more readily available and costs and benefits more tangible making them easier to quantify. In India, for example, the government for decades has invested heavily in building dams and embankments as the cornerstone of flood mitigation efforts. Similarly, for drought mitigation, investments have focused on the development of irrigation systems and on watershed management (where most of the investment goes into water harvesting structures and physical land management activities such as contour bunding). Despite the dominance of hard structural approaches in DRR, increasingly attention is being devoted to a wide variety of softer measures. These include a range of interventions to support community capacity building, develop disaster management policies and planning, spread risks through financial or other mechanisms and support adaptation. Such largely community or individual (household) based measures, both autonomous and planned, can contribute to systemic changes that in the long run may not only support the sustainability of targeted interventions but also build more enduring and resilient communities.

Community based strategies can either complement or conflict with more centralized strategies. In the case of floods, for example, large-scale programmes to regulate river flows through embankments and dams can fundamentally change both the nature of risk and the incentives facing individuals, households and communities to respond to risk. If, for example, river regulation eliminates small-scale annual flood events, then communities may feel insulated from flood impacts and have little incentive to invest time or resources in risk reduction. In addition, if the remaining risk relates only to large-scale events (for example, when control structures breach) then the scale of events may be beyond the capacity of communities to mitigate. A prime example is the embankment breach along the Kosi River in August 2008 that affected over three million people in Nepal and the Indian state of Bihar. Similar conflicts between community incentives and larger-scale initiatives may occur in cases of drought where irrigation through large systems can provide a buffer—thus eliminating the incentive of communities to reduce the dependency of livelihoods on agriculture—until the source of water itself is affected.

Although it is well recognized that the most effective points of entry for risk reduction tend to be local (Wisner et al., 2004), community based strategies often depend on enabling conditions at higher levels including:

- **Dependency on data:** Localized early warning systems often depend on weather information issued by state or national weather agencies.
- **Risk spreading:** The viability of micro-insurance generally requires mechanisms for reinsurance that spread risk beyond local communities, i.e. beyond groups who are likely to all be affected by any given event and where simultaneous requirements would overwhelm local insurance pools.
- **Institutions:** Establishment of organizations for DRR may require enabling legislation and sources of finance from national levels.

Processes for Working with Communities

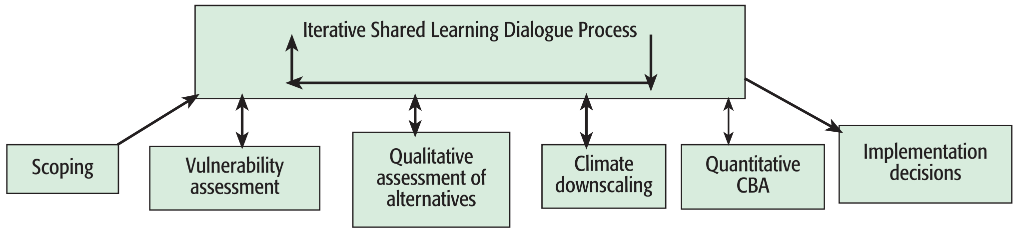
Working with communities necessitates investing time and resources to determine:

1. Who faces risk and what form that risk takes for different groups within an area vulnerable to specific hazard events; and
2. What courses of action might best address the specific risks faced by different groups.

In many situations, disaster risks and the groups that should have interest in reducing risk may seem self-evident. The reality, however, is often different. In urban Rawalpindi, Pakistan, for example, urban flood control programmes that have attracted massive donor funding focus on early warning and control of flows. Research by ISET-Pakistan and partners in the flood affected area indicates, however, that health problems created when floods deposit municipal waste across large areas are of much more significance to women in local communities than the direct flow impacts (see Chapter 5 this volume). Women represent a key group of stakeholders and the strategies they support are different from the structural measures implemented by governments.

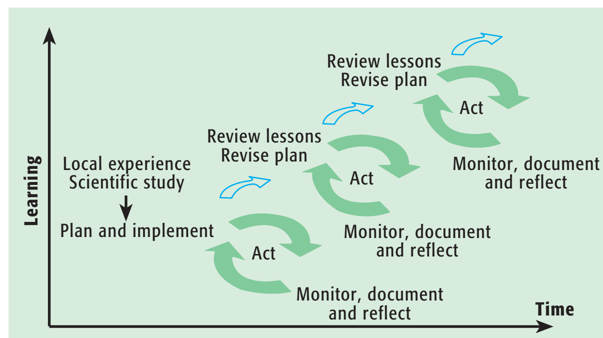
Thus, *processes that enable the integration of knowledge from different sources are essential*. Our ISET partners and field teams used a combination of methods including broad scoping activities and shared learning dialogues (SLDs) with a range of stakeholders to identify different DRR interventions, their broad cost and benefit areas, and potential disbenefits. These initial activities can serve as the basis for more detailed capacity and vulnerability analyses, qualitative techniques for ranking and prioritizing alternative DRR activities, and if desired, for a full quantitative cost-benefit analysis. Ideally the SLD process should continue beyond the initial phase as a mechanism to feed insights from more detailed vulnerability and cost-benefit assessments back to communities and other key actors as a basis for final decision-making. As a result, although the process below is presented sequentially (scoping>shared learning>vulnerability analysis>qualitative and quantitative assessment of costs and benefits>ultimate implementation decisions) as diagrammed in Figure 1 should be recognized as iterative.

| FIGURE 1 | The Shared Learning Dialogue (SLD) process



More generally, SLDs for climate and DRR grow out of iterative learning and action research processes that have been applied for decades in many research and implementation fields. These action-learning processes are diagrammed in Figure 2 following Lewin (1946). At each phase, action iterates with planning, monitoring, documentation and reflection so that experience and knowledge accumulate. This is exactly the type of process required to respond to the uncertainty and gradual accumulation of scientific and other knowledge regarding hazards, particularly those related to climate change.

| FIGURE 2 | Iterative learning and action research



Following Lewin (1946)

Scoping

Initial scoping is a critical first step to structure subsequent processes for identifying points of leverage to reduce disaster risks. Where external actors are unfamiliar with conditions and communities in target areas, scoping is essential to gain basic understanding of the region, the communities involved and the hazards they face. Even where organizations have been working with communities over an extended period, revisiting the objectives and data collected through scoping processes can help cross-check assumptions and information.

Objectives

What are the objectives of scoping? Based on our experience they need to include:

1. **Outlining the array of hazards present in a region.** This can be particularly complex in areas that recently have been affected by high-profile disasters such as earthquakes. In these situations, attention tends to focus on the recent event rather than the hazards most likely to be of consequence in the future. As a result, scoping processes may need to explicitly counterbalance attention to recent events by including activities and reports directed at other hazards. In addition, in the case of hazards that could be exacerbated by climate change, evaluation of recent overview assessments (IPCC reports) and scientific literature, particularly any available for the specific region under consideration, is essential. It also requires a focus as

much on levels of uncertainty regarding future conditions as on the results of specific future scenarios. A large part of the uncertainty in climate change projections is due to an increase in variability away from the previous long-term climatological mean. The systems literally are transitioning into a new climate state that we cannot completely know. Understanding the implications of uncertainty in hazard evaluation is as important as attempts to narrow such uncertainty.

2. **Identifying communities that are particularly vulnerable to different hazard events.** The degree of exposure to different hazards often differs greatly between communities residing in the same area. As our research in Eastern Uttar Pradesh has documented, people living in traditional (*kuccha*) houses face far higher flood losses than those residing in adjacent brick (*pukka*) houses (Chapter 6 this volume).

3. **Beginning the process of exploring how hazards translate into different types of risk.** Understanding different patterns of vulnerability serves as a basis for initial analytical activities to map the relationship between hazards and risks faced by different communities. This needs to be addressed at the outset as it is central to identifying both community interest in risk reduction and the interventions that could reduce such risk. Some of these dimensions are relatively obvious. Fisherfolk, for example, may face a very different type of risk from cyclones than other coastal communities due to the nature of their work. Similarly, high-rise office workers face different types of vulnerability to earthquakes than poor farmers living in ground-level traditional houses. Some key differences, however, are far less obvious. Such differences define what might be called "communities of vulnerability" that face similar risks and may have similar interests in approaches to risk reduction.

4. **Identifying existing projects and programmes.** In many regions, existing or recent projects and programmes have responded to specific hazards and increasingly the potential consequences of climate change. However, these experiences are rarely considered in the development of new programmes and policies. As a result, regions often "reinvent the wheel." Some level of understanding regarding what has or has not worked in the past and why should be a central part of scoping exercises.

5. **Identifying major alternative avenues for addressing risk.** Although identification of strategies for addressing risk must remain preliminary at the scoping phase, it is critical to develop initial ideas on practical avenues as a basis for discussion with key actors. It is important to think through how different types of hard versus soft, or direct (targeted) versus systemic interventions, might influence the risk faced by different communities of vulnerability. In most cases, key actors tend to move rapidly toward "tangible" hard interventions that directly control the physical impact of specific hazards. Such interventions may not, however, be particularly effective in relation to the risks faced by different communities of vulnerability. In flood affected regions, for example, development of basic health care systems might have far greater impact on disease morbidity generally associated with flood events than structural control measures. Initial exploration of how different dimensions of vulnerability relate to risk and how those relate, in turn, to broad categories of potential risk reduction strategies is essential during the scoping phase in order to

create a basis for future dialogue and shared learning with key actors and communities at later phases.

Core Elements

To meet the above objectives, scoping processes need, at minimum, to contain the following core elements:

1. **Collection and review of existing published and secondary information on hazards and their impacts:** This should include the type of hazard, its frequency and intensity as well as basic information available on impacts and their distribution (deaths, economic losses, communities affected, etc.). It should also include information available on the changing nature of regional hazards whether due to global processes such as climate change, demographic and economic changes (urbanization, shifts out of, or into, agriculture or other sectors) or other factors. Geo-referenced information (maps or the data bases required for creating them) can be useful for all of the above.

2. **Review of policy and programmes:** Targeted reviews of disaster related policies and programmes are essential in order to understand the institutional landscape. Where possible, such reviews should consider the wider policy environment that may contribute to hazard exposure. For example, policies supporting agriculture in drought prone regions or encouraging coastal development, if they exist, could be important factors contributing to hazard exposure.

3. **Collection of basic information on conditions in exposed communities:** This should include basic information on demographics, economic systems, livelihoods, etc. that may be available from secondary sources such as research publications, official government reports, and project documents.

4. **Interviews with key informants:** This is one of the most important elements I scoping processes. Carefully targeted key informant interviews can facilitate understanding both perceptions regarding the nature of hazards, patterns of vulnerability and potential response elements. It is important to interview key actors representing a wide array of social perspectives and knowledge.

The above information provides a basic starting point for the more intensive learning dialogue processes that we believe are essential in order to develop broadly shared understanding of risks and the potential avenues for addressing them.

Shared Learning Dialogues (SLDs)

Moving beyond the level of understanding that can be achieved through initial scoping requires iterative processes in which analysts and different communities of actors (local "communities", sector specialists, governmental actors, NGOs, etc.) can share insights and come to a common understanding. This is particularly true in the case of complex hazards—such as those associated with climate change—where highly specialized information from high-level scientific research must be brought together with the equally specialized, location specific, insights of communities.

The nature of hazards and the process through which highly variable vulnerability attributes create different patterns of risk within communities is complex. No single group, whether at the community level or within the government, is likely to have a comprehensive understanding of risks, particularly for hazards with long recurrence periods. Instead, different groups tend to have partial but key insights and perspectives that relate to their position within society or the specific vulnerabilities they face. Also, local groups often lack the insights that specialized groups from the international scientific or risk management communities can bring.

Furthermore, where responses are concerned, knowledge is also fragmentary. Local communities often have key insights about types of activities that could reduce the risks they currently face—but they frequently lack understanding of processes and limitations at levels beyond their immediate community. Government officials may have larger perspectives and certainly understand the operation of the formal systems within which they work—but they tend to lack understanding of the different dimensions of vulnerability within communities. As a result, the solutions they propose rarely respond to diverse priorities at the community level. This is also the case with global scientific communities. The scientific community may have unique insights into emerging hazards but generally lack understanding of both risk patterns at the community level and the strengths or limitations of government and other institutions. As a result, effective solutions rarely emerge from any one set of actors.

Ultimately, all forms of knowledge on hazards and risk tend to be partial and unless these can be integrated, risks cannot be addressed effectively. Shared Learning Dialogues are the mechanism we have developed for this purpose. SLDs are essentially iterative multi-stakeholder or focus group meetings with the following key attributes:

1. **Information sharing should be multi-directional:** the goal is for external actors to learn from the communities (local groups, government actors, etc.) they are interacting with *and* vice versa;

2. **The processes should be iterative:** People at all levels have time to absorb and think about the information and perspectives of different groups before they interact again and work towards the development of specific mechanisms for responding to hazards and the risks they create;

3. **The processes should cross scale, community, organizational and disciplinary boundaries:** They bring together local, regional, national and global scientific perspectives; and

4. **The processes should involve participants reflecting different socio-economic, gender, geographic, and cultural groupings:** Because patterns of vulnerability often differ between such groupings, the goal is to ensure, as far as possible, that shared learning processes capture these different patterns and the response strategies they suggest.

In the SLD process we have developed, each meeting starts with a presentation outlining key issues. Other participants are then invited to provide critical comments, insights, information, data and suggestions drawn from their own organizations and activity areas. Particular attention is paid to identifying areas where all participants agree on key points, knowledge gaps or the need for specific research or pilot activities. In many cases, the regular meetings lead to sharing of information or further dialogue in electronic forums. Holding SLDs throughout the duration of a project encourages the engagement of external counterparts and decision-makers in project activities. Such dialogues also provide an immediate mechanism for feedback and help to 'close the loop' between knowledge generation, testing, dissemination and application.

The primary goal of shared learning processes is common understanding regarding the nature of hazards and the potential avenues for responding to them. This takes time and requires a process in which insights from communities (and often different groups within communities) can be brought together with insights from groups and organizations working at other levels. To achieve this, iteration and interaction with multiple groups across scales and disciplinary boundaries are essential.

On a practical level, what does a SLD process involve?

1. **Iterative meetings** among diverse groups that bring together different perspectives on vulnerability, the factors that contribute to social resilience, and potential avenues for responding to disaster risks;
2. **Provision of key technical and analytical inputs** to support the joint understanding of hazards, risks and potential response strategies;
3. **Mechanisms to evaluate and prioritize alternative response strategies**.

The ultimate outcome of SLD processes should be the identification of avenues for responding to the specific risks faced by different communities that are:

1. **Practical** - they have a clear mechanism reducing risk for vulnerable communities and can be implemented with the capacities and social or financial resources available;
2. **Broadly owned** - they should be understood and supported by key actors (whether at the community level, the government or the private sector) that need to be involved in implementation;
3. **Sustainable** - they have a clear operational or business model that will ensure risk mitigation interventions remain effective until hazard events occur;
4. **Technically effective** - the activities should reduce the potential for damage when hazard events occur or mitigate them (as discussed further in the section on qualitative evaluation this can be an issue when measures depend on threshold values related to the magnitude of events); and
5. **Economically and financially cost effective** - investments in DRR should be economically justifiable relative to other potential uses of public funds.

Although the ultimate objective of SLDs is to identify avenues for responding to risk, this will occur over a process of iterative engagement and may not be an output of initial meetings. Prior to more detailed work on vulnerability or the prioritization and economic evaluation of potential options for responding to risks, SLDs should produce:

1. A detailed understanding of hazards, including those likely to emerge as a consequence of climate change, and their likely implications for different groups (communities, gender and economic groupings, geographic regions);
2. A detailed understanding of the factors that local groups view as mediating the impact of hazard events and strengthening the resilience of society when events occur;
3. An indication of groups where additional vulnerability analysis will be required;
4. Broad understanding among key actors (local, regional and external) of potential risk response strategies that reflects distinctions between hard versus soft, targeted versus systemic, community versus centralized, and risk spreading versus risk reduction concepts; and
5. Initial identification of potential response strategies for more detailed evaluation.

The above initial outcomes should provide a sufficient degree of shared understanding to support more detailed vulnerability analyses as well as qualitative and quantitative evaluations of avenues for responding to risk, as discussed in the following sections.

Vulnerability Analysis

Why is vulnerability analysis important? In virtually all situations, different groups face different levels of risk in relation to specific hazards. A tangible example is the tendency of poor populations to cluster in high-risk areas such as urban and rural flood plains. As a result, they have a far higher level of vulnerability to flooding than groups living in less hazard prone areas. Interventions to mitigate flooding can be designed that meet the needs of such groups. However, in many cases interventions that might "benefit" the larger society as a whole actually increase the risk some groups face. The fact that interventions often have differential effects or may not reach specific groups is common across most hazards and contexts. In many situations the factors causing vulnerability are not as direct or immediately evident as in the flooding example given above. Instead, vulnerability may be related to culturally based gender differences (women can be more vulnerable to floods due to cultural inhibitions on swimming or clothing styles), differential access to basic services (you cannot call for help as effectively if you do not own a phone), and a host of other factors. As a result, clear understanding of patterns of vulnerability is essential to identifying effective risk reduction strategies. This understanding needs to move beyond the immediately evident exposure to specific hazards and address deeper systemic factors that shape risk for different groups. Furthermore, we believe it is important for approaches to vulnerability analysis to be based on common metrics—indices, maps and disaggregated data—in order to provide an effective basis for planning and decision-making. At present most approaches to vulnerability analysis are narrative based. Because of this they are difficult to map in ways that illustrate the concentration or diffusion of vulnerable groups. They are also difficult to aggregate and disaggregate in ways that assist in identifying common factors contributing to vulnerability across large areas or multiple groups. For these reasons, we have developed the semi-quantitative vulnerability index developed as part of the Risk to Resilience Project (for more detail see Risk to Resilience Working Paper No. 2).

The concept of vulnerability has been one of the most insightful and influential additions to hazards and climate change research during the last three decades. Although vulnerability is a contested term, partly because of different epistemological roots which are beyond this summary, we define vulnerability as a "*set of conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of a community to the impact of hazards*," (the Hyogo Framework, 2005-2015, adopted by the UN at the World Conference on Disasters in 2005).

While vulnerability analyses from varying intellectual and theoretical perspectives have enriched the conceptual and analytical understanding of the patterns of damage from environmental extremes, their contribution to the policy realm has been peripheral at best. Some of the reasons for the lack of integration of vulnerability in policy include:

- The dissonance between policy-makers' concerns with aggregate populations at the meso and macro national scales and vulnerability analysts' general biases towards socially differentiated household and community levels at the micro and meso scale (Mustafa, 2002 and 2004);
- Policy-makers' social positions as representatives of the prevailing political and economic structures and many vulnerability analysts' concerns with fundamental inequities of the social structures and the need for systemic change (Hewitt, 1983; Wisner et al., 2004);
- Policy-makers' need for simpler, generalized, actionable, preferably *quantitative* information for input into policy process, and the spatially and temporally nuanced, complex, generally *qualitative* information directed towards understanding causation rather than prescribing action generated by vulnerability analyses (e.g. see Swift, 1989; Bohle and Watts, 1993).

Not surprisingly, measuring vulnerability has been an ongoing challenge for researchers. Anderson and Woodrow (1989) proposed the largely qualitative Capacities and Vulnerability Analysis (CVA) matrix, which came to be one of the more influential schemas for monitoring the vulnerability of communities and households, primarily used by many influential NGOs (ActionAid, 2005; Davis, 2004). Drawing on this, we developed a quantitative Vulnerability and Capacities Index (VCI) applicable at household and community levels, with slight modifications for application in rural or urban areas.

The VCI identifies eleven most critical drivers of vulnerability and its converse, capacities, from the universe of drivers of social vulnerability identified in the literature. The index is not comprehensive, but rather indicative. Because it is concerned with persistent conditions that drive vulnerability, the index does not measure them relative to any thresholds of damage from specific hazards as some other vulnerability indices (see, for example, Luers et al., 2003 and Luers, 2005). The main thematic areas in the VCI are consistent with the thematic areas mentioned by Twigg (2007) under the theme of risk management and vulnerability reduction for resilient communities, in addition to similar quantification exercises by others (e.g., Bosher et al., 2007). The overall weight distribution of vulnerability drivers between the three

TABLE 1 | A composite vulnerabilities and capacities index for the household level in rural areas (RHH-VCI)

	Types of Vulnerability and Indicators	Vul.	Cap.
	Material Vulnerability	**35**	
1	Income Source: If 100 per cent dependent on a local level productive asset, e.g., fishing, land, shop, etc. • Lower vulnerability score by 1 for every 10 per cent of non-local income reported • Subtract 2 if the income source is stable and insensitive to local hazard. • Add 2 to the score if the income source is unstable, e.g., day labour.	10/12	
2	Educational Attainment: If no member of the household is literate • Lower vulnerability score by 1 for every 5 years of schooling of the most educated male member of the household. • Lower the score by 2 for every female member's 5 year schooling.	5	
3	Assets: If none of the assets are immediately fungible, e.g., farm implements, household items • Lower the score by 1 for every Rs. 20,000 of fungible assets, e.g., tractor, animals, savings, jewellery (to be calibrated empirically).	8	
4	Exposure: Distance from the source of prime hazard, e.g., river, coastline, landslide zone. If within the equivalent of 10-yr. flood plain • Lower the score by 1 for the equivalent of every 10-yr. flood plain residence and or assets. • Lower the score by 1 for every piece of evidence of hazard proofing, e.g., building of a house on higher plinth for floods, light construction, low cost construction which could be rebuilt with local resources.	10	
	Institutional Vulnerability	**50**	
5	Social Networks: Membership of ethnic, caste, professional or religious organization or grouping. If none, then • Lower vulnerability score by 2 for every instance of past assistance by a group/organization in adversity. • Lower multiple times if multiple organizations. • Lower score by proportion of respondents reporting the organization to be efficacious.	10	
6	Extra-local kinship ties: If no extra-local kinship or other ties which could be source of shelter and assistance during adversity • Lower the score by 2 for every immediate family member living extra-locally • Lower the score by 1 for every non-immediate family member living outside	5	
7	Infrastructure:		
	Lack of an all-weather road	4	-4
	If seasonal road then		-2
	Lack of electricity	2	-2
	Lack of clean drinking water	2	-2
	Lack of robust telecommunications (mobile coverage)	4	-4
	Lack of local medical facility	4	-4
8	Proportion of dependents in a household:		
	If the proportion is greater than 50 per cent	5	
	• Lower the number by 1 for every additional earning member	or	
	If a single parent headed household	10	
9	Warning Systems:		
	Lack of a warning system	4	-4
		or	or
	Warning system exists but people are not aware of it or don't trust it	4	-4
10	Membership of disadvantaged lower caste, religious or ethnic minority	5	
	Attitudinal Vulnerability	**15**	
11	Sense of Empowerment:		
	Self declared community leadership		-10
	or		or
	Proximity to community leadership		-10
	Proximity to regional leadership structure		-15
	or		or
	Access to national leadership structure		-15
	Lack of access to community or regional leadership	10	
	Lack of knowledge about potential hazards (lower score by 1 for every type of hazard and its intensity accurately listed by respondents)	5	
	Total Possible Vulnerability Score	**100**	

categories of material, institutional and attitudinal vulnerabilities is 35, 50 and 15%, respectively. This distribution is roughly consistent with the weights used by Vincent (2004) for measuring vulnerability of African countries: 20% for economic wellbeing and stability, 20% to demographic structure, 40% to institutional stability and strength of public infrastructure, 10% to global interconnectivity; and 10% to natural resource dependence. Since we are operating at the micro scale of households and communities, our material vulnerabilities category encompasses the first and the last two of her categories, while the demographic structure category is not as applicable. Furthermore, general distribution varies slightly as we go from household to community level and from rural to urban area VCI indices. Table 1 outlines the VCI used for households in rural areas. The scoring of categories would be different for urban areas and for assessments as the community level.

For details on scoring and more information on rationale for the different indicators as well as examples of its use in different contexts, rural/urban and at the household or community level in each context, see Risk to Resilience Working Paper No. 2. Brief descriptions of the categories are given below.

Material Vulnerabilities

A diverse livelihood strategy, rather than the quantum of income, is one of the key elements of resilience against environmental hazards (Moench and Dixit, 2004). Therefore, the diversity and stability of livelihoods is listed as a key component contributing to capacity and its converse to vulnerability in this case. In urban areas, however, diversity of income sources is a little less important than the absolute magnitude of them, because of the service and industrial based monetized economies of urban areas.

Formal education, as a driver of vulnerability, is considered as this may be a factor for gaining access to livelihood opportunities and facilities both in rural and urban areas, although the degree of importance may differ.

Fungible assets can be important in terms of helping recovery. For example, maintenance and selling of farm animals to recover from flood damage is often an important component of recovery (Mustafa, 1998). It may also include sale of valuable items, e.g., jewelry, scooters, land, etc. However, sale of these assets in some cases can seriously undermine the resource picture and mobility of the household.

Exposure to specific hazards is a component of material vulnerability, but only a component and not the whole picture (Cutter, 2000). Attention has to be on the social in addition to the physical component as well.

Institutional Vulnerability

Social networks and *social capital* have been deemed to be important contributors to building resilience and helping recovery from hazards (Fussel, 2007; Bosher et al., 2007; Twigg, 2007), particularly since they can be conduits for information, preparedness, relief and recovery.

Extra-local kinship ties, although important, are difficult to assess in terms of their quality. In the case of the recent earthquake in Pakistani administered Kashmir (PAK), there is considerable evidence that extra-local kinship ties were important in terms of moral and material support to earthquake affected areas (Khan and Mustafa, 2007). However, there is also evidence that sometimes, extra-local family members are either unable or unwilling to extend significant help to disaster victims, possibly because of their own precarious livelihood situations, and can at times become a burden in terms of social obligations rather than an asset (e.g., see Mustafa, 2004).

The *proportion of dependents in the household* is similarly considered to be an institutional vulnerability because the effects of it are institutionally mediated. Having a large family by itself is not a bad thing, because of the extra labour that comes with large families in rural settings. But dependents, particularly young children and the elderly, in the absence of social systems for taking care of them, can be a drain on family resources.

The *infrastructural measures* are similarly listed as institutional vulnerability, because they are a function of the quality of governance in a society. Warning systems are a special case where just the existence of a warning system is not sufficient, but rather its credibility and awareness is just as important.

The last category of *belonging to an ethnic minority and/or a lower caste* can be an important factor in determining vulnerability. Bosher et al. (2007), while investigating the impact of caste on vulnerability in India, found that the contribution of caste towards vulnerability was much more complex and mediated by many other factors, e.g., the characteristics of the community they lived in and the lower caste people's access to specialized social networks. Similarly, for ethnic or religious minorities, sometimes specialized networks can facilitate access to resources for relief and recovery in addition to employment and education opportunities, e.g., the Aga Khan network primarily catering to the Ismaili religious community in South Asia and Africa, various church groups helping minority Christian communities in South Asia, as well as schedule caste politicians directing state resources towards their constituencies.

Attitudinal Vulnerability

Among the attitudinal vulnerabilities, *sense of empowerment* is considered to be the key category (Delica-Willison and Willison, 2004). Proximity to local and regional power structures in addition to a personal sense of efficacy—all self perceived—is evidence of a sense of empowerment in the face of adversity. Proximity to power structures can be very effective in terms of channeling relief and recovery in the aftermath of disasters and even gaining access to government services in addition to critical productive resources which otherwise may not be possible for disadvantaged poor, minority or low caste groups (Mustafa, 2002; Bosher et al., 2007). Furthermore, knowledge about and attitude towards potential hazards can also be critical in determining behaviour and vulnerability to hazards (e.g., see Crozier et al., 2006; Burton et al., 1993).

Data to compile the VCI can be drawn either from primary sources (e.g. household surveys or focus group discussions for the community level VCI), or from secondary data sources (existing surveys). All data collection tools that we developed and used were simple enough for community researchers to adopt; the idea being that they could repeat this exercise six months or one year down the line to look at the impact of the various adaptation or DRR interventions. Before undertaking data collection, there must be thorough discussion of the scoring technique amongst field team members. Scoring should be done by at least two field researchers, particularly for some of the more difficult calibrations on livelihoods, assets and exposure. We also recommend that scores and their rationale are discussed in the group before being finalized, and the discussions thoroughly documented before being shared with a wider audience.

In sum, formulation of an index of anything is invariably an exercise in generalization; one is bound to exclude what many may consider important variables, and present a static snapshot of a dynamic reality particularly when it comes to such a concept as vulnerability. While the impact of the full conceptual and analytical weight of vulnerability may indeed be reduced by a quantitative measure, the communicative impact of the VCI, particularly in a comparative sense and in terms of relaying critical information for non-expert policy-makers, cannot be underestimated. The VCI as it has been developed and field-tested here, can be used by NGO teams and community animators to collect baseline information on vulnerability in a village or urban community so as to not only target specific interventions and limited resources at vulnerable households, but also to later monitor impacts and outcomes of the same. In looking at vulnerability at both the household and community level in a given context, whether urban or rural, the VCI provides an objective understanding of the differential dimensions of vulnerability. However, as with all quantitative indicators, the VCI is only an approximate measurement of reality and not *the* reality. Hence, its use ideally must be supported by narrative exploring the complex social and institutional context underlying the measurement of vulnerability.

Results from a comprehensive vulnerability analysis using the above index can be mapped using geographic information systems or statistically analyzed in order to identify groups where vulnerability is concentrated. They can also be disaggregated to show the mix of factors why groups are identified as more or less vulnerable than others. When used in SLDs, the results from this type of analysis provide a solid basis for identifying specific factors that appear to contribute to risk as well as their relative importance or weight. This, in turn, provides a tangible basis for identifying and justifying specific intervention strategies to address risk.

Processes for Qualitative Evaluation and Prioritization of Risk Reduction Measures

Once an array of potential avenues for responding to risk have been identified through a combination of scoping, SLDs and vulnerability analysis, these options need to be evaluated in a systematic manner to understand tradeoffs and potential costs and benefits for different vulnerable groups. At a minimum, the types of qualitative evaluation described in this section should be undertaken. If it is viewed as important and sufficient resources (data, financial and human) are available this can provide the basis for a full cost-benefit analysis.

Initial Evaluation

The qualitative evaluation should subject specific interventions to a number of critical questions:

1. **Can the relationship between the proposed intervention and the risks faced by communities be clearly demonstrated?** This may seem obvious but in practice the connection between implementation activities and risks is often not clear or direct. Key questions to consider include:
   - Does the strategy affect risk by directly targeting the impact of a hazard event (e.g. by reducing damage to buildings or keeping flooding out of an area) or through systemic changes in vulnerability (e.g. by encouraging livelihood diversification or improving communications)?
   - If the strategy directly targets specific hazard events, are they the most important hazards? Will targeted interventions be sustainable given the anticipated frequency of events? (e.g. will changes in building regulations "last" if earthquakes are extremely rare?)
   - If the strategy focuses on systemic changes, do interventions relate to specific risks? (e.g. do improvements in general communications systems actually improve early warning capacities?)

2. **Does the proposed strategy have major distributional implications?** When DRR strategies are implemented there are often clear winners and losers. For example, in the case of embankments for flood protection, those living in areas between the levies "lose" (i.e. they are subject to more flooding) while those living in areas protected by the levies "gain". Similar differential impacts also exist with mechanisms such as insurance or zoning that tend to benefit wealthy groups, in some cases at the expense of those less well off.

3. **Is the strategy accessible to the intended beneficiaries?** Insurance, for example, may not be affordable for the poorest sections of society, or for women who may lack collateral, however much they might benefit from it. Similarly, early warning systems may only serve that portion of the population that has regular access to specific technologies such as cell phones or radios.

4. **Is the proposed strategy based on a sustainable operational model?** In many situations, interventions to reduce risk are not sustainable over the indeterminate, and often long period, between events. In Pakistan, for example, building codes were established following the 1975 Quetta earthquake. These codes existed only on paper and in the memory of a few actors by the time the earthquake in Muzafarabad/ Kashmir occurred in 2005. Similar challenges exist with other types of interventions as well. Expensive "high-tech" interventions (such as tsunami warning systems) often suffer from lack of maintenance between events. Unless a clear operational model ensures risk responses remain alive between events, then the viability of such responses is highly questionable. Here, systemic interventions may have a substantial advantage over interventions targeted at specific hazards. Many systemic interventions (such as the improvement of communication, transport, education and financial systems) serve multiple immediate purposes and are maintained by the business models associated with those services. This is a distinct contrast to more targeted

interventions (such as flood warning systems or earthquake building codes) that may need public funding for ongoing maintenance.

5. **Is the strategy consistent with emerging and projected social or other trends?** As illustrated in the cases in this volume, climate change may reduce or increase the effectiveness of different strategies. However, the effectiveness of strategies also can be affected by social trends. Community based risk reduction strategies, for example, may face major challenges where migration or other major economic or demographic shifts increase mobility and reduce the links and commonalities between individuals living in vulnerable regions. Similarly, strategies reliant on government inputs may not be viable in regions where formal institutions are weak, disrupted or limited by declining financial, technical and other resources.

6. **Is the effectiveness of the proposed strategy dependent on key assumptions or threshold values that may be incorrect or change?** In the case of flood control, the viability of embankments and other protective structures depends heavily on the specific frequency and magnitude of projected flood events. If flood events exceed embankment design criteria then the partial protection provided by such embankments may actually increase the ultimate scale of disasters by providing an illusion of protection and encouraging settlement and investment in the "protected" areas. The effectiveness of some types of interventions depends heavily on specific assumptions while others are much more robust under uncertainty. This is particularly important in the case of weather related disasters since climate change processes undermine the reliability of many basic projections regarding flood, storm and drought frequency, intensity and duration.

7. **Are the capacities for implementing a given strategy readily available or can they be easily developed?** In many situations, strategies are developed based on the assumption that either technical or institutional resources are available. This may range, for example, from data availability to law enforcement. However, these resources or capacities may not exist or be developed easily.

8. **Are there additional questions beyond the above that relate to the viability of proposed strategies in the specific region of concern?** All risks are ultimately inherently local. In all situations, additional criteria should be added.

The evaluation process involves direct input from participants in SLDs. It is through discussions of different perspectives on potential options with community members, technical specialists and other key actors, that key advantages and constraints associated with each option—i.e. the answers to the above test criteria—become clear. This qualitative comparison of potential strategies can be facilitated by constructing a matrix listing potential interventions on the vertical axis, and responses to the above test criteria on the horizontal axis. In the example below, clear answers supporting the strategy are green, answers not supporting a viable strategy are red, and major questions are blue. This evaluation provides a fairly robust, although preliminary, indication of strategies that are likely to be viable, others where significant questions remain to be resolved, and a final set where problems are known to exist that are likely to undermine the strategies effectiveness.

TABLE 2 | Qualitative comparison matrix

Potential Implementation Strategies (examples)	Answers to test criteria (numbers in relation to bulleted criteria above)							
	1	2	3	4	5	6	7	8
Embankments for flood control	Y	Y	?	?	Y	Y	?	?
Early warning system as part of cell network	Y	N	Y	Y	Y	N	?	?
Dedicated flood early warning system	Y	N	?	N	?	N	?	?
Encouraging drainage and maintaining flood plains	Y	N	Y	?	?	N	N	?
Building small protected areas and structures	Y	N	Y	?	Y	N	N	?
Improve banking and financial systems	?	?	?	Y	Y	?	?	?
....								
.... (More strategies can be added)								

Prioritization and Ranking

Simple matrix-based ranking techniques in focus group and SLD processes can also be used to prioritize alternative strategies reflecting social perceptions of their relative costs and benefits. Groups rank the relative costs and benefits of each response measure in relation to their impacts on both hazard specific and more general risks. Discussions on the reasons for their ranking rapidly lead to identification of benefits that are high-benefit and low-cost. Because perceptions of costs and benefits will differ among and between communities, these ranking exercises should be conducted along transects of communities with diverse stakeholders.

Example of Cost and Benefit Matrix Exercise

1. List possible actions to reduce climate risks in the first column. Suggestions should emerge from the SLD participants, then facilitators may also list potential interventions.
2. The group ranks options on a scale of 1 to 10 in relation to how effective they might be in reducing climate risk and impacts (1 = low effectiveness; 10 = high)
3. The group ranks interventions on a scale of 1 to 5 in terms of cost (1 = low cost, 10 = high cost). This cost should include not just the financial cost of the intervention but also any negative impacts or "disbenefits" it may have.
4. Questions to the group to probe reasons behind ranking: Why are certain interventions likely to be more or less effective? Why do you think they will be more or less cost?

While ranking ratios between benefits and costs do not actually reflect economic returns, they do indicate social perceptions of the types of intervention that are likely to be most effective in relation to the level of investment required. In combination with the other analyses and SLD outputs, this may provide sufficient information to choose effective strategies. For large investments, however, more systematic quantitative evaluation of costs and benefits are important as these may differ from community perceptions. In the Pakistan case study (Chapter 5 this volume) the specific early warning system implemented was shown to have a very low benefit/cost ratio, quite different from the ranking ratio shown in Table 3.

This approach can be complemented by other qualitative ranking methods. For example, in the Nepal case study (Chapter 4 this volume) a simple +/- system was used along a series of transects to assist local populations in identifying the costs and

TABLE 3 | Qualitative ranking (illustrative)

Potential Intervention	Effectiveness/Benefits	Cost	Ranking Ratio
Embankments for flood control	5	10	0.5
Early warning system as part of cell network	8	4	2.0
Dedicated flood early warning system	4	8	0.5
Encouraging drainage and maintaining flood plains	9	10	0.9
Building small protected areas and structures	8	6	1.3
Improve banking and financial systems	6	3	2.0

benefits of specific risk mitigation measures across flood-affected areas. SLDs were held at regular points along the transect where local groups weighed each of the costs and each of the benefits as small, medium, or large, using between one and three +/- symbols to indicate relative magnitudes. Discussions emphasized both direct costs (e.g. amount invested to construct embankments, to buy a boat or raise the level of houses) and indirect costs (e.g. losses due to water logging outside embankments). In addition, costs and benefits related to both tangible indicators of wellbeing (e.g. secure drinking water, food and shelter) as well as those less tangible indicators (e.g. livelihood resilience, social equity, clean environment). Implementing this approach along several communities with different actors enabled development of a systematic picture of perceived benefits and costs of each set of interventions for the region as a whole.

In sum, qualitative evaluations result in:

a) a list of potential strategies that respond to hazards or contribute to strengthening the resilience of individuals and communities;
b) a list of direct and indirect benefits and costs associated with each strategy; and
c) relative weighting of costs and benefits of various strategies indicating societal perceptions of those interventions that may be the most viable.

Results should be discussed with key actors through SLDs in order to identify next steps and forward directions based on the analysis. Particular attention may be paid to the viability of strategies under projected climate change scenarios. This qualitative evaluation provides a foundation for quantitative cost-benefit analysis if desired.

Quantitative Methodologies

Moving beyond qualitative approaches to evaluation, such those described in the preceding section, represents a significant shift in the level of data, analysis and information required. As a result, time and analytical capacity requirements—and consequently cost—increase. Whether or not to proceed with quantitative analysis requires careful evaluation of the degree to which the analysis will inform the choice of risk management strategies and whether or not the types of information desired can actually be produced. As the Pakistan and India case studies (Chapters 5, 6 and 7 this volume) illustrate, even with substantial quantitative data, cost-benefit analyses for risk reduction often require numerous assumptions and estimates. Furthermore many of the costs and benefits associated with disasters and alternative risk reduction strategies cannot be easily measured. Consequently, despite substantial data collection, such analyses are not complete. This said, quantification and the process required to do so, can fundamentally alter understanding of the effectiveness and the underlying factors affecting cost and benefit magnitudes.

Many types of quantitative analysis can generate information required for evaluating the costs and benefits of climate and disaster risk. These range from basic hydrologic modelling (essential for projecting flood impacts) to extensive field surveys designed to collect basic data on assets, demographic characteristics, disease, etc. Cataloguing and discussing all these methodologies is beyond the scope of this summary. Instead, we briefly introduce methods for projecting future climate conditions (discussed in more detail in the following chapter), and focus discussion on quantitative cost-benefit analysis. Climate change, although highly technical, needs to be considered in analysis of risk reduction to different potential climate futures with regard to weather-related hazards.

Climate Downscaling

In order to understand the manner in which floods, droughts, storms or other weather related disasters may change as climatic conditions evolve, analysis is limited by the current state of scientific understanding. Projections, such as those synthesized by the IPCC in its reports, are very general discussing trends and broad patterns of change. Also, there is a lack of scientific consensus about models and future projections, resulting in uncertainty. Moving beyond general projections requires familiarity with the scientific literature on climate change and the ability to scale the scenarios that can be generated using large-scale General Circulation Models (GCMs) to the specific area and hazard of concern. Still, the resolution of the GCMs (100km-200km) is too broad to be of use in developing specific disaster risk reduction and adaptation measures. In the India cases (Chapters 6 and 7), a climate downscaling model was used to project conditions under different climate scenarios. The flood and drought models used for estimating weather related hazards within river basins require climate information at a much smaller geographic scale. Hence, the ability of cost-benefit analysis and other techniques to assess the economic viability of DRR investments requires probabilistic information (frequencies and magnitudes) of potential events such as floods and droughts.

The climate downscaling model employed in the project involved a statistical technique to relate large-scale climate information, such as wind or atmospheric pressure, to rainfall patterns in the Rohini basin in Uttar Pradesh, India. The model produced potential future climate scenarios against which cost and benefits of interventions for disaster risk reduction were assessed. Details of the methods and results of this climate downscaling method are described in the following chapter. However, it is important to highlight that the downscaling method:

a) provides evidence that realities likely to be experienced in specific basins or locations differ greatly from broad climate projections. This is critical for discussing specific response strategies; and
b) generates a range of scenarios in which cost-benefit analysis for interventions may help determine robustness of the strategy. If cost-benefit results are positive under all future scenarios, then confidence is much higher than if they are positive under only a portion of scenarios.

However, given that uncertainty inherent in projections of future climate conditions is very high, probabilistic approaches to cost-benefit analysis can be used to generate scenarios but not forecast probable returns. As a result, while still reflecting estimates of potential economic returns from DRR investments, the inherent uncertainty and scenario characteristics of such cost-benefit analyses must be transparently reported.

Cost-Benefit Analysis: Quantitative Decision Support for Assessing the Costs and Benefits of Disaster Risk Management

Why Cost-Benefit Analysis?

Cost-benefit analysis is an economic technique used to organize, appraise and present the costs and benefits, and inherent tradeoffs of public investment projects and policies taken by governments and public authorities in order to increase public welfare. Broadly speaking, if benefits exceed costs, then an investment/project should be undertaken. The task of cost-benefit analysis is to systematically assess the costs and benefits and check whether social welfare is indeed maximized. Its main strength is its explicit and rigorous accounting of gains and losses that can be effectively monetized, and in so doing, making decisions more transparent.

In the context of DRR, two important issues deserve additional attention when undertaking a cost-benefit analysis:

1. **Risk:** The analysis should be performed in a stochastic manner in order to account for the specific nature of natural hazards and associated disaster impacts. That is, analyses must take into account the probability of future disaster events occurring. As discussed above, the substantial uncertainty inherent in most projections of climate change complicates such an analysis.

2. **Benefit:** The core benefits generated by investments in disaster risk management are the avoidance and reduction in impacts and losses. Consequently, assessments focus on the downside risk (i.e. adverse outcomes) to benefits created by prior investments.

BOX 1

Surveying floods and risk reduction in Uttar Pradesh, India

For the cost-benefit analysis these aspects are ultimately needed in financial values, with social and environmental factors often being difficult to monetize. Despite intense data acquisition efforts, data availability and quality often become key issues in determining not only the analysis structure, but also the robustness of the results. This is especially true when possible climate change impacts are considered. For example, in the Uttar Pradesh flood analysis (Chapter 6 this volume), data shortfalls greatly affected the final cost-benefit analysis. Table 5 summarizes key data elements required just for the flood risk analysis in the Rohini Basin, highlighting the issues that arose.

In many cases, assumptions need to be made to account for insufficient data. These should be based on some real information, whether direct or proxy data, and transparent in the analysis.

Data Collection

By definition, quantitative cost-benefit analysis requires data to sufficiently reflect current and future risk, as well as the costs and benefits of the strategy being analyzed. Data are usually acquired primarily from secondary sources, such as government agencies, NGOs and other organizations working or monitoring in the area. If insufficient, data can also be collected through direct surveying of stakeholders, but as described in Box 1, gathering appropriate and sufficient data through surveys can be a resource-intensive undertaking.

TABLE 5 | Data requirements and issues for the Rohini Basin flood risk analysis

Key Data Required	Issues
Past flood losses	Secondary data incomplete, survey data likely not representative of full basin. Only two events available.
Maps of flooded areas	Some satellite photos available, insufficient resolution for analysis.
Basin topography	Topographical maps of insufficient and mismatched resolution. Only one cross-section available for the entire river.
Hydrometeorologic time-series	Rainfall data was available only for the Nepali side of the Rohini Basin, but its validity was unknown. Significant gaps exist in the streamflow data of the Rohini River and the record is short. Both rainfall and streamflow datasets had to be corrected and estimates used to fill significant gaps.
Embankment details including past performance	Failure data limited, specific maintenance information not available.
Demographic information	Recent census at village level but projected future trends only available at state level.
Ongoing flood risk reduction activities (explicit and/or autonomous)	Very limited information, some trends on autonomous risk reduction could be inferred from surveys (primarily housing dynamics).
Climate change projections	Downscaling of regional climate model results and transformation into changes in flood regime highly uncertain.

Quantitative data are needed to describe all aspects of disaster risk reduction:

- Current hazard and vulnerability
- Information to support estimates of future hazard and vulnerability
- Costs (capital and recurring annual) of disaster reduction strategies
- Benefits of disaster reduction strategies
- Possible disbenefits (negative impacts) of disaster reduction strategies

For the cost-benefit analysis these aspects are ultimately needed in financial values, with social and environmental factors often being difficult to monetize. Despite intense data acquisition efforts, data availability and quality often become key issues in determining not only the analysis structure, but also the robustness of the results. This is especially true when possible climate change impacts are considered. For example, in the Uttar Pradesh flood analysis (Chapter 6 this volume), data shortfalls greatly affected the final cost-benefit analysis. Table 5 summarizes key data elements required just for the flood risk analysis in the Rohini Basin, highlighting the issues that arose.

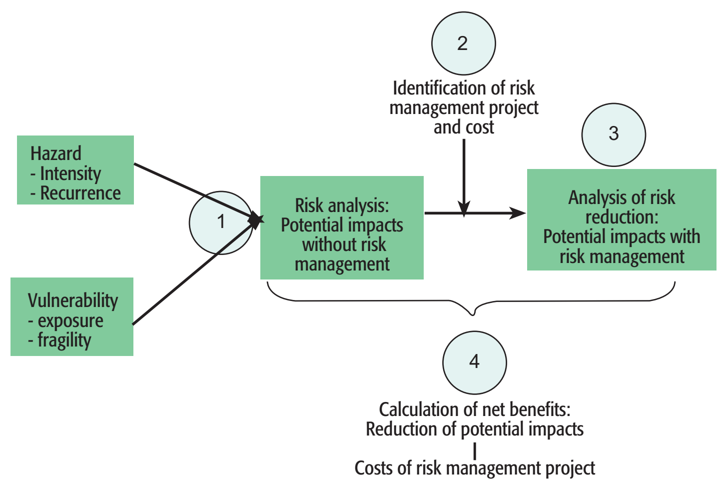
In many cases, assumptions need to be made to account for insufficient data. These should be based on some real information, whether direct or proxy data, and transparent in the analysis.

Analysis

In this project, the cost-benefit analysis has been operationalized in four steps (see Figure 3):

1. **Risk analysis:** risk in terms of potential impacts without risk management was estimated. This entailed estimating and combining hazard(s) and vulnerability.
2. **Identification of risk management measures and associated costs:** based on the assessment of risk, potential risk management projects and alternatives and their costs were identified.
3. **Analysis of risk reduction:** benefits of reducing risk were estimated.
4. **Calculation of economic efficiency:** economic efficiency was assessed by comparing benefits and costs.

| FIGURE 3 | **Framework for operationalizing risk-based cost-benefit analysis**



These four steps are now reviewed in greater detail.

STEP 1: Risk analysis

Risk is commonly defined as the probability of potential impacts affecting people, assets or the environment. Natural disasters may cause a variety of effects that are usually classified into social, economic, and environmental impacts, as well as according to whether they are triggered directly by the event or occur over time as indirect or macroeconomic effects.

The standard approach for estimating natural disaster risk and potential impacts is to analyze natural disaster risk as a function of hazard, exposure and vulnerability:

- *Hazard* analysis involves determining the type of hazards affecting a certain area with specific intensities and recurrence periods in order to derive a statistical representation of the hazard.
- The *exposure* of people and property to a certain hazard needs to be identified next. This involves assessing quantities and locations of people, property, assets, infrastructure, natural resources and any other items of utility possibly impacted by the given hazard future. Accounting for changes in exposure is important, such as those based on socio-economic trends, as reductions in future damages and losses often may be compensated by the sheer increase in people and assets in harm's way.
- In order to operationalize and quantify *vulnerability* for cost-benefit analysis, it can be defined more narrowly as the degree of impact observed on people and exposed elements as a function of the intensity of a hazard.
- *Resilience* plays a key role in defining vulnerability, but it is difficult to capture the numerous contributing factors in quantitative terms (such as availability of organizational structure and knowledge to prevent and deal with disasters). As a result, in quantitatively oriented assessments, resilience often is not addressed effectively. This is, again, a major reason for coupling quantitative techniques with more qualitative assessment measures and processes.

Combining hazard, exposure and vulnerability leads to risk and the potential impacts a natural disaster may trigger. Risk is commonly defined as the probability of a certain event and associated impacts occurring. While potentially there are a large number of impacts, in practice, only a limited number of those can be, and are, usually assessed. Table 6 presents the main indicators for which at least some data usually can be found.

TABLE 6 | Summary of quantifiable disaster impacts/benefits

	Monetary		Non-monetary	
	Direct	**Indirect**	**Direct**	**Indirect**
Social				
Household			Number of casualties Number of injured Number affected	Increase of diseases Stress symptom
Economic				
Private Sector Household	Housing damaged or destroyed	Loss of wages, reduced purchasing power		Increase in poverty
Public Sector Education Health Water and sewage Electricity Transport Emergency spending	Assets destroyed or damaged: building, roads, machinery, etc.	Loss of infrastructure services		
Economic Sectors Agriculture Industry Commerce Services	Assets destroyed or damaged: building, machinery, crops, etc.	Losses Due to reduced production		
Environmental			Loss of natural habitats	Effects of biodiversity
Total				

| TABLE 7 | Categories and characteristics of disaster impacts

Categories of impacts	Characteristics
Direct	Due to direct contact with disaster, immediate effect
Indirect	Occur as a result of the direct impacts, medium-long term effect
Monetary	Impacts that have a market value and will be measured in monetary terms
Non-monetary	Non-market impacts, such as health or environmental impacts

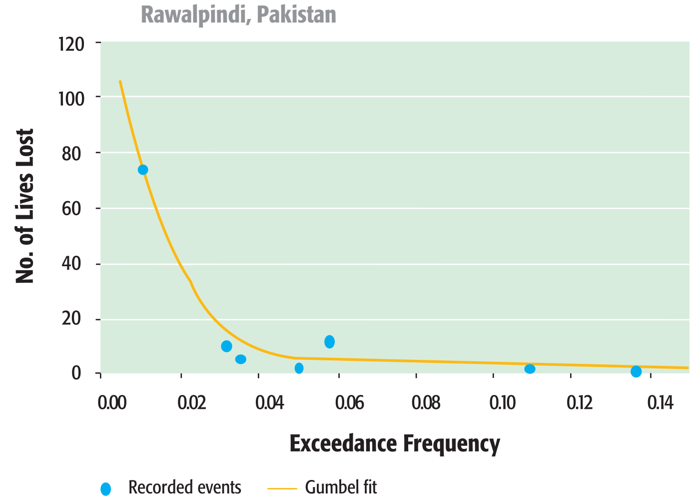
The list of indicators is structured around the three broad categories: social, economic and environmental, whether the effects are direct or indirect and whether they are originally described in monetary or non-monetary terms (Table 7).

Disaster risk so far has been defined as the probability of potential impacts affecting people, assets or the environment. If the probability of events and impacts can be determined, one talks of *risk* ("measured uncertainty"); if probabilities cannot be attached to such events, this is the case of *uncertainty.*

A standard statistical concept for the representation of natural disaster risk is the loss-frequency curve, which indicates the probability of an event not exceeding a certain level of damages *(exceedance probability)*. Another important concept is the inverse of the exceedance probability, the *recurrence period*. For example, an event with a recurrence period of 100 years will on average only occur every 100 years. This is a standard statistical concept allowing calculation of events and their consequences in a probabilistic manner. A 100 year event could also occur twice or three times in a century, the probability of such occurrences however being low. In order to avoid misinterpretation, the exceedance probability is often a better concept than the recurrence period. Figure 4 shows an example of a loss-frequency curve for floods in the Lai River in Rawalpindi, Pakistan.

An important property of loss-frequency curves is the area under the curve. This area (the sum of all damages weighted by its probabilities) represents the *expected annual value of damages,* i.e. the annual amount of damages that can be expected to occur over a longer time horizon. This concept helps translate infrequent events and their potential damages into an annual number that can be used for planning purposes. In a typical stochastic cost-benefit analysis, benefits reflect the potential reduction of expected annual value of damages every year.

| FIGURE 4 | Loss-frequency curve for floods on the Lai River in Rawalpindi, Pakistan



STEP 2: Identification of risk management project and costs

The selection and design of appropriate risk management options are discussed in the processes and qualitative methodologies sections of this report. The costs in a cost-benefit analysis are the specific costs of conducting a project. There are the financial costs, the monetary amount that has to be spent for the project. There are also *opportunity costs*, which are the benefits foregone from not being able to use these funds for other important objectives. These opportunity costs, generally captured within the discount rate, are discussed later.

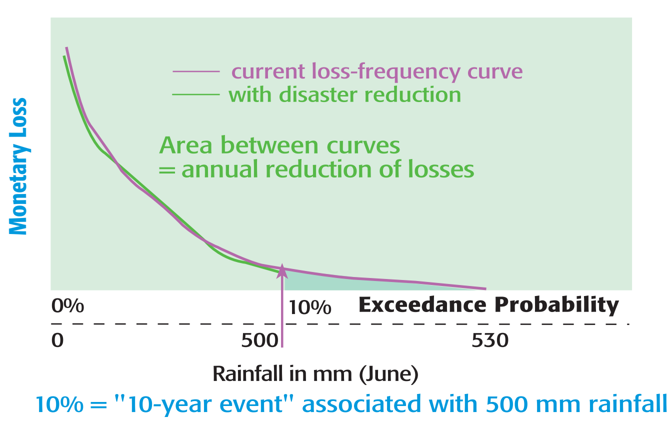
Key information on risk management measures required for quantitative cost-benefit analysis includes:

- the exact type and design of the DRR intervention under consideration,
- its planned lifetime,
- the costs including investment/capital costs, maintenance/operations costs, planned funding sources and
- possibly information on planned funding sources, and
- potential additional (non-DRR) benefits and negative impacts.

Usually there are major initial or capital outlays for the investment effort (e.g. building embankments), followed by smaller maintenance and operational expenses that occur over time (e.g. maintaining embankments). Alternatively, risk transfer measures usually demand a constant annual payment (e.g. insurance premium guaranteeing financial protection in case of an event.) These costs normally can be determined in a straightforward manner as market prices exist for cost items such as labour, material and other inputs. Some uncertainty in these estimates usually remains as prices for inputs and labour may be subject to fluctuations. Often, project appraisal documents make allowance for such possible fluctuations by varying cost estimates by a certain percentage when appraising the costs.

STEP 3: Analysis of risk reduction: Potential impacts with risk management
Next, the benefits of reducing risk are estimated. Whereas in conventional cost-benefit analyses of investment projects, benefits are additional outcomes generated by the project compared to the situation without the project, in the DRR case, benefits are the risks that are reduced, avoided or transferred.

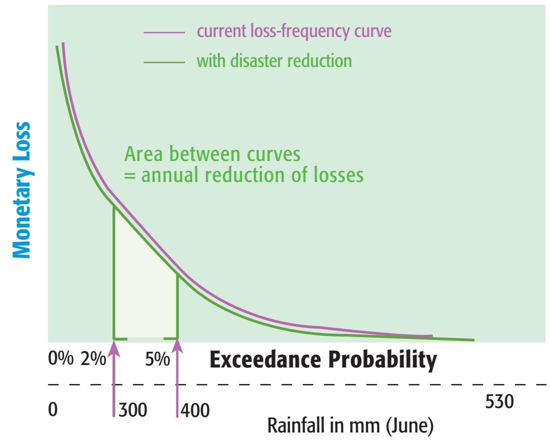
FIGURE 5A | Mechanics of irrigation in the UP case



The effect of interventions on risk needs to be evaluated and represented as a new, changed loss-frequency curve. To assess potential returns from the intervention, this new "with intervention" loss-frequency function must be compared to that of the original "without intervention". Risks may be completely avoided, reduced, or transferred. As an illustrative example, we consider the Uttar Pradesh case on drought risks to farmer livelihoods (Chapter 7 this volume). Disaster risk reduction interventions considered in this case study involve irrigation and insurance. As can be seen in Figure 5A and 5B, the mechanics of how these interventions reduce the area under the loss-frequency curve differ. The ultimate benefits are computed as the green areas in Figure 5A & 5B, representing the expected average annual reduction in losses.

In addition to benefits, DRR options may also create negative impacts, or "disbenefits." For example, water logging caused by flood control embankments, resulting in losses of productive agricultural land and increases in waterborne health problems. These negative benefits need to factored in computations of benefits. While they can be calculated as costs (and as they represent negative monetary flows it may appear more appropriate to do so) in order not to confuse disbenefits with the fixed and variable costs of an intervention, it is more appropriate to treat disbenefits as negative benefits.

| FIGURE 5B | Mechanics of insurance intervention in the UP case



Insurance may protect from 20-year (5% probability) to 50 year (2% probability) drought

STEP 4: Calculation of economic efficiency

The final step is to assess economic efficiency by comparing the benefits and costs associated with interventions to reduce risk. Costs and benefits arising over time need to be discounted to render current and future effects comparable. From an economic point of view, $1 today has more value than $1 in 10 years. Thus, future values need to be discounted by a *discount rate* representing the preference for the present over the future. Last, costs and benefits are compared under a common economic efficiency decision criterion to assess whether benefits exceed costs. Generally, three decision criteria are of major importance in cost-benefit analyses:

- **Net Present Value (NPV):** costs and benefits arising over time are discounted and the difference taken, which is the net discounted benefit in a given year. The sum of the net benefits is the NPV. A fixed discount rate is used to represent the opportunity costs of using the public funds for the given project. *If the NPV is positive (benefits exceed costs), then a project is considered desirable.*
- **Benefit/Cost Ratio:** The B/C ratio is a variant of the NPV. The benefits are divided by the costs. *If the ratio is larger than 1, i.e. benefits exceed costs, a project is considered to add value to society.*
- **Internal Rate of Return (IRR):** Whereas the former two criteria use a fixed discount rate, this criterion calculates the interest rate internally, representing the return on investments of the given project. *A project is rated desirable if this IRR surpasses the average return of public capital determined beforehand (for example, 12%).*

In most circumstances, the three methods are equivalent. In this project, due to its intuitive appeal, we mostly focus on the benefit/cost (B/C) ratio.

Table 8 shows the cost-benefit calculations for a river channel improvement project on the Lai River in Rawalpindi, Pakistan. In this engineering-driven project, initial capital costs (i.e. construction) were large, followed by lesser annual maintenance and operations costs. Benefits begin to accrue only in the second year, after completion of construction,

| TABLE 8 | Cost-benefit analysis of river channel improvements in the Lai Basin, Rawalpindi, Pakistan

Strategy/ Intervention	Net Present Value of Investment*	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

* Pakistan Rupees in Million

Projects duration = 30 years
Social discount rate = 12%

and increase over time due to increases in exposure (in this case based on population projections). In other words, as more people move and property develops in the area under protection, benefits increase because greater potential losses are being reduced.

The effects of the discount rate can be most clearly seen in the costs; in this case 12% was used. When discounted, the constant maintenance cost from 2009 reduces to negligible values over time (compare "Costs" with "Discounted costs" columns).

It can be seen that with a net present value of PKR 10,976 million (greater than 0), benefit/cost ratio of 1.88 (greater than 1.0) and internal rate of return of 27.6% (greater than the chosen discount rate of 12%), the project is considered economically efficient by all decision criteria. The discount rate has a key influence on the results: if a discount rate of 0% is applied, the B/C ratio increases to 3.87, while with a discount rate of 20%, the B/C ratio is 1.30.

Given the many uncertainties inherent in a quantitative cost-benefit analysis, it is prudent to perform a sensitivity analysis. By varying the assumed costs and benefits as well as the discount rate over a range, the robustness of the results can be tested. In the example above, if under a "worst case" assumption the benefits are reduced by 25% and the costs increased by 25%, the B/C ratio at a 12% discount rate becomes 1.13, and at a discount rate of 20% it is 0.78, below the economic efficient threshold. As the B/C-ratio is near the threshold of 1.0, it should be concluded that the confidence in potential efficient economic performance, is not too high. Results of stochastic cost-benefit analysis should be viewed in terms of orders of magnitude rather than exact values.

Limitations of Cost-Benefit Analysis

Experience has shown that cost-benefit analysis faces major limitations, particularly in the context of disaster risk management (Benson and Twigg, 2004; Mechler, 2005):

- Cost-benefit analysis requires some *assessment of non-market values*, such as health and the environment. Although methods exist for quantifying these in economic terms, this often involves making difficult ethical decisions, particularly regarding the value of human life for which cost-benefit analysis should be used with great caution.
- The issue of *discounting*. In economic calculations, future benefits are discounted in relation to current benefits to reflect the cost of capital (generally the equivalent of long-term interest rates). This is justified on the assumption that the current value of future benefits from investments should be compared to existing secure investment alternatives for the same funds. Applying high discount rates expresses a strong preference for the present while potentially shifting large burdens to future generations.
- It is *difficult to quantify some of the benefits* that DRR interventions have on the community. For example, collective mobilization to reduce risk through village disaster management committees, building confidence in dealing with external government agencies, and empowering women are all important benefits of DRR. While in the long run they reduce the vulnerability of communities and strengthen their capacity to deal with disasters, they are not easily quantifiable or given financial values.
- Cost-benefit analysis relies on the best available information, which in developing countries is often problematic with *data being non-existent, unreliable or simply*

difficult to access. It is particularly difficult to access data viewed by the state as "confidential" and affecting national security.

- Cost-benefit analysis *depends on a number of assumptions*, some of which can be tested through sensitivity analysis, while others are driven by possibly diverging opinions and can significantly affect the results. This is particularly evident in the case of climate change, where high levels of uncertainty exist regarding future conditions.
- The *lack of accounting for the distribution of benefits and costs* in cost-benefit analysis. In calculations, benefits and costs are considered of society as a whole rather than differences among individuals. A focus on *maximizing* welfare, rather than *optimizing* its distribution is a consequence (Dasgupta and Pearce, 1978). Changes in outcomes of "winners" are lumped together with those of "losers", and compensation between those two groups is not required. Moreover, as often perceptions on who "loses" or "wins" is subjective, cost-benefit analysis cannot resolve strong differences in value judgments that are often present in controversial projects (e.g., nuclear power, bio-technology, river management, etc.). This issue has been a major reason that the project ensured distributional factors were incorporated in the qualitative analyses and SLDs. Generally, it is advisable to use cost-benefit analysis in conjunction with other decision support methods, such as cost-efficiency analysis or multi-criteria analysis.

Despite the above challenges, cost-benefit analysis can be a useful tool in DRR if a number of issues related to its conduct and use of results are properly taken into consideration.

Clarify objectives of conducting a cost-benefit analysis on DRM

It is necessary at the outset to clarify the objective(s), foreseen process, information requirements and data situation among the different potential stakeholders, and the analysis and process should be closely linked to its potential users. A cost-benefit analysis may be conducted for informational purposes (such as in the Lai Basin case Chapter 5), for a pre-project appraisal (similar to the India Uttar Pradesh flood study Chapter 6), as a full-blown project appraisal (the India Uttar Pradesh drought Chapter 7) or as an ex-post evaluation (presented in the India Uttar Pradesh flood study as well). Necessary resources, time commitments and expertise required differ significantly for these products. At a very early stage of the process, it is critical to achieve consensus among the interested and involved parties on the scope of the cost-benefit analysis to be undertaken.

Acknowledge complexities of estimating risk

Estimating disaster risk and the costs and benefits of risk management is inherently complex, with climate change adding more uncertainty or "noise" to the system. Disasters are inherently stochastic and, as a consequence, benefits from risk reduction are probabilistic, arising only in case of an event occurring. Accordingly, benefits should be assessed in probabilistic risk terms, requiring estimates of hazard, vulnerability and exposure. While great progress has been made in better understanding and modelling disaster risks, climate change will affect the nature and frequency of many hazards (such as rainfall, cyclone occurrence and intensity). This adds both complexity and uncertainty to any cost-benefit analysis of weather-driven risk management, due to the inherent difficulties of modelling the climatic system and anthropogenic interventions.

Probabilistic estimates of future disaster risk incorporating climate change considerations may sometimes not be possible due to a lack of reliable information. Even with sound understanding of the system as a whole, analysis relevant for DRR and cost-benefit analysis can also be difficult due to lack of expertise and operational resources. Methodological shortcuts often have to be applied to arrive at a broader understanding of key risks and benefits of DRR. These specific challenges and characteristics of DRR need to be transparently communicated and clearly understood in order to properly interpret results derived in a cost-benefit analysis.

Process-orientation

Given the complexities involved in estimating the costs and benefits of DRR and the historical and current usage of cost-benefit analysis as a decision support tool, it seems appropriate to conclude that the focus should be strongly on *process* rather than *outcome*. Cost-benefit analysis is a useful tool for organizing, assessing and finally presenting the cost and benefits, and pros and cons of interventions, and it demands a coherent methodological, transparent approach. Yet, given the difficulties of properly accounting for extreme event risk and climate change, cost-benefit analysis is likely not as well suited to be employed as a purely outcome-oriented tool in DRR, at least in environments where data are limited—a common case in development cooperation. The evaluative process involved in conducting a cost-benefit analysis is generally more important and more reliable as a basis for decision-making than the final computed benefit-cost ratios.

If this is properly understood, the key role it can play in DRR becomes clear. In many ways, cost-benefit analysis represents a process for organizing and evaluating information on interventions to reduce risk in ways that can lead to common understanding and provide a basis for decision-making. To achieve this, however, organization of the process is as important as the analytical results it generates. SLDs facilitate this process, by bringing together the perspectives of diverse community, expert and government groups, and can be used to assess uncertainties and build awareness and ownership of the results from the analysis. SLDs can also be used to refine and bound assumptions of disaster impacts, valuations, and utility of interventions. SLDs provide perhaps the best avenue of assessing many of the variables where quantitative data are lacking or insufficient.

Conclusions

The steps outlined in this methodology summary represent a systematic process for translating broad concepts of disaster risk reduction into tangible strategies where their economic viability can be evaluated. As highlighted here, cost-benefit analysis should be viewed not as a "stand alone" activity but rather as part of a larger process of decision-making. The numerical results from cost-benefit analysis can be misleading and inappropriate to utilize for decision-making unless they emerge from such a process. That is, in cost-benefit analyses of disaster risk management, assumptions must be made, data must be evaluated and uncertainties are likely to be high. This is particularly true in the case of weather related disasters where the impacts of climate change at a local level are poorly known and inherently have high levels of uncertainty. In addition, ethical decisions must often be made regarding who benefits and who bears the cost of interventions. As a result, utilizing the results of cost-benefit analysis as a basis for decision-making requires understanding and appreciation for the nuances inherent in the analysis. Overall, cost-benefit analysis needs to involve a larger process involving extensive stakeholder involvement that moves from initial assessment, to analysis of vulnerability and initial qualitative evaluation of potential risk management strategies, to more quantitative techniques. To put this in another way, the process involved in conducting a cost-benefit analysis is of more utility as a basis for decision-making than the final computed benefit-cost ratios or rates of return.

That said, it is important to emphasize that the suite of methods presented here, including quantitative cost-benefit analysis, represent powerful tools for translating broad concepts for DRR into practical strategies that can be justified on a combination of economic and other grounds. Shared learning dialogues provide a framework for incrementally building shared understanding of the nature of risk and the types of interventions that might be undertaken to reduce it. Supporting this type of dialogue with inputs that move progressively from qualitative to more quantitative forms of evaluation enables learning and the gradual evolution of shared understanding. Furthermore, particularly when systematic approaches to vulnerability analysis are used, strategies can be targeted at the communities that are most at risk and most likely to benefit from different interventions. Qualitative evaluation methods can enhance understanding of societal perceptions of disaster risk strategies, and distributional effects within and among communities. Quantitative techniques for climate downscaling and cost-benefit analysis scenario generation can enable groups to understand the implications of different strategies even given the high levels of uncertainty that exist concerning future conditions. This is absolutely central if society is to develop approaches to risk reduction and adaptation that are robust in relation to the wide arrange of directions in which climate conditions can evolve. As a result, the methodologies outlined in this summary can be critical in developing effective and equitable responses to hazards including those emerging as a consequence of climate change.

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CHAPTER 3

Downscaling Climate Information in Data Limited Contexts:

Potential Changes in the Rohini Basin, Nepal and India

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Introduction

Floods, droughts and other weather related disasters are major factors contributing to endemic poverty in regions such as South Asia, and this is likely to increase as climate change proceeds. Disaster risk reduction interventions represent a major avenue for responding to both existing flood and drought hazards and the increases in these hazards likely to emerge as a consequence of climate change. Investments in risk reduction are, however, difficult to economically justify unless their returns can be assessed. Cost-benefit techniques are the primary set of economic tools through which such assessments are currently made. The ability to make such assessments depends on the availability of probabilistic information. We need to know the frequency with which events such as floods and droughts will occur and we need to know the magnitude of such events. Such natural hazard information is generally not available or is sparse, particularly at the local level in developing countries where the resources and abilities to collect weather and hydrologic data are limited. Yet, populations in developing countries are particularly vulnerable to weather related hazards and are likely to be more negatively impacted by climate change than populations in developed countries. Thus, it is critical to attempt to quantify the impacts of disaster risk reduction interventions in such areas as much as is possible.

The Rohini Basin, part of the larger Ganga Basin and straddling the border of India and Nepal (Figure 1), is home to some of the poorest populations in the world. Populations in the Nepal Tarai and in the Indian state of Uttar Pradesh are particularly affected by weather related disasters (Moench and Dixit, 2004). Social, political and economic factors, in combination with geography, make this basin vulnerable to flooding during the monsoon months. During the 2007 monsoon, over 2 million in Uttar Pradesh were adversely affected by floods through habitat loss, destruction of villages, inundation of cropland and livelihood disruption. Likewise, droughts in the region are equally detrimental to agriculture and livelihoods. The combination of the two weather related hazards, almost on an annual basis, steadily erodes assets and livelihoods in the basin and contributes to endemic poverty. This chapter highlights the challenges of accessing hydrometeorological data for a data-poor region (the Rohini Basin) and the strengths and limitations of climate downscaling for assessing potential climate change impacts in the basin.

Little published information exists on the hydrometeorological cycle of the Rohini Basin and none at all on potential basin-specific climate change impacts. Broadly, the Intergovernmental Panel on Climate Change (Christensen et al., 2007) estimates that average June-August precipitation throughout South Asia (defined as the region 5^{0}N, 64^{0}E to 50^{0}N, 100^{0}E – a region bordered by India in the south and Kazakhstan in the North, Pakistan in west and Burma in the east) will increase approximately 11%, as will heavy precipitation events by 2099. This is an extremely large area (marked by diverse precipitation and temperature regimes), with some areas dominated by the monsoon and others not experiencing the monsoon. The general circulation models' (GCMs) projections do not say how the precipitation will be spread throughout the area or give consistent projections in changes to the timing of the precipitation. Actual climate change impacts at smaller geographic scales, such as river basins like the Rohini, are likely to be different than those aggregated at larger scales. This is due to the fact that precipitation patterns vary greatly, even within small areas. Furthermore, such information is often not specific enough to be used in planning and implementing adaptation and disaster risk reduction measures. In order to effectively support such measures, information about potential climate change impacts is needed at smaller geographic scales. Quantifying climate change impacts at smaller scales requires translating results from general circulation models.

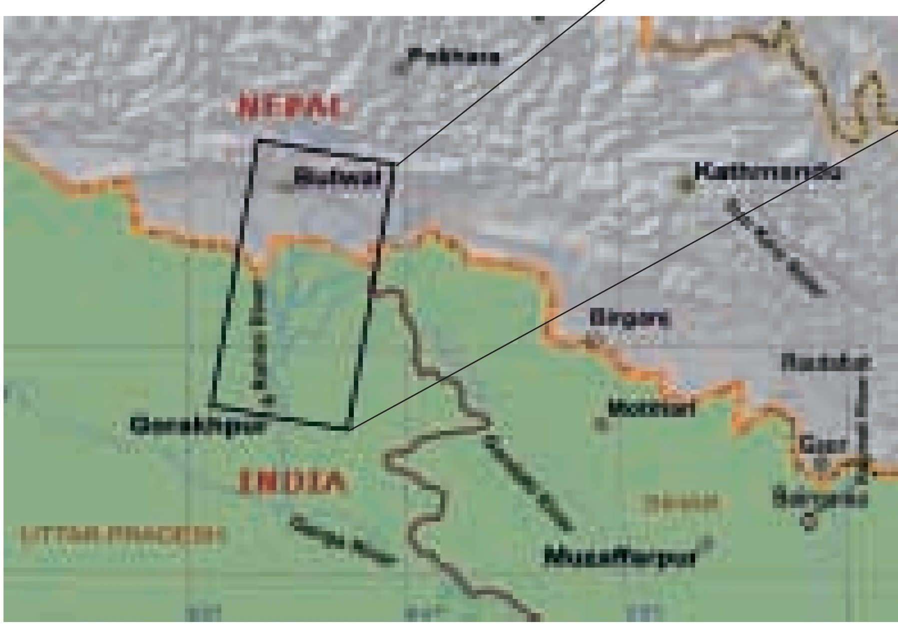
General circulation models are complex computer models that simulate global weather (timescales under 10 days) and climate (anything over 10 days) patterns by modelling the physical processes and interactions between the land, ocean, and the atmosphere. The horizontal grid resolution of GCMs is typically on the order of 100-200 km, insufficient to capture trends or make projections of potential climate change impacts at smaller scales, such as river basins. Furthermore, there are large discrepancies among precipitation estimates derived from the various GCMs utilized by the IPCC (Kripalani et al., 2007; Tolika et al., 2006). However, GCMs generally simulate large-scale climate fields, such as wind and humidity (Trigo and Palutikof, 2001; Osborn et al., 1999) quite well. Thus, the climate fields simulated by GCMs can be used to drive downscaling models that simulate climate change impacts at smaller geographic scales.

Various downscaling techniques have been developed that attempt provide forecasts of potential climate change impacts at smaller scales, guided by output scenarios from GCMs (Dibike and Coulibaly, 2005; Gangopadhyay et al., 2005). The techniques range from numerical methods (for example, PRECIS developed by the UK Hadley Centre) and statistical techniques. Numerical methods forecast the physical responses of an area (from regional-scale to global-scale) to various sets of inputs (e.g., soil moisture or greenhouse gas concentrations). Numerical climate models run at any geographic scale require large sets of reliable data; data that may not exist in developing country contexts such as the border region of Nepal and India. Statistical downscaling techniques attempt to establish a statistical relationship between point source or smaller, area-averaged (weather station) weather variables, such as precipitation or streamflow, and large-scale climate fields such as wind or air pressure at different atmospheric levels. The quantity that we are trying to predict (rainfall in the case of the Rohini Basin) is known as the predictand. The variables used to forecast the rainfall are known as predictors. We will use these definitions throughout the chapter.

The choice of which method, numerical or statistical, to use is determined by the quality and quantity of historical climate data available for the region for which downscaling will be attempted. Numerical methods model the physical processes that govern an area's climate, but require significant amounts of quality data and computational time. There are many statistical methods, ranging from neural networks, weather generation schemes and non-parametric, K-nearest neighbor schemes, to name a few. All of the downscaling methods are complex and are usually chosen based on data availability and computational resources. It is not possible to discuss the myriad of downscaling techniques in great detail here. Therefore, we focus only on the one downscaling method developed for the Rohini Basin. We used a non-parametric, K-nn analog model to generate future rainfall ensemble[1] scenarios for the Rohini Basin conditioned on climate change scenarios. The method we developed is general however, and can be used to downscale climate change scenarios for many areas of the world other than the Rohini Basin.

The Rohini Basin straddles the border of Nepal and India (Figure 1) and is a data poor region, precluding the use of numerical downscaling techniques. Therefore, a robust stochastic technique was developed to generate precipitation ensembles that can be utilized to test climate change scenarios at the river basin scale. The potential effects of climate change on the precipitation patterns of the basin generated by this downscaling technique were then used by other partners to calculate possible changes in the severity and frequency of droughts and floods in the area and assess the costs and benefits of various DRR measures.

| FIGURE 1 | **The Rohini Basin and its location along the Nepali-Indian border**



[1] Ensemble forecasting is a way of generating multiple estimates of, say rainfall, for an area to give an idea of the possible range of rainfall values that might occur under a given set of climate conditions.

We must caution, however, that while the downscaling method here is robust and the results can provide key insights into potential climate change impacts, the predictions are just that, predictions. Our confidence in the climate change projections is limited by the quality and quantity of historical data available for the Rohini Basin. We can present the probabilities with which we think various amounts of rain might fall and describe the amount of variability that we might see in the future. Quantifying our confidence in the projections is a little more difficult. Nonetheless, we are extremely confident that climate change is impacting and will continue to impact the hydrometeorological cycle of the Rohini Basin. While we cannot be certain which of our climate change projections will come true, the collection of projections point to specific trends in the timing and amount of precipitation in the basin that can be used in disaster risk and cost-benefit analysis.

The chapter is organized in the following manner: First we describe the Rohini Basin's hydrometeorological characteristics. We then discuss the data collected, the process through which data were collected and analyzed, and the limitations to our datasets. We then present the model methodology and assess the skill of the model over a training period. Finally, we make the climate change projections and interpret the projections within the limitations of the historical data. The majority of the chapter is slightly technical in nature, as it describes data characteristics, the physical relationships that govern the Rohini's precipitation and the model. The discussion of the climate change projections and their limitations is not as technical.

The Rohini Basin

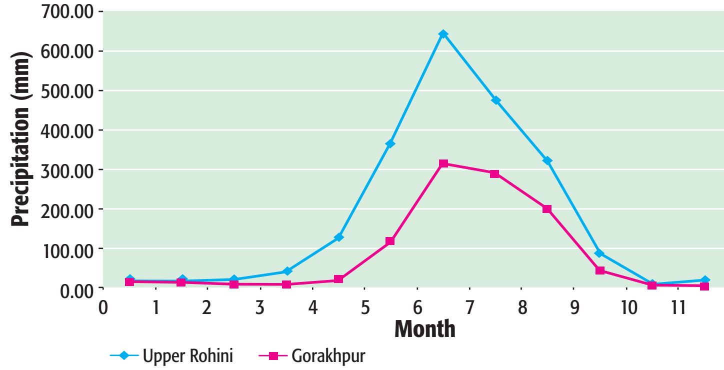
The Rohini Basin is relatively small, with a catchment area of 2701 km^2 that straddles the borders of Nepal and India (1943 km^2 in India and 758 km^2 in Nepal). The basin lies just south of the Himalayan Range, which rises to 8000 m in less than 100 km from the basin. Precipitation patterns in the basin are strongly linked with the seasons and falls always as rain (as opposed to snow). While only 30% of the total catchment area lies within Nepal, the majority of the rain that feeds the basin falls within the headwater reaches in Nepal (Dixit et al., 2007; NWCF, 2006). There are strong geographic rainfall gradients in the basin, largely controlled by orography and the angle at which monsoon storm tracks impinge upon land features. Evidence suggests that even across small scales (>100 km) areas on the upwind side of land features (e.g. hills and ridges) will receive considerably more precipitation than areas on the downwind side (Barros and Lang, 2003). The average annual precipitation for the Nepali portion of the basin is approximately 2100 mm compared with 1000-1200 mm in Gorakhpur district on the Indian side of the basin (India Water Portal, 2008).

Nearly 90% of the basin's annual precipitation falls from roughly mid-June through mid-September (Figure 2) and is associated with the larger South Asian Monsoon. The South Asian Monsoon is an annual pattern of increased rainfall over South Asia, typically beginning around late May and ending in September[2]. The monsoon is a

[2] The exact timing of monsoon onset and termination depends on the location. For the Rohini Basin, the monsoon typically begins around mid-June and ends mid-September. There is, however, considerable variation each year.

highly complex system, and we provide only a basic description of its physical mechanisms. The monsoon develops when a low-pressure system forms over the Tibetan Plateau and the winter-spring upper-level westerly jet stream over the southern Himalayas disappears. The low-pressure system induces the winds to shift direction and blow from the southwest over the Indian subcontinent, bringing moisture from the northward-shifted Intertropical Convergence Zone. The temperature difference between the land and the Indian Ocean contributes to the formation of monsoon thunderstorms, in conjunction with the orographic uplift induced by the Himalayas. Tropical cyclones and depressions moving pthrough the Bay of Bengal or other parts of the Indian Ocean enhance extreme rainfall events during the monsoon and contribute to severe flooding in the Rohini Basin. The monsoon ends when the Tibetan low pressure breaks down and the upper-level westerly jet resumes, generally during September (Torrence and Webster, 1999; Fasullo and Webster, 2003; Meehl and Arblaster, 2002). Post-monsoon atmospheric conditions are not completely re-established and stabilized until mid to late October. Occasionally, weak depressions beginning in the Mediterranean bring rainfall to the area during December and January, but this does not happen every year.

FIGURE 2 | Average monthly precipitation in the Rohini Basin



Annual average precipitation cycle in the Nepali side of the Rohini Basin (blue) and for the Gorakhpur District[3] (red). The monsoon season occurs during the months of June-September and corresponds with the peak seen in the figure.

The primary weather related hazards in the basin are drought and flood. The timing and amount of precipitation is important to the agricultural activities that are the primary sources of income. There are three crop seasons: *rabi, zaid* and *kharif*. Much of the agriculture is rain fed, although those with the financial means are able to provide supplemental and timely irrigation to their crops. Insufficient, untimely or lack of rainfall can lead to drought conditions in the basin and significantly impact agricultural yields. Drought impacts are slow-creep impacts that gradually erode the economic and food bases of many households and contribute to endemic poverty in the region. The impacts of floods are much more dramatic: loss of life, increases in waterborne illness, destruction of houses and household items and long-term waterlogging of crop lands. Being able to provide possible projections of precipitation patterns conditioned on climate change scenarios for the Rohini Basin is key to planning, justifying and implementing various disaster risk reduction measures that can help mitigate flood and drought risk.

[3] The Gorakhpur District rainfall data were sourced from the India Water Portal (2008). The India Water Portal data are derived from interpolated global monthly rainfall data from the Tyndall Centre's CRU TS 2.1 dataset. The TS 2.1 dataset is a grid interpolation of available weather station data. As will be explained in the next section, weather station spacing in this region of India is extremely sparse, and the data incomplete. Therefore, the TS 2.1 dataset can be used to give a rough estimate of annual behavior on the Indian side of the Rohini Basin, but should not be used in this downscaling effort.

Datasets and Assumptions

Rainfall Data

The most important aspect of downscaling climate change scenarios to smaller scales is the selection of relevant data. As mentioned in the introduction, the IPCC projections cover an extremely large geographic area encompassing the highest mountain range in the world, deserts and rainforest. The Rohini Basin, though tiny in comparison, still has a remarkable north-south rainfall gradient in which small perturbations in precipitation can have large effects. Thus, selecting data that captures the long-term historical variability of an area is critical to making confident projections of potential climate changes. However, in many parts of the world, data records are of insufficient length and are incomplete with little to no information on how the data are collected and verified. This implies that downscaled models for certain regions are compromised from the beginning of the effort. Despite these limitations, it is still possible to make projections about general trends in precipitation and temperature that can be useful in DRR efforts.

Obtaining daily precipitation data of sufficient historical length for the basin was extremely difficult. ISET-Nepal was able to purchase complete, primary rainfall data for five weather stations in the basin for the period 1976-2006. The validity of the datasets cannot, however, be verified. The Nepal Department of Hydrology and Meteorology informed us that significant sets of missing rainfall data had been back-estimated. Thus, there are potential flaws in the Nepali datasets that cannot be verified or corrected because of lack of information.

There are only two weather stations on the Indian side, one at Gorakhpur Airport and one in the Nautanwa Block. Purchasing datasets for Nautanwa and Gorakhpur Airport from the Indian Government was beyond the scope of the budget allocated for this project. The Nautanwa station data, even though an extremely incomplete record, would have cost INR 50,000 or roughly USD 1,600 (at the time) to access. In the end, due to cost limitations, no datasets for India were purchased or utilized in the downscaling model.

We attempted to acquire Indian rainfall data and to verify the Nepali data from other sources. Supplemental data was acquired for Bhairhawa Airport (Nepal) and Gorakhpur Airport (India) from the National Climate Data Center (NCDC) for the periods of 1977-2006 and 1954-2006. Roughly 35% (excluding the 1960's and '70's, which were almost completely missing) of the NCDC dataset for Gorakhpur Airport was missing and could not be filled using traditional hydrology methods because we had no other datasets for stations on the Indian side. Nor were we willing to backfill the Gorakhpur data using a weather generator because the spotty sample we had did not capture the long-term climatological variability possible at that location. The NCDC dataset for Bhairhawa Airport was used to fill gaps in the Bhairhawa Airport set compiled by ISET-Nepal and to check the validity of the dataset. The two datasets were strongly correlated at 0.98, which is to be expected as NCDC relies on the government reported data as well. *Thus, no Indian rainfall stations were included in* *this modelling effort, which makes it difficult to project potential climate change impacts on the Indian side of the basin.* The lack of Indian rainfall data presents a severe limitation of the model's ability to accurately make predictions of potential climate change impacts in the Rohini Basin.

All of the Nepali stations, except Dumakauli, lie within the catchment area of the river. Dumakauli is not in the basin, but it is extremely close and its precipitation patterns are similar to the other stations in the basin both in amount and timing. Due to the limited amount of rainfall data and the geographic distribution of raingauges in the basin, we felt it necessary to include Dumakauli in model predictions. Less than 3% of the data were missing for any given year from each of the Nepali stations over the period of 1976-2006. Daily precipitation values were aggregated to obtain monthly rainfall totals for each of the five stations for the 31-year timeframe. While 31years of data might seem sufficient, this cannot be discerned until the model is run for a test period and the results verified over the test period.

The model was run for two separate time periods, 1976 to 2006 and 2007 to 2050. The first time period formed the testing phase of the model, during which we could see how well the model was able to replicate past precipitation patterns and quantify the model's strengths and weaknesses. It is through the testing phase that we were also able to verify the data limitations. While there are some differences in the precipitation patterns between the stations on the Nepal side, the five stations' rainfalls were correlated well enough to justify using the five station-averaged monthly rainfall to test the model. The actual downscaling of climate change scenarios for the period 2007-2050 was done separately for each station.

Large-scale climate data

Once rainfall data were collected for the basin, we began searching for the appropriate large-scale climate features that relate to the basin's rainfall. Large-scale climate field predictors for this study were obtained from the NCEP/NCAR reanalysis archive (Kalnay et al., 1996). Much of the rainfall associated with the monsoon is due to thunderstorm (convective) activity over the basin embedded within the extra-tropical monsoon waves moving off the Bay of Bengal. The processes governing convective activity are complex and we chose a simplified set of physical mechanisms that give rise to convection. Selection of large-scale climate fields is governed by two sets of assumptions that determine the physical relationship between the local variable (rainfall) and the large-scale variables. The first set is based on the necessary atmospheric conditions that allow for convective activity on which most of the Rohini's rainfall is based:

1) changes in air pressure that lead to atmospheric instability (measured through geopotential height)
2) moist air (measured through specific humidity)
3) warm air (measured through air temperature)
4) a transport mechanism to move the warm, moist air (measured through meridional and zonal winds)

The second set of conditions is governed by their climate change relevance (von Storch et al., 2000):

1) The large-scale climate predictors have a direct physical relationship with the local variable and are realistically modelled by the GCMs
2) The physical relationship between the large-scale predictors and the rainfall is expected to remain relevant in the future, regardless of climate change
3) The large-scale climate predictors reflect the climate change signal

We obtained monthly mean large-scale climate variables – geopotential height, zonal or meridional winds, specific humidity and air temperature at different vertical levels for the years 1976-2006. The variables cover the geographic region of 25-30°N and 80-90°E and represent area averaged data over fifteen grid spaces with a 2.5° x 2.5° (latitude-longitude) resolution. These datasets can be accessed and analyzed from the National Oceanic and Atmospheric Administration (NOAA) online database at: http://www.cdc.noaa.gov/Timeseries.

The final step in choosing data for a statistical downscaling model is figuring out which GCMs' output to use. An extensive literature review was conducted in order to compare the GCMs' capabilities over South Asia. The IPCC report synthesizes climate change projections from 22 different GCMs operated by various universities and research centres from around the world. Kripilani et al. (2007) analyzed each of the GCMs to see how well each could replicate important features of the South Asian Monsoon. They investigated each model's ability to reproduce historic inter-annual behaviour, intra-seasonal variability and historic mean precipitation. Only 6 out of the 22 models were able to reproduce historic observations of monsoons from the 20th century. We selected one of these six, the Canadian Third Generation Coupled Climate Model (CGCM3) because of its ability to replicate the South Asian Monsoon and the ease of acquiring climate change output data from this model. Lack of time prevented investigating and using data from the remaining five GCMs candidates.

For this project, we agreed to use the climate change scenarios A2 and B1. The choice of these scenarios was arbitrary. The A2 scenario assumes that population growth and fossil fuel usage will continue to be quite high for a number of years to come, whereas the B1 scenario assumes that the amount of carbon dioxide in the atmosphere will stabilize at around 550ppm. The IPCC (2007) reports typically present results from a climate change scenario known as A1B, which is in between A2 and B1. In the A1B scenario, carbon dioxide stabilizes at around 720ppm. For a more detailed explanation about the IPCC scenarios, refer to the IPCC (2000) special report on Emissions Scenarios. Due to the rapidity with which the climate is already changing (for example, the faster melting of the Artic and Greenland ice sheets) and the GCMs' current inability to capture these rapid changes, we felt potential climate change scenarios are not likely to be valid beyond 2050. Furthermore, while these scenarios were created using the best knowledge available about societal structure and energy consumption, it is difficult to know how quickly we will or even *if* we will transition away from fossil fuel dominated economies. Thus, the downscaling model projects climate change impacts on precipitation in the Rohini Basin only for the period 2007-2050, even though the IPCC scenarios are available to 2099.

Data for the four large-scale climate predictors mentioned above were obtained from the CGCM3 for the period of 2007-2050 over the same geographic range as the NCEP data. The resolution of the CGCM3 data is coarser, with grid divisions of 3.75°x3.75° or only 9 grid squares over the same geographic domain as the NOAA data. The CGCM3 model is run in ensemble mode, that is, the model is run five times for a scenario (say A2) using slightly different starting conditions, to generate a small range of possible climate change conditions for a particular scenario and provide a better sense of what variability exists in the model. Thus, we collected CGCM3 output data for 10 different ensemble runs: five runs from A2 and five runs from B1. For the remainder of this chapter, we refer to these ensemble runs as either A2R# or B1R#, with the # sign indicating runs 1 to 5.

The NOAA datasets and the CGCM3 datasets have different grid spacing, which had to be resolved before selection of the final predictor set for the model. In each dataset, the variable (e.g. wind) is measured at the centre of the grid space. The NOAA dataset is comprised of fifteen measurements–one per grid space, and the CGCM3 has nine values, one per grid space. Thus, the NOAA dataset needed to be reduced to nine grid points that are spatially matched with the CGCM3 grid spacing. We used the great circle distancing method[4] to map the NOAA dataset grid points onto the CGCM3 grid spacing.

The final NOAA and CGCM3 datasets contain data from four variables (wind, geopotential height, specific humidity and air temperature). The final data matrix for both contains thirty-six columns (9 columns corresponding to the measurements at 9 grid points per variable). The NOAA dataset contains values from 1976-2006. The CGCM3 dataset is actually comprised of 10 different datasets, five runs from each climate change scenario A2 and B1 for the years 2007-2050.

Methodology

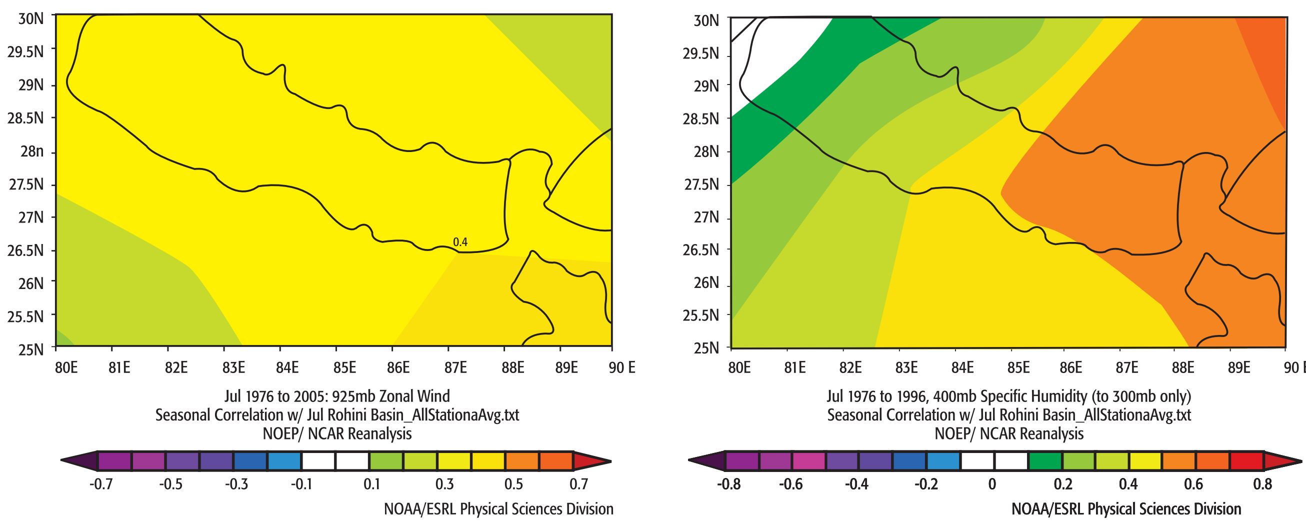
Climate Diagnostics

The physical relationships between the large-scale climate indices and the basin rainfall are established using correlation analysis. While correlation does not imply causation, it is well established in meteorology that certain physical processes contribute to the formation of thunderstorms and the monsoon. We performed correlation analysis between each month's rainfall and various large-scale climate features at different height levels (geopotential height, specific humidity, air temperature, and meridional and zonal winds). A correlation was deemed to be significant at the 95th percentile in a two-tailed test. Each month was performed separately because we chose to model each month separately. This allows us to better capture the seasonal and intra-annual variability that are characteristic of rainfall patterns in the Rohini Basin. See Figure 3 for an example of the correlation analysis. The correlations were tested for significance and the features that had the highest correlation with the month's rainfall were identified and used to form the predictor set.

[4] Great circle distancing can be found in any standard geometry book.

While historically the monsoon has been strongly correlated with snowfall amounts over the Tibetan Plateau and the El Niño Southern Oscillation (ENSO), these relationships are changing and it is not certain what the nature of the relationship will be in the future due to climate change. Furthermore there is strong disagreement amongst the GCMs on the evolution of ENSO under differing climate change scenarios (Saji et al., 2006; de Szoeke and Xie, 2008). Therefore, we decide not to use these large-scale climate indices in our modelling efforts.

| FIGURE 3 | **Spatial correlations of July's (1976-2006) rainfall with zonal wind and specific humidity.**



The correlation analysis revealed that the most important large-scale climate variables in all months are specific humidity and wind. Physically, this is logical, as there cannot be precipitation without sufficient moisture in the air. And, as established earlier, the monsoons are marked by a shift in winds that transport the moist air from several centres of convergence over the Indian sub-continent. During the non-monsoon months, the primary transport mechanisms are meridional (north-south) winds at upper levels. The southwesterly shift of the winds is strongly signaled in the low-level (925mb and 850mb) zonal winds that dominate the monsoon season. The signal propagates through multiple height levels.

The direction of the winds is modulated by centres of low and high-pressure, hence the correlation with geopotential heights at various levels. In all months except for January, September and October, significant relationships existed between the basin's rainfall and geopotential heights. In monsoon months, the low-level (925mb and 850mb) Tibetan low-pressure system is a consistent feature in the correlation analysis. The lack of strong relationships between geopotential height and rainfall in certain months later proved critical in the ability of the model to accurately forecast rainfall in these months during the testing period of 1976-2006.

Finally, correlations were calculated for air temperature at various height levels and the rainfall. During the monsoon months of June-August, the land-ocean temperature difference contributes greatly to the formation and sustenance of the monsoon and correlations were indeed significant. Correlations with air temperature at various levels were also found to be significant for the months of February-May and December although with an inverse relationship to that seen in the monsoon months. No significant relationships were seen in January and September-November.

Statistical Downscaling Model

The goal of the statistical downscaling model is to project how various climate change scenarios will alter precipitation patterns in the Rohini Basin for the years 2007-2050. The modelling method utilized for this study is a robust, simple analog method run in ensemble mode (Gangopadhyay et al., 2005; Opitz-Stapleton et al., *in press*). Ensembles are multiple forecasts made for a particular time period. Ensembles allow us to see how well the model is able to capture the long-term variability in rainfall and quantify the probability of (how frequently occurring) different rainfall amounts. Since we have no way of testing the validity of the model's projections in the future, we assess the model's performance by how well it is able to replicate each month's historical precipitation for 1976-2007. This is termed the model "testing period".

During the model "testing period" of 1976-2006, the model is run in drop-one, cross-validation mode. There are several cross-validation schemes in common use in climate downscaling. In the particular variation we used, the model drops the year we are trying to predict (say May, 1980) from the overall dataset and tries to make the prediction for that month/year using only the remaining data. If the dataset of observed rainfalls is of sufficient length and captures the full long-term variability of the basin, then drop-one cross-validation techniques work well. However, if the datasets are insufficient the method will not work so well and it might be necessary to include all years of the dataset to make the prediction.

The model steps for the testing period are laid out below, with a translation of each step following. We use the example of trying to forecast May 1980 in describing the model steps.

STEP 1: Let *[X]* represent the data matrix of large-scale climate indices for n years (rows), and M grid boxes (columns). The NCEP reanalysis dataset contains variables from nine grid squares (9 columns). Matrix *[X]* represents data for the entire period of record (1976-2006), which is equal to 31 rows.

STEP 2: For feature year and month i (the year and month for which reconstruction is sought, say May 1980) select the corresponding climate variables of year and month i. The x_i variables of the feature year i represent the feature vector *{F}* (row vector of length x_i). For example, *{F}* is a vector containing the large-scale climate indices for May 1980.

STEP 3: Obtain a subset of data matrix *[X]*, say *[S]* of order $t \times m_i$. *[S]* contains the large-scale climate variables from all years of *[X]*, except the feature year i. t is one year less than the order of n years. *[S]* is a matrix consisting of all the large-scale climate variables for all Mays 1976-2006, except for May 1980.

STEP 4: Estimate the correlation matrix *[C]* (order $m_i \times m_i$) from the data matrix *[S]*.

STEP 5: Perform PCA (Principal Component Analysis; see von Storch and Zwiers 2001; Wilks 2006) using matrix *[C]* to obtain the m_i eigen values $\lambda_{(1)}, \ldots, \lambda_{(m_i)}$, and the eigen matrix (matrix of eigen vectors as columns) *[E]* (order, $m_i \times m_i$).

STEP 6: Project the feature vector *{F}* for feature year *i* onto the eigen vectors in matrix *[E]*. The projected feature vector, $\{F^{'}\}$ is given by,

$$\{F^{'}\}_{1\times m_i} = \{F\}_{1\times m_i}[E]_{m_i\times m_i} \tag{1}$$

STEP 7: Calculate the m_i principal components. The principal component matrix *[Z]* is obtained from,

$$[Z]_{n\times m_i} = [S]_{t\times m_i}[E]_{m_i\times m_i} \tag{2}$$

STEP 8: For each element *m* (*m=1, …, n*) compute the weighted Euclidian distance (d_t) between the projected feature vector, $\{F^{'}\}$ (Step 7), and the principal components contained in matrix *[Z]* (Step 8).

$$d_t = \left[\sum_{j=1}^{nret} \frac{\lambda_j}{\sum_{p=1}^{m_i}\lambda_p}\left(f_j^{'} - z_{tj}\right)^2\right]^{1/2} \tag{3}$$

where, *nret* is the number of principal components retained such that $\sum_{j=1}^{nret}\lambda_{(j)} \approx 0.90$; z_{tj} are the elements of *[Z]*, and $f_j^{'}$ are the elements of the projected feature vector $\{F^{'}\}$. This gives a set of *n* distances as possible neighbours from the overlap period to feature year *i*.

STEP 9: Sort the distances d_t in ascending order, and retain only the first *K*-neighbours (Gangopadhyay et al., 2005). The prescribed choice for *K* is $\sqrt{n} \approx 6$ in this case. The *K*-nearest neighbours represent the *K* most similar years from the dataset to the feature year *i*.

STEP 10: Select the observed rainfall for each of the *K* neighbour years from the subset period, this represents the set of possible rainfall magnitudes for feature year *i*.

STEP 11: Assign weights to each of the *K* rainfall values. Several weighting schemes based on either *K* (Lall and Sharma, 1996; Rajagopalan and Lall, 1999) or distance such as the bi-square weight function (Gangopadhyay et al., 2005) and inverse distance weighting (Chow et al., 1988) are available. We utilized the bi-square weighting (BSW) scheme in the final modeling effort. The bi-square weight, w_k, for neighbour k is given by,

$$w_k = \frac{\left[1-\left(\frac{d_{(k)}}{d_{(K)}}\right)^2\right]^2}{\sum_{k=1}^{K}\left[1-\left(\frac{d_{(k)}}{d_{(K)}}\right)^2\right]^2} \tag{4}$$

In essence, steps 6 through 12 involve a comparison of the climate variables of the feature vector *{F}* to all the other climate variables from the matrix *[S]*. In these steps, we find the years in *[S]* which have the most similar large-scale climate conditions to *{F}*. We then keep only the years that are most similar to *{F}* and call these years the "K-nearest neighbours" (K-nn). We then take the rainfall values from each of the K-nn years as the set of possible rainfall values for the year we are trying to predict. Each of these rainfall "neighbours" is then assigned a weight depending on how close its corresponding climate variables are to the climate variables of *[F]*.

STEP 12: Bootstrap (Venables and Ripley, 2002) the K rainfall values (Step 11) using the weights w_k, $k = 1, \ldots K$ (Step 12) to generate an ensemble of rainfalls for year i (May 1980). In essence, this means that the model makes multiple rainfall predictions for May 1980 by resampling from the weighted K-nn rainfall values.

STEP 13: For each of the years 1976-2006, repeat Steps 3 through 13 to obtain an ensemble rainfall reconstruction.

Climate Change Downscaling

The model steps for generating rainfall predictions for the years 2007-2050, conditioned on climate change scenarios are slightly different from the above steps for the test period. The major difference is that drop-one cross-validation is not used. When forecasting rainfall for this period, the feature vector *{F}* is formed from the CGCM3 dataset, that is, the variables from A2R1-A2R5 and B1R1-B1R5. For example, if we are trying to predict rainfall for May 2020 under the A2R3 scenario, *{F}* is formed from the May 2020 A2R3 large-scale climate indices. *{F}* is then compared directly with the entire matrix *[X]*, which contains the entire set of large-scale climate indices from the period of 1976-2006. The K-nn rainfalls in the historic set are found and resampled to generate estimates of rainfall conditioned on the particular climate change scenario selected. Bootstrapping is done and the whole process repeated for each month, each year of 2007-2050 to generate ensembles.

The final step involves disaggregating the monthly rainfall projections to daily time steps. The flood and drought models created for the Rohini Basin require daily rainfall data. Disaggregation to a daily time step was achieved through use of the daily rainfall percentage distributions from the historical record. For example, say May 2020 had six K-nn: 1978, 1987, 1992, 1995, 2001 and 2003 and that in May 1978, rain fell on six days throughout the month, with each day receiving some percentage of the total monthly rainfall. The daily rainfall percentages of each K-nn were then multiplied by May 2020's monthly rainfall projections to produce hypothetical, but probable daily rainfall distributions.

Model Verification

Each ensemble forecast is equally probable for the period 2007-2050. We will not know until the future has become the past which forecast was the most accurate. We can only test the model's accuracy, and whether or not we chose the correct large-scale climate variables, by seeing how well the model could replicate the historical rainfalls for 1976-2006. There are several methods used to verify ensemble forecast skill (testing the forecast performance). We used four verification measures that are subsequently described: boxplots, correlation analysis, the Ranked Probability Skill Score, and reliability diagrams. For the remainder of this chapter, we only discuss the monthly ensemble rainfall projections and all verification of the forecasts' skill is over the monthly forecasts.

One method is to visually compare the ensemble rainfalls with the historical rainfalls, such as seen in Figure 4. Boxplots provide a pictorial comparison of the historical rainfall with the model's ensemble rainfalls. Each box represents the interquartile (25^{th}-75^{th} percentile) range of the rainfall ensembles generated by the model. The bottom "whisker" coming out of the box presents some of the lowest rainfall ensembles and the top "whisker" represents approximately the highest rainfall projections. Open circles signify values greater than the 95^{th} percentile or less than the 5^{th} percentile and are outliers. The box represents the spread of the majority of the rainfall ensembles. The black line in the middle of the box represents the middle value ensemble rainfall. The red triangle represents the actual, historically observed rainfall.

The second method involves correlating the median rainfall ensemble value with the observed, historical rainfall. This allows us to test how close the median prediction was to the actual value. A strong correlation (significant above the 95^{th} percentile) indicates that the median prediction was consistently similar to the historical observation over the test period.

The final two methods (Ranked Probability Skill Score and reliability diagrams) were designed specifically by meteorologists and climatologists to test the performance of ensemble forecasts. If there were only one forecast value, it would be easy to see how close it came to the actual value. However, we needed to run the model in ensemble mode in order to test the characteristics of our historical rainfall dataset: 1) was it long enough? and 2) even if it is not of the ideal length, are the model's forecasts still reliable enough to give us confidence in making climate change projections?

The Ranked Probability Skill Score (RPSS) tests how reliable the ensemble forecasts actually were in predicting the observed rainfall in comparison with the performance of a forecast based on chance. The RPSS is based on the ranked probability score (RPS) (Murphy, 1972), which measures the ability of the forecasts to predict the actual category, such as above or below the historical median, into which the historical observation fell. It is calculated by finding the squared Euclidean distance between the ensemble forecast probabilities and the observation's probability of being in a certain category. The RPS is defined as follows for "n" equally probable categories (Kumar et al., 2001; Wilks, 2006):

$$RPS = \sum_{m=1}^{n} (Y_m - O_m)^2 \quad (5)$$

where Y_m is the cumulative probability that a particular ensemble member falls into one category and O_m represents the cumulative probability of the observed values. The probability distribution of the observation is one for the category that was observed and is zero for other categories. We chose two[5] categories to test our forecasts, above the historical median and below the historical median. The RPSS is then calculated as:

$$RPSS = 1 - \frac{RPS_{forecast}}{RPS_{climatology}} \quad (6)$$

For the two-category situation, by chance we would expect that approximately half of the time our estimate would be above the median observation and half of the time it would be below. This is known as the climatological or reference forecast against which we compare our actual ensemble forecast's performance. The RPSS values range from +one to -8. An RPSS value greater than zero indicates that the ensemble forecasts performed better than chance. A score of zero or less indicates that the forecasts had no skill. If the forecasts had perfect skill, the score would be one, but in reality no forecast can be perfect because it is only a model of reality. The RPSS is not reliable for really small datasets and the score will oscillate widely between positive and negative values if the historical observation set does not capture the long-term variability (Stanski et al., 1989). Thus, if the score exhibits oscillatory behaviour, it has little value as a reliable indicator of the true skill of the forecasts. However, it does provide a concrete way of quantifying whether the historical datasets were of sufficient length or not.

Finally, another common metric of forecast verification is the reliability diagram (Wilks, 2006; Stanski et al., 1989). Reliability diagrams compare the forecast probability distribution with the historical observation's probability distribution by plotting the two distributions. This means that if 30% of the forecasts predicted rainfall amounts less than, say 15 mm, and exactly 30% of the historical observations actually were for rainfall amounts of less than 15 mm, then the forecasts are extremely reliable. A one-to-one relationship indicates that the forecast probability is the same as the historical probability. If the plot line deviates away the one-to-one diagonal line, the direction of the deviation indicates that the forecast was biased to either underprediction (deviation above the diagonal) or overprediction (deviation above the diagonal). The slope of the plot line provides information on the ability of the forecasts to sort the observed events into different groups (e.g., the 30th percentile or 60th percentile), which is also known as resolution. A forecast with good resolution will have a slope close to one. A forecast based on climatology (the long-term average behaviour) has no resolution and a slope of zero. The sharpness of the forecast, or its ability to more frequently measure an event is displayed as a histogram inset to the reliability diagram.

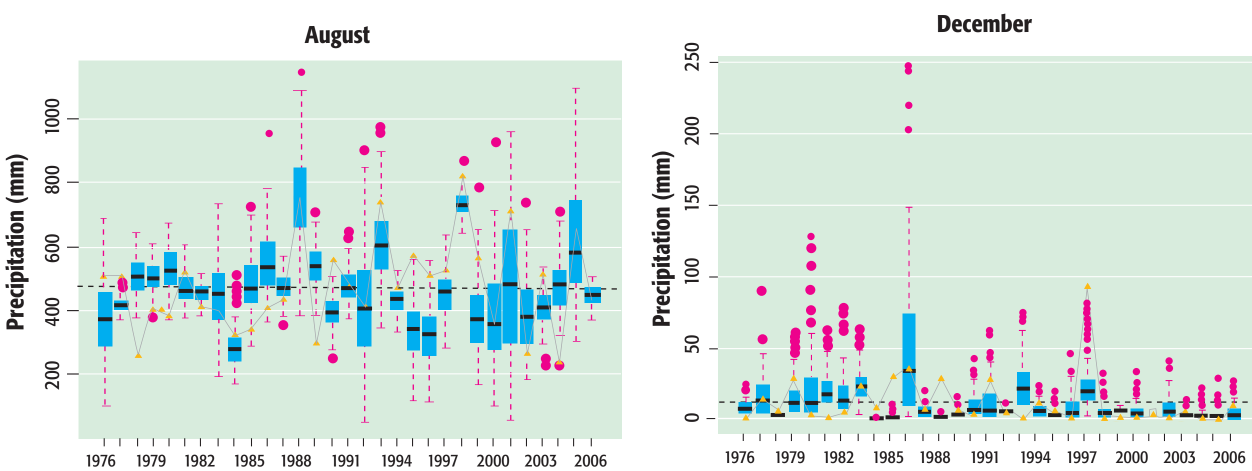
[5] Having only two categories for our RPSS test actually reduces it to another type of test called the Brier Skill Score. Both the Brier Skill Score and the RPSS are unstable for small datasets.

Forecasting Results

Testing Phase: 1976-2006

Each month was modelled separately to try to account the different large-scale climate processes that cause rainfall in each month. Consequently, the model's rainfall predictions are better in some months than in others. If a box (seen in Figure 4) is really narrow and centred around the red triangle, this indicates that the model was relatively "certain" about its rainfall predictions. If the box is relatively wide or the red triangle falls in a whisker, this indicates that there was a wide range in the large-scale climate conditions and that there is a lot of variability in the ensemble projections. For all months except the transition months of January, September and October, the model replicates the historical precipitation values quite well. The historical observations generally fall inside the interquartile range (the box) or the marginal spread (the whiskers) of the ensembles.

| FIGURE 4 | **Boxplots of the ensemble forecasts for the months of August and December during the test period of 1976-2006. The dotted horizontal line represents the 50th percentile of the historical rainfall.**

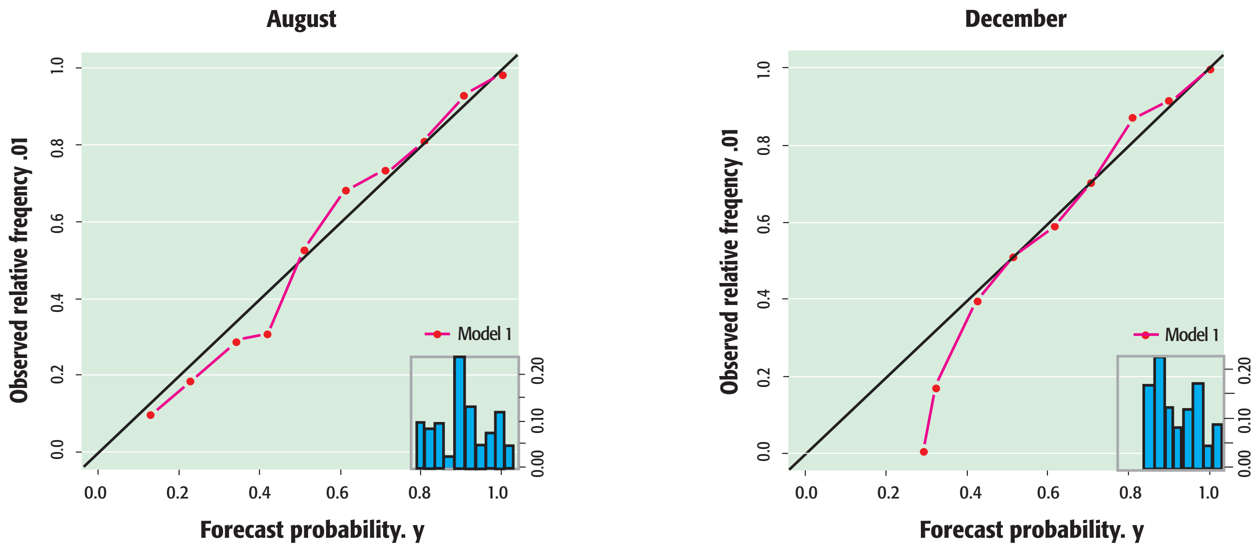


The model does have a tendency to underpredict the above normal (50th percentile or higher) rainfall amounts in most months, especially during the monsoon months of June-August. This means that model has a dry bias and is not likely to capture the full magnitude of possible large-magnitude rainfall events in the future. This bias toward dryness is also apparent in the reliability diagrams (see Figure 5).

The reliability diagrams provide information on the reliability, resolution and sharpness of the forecasts. For all months of the year, the forecasts are quite reliable in predicting the correct distribution the correct rainfall distribution frequencies. The model bias in each month is also apparent in the diagrams. If the model line deviates below the one-to-one line, the model is exhibiting a wet bias for that category of rainfall event. The opposite behaviour is seen when the model has a dry bias. During the two driest months of November and December, the model is not reliable for rainfall events below the 40th percentile, but is quite reliable for events above this threshold. The low reliability for minuscule rainfall amounts is demonstrated by the extreme deviation from the one-to-one curve in the November and December diagrams. For the period of 1976-2006 for which we have data, the median monthly rainfalls in

November and December are close to zero and in many years, these months received no rain at all. In the monsoon months of June-August, the model's dry bias is apparent in its deviation above the one-to-one diagonal line for events greater than the 60th percentile. Figure 5 displays the reliability diagrams for the months of August and December. Furthermore, the sharpness of the model varies from month to month. The sharpness is displayed as the histogram inset. In some months, such as August, the model tends to predict the climatological mean with greater frequency but still breaks down the rainfall categories and is somewhat sharp.

FIGURE 5 | Reliability diagrams for the months of August and December. The red line is the actual diagram and tells about the model's reliability and resolution. The histogram inset displays the sharpness (relative frequency) of the model's predictions.



In addition to the reliability diagrams and boxplots, we performed correlation analysis between the mean and median ensemble members and the observed rainfall. Table 1 presents the correlation coefficients for each month. The two coefficients were calculated to provide further insight into the skew that exists in the ensemble projections. The difference in correlation values in some months indicates a higher amount of skew in the ensemble projections for those months than in other months. Much of the skew seen in the correlation analysis and in the boxplots comes from the original rainfall datasets, which also contained a high amount of skew (the analysis of which is not shown here). In order to be considered a significant correlation for the 31-year record, the correlation coefficient had to be at least 0.366 (95th percentile) or 0.311 (90th percentile). Ideally, the correlations should be greater than the 95th percentile significance level, as even this indicates a 1 in 20 chance of randomly choosing the correct forecast.

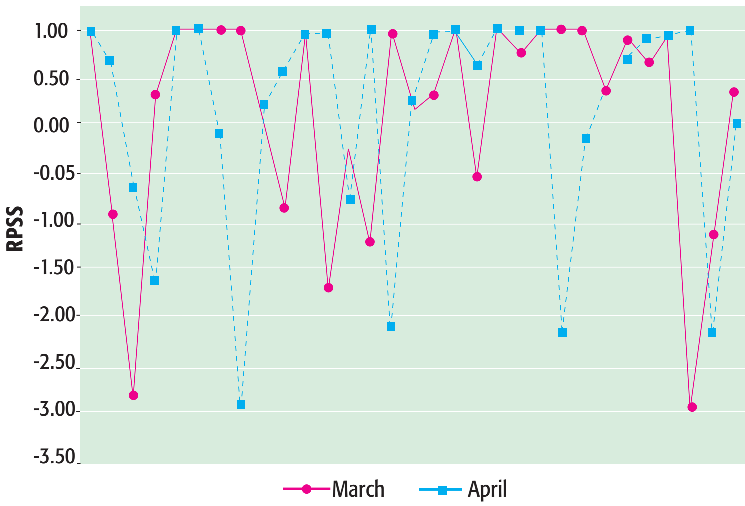
From the correlation analysis, we conclude that we have high confidence in our ability to project rainfall for the months of February-May, August,

TABLE 1 | Correlation of the mean and median ensemble members with the observed rainfall for each month over the period of 1976-2006

Month	Correlation -Mean	Correlation -Median
January	-0.17	-0.11
February	0.39*	0.36*
March	0.65*	0.65*
April	0.47*	0.49*
May	0.62*	0.63*
June	0.33**	0.31**
July	0.33**	0.31**
August	0.53*	0.50*
September	0.22	0.17
October	-0.23	-0.20
November	0.43*	0.53*
December	0.48*	0.42*

* is significant at the 95th percentile.
** is significant at the 90th percentile.

FIGURE 6 | **Oscillatory behaviour of the RPSS for the months of March and April. This indicates that the historical rainfall datasets were not of sufficient length.**



November and December. Our confidence in projecting rainfall is slightly lower for the months of June and July, but still significant. Our confidence in the forecasts is conditional however, based on the fact that we know the historical rainfall datasets are not long enough. We have very little confidence in predicting rainfall for the months of January, September and October. However, this lack of confidence in these three months is not surprising, due to the lack of significant relationships with large-scale climate indices. We'll discuss the possible physical mechanisms of why it is difficult to forecast in these three months in the concluding section.

The final skill test that we performed was the RPSS. If the historical rainfall datasets are of sufficient length, the test measures how close the forecasts came to the observed rainfalls in comparison with how well a dummy forecast based on climatology performed. If the historical rainfall datasets were not long enough to capture the long-term climatology of the basin, the test behaves erratically. In either case, the RPSS is a useful indicator of forecast skill or the sufficiency of the historical dataset. Given the shortness of our historical dataset, we chose only two categories for the test: wet (above the historical median) and dry (below the historical median). For each category, this effectively reduces the dataset to about fifteen years in length. Upon calculating the RPSS for each month, it was quickly apparent that the test proved that the historical rainfall datasets were not long enough. In each month, including those months for which we established that the forecasts did have skill, the RPSS value oscillated widely between positive and negative values. Figure 6 displays the oscillatory behaviour for the months of March and April. Plots of the RPSS for the other months display almost identical behaviour, moving from near +one to negative numbers.

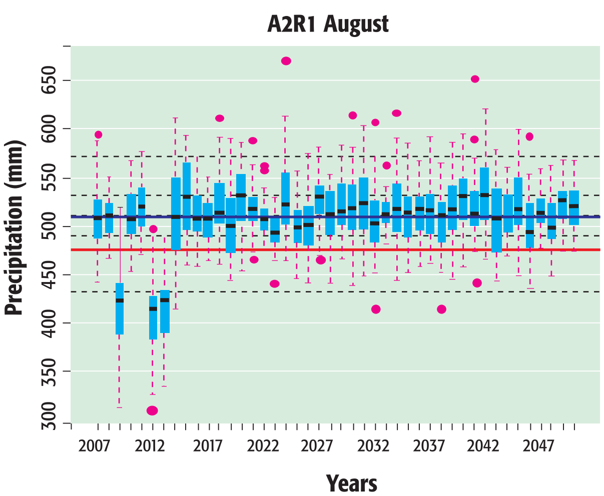
Based on the outcomes of each of the four skill tests, we can say with confidence that the downscaling model developed here is robust and can generate skillful rainfall projections for most months. However, we can also say with confidence, that the model's performance and ability is constrained by a historical rainfall record of insufficient length. The model is skillful in reproducing historical rainfall patterns in all months except January, September and October for the period of 1976-2006. The model's skill and our confidence in its projections would likely be higher if we had longer rainfall datasets, beginning in at least 1950. Given the now quantified limitations of the model, we conclude that we have greater confidence in the model's projections of rainfall under different climate change scenarios for the months of February-May, August, November and December. We have some confidence in the model's projections for June and July and little confidence in the remaining months.

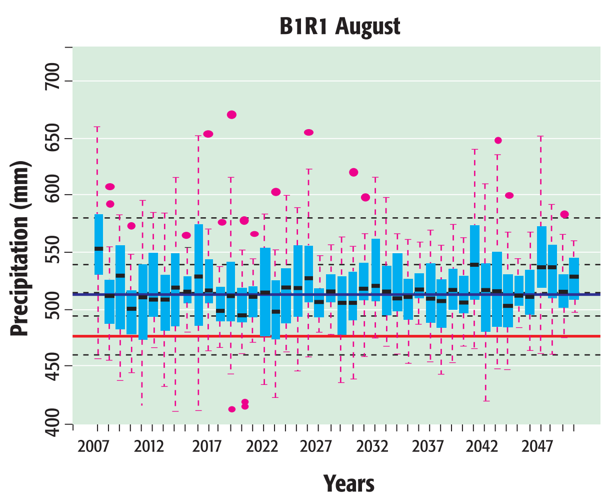
Climate Change Scenarios: 2007-2050

We performed the climate change scenario downscaling after running the model for the testing phase of 1976-2006 and verifying the model's strengths and weaknesses. We actually downscaled ten different climate change scenarios, the A2 Runs 1-5 and B1 Runs 1-5. These various runs are generated because the CGCM3 is run in ensemble mode, with five ensemble members per climate change scenario A2 and B1. We used each ensemble member's projection of large-scale climate features to drive the downscaling model, which itself is run in ensemble mode. The downscaling model generates thirty ensemble members per climate change scenario (A2 or B1) per ensemble run (Runs 1-5). Thus, our model generates 150 ensemble members for the A2 climate scenario and 150 ensemble members for the B1 climate scenario. Furthermore, we ran the model separately for each rainfall station (Belwa, Dumakauli, etc.) rather than as an aggregate as we did for the testing period. The model was run this way so that each station's rainfall contribution could be added into the flood and drought models described in Chapters 6 and 7.

There is a great deal of uncertainty in future projections of climate change impacts on the precipitation patterns of the Rohini Basin, as seen in Figure 7. There is also large variability in the precipitation patterns between months. The uncertainty of the climate change projections is due to a number of factors, which are described in greater detail in the next section. The boxes in the plots are not narrow and the whiskers (dotted lines) extend beyond the boxes, indicating potentially enhanced variability, particularly in

| FIGURE 7 | August's rainfall projections under the A2R1 and B1R1 climate change scenarios. The red line displays the median historical (1976-2006) rainfall. The blue line indicates the new, projected median rainfall.





| TABLE 2 | Comparison of the interquartile IPCC projections for the entire South Asia region with the downscaling interquartile projections for the Rohini Basin.

	A1B			B1			A2		
Season	25th	50th	75th	25th	50th	75th	25th	50th	75th
Dec - Feb	-9	-5	1	-104	-89	-59	-37	-24	-1
March – May	-2	9	18	-59	-52	-28	-60	-55	-35
June – Aug	4	11	16	-4	1	11	-3	0.5	10
Sept – Nov	8	15	20	-19	-13	-1	-15	-9	2
Annual	**4**	**11**	**15**	**-12**	**-7**	**4**	**-10**	**-6**	**5**

There are significant differences in the methodology between the IPCC projections and the Rohini Basin projections and the meaning of the projections, which are explained in the paragraph preceding the table.

the monsoon months. During the non-monsoon months, the boxplots are tighter and less variability in rainfall is seen. It is better to utilize the ensemble projections as a range of possible precipitation, and not try to expect a single rainfall value, which no climate model could give. The best way to acquire a sense of how rainfall might change is to compare the 25th, median and 75th percentile ensemble projections (A2: runs 1-5 and B1: runs 1-5) with the historical median to figure out, on average, if the month is likely to be wetter or dryer than the historical period. The comparison of the interquartile range with the historical rainfall is displayed in Table 2.

The IPCC (Christensen et al., 2007) projections for the entire South Asia region are broad, indicating a general decrease in precipitation in non-monsoon months and an increase in precipitation during the monsoon months. Table 2 provides a comparison between the IPCC's projections for the entire region and the downscaled projections for the Rohini Basin. There are caveats to the IPCC's projections:

1) Their projections are run for the period of 2010-2099 and our downscaled projections are for 2007-2050. Furthermore, their projections take a longer time to converge (reach agreement between models).
2) IPCC projections are based on a summary of results from a minimum of 14 out of 22 different GCMs. Our downscaled projections are based on the output of a single GCM. The GCMs are numerical models taking into account physical processes between the land, ocean and atmosphere. Our downscaling model looks at the statistical relationship between large-scale climate features and rainfall.
3) The IPCC projections are for an extremely large geographic area. Ours are basin specific and there are significant differences of scale.
4) The most crucial difference is that the IPCC projections mentioned in the report are for the scenario A1B, which is different from our choice of scenarios A2 and B1. The A1B scenario is based on carbon dioxide emissions stabilizing at about 720ppm, which is different than the A2 and B2 scenarios.

Overall, the IPCC (Christensen, 2007) projections for the entire South Asian region indicate a slight drying of the area for the December-February season under the A1B scenario. In other seasons of the year, the IPCC broadly projects an increase in precipitation. Our basin specific projections are different, and a little more extreme than the IPCC projections. Given the dry bias of the downscaling model and the limitations of the historical rainfall dataset, we believe the projections toward dryness are a bit extreme. Therefore, we recommend the 75th percentiles rainfall projections under both the A2 and B1 climate change scenarios. In all seasons except the monsoon season, there is a general tendency toward drying, which we believe to be accurate. During the monsoon season, there is potentially a significant increase in the overall seasonal precipitation. Given the nature of monsoon rainfall as intense, localized events lasting only a day or two, a wetter monsoon season indicates more extreme, high intensity rainfall events. These projections point to increased precipitation variability throughout the year, with a greater chance of both floods and droughts depending on the season.

The seasonal aggregation of climate change projections masks the variability between months. For the A2 and B1 scenarios, the Rohini Basin appears to be drying out in all months except for the monsoon months of June-September. Under the B1 scenario, July is projected to be dryer than the historical record. For the both A2 and B1 scenarios, there is strong agreement amongst all the model runs (i.e. the median ensemble member from A2R1 is very similar to all the other runs of A2). The implication of a wetter monsoon season is the potential for increased flooding. Furthermore, because the model had a tendency to underpredict very high precipitation events during the monsoon, it is likely that these future projections are lower than their potential in the A2 or B1 scenarios. The drying of the other months has potentially negative implications on the agricultural seasons, reducing the ability to plant certain types of crops. Dryer Julys under the B1 scenario would negatively affect the crucial nursery stage of paddy crop. Nonetheless, the magnitude of the projected drying is likely to be too large and an artifact of the model bias and short, historical rainfall dataset. We are fairly confident in the projections for the month of August, though, as the model was able to perform well over the test period. This is likely due to well established, stable atmospheric conditions sustaining the monsoon during August, that are not as well established in other monsoon months. The ensemble spread (the range of rainfall values either replicated or projected) is much smaller in non-monsoon months than in monsoon months, indicating smaller less variability in rainfall.

As noted earlier, it is the degree of uncertainty and variability in the rainfall projections that is extremely important. While we might say with confidence that during the monsoon month of August, both the A2 and B1 scenarios are projecting an average precipitation increase of 6% from the historical mean, the spread of the ensembles is also critical. Even though the average increase might be 6%, there is large year-to-year and inter-month variability, as seen in the boxplots. The increased variability implies the potential for more frequent, low-magnitude flood and drought events in the basin. The ability to predict high magnitude events (say, the 100-year flood or drought) is difficult with this model. However, the greater variability in small events indicates that effective climate adaptation and disaster risk reduction measures need to account for increased variability.

TABLE 3 | Major sources of uncertainty in projecting potential climate change impacts for South Asia and the rest of the world

Climate Change Uncertainty	
Sources	**Model**
Rohini Basin rainfall datasets too short	DS
Temporal resolution	DS & GCMs
Ability to model the Himalayas' effect on global weather and climate patterns	DS & GCMs
Incomplete understanding of the physical monsoon processes	DS & GCMs
General lack of quality data for the South Asia region	DS & GCMs
Inability to reach consensus on how ENSO will change under various climate change scenarios	GCMs
Uncertainty in society's ability to transition away from fossil fuel, energy intensive economies and high population growth	DS & GCMs
Uncertainty in how Asia will pursue the process of development, poverty alleviation and land use change.	DS & GCMs

DS = this study's downscaling model
GCMs = general circulation models

Climate Change Scenario Uncertainty

Our certainty in the model projections is constrained by the length of the historical rainfall dataset, upon which this model is based. Quantifying our uncertainty, and hence our confidence, in the projections is a little more difficult, as it is compounded uncertainty from several different sources. Table 3 outlines the major sources of uncertainty in our climate downscaling projections for the Rohini Basin. Several of these sources of uncertainty are discussed in greater detail below.

Data Limitations

The primary source of uncertainty in our downscaling methodology is the lack of rainfall data of sufficient length and of the Indian side of the Rohini Basin. In a more ideal climate modelling situation, such as seen in the developed world, datasets of weather and climate indices (such as rainfall or temperature), are available for fifty years or more. The longer datasets give climatologists greater confidence in their ability to make forecasts because longer records provide better insight into the range of weather events that are possible in an area. The number or weather stations per area and the methodology used to collect data are also very important. For instance, Boulder County, in the state of Colorado in the United States, is roughly half the size of the Rohini Basin and has twenty weather stations in which data has been collected since 1948. The measurements of temperature, rainfall and wind speed, amongst other variables are fully automated and recorded hourly. Moreover, the weather data from the Boulder County stations are easily accessible online for a minimal fee.

The situation is not so fortunate in the Rohini Basin. On the Nepali side, data were only available from five weather stations located primarily on the upper, western edge of the basin. Weather records for points in the middle of the basin do not exist. Given the sometimes highly localized nature of cloudbursts and heavy rainfall events during the monsoon months, we cannot be certain that the geographic distribution of the weather stations for which we do have data are really representative of average rainfall conditions in the basin. Furthermore, Nepal has been experiencing civil unrest for a number of years. The Nepal Tarai, in which the Rohini Basin is partially located, has experienced significant instability, hindering the ability of the individuals in charge of the weather stations to collect data. The government official (anonymous) who provided the weather data indicated that gaps of daily data had been filled in from memory.

The Nepali rainfall records only extend back to 1976, which is not a statistically long period for recording if there have already been climate shifts in the basin or for capturing the full range of potential rainfall behaviour. The precipitation patterns of the basin are associated with the larger South Asian Monsoon (SAM) phenomenon, although the nature of the monsoon is different in Nepal than in India, largely due to the proximity to the Himalayas. The SAM has historically been strongly related to the El Niño Southern Oscillation (ENSO) pattern, although this relationship is not completely understood. Over the period of record of the all-India monsoon rainfall index (IMR) and ENSO indices, ~1870-present, the general relationship has been noted; El Niño (La Niña) events tend to correspond with dryer (wetter) IM conditions (Reason et al., 2000; Kumar et al., 1999; Ihara et al., 2006; Lau and Wu, 2001). Scientists have noted that ENSO changed around 1976 (Wolter and Timlin, 1998; Federov and Philander, 2000). After ENSO changed, the relationship between ENSO and the SAM has also begun shifting (Kumar et al., 2006; Douville, 2006). These important shifts in ENSO and how they affect the rainfall patterns of the Rohini Basin are not known because the rainfall records only extend to the year of the approximate shift. We have no idea what rainfall conditions existed in the basin prior to the shift, which is an important missing link for a model based on historic statistical relationships between rainfall and large-scale climate patterns.

On the Indian side of the Rohini Basin, which encompasses 1943 km^2, only two weather stations are/were in existence: one at Nautanwa and another at Gorakhpur Airport. The Nautanwa station collected data only for a brief period in 1978 and at sporadic intervals until 2003. The Gorakhpur Airport weather station began collecting data in 1954, with several decades completely missing. For the period of 1976-2006, nearly 35% of the Gorakhpur dataset was missing, rendering it useless for this modelling effort. Furthermore, we procured these datasets from the World Meteorological Organization (WMO). The price for the Indian government's Nautanwa dataset alone was 50,000 rupees and their version proved to be almost identical to the WMO version. We did not inquire about the price of the Gorakhpur Airport dataset. Thus, we have no idea about the true rainfall distribution in the majority of the area of the basin. The lack of Indian rainfall data is a major gap in the model, as nearly 70% of the land area of the basin lies in India.

We can say with certainty that the model's ability to project rainfall is severely limited by the data constraints under which we had to operate. The Nepali saying "*Ké garné*?– What to do?" is particularly apropos. The reality of the weather data available for the Rohini Basin is the same reality in the majority of the developing world. It is in developing nations that individuals are more vulnerable to current climate hazards and likely the most vulnerable to climate change impacts. Without a better sense of potential climate change impacts at smaller geographic scales than 100-200km, it is difficult to begin planning and implementing adaptation or disaster risk reduction measures.

Changing Nature of ENSO and the Monsoon

The changing relationship between monsoon rainfall and large-scale climate predictors such as ENSO or the snow cover over the Tibetan Plateau, hinders confidence in the ability of all climate models to project how climate change will impact the monsoon. For many years, there was a strong relationship between the monsoon and ENSO: during El Niño years the monsoon tended to be weaker and drought was widespread; during La Niña years, the monsoon was stronger. Over the past fifteen to twenty years, however, the relationship between ENSO and the monsoon has been breaking down (Ihara et al., 2006; Kumar et al., 2006; Douville, 2006). Furthermore, none of the GCMs can reliably replicate all the features (sea surface temperature, cloudiness, pressure changes, etc.) of ENSO and all of the projections of ENSO under climate change scenarios are different (de Szoeke and Xie, 2008). Due to the breakdown in the relationship between ENSO and the monsoon, the inability of the GCMs to project ENSO, we did not incorporate ENSO into our downscaling model.

Orography

The incomplete understanding of the physical interactions between the land, ocean and atmosphere that give rise to the SAM is influenced by scientists' incomplete knowledge of how mountains affect weather and climate patterns. There is a fair amount of evidence that the SAM would not exist in its current state without the presence of the Himalayas. The Himalayas are the highest mountain range in the world and the area extent of their weather/climate influence is quite large (Barros and Lang, 2003). Atmospheric processes are affected by heating, pressure, moisture transport and wind changes around mountain peaks. The very height and extent of the Himalayas has an incompletely understood influence on the weather and climate of Asia. All climate models, whether numerical or statistical, have difficulty in replicating historical weather patterns for areas near or in the major mountain ranges of the world. Every GCM from which the IPCC compiles climate change projects has difficulty in modelling the physical weather and climate processes over the Himalayan, Rocky Mountains, Alps, and Andean mountain ranges. Furthermore, as our downscaling method relies on statistical relationships between rainfall and climate, the influence of the Himalayas is only indirectly captured in our model. The actual physical effects of the Himalayas are not represented in our model.

Temporal Resolution of Models

Our downscaling model was run on a monthly time step. A monthly time step is too long to capture the important weekly-scale to daily-sale atmospheric dynamics that influence rainfall in all months in the Rohini Basin. There can be significant day-night differences in the amount and distribution of rainfall during the monsoon. The monsoon also undergoes active (strong rainfall) and break (no rainfall) periods that occur at several timescales from a few days and to weeks. Breaks and active periods occurring on a 30-60 day timescale are often associated with the Madden Julian Oscillation (Webster et al., 1998; Saith and Slingo, 2006). Atmospheric phenomena occurring at timescales of less than a month, or incompletely span months, are not captured in the monthly time step of our model. The temporal resolution of our model might contribute, in addition to the other factors described, to its difficulty in replicating rainfall during the months of January, September and October. These months are transitional months. In some years, but not all, depressions forming over the Mediterranean on a weekly timescale bring moisture to Nepal and contribute to rainfall in January. These weekly-scale disturbances are not captured in the January models. In September and October, the atmospheric features that give rise to the monsoon are falling apart and the monsoon ends. However, the timeframes of the stabilization of the atmosphere and the re-establishment of the upper-level westerly jet are beyond the temporal resolution of our model.

Social Uncertainty

Finally, we have to caution about treating the climate change projections of GCMs as completely certain. The IPCC climate change scenarios were developed by a consortium of scientists, after careful analysis of social, economic, and energy use trends. Despite the detailed scientific analysis, the IPCC climate change scenarios are only educated guesses of future energy use and how societies will evolve in the next century. The climate change projections by the GCMs are conditioned on these best-guess climate change scenarios. The lack of certainty in climate change scenarios, coupled with lack of complete understanding about the relationships between various physical land, ocean and atmospheric processes warrants caution in relying upon traditional engineering solutions as adaptation measures. The lack of complete certainty in climate change scenarios does not imply that we should not believe in climate change. Indeed, the effects of climate change are already beginning to be felt around the world. Some effects, such as the rapid melting of the Artic and Greenland ice sheets is more profound than that being projected by the GCMs, indicating that climate change processes might be occurring faster and be more severe than we can guess.

Conclusion

In summary, the analog, statistical downscaling method just discussed provides a robust method for translating large-scale climate change scenarios generated by GCMs to potential scenarios at river basin scales. The accuracy and skill of the downscaled outputs is constrained by the quality and quantity of the data available for the Rohini Basin. We have concretely demonstrated that the Nepali datasets were too short to capture the full range of historical climate variability in the basin. We did not have any data for the Indian side of the basin. The incompleteness of the data is an important source of uncertainty that propagates into the climate change scenarios. Lack of data and the inability to establish large-scale climate feature relationships in certain months made it difficult for the model to replicate historic rainfall for the months of January, September and October. Nonetheless, the model is skillful in replicating rainfall in the months of February-May, August, November and December. The model has a little less skill in the months of June and July, but is still useful. During the driest months of November and December, the model does not do well in capturing years without rain and is biased toward being too wet. In other months, including the monsoon months, the model is biased toward being too dry.

This bias toward dryness in most months influences the climate change projections under the A2 and B1 scenarios. During the monsoon months, both the A2 and B1 downscaled scenarios indicate an increase in precipitation in the Rohini Basin. As much of the monsoon rainfall occurs as intense, short duration (less than a few days) events, an overall increase in monsoon rainfall indicates an increased probability extreme rainfall events and flooding. The model projects a decrease in precipitation in non-monsoon months. In all months, precipitation variability will increase. Given the model's dry bias in all months except November and December, the climate change projections are likely too dry. Thus, while we do believe that there will be less rainfall in the Rohini Basin during the non-monsoon months, the magnitude of the dry projections is likely too high. Conversely, the magnitude of rainfall during the monsoon months is likely underestimated. However, there are many sources of uncertainty that could be contributing to the model bias and the variability in the rainfall projections.

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CHAPTER 4

Qualitative Assessment of the Costs and Benefits of Flood Mitigation:
Lower Bagmati Basin – Nepal and India

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Location: Lower Bagmati River Basin: Rautahat and Sarlahi districts in the Nepal Tarai, and Sitamarhi District in Bihar, India.

Issue: Flood hazards in the Bagmati Basin arise both because of the monsoon and because of flood events and land use changes in the headwater reaches of the river. The high concentration of sediment and the flatness of the terrain in the region of the study cause the Bagmati River to shift course regularly and contributes to the regular flooding that inundates agricultural land and villages. In an attempt to control flooding, embankments were constructed on both banks of the Bagmati from Bihar upstream to the Nepal border. Within Nepal, embankments along the river are partial and discontinuous.

Key Concepts

- Rautahat and Sarlahi districts receive nearly 80% of their annual rainfall during the monsoon months of June through September, with the majority of that rain falling during July and August. Most of the monsoon precipitation is associated with thunderstorm (convective) activity, in which large amounts of rain falls in high intensity, short-duration events.
- As seen in the Uttar Pradesh case, low and moderate levels of flooding were historically beneficial, restoring soil fertility through deposition of micro-nutrients and silt. Major floods, both historical and recent, however, tend to destroy agricultural lands by removing productive topsoil, destroying assets, and causing fields to become water logged. Major floods also contribute to significant loss of life and increases in waterborne disease. Flood control was attempted through patchwork and piecemeal construction and maintenance of embankments in both the Nepal Tarai and in Bihar.
- Given lack of sufficient (and quality controlled) data, only a qualitative cost-benefit analysis of various flood risk reduction measures could be undertaken. Nonetheless, this study provides key insights into the challenges, limitations and opportunities for disaster risk reduction in the Bagmati Basin.
- Embankments are a cost effective flood mitigation strategy only if they are properly maintained and if constructed in a planned manner considering upstream and downstream effects. Given the reality that they are not maintained, embankments are likely to become more of a flood liability, especially in the future, when climate change is likely to exacerbate the frequency and intensity of rainfall events in the basin.
- People-centred flood risk reduction interventions, such as raising the plinth heights of houses, early warning systems and forest buffer zones, are also cost effective strategies. People-centred interventions have the additional advantage that they provide benefits in all years, not just those in which floods occur.
- Cost-benefit analysis is a useful tool, when used in conjunction with social assessments, for assessing whether to pursue an intervention or a suite of interventions, but is limited by data availability, people-hours and should not be used as the sole tool for deciding a project's efficacy. Cost-benefit analysis does not answer the questions of *Who benefits?* and *Who pays?*

Key Messages

In the northern Ganga plains floods are common and constitute a major cause of the poverty endemic to the region. The largest investment governments have made in response to the risk of flooding has been in structural measures such as embankments and spurs. The relative costs and benefits of building embankments are widely debated but have never been systematically evaluated. Alternative strategies for managing floods also exist, but no cost-benefit analysis of such interventions has been undertaken either.

The purpose of this paper is to present the results of a systematic qualitative analysis of the costs and benefits of constructing embankments in the lower Bagmati River basin, which stretches across the Nepal Tarai and into northern Bihar. The methodology we employed provides insight into the trade-offs among strategies that are similar to, but more transparent than, those used in a full cost-benefit analysis. In particular this methodology also reveals the differences in costs and benefits for different sections of the population, information not generated by conventional approaches to quantitative cost-benefit analysis which focus primarily on the aggregate benefits and costs to society as a whole. Our methodology also enriches conventional approaches because it includes many costs, benefits and dis-benefits that are often excluded as externalities. The method is useful in a data-deficient environment.

Our analysis suggests that constructing embankments and spurs for flood control in the Ganga Basin has different implications for different groups. In particular, while some people do benefit from embankment many also lose. Embankments and other similar structures provide short-term benefits to the communities nearest them but have negative consequences downstream and in other locations not directly protected. In addition, in a region where rivers and their tributaries transport high sediment loads, embankments play only a limited role in flood alleviation. In many cases, they block tributaries from draining into main rivers, impede the drainage of precipitation within basins, and cause sediment deposition in river beds, thereby raising their level above the surrounding land. As they age, embankments become highly vulnerable to breaching even during normal-flow stages. The embankment breach and subsequent flooding of North Bihar and the Nepal Tarai by the Kosi River, which occurred as this paper was being written, was devastating.

The role embankments play in flood mitigation provides a useful vantage point for exploring the link between the impacts of climate change and disaster risk reduction. As climate change alters regional weather patterns and hydrological systems, the frequency and magnitude of extreme storms and the incidence of the floods they generate are likely to increase. These changes, in turn, are likely to trigger higher rates of erosion and sediment transport within river systems. As flow variability and sediment loads increase, the technical effectiveness of structural measures designed to control flood flows declines and the frequency of floods and flood related disasters is likely to increase. In data-limited environments common across much of the developing world, it is often impossible to conduct quantitative assessments of the characteristics of such hazards. Much of the data required are unavailable and even recorded trends are too short to yield meaningful analysis. As a result, it is necessary to turn to qualitative approaches in order to evaluate the costs and benefits of embankments and of alternative risk management strategies for local populations and for society as a whole.

In this paper we analyze the costs and benefits of both structural flood control measures, and a wide array of local, "people-centred" strategies. These strategies range from the planting of forest buffers to the raising of houses and villages. They also include the development of early warning systems and the expansion of existing local strategies (such as the provision of boats) for coping with floods. Our analysis indicates that the costs of current structural approaches have exceeded their benefits. Reliance on such measures should be reduced, and instead a combination of people-centred and appropriately designed and maintained structures adopted. If they are designed carefully and accompanied by measures to improve drainage and address location-specific effects, structural approaches can form part of a package of complementary interventions.

Where climate change impacts are concerned, the effectiveness of the approaches to flood risk management will change significantly. Increases in flow peaks and sediment loads appear almost certain to undermine the efficacy of existing embankments, spurs and other structural interventions. In particular, the associated water logging and embankment breaches are likely to increase. As a result, structural measures cannot be an effective primary strategy for responding to the increased flood risk anticipated as a consequence of climate change. In contrast, the benefits of people-centred interventions appear relatively resilient to the impacts of climate change.

Introduction of the Lower Bagmati Basin: Location, Issues and Responses

Our study area is the lower Bagmati basin, which straddles the two districts of Rautahat and Sarlahi in the Nepal Tarai, as well as the adjacent Bairgania block in the state of Bihar in India. It falls in the *doab* (inter-river zone) between the Bagmati and the Lal Bakaiya rivers. It lies in the northern Ganga plain, which extends across eastern Uttar Pradesh, Bihar and parts of West Bengal.

From a modern developmental perspective, the region is one of the poorest and most densely settled in the world. It represents a microcosm of other regions in the Ganga plain. As table 1 below demonstrates, the region's physical characteristics exacerbate the social vulnerability of its people. Currently, the risks of hazards are augmented by human-built infrastructure systems and the institutional, social and political context of the region and these risks will only increase as the climate continues to change.

TABLE 1 | **Hazards and their intersection with human built and social, institutional, and political systems**

Hazards	Human Built Systems	Social, Institutional and Political
Dynamic physical context that will alter due to impacts of climate change	Ring embankments	Poor data institutional base
	Partial embankments	High social vulnerability
Intense in-basin rainfall	Spur	Political restructuring
Flash floods from Chure rivers	Revetment	Inappropriate conventional methods
Flood	Irrigation canal	Conflict
Changing plan-form	Road and highways	Poor governance
Regional sedimentation: erosion, transportation and deposition	Buildings	
Impacts due to climate change		

Substantial investments have been made in the construction of large-scale infrastructure, specifically irrigation systems and flood protection embankments in the Ganga plains since the 1950s. While irrigation systems have promoted agricultural growth, embankments have not been beneficial and many social activists argue that these structures have not had significant benefits in comparison to the environmental, social and other costs. Despite the debate, however, embankments are still the primary mechanism for flood control that state agencies pursue.

TABLE 2 | Status of road system

	Type of road			National Highway
	Gravel	Earthen	Total	
Rautahat	41.0	83.5	200.3	26.4
Sarlahi	279.4	102.3	446.3	30.2

Source: Road Statistics, 2004

Our purpose in analyzing the performance of embankments along the Bagmati River is to as systematically and, as objectively as possible, evaluate the costs, benefits and impacts of both existing flood control infrastructures and potential alternative "people-centred" flood risk management strategies. Before we discuss these strategies in detail, we describe the regional context into which they fit.

Administrative Characteristics

Bairgania is one of the seventeen bocks in Sitamarhi District of North Bihar. The town of Bairgania lies in this block. According to 2001 census, Bairgania has a population of 34,821. A metre gauge or narrow railway line to Raxaul running parallel to the Nepal-India border passes from Bairgania. Since no information on Bairgania Block, in Bihar is available, the following section focuses on Nepal. Besides, the two regions are similar. In Nepal, the Bagmati Basin lies in Rautahat and Sarlahi districts, which extend from the Chure hills (the foothills of the Himalaya) in the north to the Nepal-Bihar border in the south. Rautahat is one of 11 districts in the central development region of Nepal and lies in the Narayani Zone south of the capital Kathmandu. The district has 97 village development committees (VDCs), which are the lowest administrative level of government. Rautahat covers an area of 1,126 km^2 and, according to the 2001 census, has a population of 545,132 living in 88,162 households. Sarlahi District, which falls within the large administrative region of Janakpur Zone, is located east of Rautahat District. It contains 100 VDCs and covers an area of 1,259 km^2. As of 2001, Sarlahi District had a population of 635,701 living in 111,076 households.

Large portions of both districts were covered by forest until the 1960s. This forest was part of an area known as the Char Kose Jhadi, where, until the 1960s, malaria was endemic. After malaria was eradicated, the inflow of people increased gradually. At the same time, the government investments in water development projects, including flood control. Before the construction of the East-West Highway (the main transport corridor extending right across Nepal and lying in the northern bhabar1 region of Rautahat and Sarlahi districts), Gaur, the district headquarters of Rautahat, had to be

TABLE 3 | Status of land ownership

River Basin	Landholding in flood affected area		Landholding outside flood affected area	
	HH having land (%)	Average holding size (ha)	HH having land (%)	Average holding size (ha)
Bagmati	49.7	0.91	24.0	0.86

[1] *Bhabar* - a narrow, but deep zone of boulders, gravel and coarse sediment deposited at the base of the Chure hills – the southernmost range of hills before the Ganga plains.

accessed via the town of Bairgania in Bihar. After 1969, however, Gaur became accessible through Chandranigahapur, which lies on the highway about 40 kilometres north of the district centre. Once the region had been opened still more roads were built. Development in Sarlahi District followed a similar pattern. Still this region is less developed than other parts of the Nepal Tarai. More specifically, the length of roads in Rautahat and Sarlahi districts is much lower than the national average in 2004 of 11.7 kilometres per 100 km^2. Most land in both districts is cultivated; the second most common land use is forest.

TABLE 4 | Household's average annual income

Source	Income (NPR)	%
Agriculture	17,862	41.3
Livestock	3,334	7.7
Service	8,633	19.9
Trade/Business	4,279	9.9
Cottage Industry	445	1.0
Other (Specify)	8,729	20.2
Total	43,282	100.0

Source: Survey 2003

Social and Economic Characteristics

Despite rapid increase in settlements in recent decades, the area is not developed. Large sections of the population face social and economic hardships, particularly during the monsoon season, because they lack access to safe drinking water supplies, sanitation, basic health services and nutritious food. As is common throughout most of Nepal, the literacy rate is highly skewed: the rate for males is 45%; for females, 24%. Just 35% of households have access to water supplies and only 20% to sanitary toilets.

TABLE 5 | Population distribution of *panchayats* within Bairgania Block

S.N.	Grampanchayat	Villages	Population			
			SC	ST	Others	Total
1	Bairgania (Municipality)	Asogi, Senduriya, Baluwatole, Bhakurahar, Nuniyatola, Dumarwana, Shivanagar, Sekhauna and Chikana Tola	NA	NA	NA	NA
2	Pastaki Jadu	Pastaki Jaddu, Pastakki Ram, Barahi	951		8,378	9,329
3	Mushachak	Musachak, Adambaan, Masaha Nawaratan, Masaha Aalam	1,064		5,020	6,084
4	Nandbara	Nandabara, Bengahi, Adambaan, Masaha Aalam, Bel Bengahi	1,489		6,622	8,111
5	Belgunj	Bakhari, Bel, Gunj, Bakhari Tola	533		6,551	7,084
6	Parsauni	Jodiyahi, Bhatauliya, Parsauni	816		8,574	9,330
7	Patahi	Bahiri, Chhoti Bahiri, Patahi, Marpa, Kudhwa, Dhangar Tola	1,580		7,076	8,656
8	Jamua	Jamuwa, Pakadiya, Bilardeh, Hasima, Madhuchhapara	848		9,726	10,574
9	Akta paschim	Akta Paschim, Chakwa, Barwa Tola, Takiya Tola, Lohari Tola, Satparuwa, Pipradi Sultan	55		7,554	7,609
	Total		**7,336**		**59,441**	**66,777**

Source: Field Study, 2008

Rautahat and Sarlahi are inhabited by various groups, including Yadhavs, Tharus, Rajputs, Brahmins, Chhetris, Kurmis, Baniyas, Musahars, Telis, Dhobis, Malis and Muslims. A similar ethnic and caste structure is present in Bairgania block of Bihar. Agriculture is the mainstay of the region's economy. Table 5 shows the population and caste distribution within the Bairgania ring embankment portion of our study area.

According to the district agriculture office (DAO) of Rautahat, 79% of the population depends on agriculture to earn a livelihood. The remaining 21% are engaged in non-agriculture livelihood like service, trade and business. Some households also work as agricultural labourers. Twenty-six per cent of households are landless. Female and child labourers also work as labourers in agriculture. Paddy is the main crop; but sugarcane, mustard, wheat and potato are also commonly cultivated. Because landholdings are small (an average of 1.06 ha in Rautahat and similar in Sarlahi), very little surplus is generated. Most production is merely subsistence level; only a few wealthy farmers practice commercial farming. Opportunities for livelihood diversification are limited.

Hydrologic and Geologic Characteristics

The hydrologic and geologic context of the Nepal Tarai and the adjacent area in northern Bihar, is dynamic. The region lies in the northern Indo-Ganga plain, which extends from the base of the Himalayan mountain range across the Nepal-India border into Bihar. Its large alluvial fans, which have been deposited at the base of the mountains by rivers originating in the Himalaya and in Tibet, include alluvium dating back to the Pleistocene Era. The average thickness of these sediment deposits in the Tarai is approximately 1,500 metres, but their nature varies across north south. Immediately south of the Chure range (the unconsolidated foothills at the southern base of the Himalaya), are alluvial fans composed of boulders, gravel and coarse sediment. They create what is known as the bhabar zone, a narrow but deep band of boulders and course gravel, where water infiltrates rapidly to contribute substantially to overall recharge of the Ganga Basin.

At Karmaiya, where the Bagmati River enters the Tarai, sediment is about the size of gravel but changes to sand, then to silt and finally to clay along the downstream. This reduction in sediment size is a result of progressive decline in the capacity of rivers to transport materials as topographic gradients flattens once rivers exit the mountains and flow on the Tarai. All alluvial deposits right across the Tarai, regardless of the size of their sediment, form good aquifers. Groundwater is generally available although it is found at different depths and, in some locations, only in pockets.

The study area is drained by numerous large and small rivers, including the Bagmati, Lal Bakaiya, Chandi, Manusmara and Jhanjh, all of which are tributaries of the Kosi River and, ultimately, of the Ganga. The Bagmati River originates in the Mahabharat hills (the middle range of the Himalaya below those areas fed by snow or glaciers). Its headwaters are in the Shivapuri range about 16 kilometres northeast of Kathmandu at an elevation of 2,800 metres. The river merges with the Kosi River at Badlaghat in Bihar after travelling a distance of 195 kilometres in Nepal and 402 kilometres in India. Its total catchment area is about 13,400 km^2 of which about 7,000 km^2 are in Nepal.

For the first 154 km from its headwaters, the river catchment is mountainous. The average slope of the Bagmati River between Teku Dovan in Kathmandu and the confluence with the Kokhajhor Khola, a stream at the base of the Mahabharat mountains, drops 10 metres in a kilometre. Further south, the slope within Nepal declines to approximately to a drop of one metre in a kilometre. At Karmaiya, where the river debouches onto the plains, the elevation is about 140 metres above sea level and the river slope begins to reduce further. From Karmaiya to its confluence with the Kosi River, the Bagmati flows in the low-gradient Tarai plain. At Karmaiya the maximum flood with a return period of 100 years is estimated to be 10,500 m3/s, but the peak flood ever recorded was 16,000 m^3/s in 1993.

After the river exits Nepal and enters the Indian state of Bihar, the slope of Bagmati decreases to a drop of 0.87 metres per kilometre. In contrast with the upper reaches of the basin, where the river drops 1,000 metres in a 100 kilometres stretch, the much flatter gradients of the lower basin give the Bagmati a highly dynamic character. In our study region in Nepal and in Bihar, the Bagmati and its tributary rivers deposit sand on large areas of the flood plains. The deposition of sand is a regular process and one which damages agricultural land. The regional sedimentation pattern of the rivers is a product of both the fragility of formations in the upper catchment (a consequence of the rapid tectonic uplift that created the Himalaya) and the intense rainfall in the middle hills and Chure range. In the upper catchment, the geology is unstable and prone to natural weathering. Erosion continually provides sediment to the Bagmati River; landslides and bank cutting also make regular contributions. All this sediment is then transported downstream. Much of it is deposited rapidly as the Bagmati flows from the mountains to the plains.

The stream channel in the Nepal Tarai is mostly braided until it reaches the Nepal-India border and enters Bihar, from where it meanders extensively as is common for rivers within the central Ganga plains. The high concentration of sediment and the flatness of the terrain cause the Bagmati River to shift course regularly and contributes to the regular flooding that inundates the agricultural land and villages along its banks. In an attempt to control flooding, embankments were constructed on both banks of the Bagmati from Bihar upstream to the Nepal border. Within Nepal, embankments along the river are partial and discontinuous.

One of four major tributaries of the Bagmati, the Lal Bakaiya River joins the Bagmati downstream of the Bairgania ring embankment south of Pipradi Sultan. Of its total length of 109 kilometres, 80 kilometres are in Nepal and 29 kilometres in Bihar. The river has a total catchment area of 896 km^2. The Lal Bakaiya's maximum discharge having a 100-year return period is estimated to be 500 m^3/s. The river is dynamic, highly mobile; it cuts its banks regularly, affecting settlements and cultivated land abutting it. Flooding is common too. During the monsoon, both the left and the right banks of the river flood in both Nepal and Bihar. The other three tributaries of the Bagmati are also dynamic and, depending on the volume and nature of rainfall in their catchments, can become hazardous. In particular, intense rainfall can cause damaging flash floods.

TABLE 6 | **Impacts of 2007 floods in Rautahat District**

Category	Population	Households
Severely affected	10,048	1,421
Highly affected	8,732	1,158
Moderately affected	13,150	2,331
Total affected	31,930	4,910

Source: Compiled from Nepal Red Cross Data, 2007

Flood hazards in the Bagmati River and its tributaries are heavily influenced by both the monsoon, which lasts from June to September, as well as by events in upstream tributaries. In particular, cloudbursts, mud flows, debris flows, flash floods and bishyari (major floods caused when landslides that dam rivers breach) are common in the mountains. The lower Bagmati region receives a substantial amount of rainfall during the monsoon season and it is this precipitation which serves as a primary trigger for most flood events. After the monsoon, in contrast, conditions are often drought-like. The characteristic alternation of flood-drought in the region is a natural outcome of the region's climate.

What is the impact of flooding? Moderate flood events benefit agriculture but can result in three types of hazards: inundation, the erosion of banks and loss of land, and the deposition of sediment on land. Floods carry mirco-nutrients, fine silt and loam and, after waters recede are deposited on fields, where they improve soil fertility and productivity. During major flood events, however, no such benefits accrue. In 1954, for example, a major flood deposited so much sand on agricultural land in Brahmapuri VDC that the entire paddy crop was destroyed. The land could not be cultivated again until 1961, when a low-intensity flood deposited a layer of silty loam, restoring its fertility. In the seven years between these flood events, the residents of Brahmapuri faced food shortages. Wealthy households bought food in the local market while the poor migrated to India and to neighboring villages in search of jobs.

TABLE 7 | **Loss of life and property during 1993 floods in Bagmati Basin, Nepal (in NPR)**

District loss	Affected		Death	Houses damaged		Land Loss	Livestock loss	Infrastructures					Food grain loss	Total Worth (NPR)
	HHs	Popn.		Completely	Partially	(area in ha)	(Km)	Road	Bridge	Dam	FMIS building	Public		
Kathmandu	10	58*	2	8	0	3	159	0	0	0	0	0	0	867,274,750
Lalitpur	0	0	6	57	51	135	0	0	1	0	1	0	0	**
Makwanpur	14,748	101,482	242	1,732	1,879	4,656	665	8	16	1	251	118		119,864,381
Kavre	2,958	10,642	20	914	92	1,030	159	0	0	0	0	0	0	86,274,750
Sindhuli	11,051	59,142	52	1,206	1,314	4,061	1,930	26	41	5	6	24	1,186	86,349,764
Rautahat	14,644	89,146	111	2,003	4,541	1,366	3,211	40	13	0	1	37	31,673	899,680,261
Sarlahi	15,560	53,265	687	7,066	8,494	25,966	17,736	266	81	4	117	184	0	1,118,918,500

Note * Generated data
** Missing data

Source: Developed from Photo Album, Disaster of July 1993 in Nepal, December DPTC (1993)

Although monsoon rains and the floods they create are crucial for sustaining agriculture in the region, they also pose a major hazard. Sediment eroded from the upper regions of rivers is transported to their lower reaches and deposited on the flood plains of the Tarai. Rivers cut their banks and shift laterally, creating serious problems as they erode land and destroy crops. In 2007, when this study was being conducted, 93 out of the 97 VDCs of Rautahat District were affected by floods (Table 2) and in some section of the study area, farmers were unable to cultivate kharif (monsoon) crops. In some years, as was the case in 1993, the loss of life and property can be extensive.

Climate Change Impacts

Relatively little scientific information is available on the implications of global climate change for the Nepal Tarai and what is available is general and does not capture local dynamics. Projections by the Intergovernmental Panel on Climate Change (IPCC) for the Himalyan region indicate that overall precipitation is likely to increase by approximately 20%. Variability is also projected to increase, as is the frequency and intensity of extreme storms. In general, increases in the variability and intensity of climatic events are likely to increase by existing natural features such as the dynamics of the monsoon and the orographic impacts of the Himalayan range. As air moves northward and encounters the Himalayan uplift during the hot summer pre-monsoon and humid monsoon seasons, intense storms are generated within the Ganga Basin, especially in the middle and lower hills of the mountain range. Although no quantitative scientific studies are available, logic suggests that this phenomenon is likely to be intensified by the anticipated increases in the volume and variability of precipitation.

If the volume and variability of precipitation and the intensity and frequency of extreme events do increase, the hydrology of the region is likely to become more dynamic as well. Extreme events often trigger erosion and large-scale sediment transport as well as bank cutting and the natural migration of rivers as across alluvial fans. For this reason, mechanisms for managing flood risk can still function effectively as sediment loads and flood flows increase need to be a core element of any strategy for adapting to climate change in the basin.

Embankment along Bagmati River at Brahmapuri, Rautahat District, Nepal.

Evaluating Alternative Flood Management Strategies

Given the dynamic nature of the Bagmati River and its tributaries, the adverse impact that existing patterns of flooding already wreak on with region's population and the likelihood that such impacts will worsen as climate change makes the regional hydrological systems more erratic, there is an urgent need to identify effective mechanisms for flood risk management. As discussed above, the current approaches to flood management implemented by the governments of India and Nepal rely primarily on embankments and other structural measures. In addition to such formal interventions, local populations have developed an array of strategies for coping with or adapting to the dynamic nature of the region's hydrology.

There is little data on the effectiveness of either these structural measures or the informal self-initiated responses of individuals or communities. There is a dearth of even the most basic of data, such as precipitation within the basin, river flow levels, areas of flooding, and investment in the construction of flood control structures, whatever data is available is often incomplete or of uncertain quality. With so little information, making effective decisions regarding flood control strategies is difficult.

Because there is so little quantitative information, it is essential to turn to qualitative approaches to identifying and evaluating alternative strategies as a first most basic step towards making informed decisions. What sort of information is needed? At the very least, an understanding of the potential strategies for responding to floods is essential. Beyond this, developing an understanding of the effectiveness of such strategies as well as benefits they generate and, the costs they entail, who benefits and who loses is central to strategic decision-making. Qualitative approaches to cost-benefit identification and evaluation, such as the methodology outlined below, can provide much of this insight. If necessary, such approaches can also provide a foundation for quantitative approaches to evaluating the costs and benefits of specific strategies for flood risk management.

The Qualitative CBA Methodology using Shared Learning Dialogues

How does one evaluate the potential gains and losses associated with a flood or other disasters. Gains help meet basic societal goals such as those listed in Box 1, while losses reduce the ability of society to reach them. Reaching these indicators of wellbeing is central to development efforts, but far beyond the capacity of disaster risk reduction interventions to achieve on their own. Besides, only the first four objectives are tangible enough to be directly identified and measured. It is these four objectives that our methodology assesses to estimate the costs and benefits of flood risk management strategies though it could also be used to identify these strategies influence a society's ability to reach some of the other goals as well.

BOX 1

Indicators of wellbeing

A society is doing well when its members enjoy

- Secure access to food, clothes, shelter, drinking water and energy
- Affordable health services, hygiene and sanitation
- Access to education
- Access to reliable communication systems
- A reliable source of livelihoods, i.e. livelihood resilience
- Social harmony
- Individual and collective security
- A clean environment
- Harmonious cultural and religious identity
- Voice and representation
- Social equity

Adapted from Kuiper (1971)

To assess cost and benefits, we followed the relatively simple set of steps listed below though the process was not as linear or smooth as the step suggests. Indeed, lines dividing steps became evident only in retrospect and the order sometimes varied. That said, the overall process of evaluation did move through the phases identified below.

STEP 1: coping and initial engagement: Since ISET-Nepal and its partners have been working in the region for several years, our initial scoping activities focused on reviewing the relevant information (maps, background documents, etc.) already available as well as on making a series of visits to the region. During these visits team members discussed flood-related issues with existing contacts, identified new contacts and met with local communities. In addition, we gathered published and other information related to the region's hydrology and the impacts of climate change that ISET-Nepal had not collected earlier. This step identified areas affected by and vulnerable to floods as well as local perceptions about existing governmental, community and individual strategies for responding to floods and, in effect, set the stage for more detailed discussions with local communities regarding the specific nature of flood hazards and response strategies. In addition, our review of global and regional climate and water-related literature identified key issues that did not emerge in discussions at the local level.

STEP 2: Intensive shared learning dialogues to identify key risks and potential response strategies: The next step was to hold a series of focused group and one-to-one discussions in local communities in order to outline flood hazards and responses to them. The discussions focused specifically on the nature, condition and location of the flood mitigation measures the government had implemented as well as on systematically identifying what people do during floods and what measures they take to meet their key needs, including how they protect their lives, livelihoods and assets. Using information from global scientific literature on climate change, study team members asked individuals and groups what they thought the major issues and challenges would be if climate change projections became a reality and if floods and drought impacts become more intense and more frequent.

STEP 3: Intervention-specific evaluations to identify the benefits and costs associated with each response strategy. The results of the shared learning dialogues were used to identify key risk management measures for evaluation. In the lower Bagmati River Basin these measures consisted of (a) structural interventions, specifically the network of flood control embankments that has been constructed over recent decades; and (b) an array of alternative measures, undertaken by individuals, communities and NGOs to minimize the risks they face. In the case of embankments, the evaluation involved mapping existing structures and then holding a series of shared learning dialogues with communities along a series of transects cutting across the region. The purpose of this exercise was to identify and discuss local perceptions of the benefits of these interventions and if the negative impacts associated with them. Since alternative measures do not cut right across the landscape, discussions were not organized along the transects.

STEP 4: Ranking and related techniques to assign relative weights to perceived benefits and costs: In consultation with local communities, we ranked the relative costs and benefits of each response measure identified. People were asked to identify all the benefits associated with each measure and then weight each benefit on a simple scale from small to medium to large. In the case of embankments, the ranking of both benefits and costs was done along transects that cut across protected and unprotected areas both up and downstream from the protected locations. During the shared learning dialogues process we listened to the perspectives and insights of local communities but also had them consider information that they had not previously known. Discussions emphasized both direct costs (like how much was invested to construct embankments, what it costs to buy a boat or raise the level of houses) and indirect costs (like the losses due to water logging outside embankments). The end result of this process was (a) a list of strategies that either had been implemented to respond to floods or that contribute to the ability of individuals and communities to manage flood risks; (b) a list of the direct and indirect benefits and costs associated with each strategy; and (c) a weighting of those costs and benefits using a simple plus-minus system. Examples of how this worked in practice are outlined in the next section.

STEP 5: Shared learning dialogues to identify directions of change in perceived benefits and costs as climate and other processes of change proceed: In this final step discussions were held with communities to consider the implications of climate change would have on the direct and indirect benefits and costs currently associated with each of the main response strategies. The focus was on whether or not the strategies would remain effective in the projected climate change scenarios. Participants were asked, for example, whether or not they thought water logging and the tendency of embankments to breach would increase. They were also asked whether or not the benefits of the community and household-based strategies listed of Box 2 (such as the traditional practices of using boats, raising the level of plinths and constructing silos to protect grains in locations safe from inundation) would still be generated. Other questions brought out peoples' perception of the changes in the direct and indirect costs associated with each strategy.

After all five steps had been carried out, we had generated a list of hazards and response strategies as well as the costs and benefits associated with each strategy and their relative weights. The costs and benefits related to the tangible indicators of wellbeing identified in the first four bullets in Box 1 (secure drinking water, food and shelter, energy, and health and education and communication services). The methodology also enabled us to identify and weight the impacts of various strategies on some of the less tangible indicators of wellbeing, such as livelihood resilience, social equity and harmony, a clean environment, and so on. How this worked in practice is illustrated in the example below.

Example of the Methodology Employed

The five-step sequential process described above was over the qualitative yet systematic cost-benefit assessment. It involved conducting shared learning dialogues with local people, local governments and NGOs about specific risk mitigation measures, both conventional and alternative. This assessment was conducted in villages located along a series of transects selected to cut across a spectrum of conditions from those in the lower sections of the basin in Bihar to those in the adjacent upstream areas in Nepal (see Figure 1). For each transect, costs and benefits were compiled according to the type of intervention. For some local interventions, such as early warning systems, raising the plinth of houses and providing boats for use during floods, the use of transects that cut across the region was less essential than for other interventions, such as embankments, whose upstream-downstream relationships strongly influence costs, benefits and their distribution. Even in terms of community based responses, however, strategies do differ substantially in different areas because the nature of the flood hazards people face change. The use of transects enabled the evaluators to do two things:

a) capture the local nuances of the interventions carried out in various villages and their relation to the various characteristics of the flood hazard; and

b) zoom out for a wider and therefore more complete picture of the issues that is not possible if interventions carried out in just one village are the sole focus.

The shared learning dialogues conducted in villages along transects were combined with a systematic assessment of vulnerability. Other dialogues were carried out with local government agencies such as the VDCs, district development committees (DDCs), local and International NGOs as well as with sector-specific high-level institutions such as the Department of Irrigation and the Department of Agriculture. Dialogues moved through a typical sequence, beginning with a discussion of the specific local characteristics of flooding to government, NGO and community responses to it. Then discussions shifted to the advantages and disadvantages of those responses and ended with the identification of those advantages and disadvantages as specific benefits or costs. The evolution of the nature of the discussion, which often occurred over several meetings, enabled researchers to develop a disaggregated list identifying the specific direct and indirect benefits and costs associated with each individual strategy.

The costs and benefits identified differed for each type of intervention. Discussions of the benefits of embankments, for example, typically started with the direct flood protection they provide and then moved on to consider their role, as areas of relatively high elevations serving as points of refuge to secure lives and assets after villages are inundated. The costs identified often focused first on the construction and maintenance of the embankments but then moved on to consider impacts such as water logging and the increased incidence of disease due to stagnant water, impacts which are typically treated as externalities in conventional economic analysis. Finally, as discussions of such tangible costs and benefits proceeded, other benefits and costs related to gender, social cohesion, and other factors emerged. A similar evolution in the nature of discussions also took place in the case of community based strategies, but most of them had no major costs to consider aside from the initial direct financial and maintenance costs (like the cost of purchasing and maintaining a boat or installing, operating and maintaining a flood warning system).

Along each transect, each cost and each benefit was initially marked with a minus (-) or plus (+) sign respectively following dialogues with different groups selected to reflect various geographic contexts, gender, poverty and other factors that affect the level of exposure and vulnerability to floods. Once impacts were identified as plus or minus, ranking and other techniques were used to assign each cost or benefit a relative magnitude ranging from one three, plusses (+++) or minuses (- - -).

We selected three transects in the lower Bagmati basin to capture the diversity in social and natural context and in past interventions (see Figure 1). A snapshot of the main villages engaged in the shared learning dialogues along each transect is given table below. The transects crossed through the following areas:

1. The main channel of the Bagmati River
2. The Lal Bakaiya tributary to the Bagmati; and
3. The Bagmati-Lal Bakaiya *doab* across the Gaur municipality, through the Bairgania ring embankment and to Pipradi Sultan.

During the scoping phase, villages along these three transects were selected using topographic maps, Google Earth images and discussions with local stakeholders. Our earlier adaptive study project (Moench and Dixit, 2004) and the adaptation pilot activities being planned in the region gave us access to substantial background information.

The existing strategies for responding to floods that were ranked are listed below:

- Embankments along the Bagmati and Lal Bakaiya rivers
- The Bairgania ring embankment
- Raised platforms and flood shelters (community level strategy)
- Raised houses (household level strategy)
- Flexible bridges
- The Bagmati, Chandi and Gandak irrigation canal and the Bagmati barrage head works.
- Basic services: water, sanitation, health and irrigation (using mechanized pumps, including treadle pumps)
- Forests as buffer zones for bank protection, including plantations and small embankments located at a distance from flood plains, and
- Spurs and revetments

The above responses can be categorized into two major strategies for responding to floods: (1) government-led strategies that rely primarily on structural measures such

| FIGURE 1 | The three transects in lower Bagmati Basin

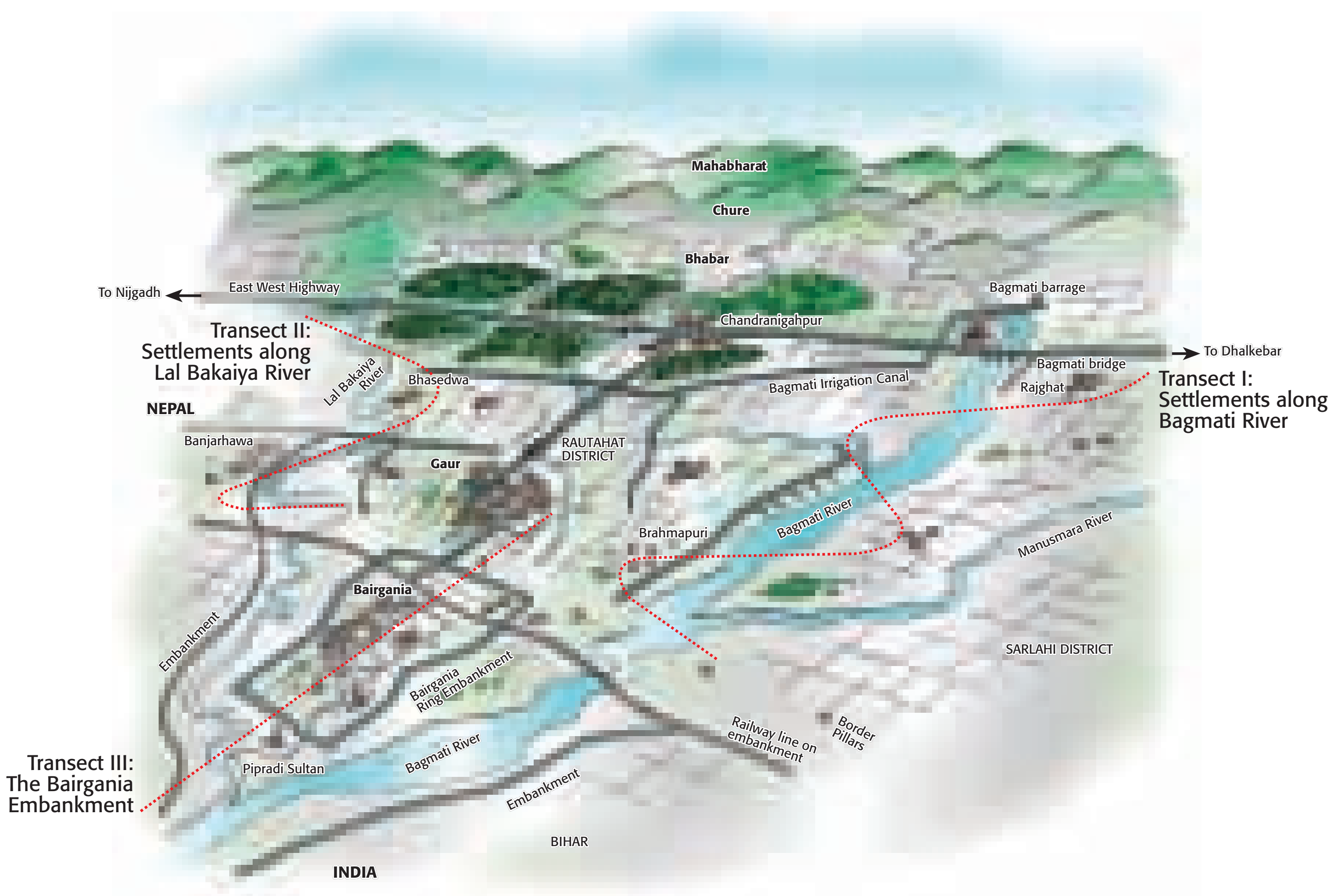

TABLE 8 | Snapshot of the main villages engaged in SLDs along the three transects

Bagmati River	Lal Bakaiya River	Bairgania-Gaur Municipality
1. Brahmapuri is situated on the banks of Bagmati River. The Bagmati and Bairgania embankments together compound the inundation problem. 2. Sedhawa village lies east of Brahmapuri and is impacted by the floods of the Bagmati River along with the backwaters of Bairgania embankment. The village is situated upstream of the railway bridge that constricts downstream flow of Bagmati. 3. Rajghat. A forest buffer along with a stretch of embankment of smaller heights compared to that of Brahmapuri and Bairgania works as flood protection. The embankment begins from the headworks of Bagmati irrigation barrage.	1. Banjarhawa - A new embankment has recently been built. Many *pukka* (cement) houses have been constructed after the embankment was constructed. Land prices have soared following the construction of the embankment. 2. Bhasedwa. Series of spurs and revetment walls constructed by the Bagmati Irrigation Project and Oxfam forms the predominant DRR strategy. 3. Phatwa Harsa. This village lies west of Lal Bakaiya and downstream of Bhasedwa. The water from Lal Bakaiya is re-directed by spurs and pitched embankment (revetment). The embankment in Bhasedwa village is built to protect the Bagmati Canal.	1. Gaur: The drainage of this municipality is affected by Bairgania ring embankment. 2. Mahadev Patti is a village situated around one kilometre west of Gaur Municipality. The Bairgania embankment obstructs the drainage. 3. Bairgania Block: Ring embankment, raised platform and settlements on the top of embankment. 4. Pipradi Sultan lies upstream of the confluence of Lal Bakaiya and Bagmati Rivers.

as embankments and spurs; and (2) people-centred strategies that emerge from the autonomous responses of households and communities at the local level and involve a broad mix of relatively location-specific, small-scale interventions. It should be noted that this is not a comprehensive listing of alternative interventions being practiced in the communities. A set of additional interventions is identified and evaluated in "Risk to Resilience Working Paper No. 4".

Results along the Transect

Transect I: Villages along the Bagmati River

As Figure 1 indicates, the Bagmati transect begins downstream of the Bagmati irrigation barrage and continues to the Nepal-India border. The northern stretches of the Bagmati River have a greater gradient than sections five kilometres downstream, where the flood plains are much wider and the slope much less. As a result, in upper areas like Rajghat VDC (the site of some SLDs) flood waters recede much faster than they do in villages in southern portions of Rautahat District. In upstream areas, the period of inundation associated with flooding is short, generally less than a day. Major floods can, however, generate longer periods of inundation, but even during the major flood of 1993, water remained for just two days. Long-term inundation is not the major issue facing upper areas. Instead, flash flood damage, bank cutting and migration of the stream channel are a greater direct concern. In the lower region (Figure 2), in contrast, the primary concern is long-term inundation that frequently lasts weeks or even months.

FIGURE 2 | Southern areas of Transect I: Bagmati River with embankment numbers

Response strategies along this transect reflect the different natures of the flood hazard in different locations. In upper northern areas (Figure 3), forest buffers and small embankments along the river are a key strategy. In the middle and southern portion of the transect, the core strategy implemented by the government involves the construction of major infrastructure for flood control, specifically embankments, spurs and revetment walls. There are four sets of embankments in the middle and southern reaches of this transect. All four are illustrated in Figure 2 and further described below.

1. The Bairgania ring embankment was constructed in 1973/74 in order to safeguard the Bairgania block

FIGURE 3 | Northern areas of Transect I: First buffer and embankments along Bagmati River

TABLE 9 | Benefits and negative consequences of embankment 1 and 2 as listed by communities engaged in SLDs

Benefits	Negative consequences
These embankments stop flood waters from damaging the houses in the village	The silt deposit is checked by the embankment and this results in declined agricultural productivity
When houses are not damaged, the cost of maintenance and repair are negligible	Soil fertility declining fast
Men who have gone for jobs in various states of India (seasonal migration) do not have to come back during monsoon. The fear factor of loosing members of family and assets are low	The land situated between the river and the embankment is rendered useless as floods deposit sand
The chance of losing cattle is lower	The problem of bank cutting intensifies as flood water returns back to river
Accessibility will not be hampered	More problem of inundation and water logging as there are no drainage facilities
Chances for establishment of small industries will be higher	Employment opportunities decrease

and the adjoining regions of north Bihar. The northern portion of this embankment runs east-west about 200 to 400 metres south, and parallel to, the Nepal-India border. It starts at Majorgunj, a market centre in Bara District, and ends north of Muzzafarpur. Except for a gap to the south of Bairgania, the embankment forms a complete ring. Although this 18 foot high embankment successfully protects the northern part of the area it encircles, it also obstructs most southward drainage. Drainage is further impeded because the sill level of the four sluices intended to allow non-monsoon waters to pass are at least two feet higher than the adjoining drain in Gaur, Nepal, and because these sluices are shut down during floods. Part of an adjoining railway embankment (described below) and the main road are also linked to and form part of this embankment system. These structures also greatly impede drainage in areas outside and upstream of the ring embankment, creating a backwater effect that causes extensive flooding in villages and in Gaur municipality, the headquarters of Nepal's Rautahat District, which lies north and outside the ring embankment.

2. The railway embankment that connects Raxaul to Darbhanga runs east-west and intercepts the worth-south drainage channels. The section connecting Ghodasahan (in eastern Champaran District and Sitamarhi, the district capital of Sitamarhi District, falls within the lower Bagmati–Lal Bakaiya catchments and is connected to the Bairgania ring embankment. The railway bridge which crosses the Bagmati River further south constricts flood flows and, as a result, contributes to flooding in northern areas. The 15 five-foot-wide piers of the 500 foot-long railway bridge over the Bagmati River reduce the waterway by 75 feet. Four hundred metres downstream of the existing bridge a new bridge is now being built following the failure of earlier efforts.

3. The third embankment starts at Harpurba in Manpur VDC in Nepal and joins the railway line near the Bagmati bridge at Rout-Chanki Tola. This incomplete embankment lies completely within Nepali territory. The existing segment extends up to the village of Sareh, west of Sedhawa. It is 30 metres wide and five metres high.

4. The fourth embankment runs along the west bank of the Bagmati entirely within Nepali territory. It runs adjacent to Brahmapuri village and begins at Samanpur, north of Brahmapuri. There are plans to connect this embankment with the Bairgania ring embankment near Musachak in Bihar and to further extend it to the northern reaches of the Bagmati. Construction of this fourth embankment was started in the year 1999/2000.

The outcomes of shared learning dialogues revealed that these four embankments have substantial negative impacts on the villages of Rautahat District of Nepal. These impacts include:

- **Water logging:** This harms crops, reduces the value of land, fosters mosquito breeding and exacerbates the spread of vector-borne diseases such as malaria.
- **Increase in inundation and severe flooding:** This impact damages household assets and reduces agricultural production. *Kuchha* houses made of locally available mud and other materials collapse and become unlivable. Stored food grains and fodder are also destroyed.
- **Restricted mobility:** Boats are the only means to get to or leave villages during floods. This is a serious problem, especially in the case of health emergencies.

TABLE 10 | Assessment of costs and benefits identified during SLDs along the Bagmati River transect

Interventions	Plusses & minuses	Details	Value (in NPR)
EMBANKMENT			
Embankment along Bagmati River: 14.2 Km long			
Initial cost		The Government of India's full contribution to the construction of embankments along the Bagmati will have been NPR 215 million. The Embassy of India gave NPR 44 million to the Department of Water-Induced Disaster Prevention, as the third installment of India's contribution towards construction of marginal embankments along the right and left banks of the Bagmati River. The first installment of NPR 42.7 million was released in October 2003 and the second installment of NPR 54 million was released in July 2004. The amount to be given in July 2008 is not known at time of writing.	
Land lost	- - -	426 ha	188,604,049
Land protected	+ +		
Land affected by sand deposition due to embankments	- - -	980 ha (agricultural land rendered non productive)	14,700,000
Crop protected	+ +	1,200 ha	
Use as roads	+ +	Rajdevi VDC uses embankment for day to day commuting	
Crop losses	- - -		
Houses protected	+ +		
Land under bank cutting and sand deposition downstream	- - -		
ALTERNATIVE INTERVENTIONS			
Bagmati, Chandi and Manusmara Irrigation systems	+ + +	1,600 ha	
Mechanized pumps including treadle pumps	+ + +		
Forest buffers	+ + +	350 metre wide, 13 Km long strip of forest adjacent to the river. Partly owned and managed by government, partly by community. Timber, fodder and fuel are all products of this forest.	
Land protected	+ + +	3,250 ha	
Agricultural land lost	- -		
Houses protected	+ +	1,650 houses	
Timber produced	+ +	Revenue from selling hard wood goes to the government. Community managed portion is new growth so will only provide timber income after10 to 15 years.	Numbers not available
Fuel and fodder produced	+ +		
Raised community shelter	+ +	20 households of Laxmipur plan to take refuge for 15 days during three months of June-August.	
Land lost	-	Land provided free of cost	

Both affluent and poor households in Sedhawa believe that the embankments built along and across the border have great costs through the populations of other locations believe embankments generate some benefits as well as entailing large costs. The costs and benefits of embankments, as well of other response strategies identified along the transect, are listed in Table 11.

Transect II: Villages along the Lal Bakaiya River

This transect runs through villages along the Lal Bakaiya River, beginning at Bhasedwa VDC and ending at the Nepal-India border. Bank cutting is a major problem for these settlements: each year it destroys many acres of land. Occasional sand deposition also takes place. The Lal Bakaiya River is embanked along its southern reaches just before it enters northern Bihar. In the upper reaches, spurs, small stretches of embankments and revetment walls have been constructed to protect villages against floods. Table 11 describes the types of spurs constructed and some of their impacts in and around Bhasedwa VDC. The railway bridge constructed over the Lal Bakaiya also constricts

TABLE 11 | **Spurs and other physical interventions made along Lal Bakaiya River in Bhasedwa VDC**

Year Constructed	Type	Results	Type
Spur, 1987	DDC and Department of Irrigation placed gabion-boxes packed with sand bags. The total cost was NPR 400,000.	Unsuccessful The entire village had to be resettled	Did not check any bank cutting. Floods in the same year did not leave any trace of the spur.
Spur, 1995	Plastic nets packed with sand bags.	Unsuccessful	The structure washed away in the same week it was constructed.
Spur, 2000	The building of the spur was initiated by the local people at the same location where attempts to build a spur in 1987 was unsuccessful. The river course was changed using bamboo piling and spur constructed out of gabion boxes filled with boulders. The total cost was estimated as 1.2 million (out of this, cash support of NPR 100,000 was provided by Oxfam GB-Nepal). Other support through DDC, DoI and DWIDP was in kind, equipments and fuel for vehicles.	Very Successful	The spur stopped bank cutting for five years. This helped save more than 25 *bigha* of land and around 60 households.
Embankment-425 metres, 2004	A sand embankment was being constructed by Bagmati Irrigation Project at a total cost of NPR 1,100,000. The work was not completed.	Unsuccessful	Embankment caused more harm. While it was being constructed, the floods deposited sand over 50 *bigha* land rendering it useless.
2005 (Spur I, II and III)	To protect the canals of Bagmati Irrigation System the project built three spurs. The cost of each spur was around NPR 2,400,000 with a total cost of NPR 7,300,000. Further in the year 2007, NPR 100,000 invested to repair and strengthen spur.	Spur I was very successful. Spur II was not even completed and Spur III did more harm than good.	Spur I checked further bank cutting, saved land and private houses. Spur II was washed away while being constructed. Its construction was never completed. There is no trace of this spur today. Spur III helped prevent bank cutting. Instead of repelling the flow, it attracted flow towards the village. The result was flooding and deposition of sand.
Embankment 2005	725 metres long embankment made out of clay. The clay embankment is strengthened using gabion boxes packed with boulders.	Successful	Initial plan was to build 1,125 metre long embankment. Completion of remaining 400 metres will prevent land cutting, sand deposition and flooding in Bhasedwa.

TABLE 12 | Spurs and other physical interventions made at Phatuwa Harsa

Year Constructed	Type	Results
Spur, 1987	Gabion boxes, sacks filled with sand and bamboo piles in a stretch of 1 Km.	Unsuccessful
Spur, 1995	Plastic nets and sacks filled with sand.	Unsuccessful
Spur and bamboo piling, 2000	Bamboo piles, gabion boxes filled with boulders. The river channel straightened.	Partly successful
Spur, 2005	Boulders and stones spur.	Successful

river flow. This area receives irrigation waters from the Bagmati irrigation project and the tail-end canals of the Narayani irrigation project. The costs and benefits and the relative magnitudes of various flood risk management strategies identified along this transect are listed in the table below.

TABLE 13 | Assessment of costs and benefits identified during SLDs along the Lal Bakaiya River transect

Interventions	Plusses & minuses	Details	Value (in NPR)
EMBANKMENT			
10.8 Km long			
Initial cost		The Government of India has contributed NPR 41 million to the construction of embankments along the Lal Bakaiya.	
Land lost	- - -	32.4 ha	NPR 14,344,533. Based on NPR 15,000 per *kattha*
Land protected	+ + +	1,116 ha	NPR 16,740,000
Crops protected	+ + +	670 ha (60% of the area protected)	
Crop losses	- - -	187.5 ha (only during *kharif* season)	
Agricultural productivity losses	- - -	1,116 ha	
Houses protected	+ + +	1,500	
ALTERNATIVE INTERVENTIONS			
Spurs			
Land lost	-		
Houses protected	+ + +	60 households for five years.	
Land protected	+ +	120 ha of agriculture land. The earthen embankment was not completed before the monsoon of 2004.	
Downstream bank cutting and sand deposition	- -	In the near by downstream area more than 100 ha of agriculture land comes under bank cutting every year as spur III attracts river flow. The 2004 floods washed an embankment under construction and spread sand over 50 *bigha* adjacent agricultural land.	
Boats	+ + +	There are three boats in the area. Each boat costs NPR 20,000.	NPR 60,000
Flexible bamboo bridges	+ + +	Three bamboo bridges connect Bhasedwa along with three other VDCs to Birgunj.	NPR 15,000 (NPR 5,000 per bamboo bridge)
Bagmati and Gandaki Irrigation system	+ + +		
Mechanized pumps including treadle pumps	+ + +		
Raised toilets	+ +		NPR 8,250,000 (NPR 5,500 per HH toilet)

Transect III: Gaur Municipality - Bairgania Ring Embankment - Pipradi Sultan

This transect begins at Gaur Municipality of Rautahat District of Nepal and extends to the confluence of the Bagmati and Lal Bakaiya rivers in Bihar crossing the Bairgania embankment built in 1973 to protect the Bairgania Block of north Bihar. The 30 kilometre long, 6 foot-high embankment occupies the *doab* between the two rivers within Bihar. Its base is 132 feet wide and top 25 feet wide. An additional 20 feet of land on each side of the Bairgania embankment has been acquired by the Bihar government. Although the structure is called a 'ring embankment' two portions in the southern end, one 100 metres and one 50 metres long are unconnected.

The 12.7 kilometres long eastern Bagmati embankment begins at the East-West Railway while the western embankment along the Lal Bakaiya River is about 20 kilometres long. The Lal Bakaiya River flows along west of the ring embankment in Bihar. Although the embankment continues further downstream along both sides of the Bagmati River, only its length up to the confluence of the Bagmati and Lal Bakaiya rivers was evaluated. Next to Jamuwa village in Bihar, its lower reaches are jacketed by two embankments spaced less than 400 metres apart: the Lal Bakaiya River has to flow through this constricted channel at this section. As mentioned above, in the northern side of the Bairgania embankment consists of four sluices.

FIGURE 4 | Transect III: Gaur Municipality – Bairgania Ring Embankment – Pipradi Sultan

During the 1993 floods, the Bairgania ring embankment breached in three different locations and flooded all the villages within the embankment. Even when there are no breaches, the villages in the southern section of the embankment are inundated by up to 10 feet of water because of the two unconnected sections totaling 150 metres in length. In addition, neither of the two spillways operates. One sluice constructed in 2005 has a water way width of three metres and a gate five metres high. Local people say that it is too small. In addition, water does not flow out of the sluice when water level increases during the monsoon at the confluence of the Lal Bakaiya and the Bagmati rivers.

In 2000, a raised platform with an area of 17 acres was built 200 metres north of the southern side of the Bairgania ring embankment. This platform is paved with bricks and was recently surfaced with bitumen. Only two acres are in use, though, as the rest has subsided and is submerged during floods. Around 15 Muslim families have built thatched huts on the raised platform.

After the Bairgania ring embankment was built, the area affected by water logging increased, particularly inside and adjacent to the southern section. Almost all of the musahar families living in the village of Marpa say that up to 150 acres of land is water logged throughout the year and that water levels can reach more than 15 feet deep. In 2007 October a local boy drowned while trying to cross the water logged section. It is not just water logging that has reduced the land available to the people of Marpa; 55

acres was acquire to build the embankment and another 17 acres purchased to build the raised platform. As a result of this acquisition most of the population of Marpa has become landless. The Bihar government compensated the landowners INR 6,000 per acre, a rate far below the market rate at that time.

Maintenance work on the embankment has been contracted, but though it was supposed to commence in 2006 it started only a year later. The work is to be completed in 2009.

TABLE 14 | 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			
26.5 Km long ring			
Initial cost of embankment		INR 1,885, 552,941 for 26.5 Km length	Total cost for 85 Km of embankment from Dheng near the Indo-Nepal border to Runni Saidpur, including the 26.5 Km, was INR 60.48 crores (1975-77)
Land lost	- - -	Around 125 ha (26.5 Km of land of width 40.4 metres width plus 6 metres additional space both inside and outside of the embankment)	INR 10,887,677 as per 1973/74 values. (The values used are based on the compensation received by some villagers. INR 3,000 per kattha of land was provided in 1973/74)
Land protected	+ + +	1,000 ha	INR 2,954,501,618 @ INR 10,000 per kattha
Crop protected	+ +	400 ha is protected within the ring embankment.	INR 9,444,960 per annum
Crop losses	- - -	*Kharif* crop not possible in 3,500 ha due to inundation caused by the ring embankment.	INR 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	INR 1,350,000. Each household spends around INR 500 to repair their house after every monsoon.
Land under permanent water logging	- - -	50 ha	INR 14,760,000. Priced at INR 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.	INR 6,075,000 as lost wages. Priced at INR 50 a day for 90 days of a year for 50% of the houses affected.
Use 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 top including that on railway embankments	+	About 600 houses. Counting done using Google Earth map. People have built their houses, though illegal.	INR 600,000. Valued at INR 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 ha. 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.

Analysis: Findings from the Transects

As transects along the lower Bagmati River illustrate, flood control measures have many trade-offs. Where embankments are concerned, the wide variety of major costs appears to overwhelm unquestionably considerable benefits. Furthermore, the distribution of benefits and costs is highly skewed. In the case of the ring embankment, for example, those who live or own land in regions that are protected, but located at a distance from water logged area benefit, while those who live north of the embankment or in the southern water logged area bear much of the cost. All embankments have similar distributional effects.

The identification of the major indirect costs of embankments and other flood-management strategy using qualitative analysis can serve as a first step toward quantifying them. Many of the costs are related to backwater effects and the blockage of natural drainage. Investments in drainage and in re-designing structural measures to reduce such costs could form part of a solution, but, at heart, there is no easy solution to many of the costs identified. Sedimentation, for example, will remain high no matter what measures are implemented. As a result, any sort of structural protection will always have a limited lifetime.

Qualitative analysis also highlights the substantial benefits that can be achieved by implementing an array of individual and community interventions ranging from the provision of boats and flexible bridges to the construction of raised platforms. While such approaches do not provide as much direct protection from floods as embankments do, they do generate major benefits and appear to involve far fewer trade-offs. The costs involved are largely just initial capital investments; there are few, if any, major externalities to take into consideration.

While the above differences between structural and people-centred categories of strategies are significant, it is important to recognize that comparisons between the two are somewhat misleading. First, in many ways, the types of benefits and costs generated by each are difficult to compare directly. Furthermore, while some of the costs of structural measures are a built-in feature of the technology itself, at least some of the associated indirect costs are due to poor initial design and maintenance. Finally, embankments have benefit unique to themselves. they can be used to protect clearly defined areas (such as towns) where high-value investments are concentrated and can serve as points of refuge during flood events. None of the people-centred measures evaluated in this study can provide either of these benefits on their own.

If designed carefully and accompanied by technically effective measures to improve drainage and socially effective measures to address the distributional impacts, structural approaches can form part of a package of interventions that complement people-centred measures. Our analysis indicates that the costs of current structural approaches exceed their benefits and that, as a result, reliance on such measures should be reduced. A combination of people-centred and appropriately designed and maintained structures that help populations to live with floods is more effective than either strategy on its own.

The effectiveness of the two different approaches to flood risk management will change significantly due to climate change. Structural approaches will probably prove to be increasingly less effective while people-centred strategies will sustain. Higher flow peaks and sediment loads will almost certainly make existing embankments, spurs and other structural interventions ineffective. As result water logging, breaches and other costs will increase further. This means, reliance on structural measures as a strategy for responding to the increased flood risk anticipated as a consequence of climate change will not be effective. In contrast, the benefits from people-centred interventions appear relatively resilient to the impacts of climate change. The benefits from boats, early warning systems and raised plinth levels on houses, for example, are likely to grow if floods increase though their benefits may not be sufficient to respond adequately to the impacts of climate change on local populations. A combination of strategies may ultimately prove more effective than reliance on one response alone.

Given that governments continue to emphasis on importance of embankments construction to alleviate the impact of flooding, we must consider the large-scale implication of our qualitative cost-benefit analysis. State reliance on embankment was markedly evident in the conclusions of many meetings between government of Nepal and India. According to Dixit (2008) the Standing Committee on Inundation Problems Along the Border Regions of the Nepal Tarai has repeatedely recommended that new embankments be built even though the problem is itself created by obstruction of natural drainage caused by an embankment built in northern Uttar Pradesh and Bihar.

The existing political and institutional dynamics have meant that state agencies strongly support the construction of embankments to serve as the primary mechanism for flood protection despite the fact that these structures have had more negative than positive impacts. A more balanced regional approach that emphasizes people-centred interventions, limited structural protection measures in conjunction with specific investments in drainage and maintenance to reduce the embankment-created costs of water logging, disease transmission and breaching, could be effective both now and in the future under changed climatic conditions.

Such efforts are likely to yield more dividends than will total reliance on relief. In 2007 the representatives of communities affected by flooding in the region themselves expressed severe dissatisfaction with relief efforts, especially the use of high-cost helicopters to distribute food and materials. They suggested that measures that focus on preparedness and incremental support are likely to be much more effective in the long run. The same criticism was made during the floods of 2008.

Issues Encountered in Conducting CBA

Although the qualitative estimate of costs and benefits was conducted in a systematic way, it has certain limitations primarily because the data available in the region is very limited. In many cases data for the last decade is not even available. Information on the direct costs of most interventions (for example, embankments and irrigation projects) is also lacking. The challenge of locating data is illustrated well in the case of the regional profiles produced by Nepal's Department of Agriculture). While the district offices of the Department do publish annual district profiles which record agricultural inputs and outputs, total food surpluses and deficits and the prevailing market prices for agricultural produce, they are rarely available for any year before 2003. In addition, district offices lack institutional memories because personnel are transferred frequently. Furthermore, although district offices do forward their annual profiles to regional offices, when these offices were moved from Hetauda to Kathmandu and back again, most data were lost.

Major difficulties also exist in obtaining reliable demographic data and maps. Officials in Bairgania block, for one, were hesitant to provide such data until letters and the scope of research were presented. Only then was the researchers directed to Sitamarhi, the district headquarters. There the local maps available at Sitamarhi Cadastral Section proved very difficult to obtain. At the Bairgania block office, even the 2001 census data was unavailable and there are no civil society actors like NGOs which could provide that information.

In addition to challenges in collecting data, assessing the losses avoided and the often non-market nature of the benefits of many disaster risk reduction investments, is complex. As a result, many indirect costs and benefits associated with interventions might be unintentionally overlooked. The political uncertainty and unrest in the Nepal Tarai that began in 2007 and has continued to date was another major impediment. Surprise strikes and protests hindered the mobility of the study team and events like beating to death 30 people in the third week of March 2007 in Gaur the headquarters were acts of political violence.

In addition to limitations in the conduction of the analysis, the very idea of using cost-benefit analysis to evaluate flood risk management strategies is a relatively new one. Most donors and government departments and their field staff are unfamiliar with this approach. Advocating use of cost-benefit analysis as a tool for evaluating flood management interventions in the policy-making process is a hurdle. To overcome such challenges, points of entry need to be identified as a part of a continuous process and attempted by engaging with agencies such as the Ministry of Finance and introducing the insights of analysis into the process of preparing the country's National Adaptation Plan of Action (NAPA).

Conclusions

Our assessment clearly reveals that current investments in constructing embankments to address flood risks produce both winners and losers. Structural measures provide short-term benefits to a few communities but generate negative consequences downstream and in unprotected areas when they prevent flood water within the basin from draining quickly. Furthermore, when embankments breach, the devastation in, and cost to the protected areas will be extremely high. The flooding caused by the breach of the Kosi embankment in Nepal's Sunsari District on 18 August, 2008, is a case in point. The resulting inundation affected over 50,000 people in Nepal and as many as 3,500,000 in North Bihar.

Analysis in the case study region suggests that the number of families benefiting from structural measures, such as embankments, as they are currently designed, is relatively few if one keeps the costs in mind. Our analysis also suggests that in a dynamic hydrologic context where rivers move laterally and transfer large sediment loads, the role of embankments is limited and that their effectiveness may decline further as hydrological dynamics become more erratic due to the impacts of global climate change. People-centred investments such as early warning systems, raising the plinth level of houses and providing boats, in contrast, have fewer costs than benefits. They also appear far more resilient to the expected uncertainty associated with climate change impacts. This said, however, it is unclear that such strategies will be able to mitigate flood risks sufficiently to reduce losses as the impact of climate change on the hydrological cycle increases.

In a context where embankments, spurs and other structural measures are the focus of government and policy-making organizations, the qualitative methodology of this study provides new insights and helps evaluate alternatives. By systematically identifying the costs and benefits of embankments and other alternatives in this method could be a useful tool for planning and implementing disaster risk reductions strategies.

Our qualitative cost-benefit analysis helped to identify (a) the types of costs and benefits associated with various flood management techniques; (b) the relative magnitudes of these costs and benefits; and (c) their distribution. While this method does not provide sufficient information for us to be able to evaluate the overall economic viability of the various strategies, it does provide critical insights, which are, at the least, sufficient to indicate major areas where work is needed on drainage and sediment management, for example, if structural measures are to be part of future flood risk mitigation strategies. The analysis also provides key insights into people-centred measures that could serve as a core element in the design of future strategies to manage flood risks and adapt to climate change impacts.

The information generated by this qualitative benefit-cost assessment can serve as a foundation for many of the similar insights that would be generated by a quantitative approach. It highlights both the direct and indirect costs and benefits associated with each type of risk reduction intervention. In addition, the methodology enables an evaluation of the differential distribution of costs and benefits to different sections of the population in a data-deficient environment. Quantitative cost-benefit techniques, in contrast, are inadequate for estimating the magnitude of the costs and benefits identified and for comparing them meaningfully. In many ways, this qualitative analysis lays the groundwork for a quantitative evaluation without replacing it. If a full cost-benefit analysis is needed to assess structural options, this methodology would strongly complement it because it identifies and includes many costs and benefits that are often excluded as externalities in standard economic evaluations.

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5

CHAPTER

Comparing Urban Flood Mitigation Options:
Costs and Benefits in Rawalpindi, Pakistan

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Country: Pakistan
Location: The Rawalpindi/Islamabad conurbation: Areas subject to flooding by the Lai River
Issue: Urban flooding along the river corridor exacerbates poor living conditions in densely populated areas with severe drinking water, sanitation and solid waste problems. The study investigated the efficacy of four disaster risk reduction measures that sought to reduce flood impacts.

Key Concepts

- The Lai River basin is prone to flooding, particularly during the monsoon season, but is not considered important enough by national-level actors to invest in disaster risk reduction measures.
- Different actors at various scales have unique views of the hazards facing the basin and how to address them. National and regional level government actors want structural remediation measures and an early warning system. Local residents identify a wider range of strategies for strengthening resiliency, including clean drinking water and solid waste management. Both of these issues, and others, are exacerbated in flood situations. Yet the government rarely consults the public when conceiving and implementing projects.
- The study utilized a qualitative-quantitative-qualitative analysis of the efficacy of four DRR measures: the Lai Expressway and Channel Improvement Project, early warning systems, flood retention ponds and channel section straightening, and the hypothetical construction of a wetland flood plain buffer on 100m of either side of the Lai River.
- Sectoral competition between government agencies and across scales hampers dialogue and action in the basin. Data problems are rife, mainly caused by secrecy, unwillingness to share “public” data with the public or other government sectors, and simple lack of data or outdated data.
- A fluid political environment transitioning toward a parliamentary democracy is causing uncertainty in disaster risk reduction (DRR) policies and lack of consistency in policies between one government and the next. This hinders the development and implementation of coherent, multi-hazard plans at any level from local to national, whether they are in response to man-made hazards, such as improper sewage disposal, or natural hazards such as floods.
- Given the data limitations and shifting political landscapes, a full cost-benefit analysis of the four selected DRR measures proved difficult to perform. Therefore, the more important results of this study are the processes and steps taken, such as shared learning dialogues (SLDs) and flood mapping exercises, than any of the numbers produced by the cost-benefit analysis.

Introduction

The Lai Flood Basin

The Lai Basin offers some interesting comparisons that are relevant to understanding the geography of exposure and vulnerability to flood hazard in an urban context. The Lai's story can be found in almost any urban metropolis in the developing world. At its heart is a growing urban poor population in a growing economy that is (mis-)managed by institutional structures incompatible with the geographical and spatial realities. The Asian Development Bank and JICA have made large investments in the Lai Basin and conducted elaborate technical studies creating a wealth of quantitative information on hydrology, weather, and some social aspects. Findings and tools developed in the course of the Risk to Resilience study are expected to be highly replicable and relevant to urban hazardscapes that have traditionally received little attention in the academic world.

The Lai[1] Basin drains a total area of 244 km^2 south of the Margalla hills, with 55% of the watershed falling within the Islamabad Capital Territory and the remaining portion within the downstream Rawalpindi Municipal and Cantonment limits (Figure 1). The stream has five major tributaries: Saidpur Kas, Kanitanwali Kas, Tenawali Kas, Bedranwali Kas, and Niki Lai, in addition to twenty other minor tributaries. The maximum length of the Lai from beginning to its final confluence with the Soan River does not exceed 45 km, thereby allowing very little time for any flood warning in its middle reaches within the Rawalpindi municipal limits. The Rawalpindi/ Islamabad conurbation is the fifth most populous urban area in Pakistan with a combined population of 2.1 million, with 1.5 million of the residents in Rawalpindi and the remaining in Islamabad (Government of Pakistan, 2003). The conurbation is an important economic and transportation node connecting southern and eastern Pakistan with the Northern Areas, Azad Kashmir

| FIGURE 1 | Map of the Lai flood plain in the Rawalpindi/ Islamabad conurbation in Pakistan

[1] This spelling comes closest to the phonetic pronunciation of the name and is most widely used. Other spellings, e.g., Leh and Lei are also in use.

(Pakistani Administered Kashmir), and the Northwest Frontier Province (NWFP). As the capital of Pakistan, Islamabad has all of the administrative structures of the federal government, while Rawalpindi is the headquarters of the Pakistan Army, the most important institution in Pakistan.

The history of the twin cities offers some interesting comparisons that are relevant to understanding the geography of exposure and vulnerability to flood hazard in the conurbation. In the pre-Independence era, Rawalpindi was the headquarters of the British Indian Army's Northern Command, the largest of the British Indian Army Commands in United India. The Pakistan Army inherited the site as its headquarters after Independence. The military dominates the social and economic life in the city, where more than 50% of jobs are associated either directly or indirectly with the armed forces. Overall, 64% of those employed in the city hold jobs in the public sector, 36% are in the private sector, and 23% are self-employed (JICA, 2003). There are really two cities within the legal boundaries of Rawalpindi city: the Rawalpindi cantonments under the Ministry of Defense, and the city of Rawalpindi, governed by the civilian-elected Tehsil Municipal Administration (TMA) and various arms of the Provincial Government such as the Rawalpindi Development Authority (RDA) and the Water and Sanitation Agency (WASA). The cantonment lies on a high ridge on the western edge of Rawalpindi city and is relatively safe from Lai floods, except in the southernmost part of the basin (Figure 1). Rawalpindi city, on the other hand, is highly exposed to flooding from the Lai. The 100-year flood inundation zone of the Lai is primarily occupied by lower middle-class and working-class neighborhoods.

Lying upstream, Islamabad is a preplanned modern city. Its grid pattern with wide, tree-lined boulevards and relatively low urban density presents a sharp contrast to the mostly curving, narrow streets of older Rawalpindi. The rationalist, militarist urban design of Islamabad symbolizes the military ethos of order and rank hierarchy. Field Marshall M. Ayub Khan, president of Pakistan from 1958-1969, commissioned the building of Islamabad city to provide a modernist model for the future of Pakistan.

A Greek architect, Constantinos A. Doxiadis, designed the city. According to Spaulding (1996), Doxiadis was an idealist who planned the city based on his conceptions of what an ideal modern city should look like rather than the material reality of how the urban geography of Islamabad might be experienced and lived by its inhabitants. The idealistic urban planning did not change social and environmental realities, but rather exacerbated them. Doxiadis projected that the lowest ranking government servants would reside in working-class neighborhoods, while the poorest—garbage collectors, street sweepers, domestic helpers, day labourers, road hawkers, etc.—were not catered for in Doxiadis' plans at all. His idealism, played out on sketches, diagrams, and scale models, overlooked the impact that local topography had on the social geography of the absolute poor in the city.

European concepts of social class and distinctions based on civil service rank manifest themselves poignantly in the geography of the city (Meier, 1985).[2] The neighborhoods in Islamabad are called sectors, which run alphabetically from northwest to southeast and numerically from northeast to southwest (Figure 1). The E and F sectors are for high

[2] European sense means the relatively recognizable division of economic classes in the industrialized societies of Europe, e.g., the working class, the petit bourgeoisie, the bourgeoisie, and the ruling classes.

ranking officials, corporate elites, and diplomats, and they are separated by a commercial and green area, called 'Blue Area', from the more middle class G and I sectors. The industrial and agricultural H sectors are sandwiched between the two middle class G and I sectors.

It is little surprise, then, that in those areas by the banks of the tributaries of the Lai where the topography dips below the plains on which the city is built, one finds unplanned shantytowns called *katchi abadis* (Spaulding, 1996). More than 3% of Islamabad's population, or about 3,000 households, lives in these *katchi abadis* and are the only neighborhoods that repeatedly suffer damage from floods, and especially the 2001 floods.

Moreover, the city was designed with very little regard for the hydrology and geomorphology of the basin in which it is located. The physical location of Islamabad creates special problems for Rawalpindi downstream. The decreased water absorption capacity of an expanding Islamabad, with significant amounts of impervious surface, further accentuates flood peaks downstream, in addition to reducing the groundwater recharge upon which much of Rawalpindi's poorer population depends for water (Malik, 2000a; Malik, 2000b).

The institutional hazardscape of the Lai is characterized by equally complex multiple, fragmented jurisdictions. At the macro-scale, the upper basin is under the federally controlled Capital Development Authority (CDA) and its various directorates, for example water supply, sanitation, and environmental management. The middle basin falls under the local Rawalpindi Tehsil Municipal Administration (TMA), as well as the provincially controlled Rawalpindi Development Authority (RDA). The lower basin is again under the federally controlled Rawalpindi and Chaklala Cantonment Boards (RCB and CCB) and their various departments. The assorted stakeholder institutions within the Lai Basin display all the specialized bureaucratic structures and disciplinary backgrounds, from public administrator to civil engineers, particular to a modernist state apparatus. Where Islamabad's urban geography may be the poster child for the high modernist ideology inherent to "seeing like a state" (Scott, 1998), the state institutions operating within the Lai Basin also manifest what Dove and Kammen (2001) call the disconnect between the fluid and diverse 'vernacular models of development' and the 'official models of development.' Bureaucratic objectives are disconnected and uncoordinated: the sanitation directorate of the CDA is preoccupied with solid and liquid waste disposal, while the Relief Commissioner of Rawalpindi focuses solely on floods. The messy interlinkages between issue areas, although widely recognized, do not and supposedly must not distract the public servants from their assigned tasks.

Methods

For this case study, the team utilized a qualitative-quantitative-qualitative (3Q) approach[3]. The study was framed by a qualitative analysis in the scoping stage. The first stage included a literature review of disaster risk reduction in the region, in Pakistan and specific interventions in the two areas scoped for the study–Muzaffarabad Tehsil in the

[3] This term was coined by the study team. The usual conceptualization (qualitative) and subsequent analysis (quantitative) was not deemed to be sufficient for drawing meaningful conclusions and hence another qualitative assessment of the results was imperative for advocacy and decision making.

aftermath of the 2005 earthquake and the Lai Basin in Rawalpindi that is prone to frequent flooding. Initial stakeholder analysis and the subsequent first round of shared learning dialogues (SLDs) were held by ISET-Pakistan's team at the institutional/organizational level and by PIEDAR at the community level. King's College London supported both teams in conceptual issues and orientation for fieldwork. A transect walk helped identify communities selected for the iterative SLD process. This process allowed the study team to rank the hazards in the area and evaluate a wide range of options that were not considered in the formal policy circles.

At the institutional level, three rounds of SLDs were organized by ISET-Pakistan's team. Initially, a stakeholder list of relevant organizations was drawn up and reviewed through out the SLD process. One-on-one interviews were conducted with key officials involved in risk reduction and disaster management. These included stakeholders from all tiers of government, civil society, media, the private sector and individuals with interest in Lai issues.

In parallel, a comprehensive literature review was conducted, including gray literature, such as project planning documents. A thorough historical review of newspapers was undertaken to understand the context of the evolution of the Lai's problems and solutions discussed over the last couple of decades.

The study team was then able to shortlist a number of options to be evaluated quantitatively. A CBA analysis of four options was carried out using the available secondary data with additional information obtained from contour maps and satellite imagery. The four disaster risk reduction options selected for analysis were: the Lai Expressway and Channel Improvement Project, an early warning project, the strategic construction of flood retention ponds and channel segment straightening, and the hypothetical construction of wetland flood plain buffers on 100m either side of the river. Initially, consideration was given to options that demonstrated a soft versus structural approach; the final decision on options evaluated, however, also depended on the availability of the necessary data to carry out a full cost-benefit analysis. The comprehensive flood mitigation plan prepared by JICA provided a wealth of information. Although collecting primary data was beyond the scope of this study, a cost-effective method of more accurately assessing assets at risk was devised by using contour mapping and Google Earth pictures to manually identify and count existing structures that might be impacted in flood damage for various flood return periods.

In order to estimate flood damage further into the future, the Lai's flood depths were calculated and projections for various flood return periods of between 5 to 200 years were calculated. In addition, a simple statistical rainfall runoff model was developed to predict flooding patterns for various climate change scenarios in the region.

In parallel, an index based vulnerability analysis was conducted in some of the worst affected areas of the Lai flood plain. Following an economic analysis of the various options, the strategies were once again evaluated with the policy and political environment in mind to assess how disaster risk reduction could be best advocated at various levels. An evaluation of the usefulness of CBA for various points of leverage in academic, policy formulation and implementation of various developmental and risk reduction activities was also undertaken, thus adding a third layer of qualitative assessment to assess the distribution of costs, benefits and vulnerability in the area.

The Contextual Environment, from Community to Policy

Strategies

The newly appointed chairman of the National Disaster Management Authority admitted, in his first contact with the research team, that the Lai was too small to be considered for risk reduction at present (Khan and Mustafa, 2007). In the past, there had been announcements about various measures to control flooding, including ideas such as covering the Lai with concrete which would be paid for with proceeds from shopping plazas built over the top. In our newspaper research, we discovered that the idea of straightening and deepening the Lai river channel had been debated since the seventies. Discussions of the encroachment along the river's flood channel and of removing these illegal settlements had also been ongoing. In reality, however, not much has been accomplished. Garbage dumping, new encroachments and continued flooding have undone whatever little channel improvement activities have been carried out. One participant at a local level institutional SLD commented, "I have seen bulldozers move up and down the Lai ever since I was child but the flooding and other problems remain unresolved." (SLD with District Government organizations, 2007).

A project on early warning was announced as an urgent project implemented as the Flood Forecasting and Warning System for Lai Nullah Project, with the technical and financial assistance of JICA. The exorbitant cost of the project, initially estimated at PKR 16 billion (about USD 260 million at the time), was only announced years later, however, in early 2007, quoted in the press as the 'Lai Expressway'.

External support agencies have also promoted mitigation programmes for the Lai that largely comprise structural measures. For example, after the flood of 2001, JICA funded a mitigation programme for the Lai that included check dams in the catchment, a lake upstream of the flood prone area, and diversion of its three main tributaries to another river. This so called "comprehensive flood mitigation strategy" was formulated with little consultation with communities living along the Lai or the proposed diversion channel. In the end, the large engineering components were not implemented despite the laborious technical preparation owing to the prohibitive cost. There was, however, a degree of improvement with removal of some of the illegal settlers along the banks of the riverbed, some removal of garbage and opening of the river channel following each

Box 1
Newspaper Review – Old wine in a new bottle

The demand for straightening, deepening, diverting, building check dams and lining with concrete the Lai Nullah has been a major recurrent theme among the residents and managers of the city, particularly whenever there is a high flood in the Lai. The Daily Jang newspaper offers numerous news items, editorials, and statements on the subject wherein people have been demanding for decades that these activities be carried out to manage floods in the Lai. In the 4th September 1971 issue of the paper, for example, a meeting of the Commissioner, Rawalpindi Division was reported on. The article states: "Commissioner, Rawalpindi Division, Mr. Inayat Mirza, has directed the Irrigation Department and the Town Planners to straighten the Lai, particularly the meander near Gawalmandi bridge. 'These meanders are as a matter of fact the real cause of surge in Lai', he stated." In the same article, the newspaper quotes a scheme put forward by a retired engineer and town planner of the Rawalpindi Improvement Trust, in which a number of small check dams would be built near Golra village, which is at the origin of the Lai. According to him, a pipe of sizeable diametre should be laid down in the Lai and covered with earth, over which a couple of bazaars could be raised.

In the wake of the 1974 floods, a news report says, "the Deputy Commissioner of the district has instructed the city municipality and the Rawalpindi Improvement Trust to clean the Lai and straighten it to avert floods on urgent basis". The Deputy Commissioner allocated PKR 70,000 for this purpose. In the same news report, residents of the city had demanded a permanent solution to the floods in the Lai and suggested that it should be lined and covered with concrete. In another news article published in the 23rd August 1975 issue, the president of a local community based organization who is also an architect states: "both sides of Lai should be lined with concrete and banks of it may be raised high." He also suggested a road be built on either bank of the *nullah*, which would not only prevent floods but ease the pressure of traffic in the city and improve the surroundings of the *nullah* at the same time.

In 1981, the then president of Pakistan was quoted as saying that a comprehensive plan should be formulated to prevent floods in the Lai and that the Federal Government would provide funds for the project. A committee headed by the Minister for Housing was set up to look into the various flood mitigation options. These included, amongst others, concrete lining of the river channel and diversion of the Lai Nullah into the Korang River.

An editorial of August 1982 says, "Either Lai is diverted or a high concrete wall may be raised on its sides to contain the flood water". In yet another editorial of June 1985, diversion of the Lai Nullah was again emphasized as a possible measure to control floods. During the 90s, particularly the 1994, 1995 and 1996 floods, demands to prevent flooding in the Lai were yet again brought up. In the aftermath of the unusually high floods of 2001, all these demands and ideas surfaced again and an urgent project was launched for cleaning, deepening and straightening the river channel as well as removing encroachments to make way for flood waters under the Lai Nullah Improvement Project funded by the Asian Development Bank.

Source: Daily Jang archives, 1970-2006.

flood. Most of the gains were lost within a year due to lack of enforcement bringing the situation back to the pre-flood levels as population moved back and garbage dumping resumed.

What is being Done?

The local authorities make an annual flood preparation plan before each monsoon (SLD with Fire Department, 2007; EDO Health, 2007) to prepare for flooding. Due to scant financial allocations, the plans are nominal and include a couple of buildings designated as shelters and meager funds allocated for food and basic necessities for flood relief. What happens in practice is that the firemen monitor the water levels during the monsoons and when these reach a certain level (a 20 foot rise), they sound their sirens and urge settlers in the flood plain to evacuate. The designated shelters were only ever used during the 2001 floods, when even the homes of those who provided shelter to friends and families living on lower ground got inundated. The only proactive disaster management efforts come from local level authorities, but the bulk of disaster related funds and resources lie at a much higher level in the institutional hierarchy and do not filter down.

Early Warning System

Due to the high cost of JICA's comprehensive flood mitigation plan, only one component of the plan has been implemented. From the array of soft resilience options proposed, an intricate flood warning system for the Lai was chosen to be implemented. Although the risk reduction operational arrangements, which involve communication and monitoring are in place, they are yet to be tested in a real disaster situation.

The operation control room is located in the Tehsil Municipal Administration. The flood warning alarm activation is entrusted with the 1122 emergency service while the overall control of the early warning system lies with the district cordination officer (DCO). The actual relief and rescue organizations at the local level—the fire department and the voluntary civil defence—belong to yet a different tier of the local government. Communication between these organizations and with other backup control stations with the Pakistan Meteorological Department, the implementation agency for the project, is informal and unreliable.

Most government projects, not just those with a high political profile such as the early warning system or the Lai Expressway described above, focus on investment and physical works with little consideration for operational aspects or provision for maintenance, let alone sustainability. For example, a recently completed project of the Rawalpindi Water Supply and Sanitation Agency augmented water supplies while cross contamination with sewage in the distribution network remains a persistent problem.

Rawalpindi Environmental Improvement Project (REIP)

Under this project (see Box 3) for the improvement of the sewage system, existing drains will be remodelled and new drains constructed at selected locations. The sewage treatment plant, the project's major component, is proposed to be built on the left bank of the River Soan. Additionally, for better solid waste management, in terms of collection and disposal, a 75 acre sanitary landfill site has been proposed near a village some 30 kilometres outside the main city. Relocation of a slaughterhouse, located in the city centre, to a more hygienic and environmentally acceptable facility at the existing Sihala Slaughterhouse will improve environmental quality. Construction of 15 public toilets is also part of the project. Forty contaminated or inefficient tube wells will be replaced and 35 tube wells rehabilitated to improve water quality and its distribution.

From its inception, the project has been slow in implementing different components and is delayed. For the sewage treatment plant, for example, 6,000 canals of land are required but only 2,000 have been acquired. The preliminary design of the plan has, however, been prepared. Remodelling of existing drains (*nullahs*) is impeded owing to limited access to those *nullahs* with people having encroached on them by building houses or markets near and over them. There is no route for machinery and equipment to have access to the *nullahs*. For

Box 2

Project for the Improvement of the Flood Forecasting and Warning System for the Lai Basin in Islamabad and Rawalpindi.

In the wake of exceptionally high floods in the Lai Nullah in 2001, the Government of Pakistan requested the Government of Japan to extend technical assistance for a study on 'Comprehensive Flood Mitigation and Environmental Improvement Plan of Lai Nullah Basin'. The Japan International Cooperation Agency (JICA) decided to conduct the study, mutually agreed on between the two governments. The study began in August 2002 and was completed in September 2003. Its objectives included the formulation of a master plan for comprehensive flood mitigation and environmental improvement in the study area, and capacity building–the transfer of skills and technology in these domains to counterpart personnel of concerned government agencies.

Non-structural measures recommended in the study included a flood forecasting and warning system and creating flood risk maps. Both these measures were proposed for implementation through an urgent project. Other non-structural measures related to environmental improvement included land use control, control of solid-waste dumped into the river, improvement of drainage and sewerage and institutional strengthening in the implementation of the flood mitigation project, which included capacity building and formulating the institutional framework with clear roles and responsibilities.

The following structural measures were recommended for flood mitigation for the Lai Nullah:

1. Improvement of the river channel by deepening and protecting the sides of the Lai Nullah and its tributaries;
2. Creating a flood retarding basin at F-9 Park;
3. Creating a flood diversion channel;
4. Building a flood control dam; and
5. Creating on-site flood detention facilities.

Following extensive discussions on the different options and their pros and cons, the flood forecasting and warning system were undertaken as an urgent project. The overall goal of the project is to mitigate flood damage, particularly death and injury to residents in the capital region through prompt evacuation of residents to safer locations. The project aims to provide early and accurate forecasting and flood warning with a lead-time of one to two hours. The Government of Pakistan requested the Government of Japan for aid in procuring equipment as well as in the construction and installation of the facilities, which included a real time observation system of rainfall and river water level gauge stations, a data processing system for flood prediction, and a flood warning system. The project also included drawing up a flood hazard map and designing a flood evacuation plan and a flood risk management plan.

The total cost of the project was PKR 360,000 million. The costs borne by Japan and Pakistan respectively were PKR 337,000 and PKR 23,000 million. The project was to be completed in 21 months.

The departments and agencies involved in the project include the Pakistan Meteorological Department (PMD), the Federal Flood Commission (FFC), the Water and Sanitation Authority (WASA) and the Tehsil Municipal Administration (TMA). An elaborate system of flood forecasting and warning has been established, which comprises six raingauge stations (automatic rainfall data observation), two water level gauge stations and ten flood-warning posts. A master control room is set up in the PMD headquarters in Islamabad, and two monitoring stations are set up at the Federal Flood Commission office in Islamabad and at the Water and Sanitation Authority's office in Rawalpindi. A Flood Warning Control Centre is established at the TMA office in Rawalpindi. The early warning system became functional in 2007 and a full drill was carried out before the monsoon of that year.

Source: PC-I, JICA Study, various newspapers.

Box 3
Rawalpindi Environmental Improvement Project (REIP)

REIP is a five years project launched in 2006. Total cost of the project is estimated to be PKR 5.142 billion, out of which Asian Development Bank, Government of the Punjab and District Government Rawalpindi has contributed 70%, 25% and 5% of the total cost respectively. It aims to improve living conditions and quality of life of the people of Rawalpindi by improving water supply, sanitation facilities, solid waste management, wastewater treatment, and slaughterhouse. It also includes strengthening of institutional capacities of the Tehsil Municipal Administration (TMA) and Water and Sanitation Agency (WASA). The project components comprised environmental sanitation, water supply services and institutional development including financial management, database development, asset management project implementation support and incremental administration support.

Source: ADB, 2008

this component of the project, five major drains were planned to be remodelled. The project for one of these drains was awarded to a contractor, but this contractor has not been able to start work because of the lack of physical access to the drain. The contractor entered into litigation to get the project revoked. Another of the five drains is currently being remodelled by the Public Works Department, while projects for the three remaining drains have yet to be awarded. Replacement of the sewage network in the most populated localities of the city is in progress. Replacement of drinking water pipes is also in progress, as is the construction of public toilets and rehabilitation of tube wells. Approximately 20% of the project's work is complete so far (SLD with WASA, 2008).

Lai Expressway and Flood Channel Project

Rawalpindi was the constituency of the former Federal Minister for Railways. In March 2007, he sought and obtained the endorsement of the president of Pakistan for the Lai Expressway Project along both banks of the Lai Nullah to provide another arterial connection between Rawalpindi and Islamabad. The project was also marketed as a flood protection project. Sheikh Rashid Ahmed, Minister for Railways, said in a newspaper interview that about 300,000 people living in the vicinity of the Lai would no longer have to face the threat of floods, as the Expressway would elevate the banks of the river (Dawn, 2007a). The then Director General of the Rawalpindi Development Authority clarified in a newspaper interview that this was not a road development project and that the full name of the project was the Lai Nullah Expressway and Flood Channel Project (Dawn, 2007b). The project was inaugurated even before it was formally approved by the Planning Commission.

Government departments and executing agencies also have vested interests in promoting politically motivated projects that are aligned with or expand their mandates. The Frontier Works Organization, for example, proudly displayed billboards boasting the Lai Expressway as the largest turnkey infrastructure project in Rawalpindi. Such departmental engagement is frequently the reason that projects survive a change of government.

The project was first reported in the press in early February of 2007, when a presentation was made to the President of Pakistan, General Pervez Musharraf, who expressed keen interest in the project. He directed to form a steering committee, comprising the Deputy Chairman of the Planning Commission, the Chief Secretary of the Punjab and the Chief Engineer at the Army General Headquarters, to work out details of the project.

Sheikh Rashid Ahmed, the then Minister for Railways and a long time resident and politician of the city, publicly claimed that the Lai Expressway Project was a result of his efforts. In the public gathering on 27 March in Rawalpindi, he said that the Expressway was his dream that had been materialized by the President (Dawn, 2007b). This was confirmed by one of the officials of the RDA (implementing agency of the project) that he floated the idea during 2002-2004 to the President for his consideration. In 2007, he began to mobilize his election campaign around this mega project. On 27 March 2007, a big public gathering was organized in Liaquat Bagh, where the President made the announcement and inaugurated the project claiming that the Lai Expressway will change the face of the city (Dawn, 2007b). At the time, the project had not been approved by the Planning Commission. The President also announced that people relocated by the project should be given a better deal than their present housing, which was also endorsed through the directive issued by the then Prime Minister the same month. The President also announced an elevated expressway on Murree Road, widening of Airport Road, a Rawalpindi bypass from Rawat, and in recognition of the efforts of Sheikh Rashid Ahmed, the Lai Expressway was renamed as the Sheikh Rashid Expressway.

On the other hand, the Government of the Punjab, which was sharing 50% of the cost of the project, did not seem to be in favor of this project because of its high cost, estimated at PKR 16 billion at that time. There were numerous smaller or medium-scale development projects that could be launched in different districts to mobilize voters for the upcoming election across the province, rather than investing so much money in one city. The dispute over costs and cost-sharing were also reflected in the minutes of the proceedings of the first Steering Committee meeting held on 15 May 2007, where the Deputy Chairman of the Planning Commission emphasized that the Government of Punjab should own the project and release the required amount at the earliest possible date. The Federal Government made a commitment to allocate 200 million in Public Sector Development Programme, 2007-2008 and the Government of Punjab was asked to make equivalent allocation in the Annual Development Programme, 2007-2008.

Given the personal interest of the President, the project processing and preparatory studies were completed in record time. The feasibility study was carried out in 15 days by National Engineering Services Pakistan (NESPAK), while approval from ECNEC (the highest body to approve the project above PKR 500 million) came immediately. The Expressway was declared a special scheme and the government-owned NESPAK was entrusted with the tasks of design and research, while the Frontier Works Organization (FWO, a subsidiary of Pakistan Army) was named the executing organization. The Rawalpindi Development Authority was supposed to act as coordinating agency. Contracts were awarded to NESPAK and FWO without competitive bidding, which is required for any development project. Additionally, the unit rates quoted by FWO for the project were higher by 25% compared to the standard approved unit rates by the Government of Punjab. According to the contract submitted to and approved by the Punjab Government, FWO was supposed to design, execute and commission the project within a stipulated period of two years' turnaround time.

When the project was submitted to the Planning Commission for final approval, the Deputy Chairman challenged the competency of FWO to complete the project within the given timeframe. He said that funds should not be released until FWO could provide assurances that the project would be completed and fully operational within two years. At this point, the FWO expressed reservations in undertaking the project based on the time condition. Prior to the formal award of project, the Director General of the RDA (a retired brigadier) signed an agreement, through which RDA was to provide FWO PKR 200 million as an 'initial advance' apart from the mobilization advance, which was not yet processed. The cheque was issued for payment to FWO by the RDA. The treasury refused to honor the cheque because there was no provision in the original project agreement to pay a contractor an initial advance.

The struggle to award the project to FWO continued and after many delays, the Planning Commission awarded the project to FWO divided into several smaller work packages without a stipulated period to complete the project.

An assistant director of the RDA was of the view that the project might take five years to complete, as mega projects routinely face continuous delays. Similarly, the project cost was projected escalate from PKR 18 billion to PKR 30 billion. Responding to environmental implications of the project, he said that as far as groundwater recharge is concerned, the water of Lai is too contaminated to use for any purpose. He also indicated that trunk sewers for sewage water on the side of Lai and the lining of the Lai bed and slopes with RCC would not only increase the velocity of the water, which would prevent recurrent floods, but also improve the environment. The assistant director also indicated that the project would incur high costs, but it would be self-sustaining, as toll would be charged from the users. (SLD with RDA, 2008)

The main aim of the project was to share the ever-increasing pressure and burden of the traffic load of the city. It would have been a traffic-signal free road with an average speed of 50 kmph. The project road was to start at the Chaklala Bridge and end at the Katarian Bridge. The total length of the two carriageways would have been 22.2 km. Three interchanges were proposed, at Chaklala bridge, Murree Road and Katarian bridge and eight flyovers would be constructed on eight major crossings.

The secondary objective of the project was to avert floods in Lai. For this purpose, the Lai's bed would be deepened by about one metre for reasonable flow velocities. The bed widths were so selected as to accommodate 100 years discharge levels within an 8 metres flow depth, with 0.5 m freeboard (the height difference between the water surface and the top of the channel walls). The side slopes of the *nullahs* would have been straightened and maintained through reinforced earthen walls and RCC box structures to create the roadway space. The *nullahs* then would be properly lined with RCC. (Government of Punjab, 2007; SLD with RDA, 2008)

Originally, the project cost was PKR 14.7 billion, a breakdown of PKR 8.0 billion for remodelling the Lai and PKR 6.7 billion for the expressway. The Deputy Chairman of the Planning Commission made a suggestion in the Steering Committee meeting to have fully separate and independent trunk sewers for sewage water along the Lai Nullah, which were capable of conveying projected sewage flow for the next 100 years.

The sewer construction further escalated the cost by over PKR 1 billion. The final project cost was projected to reach PKR 17.77 billion. Originally, 50% of the sewage water was to flow through the channel and 50% through the trunk sewers, to be laid down under the Rawalpindi Environment Improvement Project (Government of Punjab 2007a).

The expressway would have given a direct route from the current military and joint command headquarters to new headquarters planned near the headwaters of the Lai. This factor may explain the heavy lobbying from the military headed government and its deputies at various levels in the government. The original JICA flood mitigation study had recommended channel improvement of the Lai downstream from the expressway portion, as this area was identified as a "bottle-neck" for flood water flows. However, increasing the slope and capacity of channel upstrean would only aggravate the flooding downstream, which incidentally is occupied by military housing including the Army House for the Chief of the Armed Forces.

The expressway also proposed lining of the channel, which would seriously affect groundwater recharge in a basin where water tables are declining. In 2008, some newspapers reported that, due to lack of infiltration in built-up Islamabad and groundwater drafting for drinking water, the water tables have declined up to a depth of 400 feet from a historical level of 80 feet. Municipal tube wells for drinking water have to be augmented with water from nearby dams and still do not fulfill total demand. A new project for drinking water supply to the twin cities (Rawalpindi–Islamabad) has already been planned, but has awaited approval for funding for the past two years. This drinking water project, the Ghazi Barotha Water Supply System, is estimated to cost PKR 47 billion. The project will have massive pumping requirements because it is slated to transport 200 million gallons of water per day (MGD) from the Indus River to Islamabad through a 60 km long pipeline (APP, 2008). Additionally, the Expressway's design assumes that the clay soil would allow construction of a channel. The soil type has already caused problems as the walls of the river start crumbling after a small rain. The instability has already brought down a road and the boundary walls of some houses (The News, 2007; SLD with the residents of Kumhar Road, 2007).

What are the Policies?

In Pakistan, government policy remains focused on infrastructure development, especially mega-projects, and technology driven solutions to natural hazards. Disaster risk reduction is a growing buzzword, but it is little understood outside specialized agencies and civil society groups working on disaster risk management. There is little appreciation that human activities, including inappropriate development, contribute to natural hazards and vulnerability. DRR is not an explicit part of mainstream government planning documents, including the latest Vision 2030 and Poverty Reduction Strategy Paper-II. In addition, the focus of disaster related activities is mostly on response rather than proactive programming (see Chapter 8 for further discussion).

Continuous build-up areas are divided into multiple jurisdictions, each reporting to different levels of government. On the other hand, forums for basin-wide cooperation are weaker than in the past, or completely absent. In such a hierarchical organizational culture, it is not a surprise that Islamabad's Capital Development Authority takes no account of the downstream streamflow and flooding impacts of its land development projects (Mustafa, 2005).

In absence of a tacit policy and implementation of the newly drafted National Disaster Management Framework the implicit policy is dictated by the consistently applied practices. This means that lack of a policy or institutional framework for risk reduction leaves a *de facto* practice that is not necessarily a well thought out strategy, but rather a product of various influences. In the scoping stage of this research project, a few dominant issues were recorded for further exploration. They have influenced the *de facto* strategy to manage the risk in the Lai flood plain and include:

Technological versus institutional approach to DRR

In this aspect we found that technology was far more dominant than an institutional perspective to manage disasters. Both the hard resilience highway project and the elaborate early warning rely on exclusive technologies that are the *forte* of the implementation agencies. Frontier Works Organization's claim to fame is the building of the Karakoram Highway to China along the silk route. The Meteorology Department holds the monopoly on raingauges and weather stations. Such influences have far-reaching implications for disaster management and coordination of various actors required for disaster management. Lack of an institutional mechanism or planning for DRR prevents mainstreaming of tools like CBA for risk reduction (SLD with GOs, 2007). These may be employed voluntarily by those who oppose the approaches or possibly as a precondition from foreign funding agencies. In the Lai's case, we found that even the foreign funding agency was reluctant to have such an analysis conducted for fear of hindering the investments already jeopardized by the previously described fluid political conditions. They denied the research team data by saying that they did not have any more copies of the studies conducted.

The actual actors that could be useful in risk reduction and response are completely disenfranchized from the process. The Fire Department, which was mandated to deal with all calamities, remains under-resourced as mentioned by the fire chief, and does not even posses a 30 foot ladder. Responding to the shrinking role in disaster management, the Deputy Fire Officer responded by saying, "Their attitude seems to be, "Extinguish the fire if you can, otherwise let it be" (SLD with Fire Department, 2008). Similarly, the Civil Defence organization is being ignored and is a weakening institution (SLD with Non-government and local organization, 2007). Parallel departments, like rescue 1122 have been established. The concepts of incident and operational control are no longer followed, as these departments belong to different tiers of local government and do not have effective coordination mechanisms for various disasters.

Perception of Linkages between DRR an broader programmatic goals

From the highest policy to local governments, the understanding of risk reduction as a part of everyday disaster management is simply nonexistent. Even the I/NGOs have separated DRR activities their regular activities. In the SLD with the Town Planner, he clearly stated, "We have nothing to do with disaster management." According to him, they were only concerned with building control and compliance to building codes! (SLD with Rowal Town TMA, 2007). Sitting on the bank of the Lai with the early warning system in his premises, he did not realize how building standards in terms of plinth levels and control are an essential part of risk reduction in a flood plain.

He did admit that building controls were not enforced and that only after the collapse of a shopping plaza, the municipality woke up to the lack of enforcement. In addition, we realize that contour or flood maps of the Lai are not publicly available, as somehow this information is sensitive to national security. Lack of such basic information precludes the local government from taking proactive steps. Similarly, almost all of the other service providers in the Lai area, like health, education, water and sanitation, claimed that risk reduction was not their mandate and some external structural measure was the only solution to avert risk in the Lai flood plain. However, appropriate building codes, zoning and enforcement may be the most cost effective measures for risk reduction, which would not require any extra resource beyond what the local authorities are mandated to do in their day-to-day responsibilities.

Political versus techno-administrative understanding of DRR

While DRR is considered strictly a technical and sectoral issue, the impetus for risk reduction comes from political forces. The politicized nature of DRR is so well established in the area that some of the Civil Defence volunteers complained that the communities would sometimes not cooperate with them. The locals assumed that the Civil Defence was there to further some political motive and not help in reality. Despite the concrete risk reduction measure, Lai flooding has been used by politicians as means of gaining support from communities as they are photographed wading in knee-deep waters while making statements about providing relief to the affected communities (Daily Jang archives, 2007).

The launch of "Lai Expressway" which was later renamed "Sheikh Rashid Expressway" was a maneuver in electioneering and pork barrel politics. Such large-scale intervention could not have been proposed by any single organization because of their sectoral mandates and interests. It by-passed all the regular project preparation and approval stages as a "fast-track" investment made through the directive of the President of Pakistan. To get financial allocations, some documentation such as a Feasibility Report and an Environmental Impact Assessment were hastily prepared and missed critical issues like groundwater recharge due to paving of the riverbed with concrete. Expecting a governmental CBA of various options would have been unrealistic in this case, as it may have highlighted alternate options that were more cost effective. Therefore, no government CBA was conducted to evaluate the Expressway project.

Understanding concept of vulnerability and its nuances

Vulnerability is a growing buzzword in the NGO circles, but often used more in relation to gender debates and the consequences of patriarchic systems. In government planning circles, vulnerability is equated to poverty. At the local level, although the communities may not be able to realistically fathom costs, they have a very good idea of vulnerabilities and their causes. What is clearly missing from the debate at various policy levels is the concept of building resilience in communities by addressing the root causes of vulnerability to reduce risk. As a result, provision of basic infrastructure and services never enters the debate on risk reduction. Cost-benefit analysis of such strategies, if possible, would be a great tool for advocating more innovative thinking about adaptation to an uncertain environment.

Linkages between theory and practices in organizational planning

Although the technical, hierarchical structure is good in delivering standardized services, more nuanced and flexible approaches have a hard time taking root in such systems. Besides the old mandates, inclusion of cross-cutting issues such as gender, environment and risk reduction get little more than lip service. In one of the largest reconstruction efforts of Pakistan, backed but multi-lateral agencies and manpower, ERRA still does not have gender disaggregated data on casualties or compensations (SLD with ERRA, 2007). However, like the supporting agencies, it does have a well-written gender policy document. As a result, when its benevolent donors flaunt the physical progress and quick disbursements as a great success story, the comparatively meager allocation for risk reduction policy research and other measures remains under-utilized.

Use of CBA or qualitative indices for vulnerability identification would have been extremely useful for choosing strategies for reconstruction; however, no such measures were used to make priorities. Reconstruction efforts provide great opportunities to utilize and incorporate such cost-benefit analysis in reconstruction and development work, but once again, physical progress and disbursement seemed to be the leading principles for implementation.

Geographical scales of programming and perceptions of linkages between different levels

There is strong hierarchy at different scales and a trend towards centralization, especially in better-funded risk reduction activities. The local aspects and command and control systems are being diluted and becoming weaker. Measures such as risk insurance, which could actually benefit from the small scale are yet to surface in the debate of risk reduction and adaptation.

Reliance on technology and the large financing required tends to work against local institutional strengthening. Instead of delegating human and financial resources for greater programmatic activity at local level, the tendency is to usurp the functions and whatever meager resources exist at the local level. This further weakens local mechanisms for risk reduction, as we can see from the cases of the Civil Defence organization, the Fire Department and the town planning department of the Tehsil Municipal Administration.

Relationship between actors, sectors and organizations

There is fierce competition for resources among various organizations and sectoral actors. Disaster risk reduction is based on competing technologies and the monopolies that various organizations hold for such technology. Even the NGOs have resorted to the "community participation conquers all" mantra. Within the Lai area, the erstwhile Rawalpindi Development Authority (provincial) and the City District Government competed to become the implementing agency for various disaster projects. As a result, if and when these projects are completed the final operations and maintenance will fall with the local Tehsil Municipal Administration who neither has the resources nor ownership of the project. In our SLD, a TMA operative said outright "I am against this project because if the rationale is traffic improvement, then existing roads (under TMA) should be improved." He said that the project cost was too high and involved displacement of many people. Besides he did not think it was possible to raise such high concrete walls with only PKR 16 billion and even then, the walls could do nothing against 650mm of rain.

Disjuncture between Community and Government Perceptions

Among the affected communities, some men and women think of the Lai Expressway as a miracle cure that will tame the Lai forever. The deepening of the bed of the Lai is ranked second and fifth in the list of measures proposed by men and women respectively, for the protection of seven neighbouring Union Councils from floods. The men give first preference to replacement of outworn water pipes, and the women prefer solid waste management, widening of streets, better health and education facilities ahead of deepening of Lai riverbed. Based on their grounded experiences, communities typically consider a wider range of choices than politicians and government officials. They appreciate that the Lai Expressway will entail clearing and paving over graveyards, demolitions of buildings, and eviction of people. Compensations for land acquisition under the antiquated Land Acquisition Act, 1894, are often delayed for decades and benefit only titled landowners. So communities on the banks of Lai trade off the temptations of improved access between metropolitan centres, higher land values, and flood resistance against the pain of displacement.

Identification of Main Strategies Selected for Evaluation

The research team wanted to evaluate disaster risk reduction strategies of hard versus soft resilience. Lack of data (mentioned earlier) left few choices of strategies for evaluation. The strategies being evaluated are: construction of the Expressway and Channel Improvement Project, the early warning systems, and a hypothetical solution of wetland restoration through relocation on communities on the banks of Lai. The first solution was given a go-ahead by the previous government, but its fate currently lies in doldrums with the change of the government and not likely to be resurrected any time soon. The second one, the early warning system, is almost implemented and in the pilot testing stage. The third one, while hypothetical, would have large ecological benefits and will be analyzed to give us a sense of the cost of taking such non-structural, eco-friendly policies. The third option does not preclude the Lai from being used as a transportation corridor, but we suggest an elevated light rail instead of as a motorway. It is an environmentally friendly option that serves both the rich and the poor.

There are further DRR strategies and basic infrastructure services like health, clean water and solid waste management, which would contribute greatly to the resilience of the communities around Lai. However, there is not sufficient data available to determine the benefits and the costs saved to communities of these other strategies. Therefore, these options were not explored in the quantitative analyses. Yet, these options have been addressed in the qualitative analysis, which includes a capacity and vulnerability index.

Evaluating Tradeoffs

Who is Vulnerable ?

After the 2001 flood, the re-settlement of vulnerable populations at highest risk in the Lai flood plain had some justification in DRR terms, but was mishandled. An arrogant encroachment removal project has left the vulnerable people with little trust in government intentions. Similarly, an inadequate understanding of the Lai's dynamic hydrology and geomorphology has bedevilled engineering interventions. The anti-encroachment and compensation programmes were acutely flawed because officials ignored the land tenure situation in the flood plain. A sizeable number of people who were thrown out of their homes did not own them, but rather rented them from the notorious land grabbers. In certain neighbourhoods, up to 75% of the residents were tenants, according to the local property dealers and councillors. According to the rules of the project, compensation could only be granted to those who could produce legal papers in support of their claim to the property.

Consequently, landlords collected the compensation that was meant to assist those made homeless by the anti-encroachment programme. The residents of the *katchi abadi*, the poorest of the poor, rarely received compensation. Members of the land mafia, who defrauded the people by settling them in the Lai Nullah flood zone, were the main beneficiaries of the compensation programme. They either held titles or power of attorney for properties from their multiple renters. Urban land records in Pakistan have become a legal labyrinth with a multiplication of owners after each generation. In addition, total compensation paid was reduced considerably from what had been projected. The RDA originally earmarked PKR 880 million (US $15.2 million) for compensation, but only disbursed about half of that amount, PKR 445 million (US $7.7 million). Of the total of 1,200 households that were affected by the project, 200 were not paid any compensation at all, because they were located on government land in the channel of the Lai. Yet, some of these people had been living in the flood plain for more than thirty years. (Mustafa, 2004)

Methodology: Qualitative

The Lai Basin area was selected after a scoping study on a set of criteria that include relevance in multi-hazard and risk reduction issues; availability and accessibility of relevant data sources and means to collect further information; and familiarity and experience of the partners through previous work and personal exposure to the local cultural and institutional environment. Finally, the ability to generate case scenarios to highlight the benefits and cost of risk reduction and to contribute to a broader regional and global knowledge base was considered in the selection process.

In order to gain indigenous data from the Lai's most hazard prone community on their perceptions of their prioritized hazards and prioritized common solutions shared learning dialogues (SLDs) were considered the most effective methodology. Shared learning dialogues represent a direct system of feedback and facilitate to "close the loop between knowledge generation, testing, dissemination and application" (Moench and Dixit, 2007). SLDs are crucial for generating a common understanding of opportunities and constraints without bias towards preconceived notions of what constitutes disaster risk reduction. They essentially involve semi-structured dialogues with groups of key actors at regular periods throughout a research project. Each meeting starts with a brief summary and presentation of critical issues by the organizers. The other participants are then invited to provide vital comments, insights, information, data and proposals drawn from their own experience and activity areas. Particular attention is paid to classifying points of entry where all participants agree on key points, knowledge gaps or the need for specific research or action required in order to improve the current risk situation. Holding shared learning dialogues through the duration of this research project aimed to encourage the enhancement of knowledge on DRR among disaster prone communities, relating existing indigenous knowledge on disasters to relevant authorities in order to bring about a positive change from the grass root level. In essence, SLD meetings ensure that results and suggestions found at the community level are shared with local and national government authorities. Comments of the authorities will be related to the community in order to facilitate communication between the previously unrelated groups.

A research team trained by PIEDAR and experts from King's College London conducted shared learning dialogues (SLDs) along the flood prone Lai Basin in Rawalpindi. SLDs were carried out based on the assumption that there is a certain amount of knowledge within the sphere of experts and there is a certain amount of indigenous knowledge in disaster prone communities. SLDs aimed to increase the overlap between the two spheres. SLDs are an iterative process of mutual learning. In the Lai Basin, a series of SLDs were conducted with each flood prone community, sharing with them the concepts of Disaster Risk Reduction, learning about their perceptions of hazards and proposed solutions, and facilitating reflection on livelihood resilience, response to disasters, effectiveness and costs of hazard management, and effects of climate change.

Methods and Tools Used in the Field

Urban communities are diverse and complex. An overall appreciation of the Lai Basin communities was required before SLDs could be undertaken with particular communities. One guiding principle was to give the most attention to areas along the banks of Lai that are most affected by floods. Another principle was to have representation of all the reaches of the Lai as it traverses Rawalpindi city. Third, areas with varying levels of social, economic and geographical vulnerability were selected in order to obtain a mix of circumstances.

Transect Walk

PIEDAR trained its field researchers in the key concepts of Disaster Risk Reduction, in the use of Participatory Rural Appraisal tools, and in documentation of qualitative data. The team took transect walks along the Lai and in different Union Councils of Rawalpindi city. Economic, social, geographical, ethnic and political vulnerabilities were noted, comprising both of levels of exposure and capacities to deal with the aftermath of floods. The following seven areas which were identified as SLD sites: Dhok Najju, Dhok Dalaal, Gunj Mundi, Gawal Mundi, Ratta Amraal, Khayaban-e-Sir Syed and Pir Wadahi.

Shared Learning Dialogues

Shared learning dialogues were conducted in an iterative manner building on previous dialogues. In the initial rounds, the team explained their research purposes, shared information on disasters, climate change and its causes, and on building resilience through income diversification and hazard insurance options. Also during the first round, hazard mapping and problem trees were used to steer communities towards identifying their priorities. The participants raised hands to validate the results as transcribed by the facilitators. Back in the office, the results were aggregated across communities to arrive at their collective ranking. The prioritized problems and their solutions are given in Table 1.

Gender disaggregated data shows that problems and solutions are perceived differently by men and women. The men viewed lack of services as a major hazard. The women on the other hand viewed unfulfilled social services needs as the key contributor to their myriad problems.

The data have been aggregated for all the communities and there were locational variations. These priorities also changed over time as the communities were revisited and discussions took place over various issues. Their proposed solutions for various hazards, however, show a distinct trend across genders. Males tended to prefer solutions that were more infrastructure related and women focused on social services, as shown in Table 2.

With regard to the flooding problem, the community participants had all somehow agreed, by the third round of SLDs, on deepening of the river to prevent flooding. The main reason for concensus on this issue seems to be the non-intrusiveness of this solution for the residents along the Lai. It basically means that there would be no relocation, as the width of the channel will not be changed. The cost of this physical measure, whose

TABLE 1 | Prioritized common hazards

Prioritized Hazards	Male Population	Female Population
1	Flooding	Flooding
2	Contaminated water supplies	Solid waste dumping
3	Solid waste dumping	Contaminated water supplies
4	Lack of healthcare facilities	Lack of healthcare facilities
5	Blocked drains	Narrow streets, severance
6	Narrow streets severance	Blocked drains
7	Rats	Rats
8	Air Pollution	Air Pollution

TABLE 2 | Prioritized common solutions

Prioritized Solutions	Male Population	Female Population
1	Replacement of water supply pipes	Solid waste management
2	Deepening bed of Lai Nullah	Widening of streets
3	Solid waste management	Better healthcare facilities
4	Additional bridge across Lai Nullah	Better educational facilities
5	Widening of streets	Deepening bed of Lai Nullah
6	Diversion of Lai	Replacement of water supply pipes
7	Better healthcare facilities	
8	Better educational facilities	

scale the communities could not fathom, would therefore be borne completely by the government.

The reason of mistrust of the government has a history. In the previous floods, the residents were dissatisfied with how relief was distributed. Among the common complaints was that of local leaders only helping their kin, kith and political supporters. There are other issues in the system of how relief is distributed. For physical damges to structures, only the owners of the houses are paid. From our field visits, we found that a large portion of the affected residents rented their premises and hence none of the losses to contents of their houses were compensated. Also the most vulnerable and consequently those who suffered the most losses, lived in illegal houses that were not on the record of the local authorities and hence did not even figure in the relief distribution. It is difficult to imagine how these houses can be constructed and habitated without active connivance of the local authourities and service providers. Even for the house owners there were issues with relocation. The procedure for relocation in its implementation is far from fair and has since long caused serious problems with donors who demand a reasonable resettlement policy for all. Widening or vacating the banks of Lai for the residents is, therefore, potentially a more uncertain and hazardous process than the floods themselves.

The second round of SLDs consisted of sharing further information on resilient communities and reconfirmed the information from the former SLD along with some interesting new nuances. The communities were given feedback on the views of federal and local government authorities on their alleged complaints in an effort to bridge the the knowledge gap between communities and government. A backlash on government views was recorded during this round as both sides persisted on blame shifting and displaying helplessness without mutual cooperation. During an SLD held with local authorities, the Rawalpindi Development Authority did not participate. Many questions of the community on their ineffective and even non-existent solid waste management policy were left unanswered. The general view recorded in the second round was that the government is far removed from ground reality, but at the same time area improvements are impossible without government help.

Upon revisiting the list of hazards and their possible solutions, there was a convergence of ideas and it seemed that within the iterative process, a sense of focus was developed. This may have been caused by conscientization of concepts or also may be a deliberate move by the communities to focus their demands on issues that they perceived the survey team to be most likely to influence and alter in their favor. The newspapers and electioneering had focused on flood hazards and the construction of a signal-free highway on the banks of Lai. It seems a rational response from the communities to put flooding on the top of their list, as they knew that the governement was leaning towards investing in a solution for this problem.

Vulnerability/Capacity Index

During the third round, Capacity and Vulnerability Assessments and a Capacity and Vulnerability Index were recorded with the cooperation of the seven communities. These portray an image of varying vulnerabilities and capacities in the areas were SLDs were undertaken. Table 3 provides quantitative assessment of the vulnerabilities

TABLE 3 | Vulnerability and capacity index

Type of Vulnerability	Site						
	Ratta Amraal	Dhok Najju	Gunj Mandi	Khayaban-e-Sir Syed	Pir Wadhai	Gawal Mandi	Dhok Dallal
Material (35 Max.)	35	14	31	14	31	28	14
Institutional (50 Max.)	34	27	10	8	0	-3	-8*
Attitudinal (20 Max.)	11	20	10	20	10	10	20
Total (100 Max.)	**80**	**61**	**51**	**42**	**41**	**35**	**26**
Ranking	1	2	3	4	5	6	7

Note: * Negative vulnerability denotes capacity.

and capacities of the affected communities. It also provides an assessment of whether communities are improving, coping or declining in term of physical, institutional and motivational factors. Common results across all seven communities were vulnerability of livelihoods and poor motivation.

Most of the localities selected for the analysis were physically exposed to flooding hazards and were victims of the previous floods. Despite this bias, a huge differential in vulnerabilities was noticed among the communities, showing how vulnerability is a complex and subjective construct. The community visited in Ratta Amraal was judged to be the most vulenrable and the one in Dhok Dallal, was although somewhat more vulnerable on average in Rawalpindi, the most resilient among those selected. The community in Ratta Amraal owed their predicament to the fact that they had been living in illegal housing for last the three decades along the banks of Lai. The origin of the community could not be confirmed, but they were living as migrants on Railway property. They still do not even have asylum cards or ration provisions that were sanctioned. Since their status is still as migrants, they cannot get national identity cards or avail of any social services, nor can their children be issued identity cards to become future citizens. Having no opportunity in formal markets and social services, people in Ratta Amraal are the poorest of the poor and ranked highest on material vulnerability.

The least vulnerable group hailed from Dhok Dallal where the riverbanks are relatively higher, compared to most of the other areas. Most people living there are local with kinship ties in the rest of the city. The better off business and shop owners live on inner streets, away from the river. A stronger sense of community was observed in the area, as evidenced by a religion based group and active Civil Defence volunteers. Social services were better than most areas, with six tube wells for drinking water and a hospital.

The community shared the lack of trust in government with the other investigated communities and faced most of the same hazards such as solid waste dumping and rodent infestation. Yet, they were attitudinally more resilient and actively sought solutions to local problems. People living in Dhok Dallal also felt that despite the dismal performance of the local government partnership with the communities, help from the government was the only way forward. The optimism may be based on the fact that one of the members of the community was active in local politics and thus felt more empowered.

Weaknesses of the Qualitative Methods and Concepts

Communities have a fair idea of hazards and their solutions. However, a cost and benefit ranking of prioritized common solutions by the communities in the SLDs failed as a method, as the communities confused unit and total costs. They also did not have a fair idea of the cost of some projects.

Shared learning dialogues need not necessarily float ideas that will be accepted or even be considered important by the communities. A pertinent example of an unacceptable idea was "Hazard Insurance". Despite facilitating meetings with insurance experts and explaining the benefits of hazard insurance, the communities all proved reluctant to buy insurance. The reasons were lack of trust in institutions providing insurance and the inability to afford insurance owing to continuous price hikes and inflation. The impacts of climate change were acceptable and even considered already visible by most communities. However, learning about climate change was considered unimportant, as people feel powerless to reverse the impacts and are too busy struggling to survive to do anything else.

Another weakness of the process is that to obtain data from SLDs (that may represent the entire study area of Lai) requires large amounts of inputs in terms of money, time and resource persons. At the same time, the value of the process is such that with even very little investment, one can identify cross-cutting issues that are common to most localities, which may not surface in discussions at other levels. For example, the unequivocal identification of basic infrastructure and services as a key component of resilience by all communities is an important insight that the disaster risk related organizations have yet to consider in their strategies for building resilience.

As mentioned before, the SLDs in this instance ended with alignment to the current discourse at an organizational level. People demanded structural measures in risk reduction, as they were aware that chances of getting input from the governement were higher than those for asking for basic services such as clean drinking water, health etc. This falls much in line with Sameul Paul's (1990) assertion that citizens use voice in proportion to their perception of its effectiveness. Since electioneering was at its peak during the SLD period, the communities may have used the SLDs as a forum to voice their demands for invesments that the government may be considering to make for different reasons.

Methodology: Quantitative

As discussed previously, the Pakistan case study was limited to using secondary data for conducting a cost-benefit analysis of various options for disaster risk reduction. This restricted analysis to strategies for which there was enough data available. Such interventions included the channel improvement/expressway project, which has been put on the back burner because of the political motivations behind it and the subsequent change of governments. The second is a recently completed Early Warning System installed with the help of grants from JICA and a retention pond, also funded with JICA's help, and the third option, for which a CBA was attempted, is a hypothetical example of wetland restoration by relocation of people in the flood plane. For all three of these scenarios it was essential to assess the assets at risk, which was done using a somewhat generalized estimation because of lack of specific data before the 2001 flood. Now with cheap (actually free) technologies, such as satellite imagery with resolution high enough to count building units, it is much easier to precisely measure assets at risk. Conversely, finding usable data on health, sanitation and effects of drinking water issues was next to impossible without extensive primary research. Following is step by step description of the CBA process, which will make explicit not just the specific methodology for this analysis, but also the assumptions and limitations which are a part of the process.

The Cost-Benefit Analysis

This section describes the parameters and relevant data used for risk reduction in all three scenarios, namely: concrete lining of the channel, the warning system/ construction of a retention pond in the upper reaches of the stream, and relocation of the most exposed population to higher ground. Along with the general assumptions and limitations, which are a part of the process of conducting a CBA, issues specific to each strategy are described individually under that approach. Following is an overview of the process adopted for conducting the CBA.

Risk

Flooding was the primary risk identified by the communities and in institutional shared learning dialogues (SLDs). The JICA study on comprehensive flood mitigation conducted after the 2001 floods proved to be a wealth of information. However, most of the data going into it were provided neither by JICA nor the local counterpart authorities (i.e. the Federal Flood Commission) who remained skeptical of the analysis.

The flood hazard, return periods and depths have been based on JICA's estimation of various return periods (i.e. 5, 25, 50 and 100-year periods). Since JICA consultants had left accessible neither the software nor the data for its analysis, the research team decided to use its own model to fit the results that JICA had estimated based on the actual data from the 2001 flood. The team used a simple steady-state hydraulic model fine-tuned with critical, on the ground measurements, such as those at bridges, etc. As a result, the estimations came within acceptable range for a cost-benefit analysis based primarily on secondary data. For a more forward looking analysis, the team tried various commonly used statistical distributions for flood modelling such as Gumbel and Pareto, finding the best fit with Log Pearson 3 and used it to extrapolate flood levels up to the 200-year return period.

Vulnerability

The basic vulnerability analysis was conducted using assets at risk and damage data from the flood of 2001. Since there was a three-fold difference between the official government figures and what JICA had calculated, it was deemed necessary to review both studies' processes of estimation. The government had calculated damage using compensation data and hence did not include huge losses that were not compensated. The JICA study did approximate the number of structures and assigned values taking citywide averages rather than look at the specific assets that were affected. It is reasonable to assume that the pattern of settlement and distribution of different types of infrastructure would be different from the city average on the banks of Lai. The area inhabited by lower income groups and the nature of the land is likely to be different because of its exposure to flood risk. Therefore, a triangulation of property values was conducted through interviews with real estate agents along the entire stretch of the flood plain to estimate realistic figures.

According to the real estate agents, around 80% of the properties within 100 metres of the banks of the Lai are illegal and hence, it was necessary to reconfirm the number of units along the river's banks. Readily available Google Earth imagery was used to ascertain actual assets at risk rather than estimations or official figures. Contour maps of flood depths for various return periods were superimposed on the Google Earth images to calculate the number of structures likely to be affected at different flood levels.

Procuring reasonable contour maps for this analysis was extremely difficult. Official maps are considered classified because the Lai is close to the General Headquarters of the Pakistan military. The minimum size of maps required for a visual count of assets at risk was 1:50,000. The research team used the surveys done for a detailed design of the Lai expressway to make a raster and vector analysis of flood depth using ArcMap, ArcInfo and Adobe Illustrator software. These data were useful for plotting the damage estimations for floods below the 100-year return periods as there are no historical damage data for these scenarios.

Depth-Damage Analysis

As there was no local data on depth-damage ratios, the team used data from various studies in the region and globally and then used what seemed to be reasonable estimates from Rawalpindi and corroborated them with anecdotal evidence found in qualitative surveys on the area. Average depths of the 2001 flood were used as the estimator for median damage figures and applied to other return periods.

Economic Effects

The impact of the 2001 flood is the only event that is well documented for damage caused. These figures were used to interpolate and extrapolate damages for other return periods using flood depths from hydraulic modelling, area of inundation and satellite imagery of the area.

The historical data on flood damage in 2001 had huge variations. The official government estimates were several times lower than those estimated through the JICA survey, which reached a figure of PKR 53 billion as opposed to PKR 10-15 billion by the official estimates. The reason for this discrepancy may be that the official estimate is based on a flat compensation on the basis of whether the houses damaged or destroyed were of *katcha* (mud) or *pukka* (brick and cement) construction only and not by the extent of actual damage. Also, there is a flat compensation for death depending on whether the person was the family breadwinner or not and for heads of cattle lost that can be verified through official documents only. Therefore, the study team used the JICA survey results rather than the official figures.

The surveys in the JICA study measured some indirect damage, estimated from random surveys. This analysis tried to measure the damage caused by the disruption of business due to the closing of markets and factories and also that caused by damage to productive assets. The figures for these "flow" damages turned out to be to the tune of 35% of the total damages. Although the survey sample was not well designed and the results are not statistically significant, the value derived seems to be an underestimate when compared to the generic flood damage figures in other cases of flood damage estimates in the literature. Therefore, it was decided to use this figure as long as the analysis did not overestimate the benefits of risk reduction, since not using indirect costs of floods would have been a gross underestimation of damage.

Environmental and ecological effects of floods were not included in the analysis due to lack of data. Nevertheless, the qualitative assessments and the SLD process clearly indicated that diseases and illnesses due to lack of sanitation and clean drinking water are some of the major costs to the local populations. There is also anecdotal evidence that some families had to stop sending their children to school or sent them to less expensive schools as a part of a coping strategy due to long-term losses to family incomes.

The environmental and social benefits of certain risk reduction strategies can be immense and therefore it is imperative to include these for better analysis of the alternatives. These are opportunity costs or benefits that are often overlooked in analyses for project selection. In the new expressway design for channel improvement, the base of the deepened river bed was also to be paved. This would have had dire consequences to groundwater recharge in the city. For drinking water alone, the lack of recharge will exacerbate the current falling of the average water tables from under 40 feet in 1980 to over 150 feet in 2003 due to groundwater overdraft (ADB, 2005). Therefore, important issues that were not quantified are described in the following sub-sections which describe how the analysis for the four given options was structured. Besides the generic approach described above, these subsections detail the particular assumptions and challenges for using CBA in different scenarios.

Sheikh Rashid Expressway

The Sheikh Rashid expressway was the most likely option for implementation until the recent elections, after which the political forces behind the project were thrown out of power. This project was a hastily designed, dual-purpose project that would have provided flood protection through deepening and paving with concrete the section of the Lai that passes through the most densely populated areas of Rawalpindi. The second purpose of this project was to provide an expressway that joined Rawalpindi and Islamabad to ease the traffic burden between the two cities. The highway would also connect the old Army headquarters of the country with the new one being constructed upstream in Islamabad.

There were several issues with this project. First, there was little experience of maintaining a paved channel in a perennial river prone to flooding without additional measures for water diversion. Second, although the middle section of the river was being designed to carry a 100-year return period flood, there was no modeling done for the effects on the section downstream from the project area, which has a much lower carrying capacity and already causes backwater effects in the river. Third, since this was a multi-purpose project, the benefits from transportation and an increase in property value would have accrued as additional benefits that were not attributable to just flood prevention.

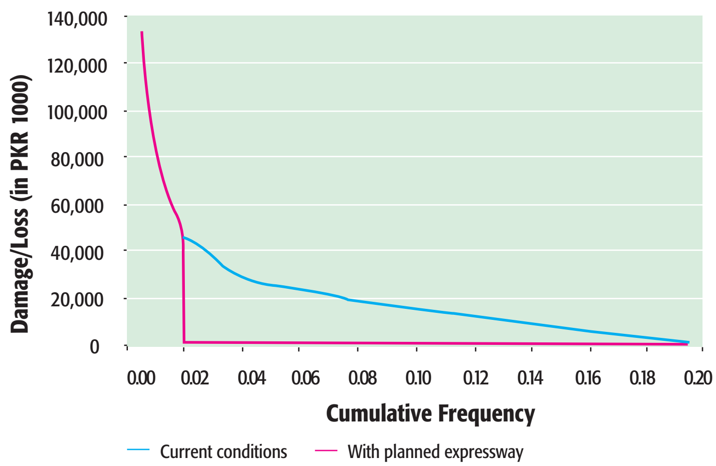
The issue of limiting channel enhancements to the expressway section as opposed to the whole river, has three implications for flood hazard:

- Due to higher carrying capacity in the intervention reach there may be increased flooding downstream;
- Due to downstream backwater effects, the enhanced channel will likely not be able to carry the designed flow, thus reducing its flood reduction impacts; and,
- Slowing the water flow in the channel due to backwater effects mentioned above could cause heavy deposition in the channel area, reducing its depth and slope and ultimately bringing it back to its current gradient.

These effects were reflected in the analysis by reducing the risk reduction capacity of the channel to a 50-year return period from 100 years and incorporating a higher maintenance cost for upkeep of the channel than that suggested in the design documents (Figure 2).

To separate the flood prevention from transportation and other benefits, we incorporated the costs for the flood protection portion only and treated the road as a separate, standalone project, although its construction is dependent on stabilization of the riverbanks with concrete. Taking this approach still leaves the opportunity cost of having the road, for which there may not be an alternative. The study team strongly recommends using much more environmentally friendly elevated mass transit in the Lai corridor, which will not restrict the channel capacity and can also be used by poorer people living along the Lai, most of whom do not own cars.

| FIGURE 2 | The loss-frequency curve for the planned expressway



| FIGURE 3 | Typical people transport along Lai

| FIGURE 4 | Typical goods transport along Lai

Social benefits of flood prevention in terms of disease burden, psycho-social effects of trauma and long-term effects, such as children dropping out of school because of post flood poverty, were not included in the analysis because of lack of credible data for analysis. These benefits of risk reduction are also omitted in all the other scenarios and hence do not affect comparative analysis too much when it comes to selecting options.

There were some alarming ecological effects of this project as it was designed because it would have stopped groundwater recharge in the areas of the river to be paved. Although not included in the mitigation strategy for reducing environmental damage, the design of the channel can be altered to allow infiltration of water without a substantial cost increase. Therefore, the cost of loss of groundwater recharge was not added to the analysis.

Despite all the issues, the "hard resilience" technical measure still yields a positive benefit-cost ratio of 1.88 at a commonly used discount rate of 12%. With lack of comparative strategies, a project like this would easily be approved in policy circles and it indeed was approved by the last government.

JICA river improvement options/retention pond

Among the options recommended by a JICA study for flood mitigation after the 2001 flood were some comparable options for channel improvement. Two of these recommendations were the construction of a pond upstream of Rawalpindi in a park, and the straightening of a river bottleneck downstream of the densely populated area to increase flood flow and reduce backwater effects.

Since the modelling software was not available to the study team and the JICA country office was reluctant to provide the data, the following parameters shown in Table 4 were used to estimate the risk reduction strategy.

The risk reduction for various flood intensities was calculated through the decrease in flooded area and subsequent reduction in damage (Figure 5). This strategy yields the best benefit-cost ratio of the four strategies reviewed and is higher by several orders of magnitude.

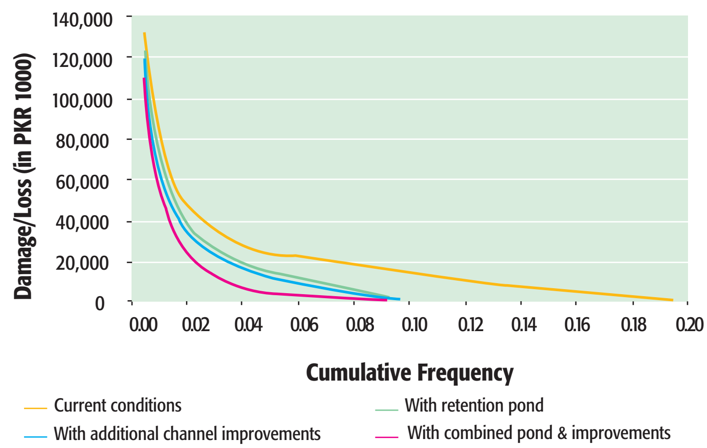
TABLE 4 | Estimated discharge by return period (m^3/s)

Reference Point	Channel Capacity	5-yr	10-yr	25-yr	50-yr	100-yr
Kattarian Gawal Mandi	640 820	640 820	640 820	640 820	640 820	640 820
With Pond (Peak reduction of 190 m^3/sec for 25-yr and 240 m^3/sec for 100-yr)						
Kattarian Gawal Mandi				960 1,320	1,450 1,970	2,030 1,840
River Improvement (Increment flow capacity of 260 m^3/sec)						
Kattarian Gawal Mandi				890 1,250	1,210 1,920	2,010 2,700
Both measures (450 m^3/sec)						
Kattarian Gawal Mandi				700 1,060	1,190 1,710	1,770 2,460

Source: JICA, 2003 and interpolation by authors

There are several reasons for this outcome. First, the analysis appeared technically sound and took into consideration the river morphology for optimization. Second, the approach makes interventions in sparsely or non-populated areas of the city, which are either government owned or of low value. Third, due to the nature of the analysis and availability of more accurate data, the CBA process is very well suited to measure the tangible benefits from engineering based solutions. This does not mean that other measures cannot give better ratios but that there must be considerable investment in measuring the benefits

| FIGURE 5 | Loss-frequency curve for JICA river improvement options



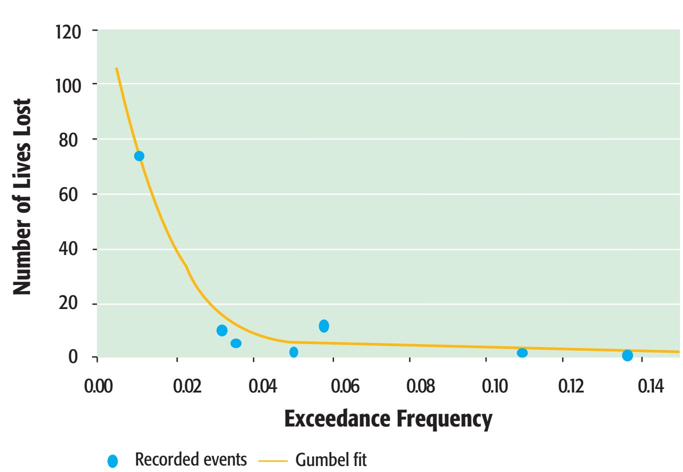
Early Warning System

An early warning system was proposed as a "soft resilience" or non-structural intervention. Although the cost of this measure is considerable, the ensuing benefits are low because of the short response time of the Lai River in which only lives and perhaps some movable property can be saved. Unlike physical damage data, loss of life in various flood periods is well documented in newspapers. We carried out a newspaper research on the number of lives lost during various floods and plotted them against return periods estimated by the flood heights or discharges reported in various sources. This resulted in the following curve fitted to a Gumbel distribution, shown in Figure 6.

Integration of the curve yielded an average of 3.34 lost lives per annum due to floods. The cost of saving lives came out to be around PKR 3 million (USD 44,000) per life. This does not mean much in absolute values, as putting an estimate on the value of a life is a matter of much debate and raises moral issues. However, for comparing risk reduction strategies this number can be very useful in making decisions. For example, one may compare this number to the number of lives saved through investment in basic services such as neo-natal healthcare and the provisioning of clean drinking water and sanitation. Although such data were not available for the Lai area population, there was a strong demand for basic services from the poorer communities as a major risk reduction strategy.

For further analysis, we also included an upper limit on household and business contents that can be removed. For this purpose, we assumed that 20% of the value of all household contents and 2% of the value of warehouse stocks can be removed in the short warning time provided by the system. With

| FIGURE 6 | Loss of life frequency curve for Lai floods



these assumptions, the benefit-cost ratio became marginally positive, although it is still very low. Although this was a "soft" strategy, the main thrust of the project was on sophisticated telemetric hardware and expensive technology. It was learned during field visits that despite multiple sophisticated control stations, communication and evacuation strategies were still not developed, indicating the strong focus on equipment alone. Moreover, the institutional setup for the system is highly complex and the front-end response agencies, such as the fire department and the voluntary civil service, have very low capacity compared to the requirements for such an evacuation.

A simpler, lesser high-tech system reliant on a short messaging service to all cell phone holders would have had significantly lower costs and much higher communication outreach. Such strategies have already proved highly effective in many similar countries (Aditya, 2007).

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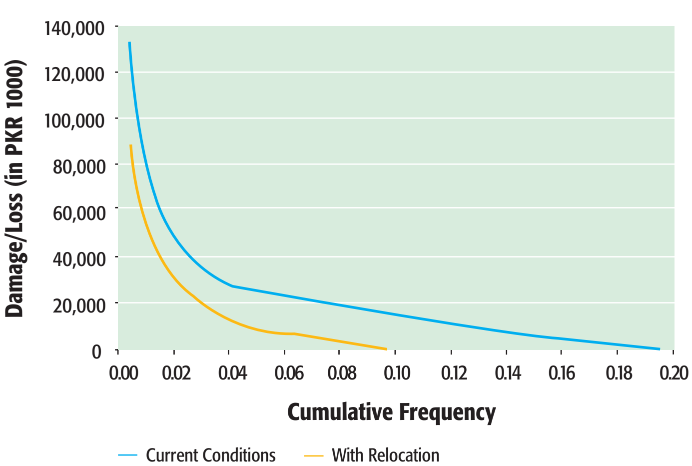
Relocation and restoration of flood plain (hypothetical)

One of the more unconventional strategies for Lai flooding that has been discussed, though never examined, is the ecological restoration of the Lai flood plain. This strategy would entail the relocation of people out of the flood plain and opening up space around the river for vegetation growth and creation of recreation areas. For a stylistic economic analysis, the study team decided to perform a CBA on clearing all housing within 100 metres of both banks of the Lai. The cost of this measure was calculated based on market value of building units and the benefits from the reduction in flood damage. The damage is reduced by buildings and people being moved out of harm's way, but also by the associated clearing of part of the flood plain flow area such that water levels and thus, flooded areas are reduced.

FIGURE 7 | **Loss-frequency curve with relocation**



This approach also yielded a very low benefit-cost ratio compared to river improvement measures, as seen in Figure 7. The main damage averted was that to the houses that were removed while the increased channel capacity actually had little effect on the reduction of the flood plain area. The high cost and density of urban infrastructure once again was driving the results of the analysis.

There are ecological benefits to river restoration, but relocation alone will not be enough and enormous investment and coordination will be required. It would entail the provisioning of piped sanitation to all households in Islamabad and Rawalpindi and convincing the Capital Development Authority to treat all its sewage before dumping it into the Lai. A complete solid waste management collection and disposal system would also be needed in the twin cities.

Another issue with this approach is its implementation. Pakistan still follows outdated and unjust resettlement laws from the colonial period framed in the 1890s. Because of this, resettlement has been a money minting business for bureaucracy and works against the poor and powerless. For example, around the Lai, 80% of the most flood-exposed housing is illegal. Hence, the most physically vulnerable would not be compensated. Moreover, most of the people living in these houses are tenants rather than owners, which further lowers the chance of reducing the vulnerability of those who deserve the most assistance.

Limitations of Quantitative Methods

Secondary data availability precluded analysis of health and related services in this study, although they were termed high priority risks and among the key targets of risk reduction strategies identified by the community (Khan and Mustafa, 2007).

The analysis also does not consider distributional aspects of costs and benefits because of the aggregate treatment of costs and benefits in CBA methodology. Qualitative analysis based on vulnerability indices showed varying level of resilience within communities living along Lai. Therefore, any decision based purely on CBA analysis would be misguided without qualitative assessments of the winners and losers in Lai flood basin, particularly if poverty reduction in the face of climate change and variability is the objective of the risk reduction strategy. However, pinpointing high vulnerability within the area would allow much more cost effective approaches to resilience building strategies than those evaluated generically in this study.

Conclusions

Our analysis based on secondary data show that all four interventions for flood risk reduction have a favourable benefit-cost ratio, indicating economic efficiency (see Table 5). There is a wide difference between these ratios, however, with some of the interventions proposed by JICA having by far the greatest impact on flood peak reduction. The CBA tool is extremely useful in comparing two similar, technology-based strategies, showing that the concrete paving of the channel in the midsection is far less economically beneficial than channel improvement in the lower reaches of the river.

TABLE 5 | Benefits and costs of interventions in the Lai Basin

Strategy/ Intervention	Net Present Value of Investment*	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

* Pakistan Rupees in Million

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

Due to the short length of the Lai and the over-design of the project in terms of equipment, the early warning system does not have a favourable benefit-cost ratio. In terms of cost per life saved, it would not compare with improvement of basic services such as health, water and sanitation. The use of newer technologies for outreach such as Short Messaging Services on cell phones and fewer telemetry stations offers a very cost effective system that could be developed. Despite the lack of cost effectiveness, the lower scale of investment made early warning the most viable project, and it was implemented.

Many conservationists and locals of Rawalpindi would like to see the Lai restored to its natural state. The CBA analysis shows that although the results are still positive, the cost of restoration (through relocation) is the highest of all the strategies. There are also other multiple issues of untreated sewage from both Islamabad and Rawalpindi and solid waste from the localities around the Lai being dumped in the river that need to be looked into. Installing and enforcing water treatment in so many administrative jurisdictions is a task which is yet to be achieved in South Asia. Moreover, the archaic relocation laws tend to benefit the richer and work against the poor. Most of the people living along the Lai rent their houses, but it is the landlords who are compensated for damage. In addition, a large portion of the houses encroach on public property making them illegal. Hence, the owners are unable to claim benefits. In terms of cost of land, the Capital Development Authority has the mandate to develop new housing and owns large tracts of land for low cost housing. If the houses along the Lai were to be exchanged for units upstream the prospect of relocation would become highly feasible as the authorities would have to pay for land development only and not for the cost of the land. However, this would have to be done under a special project with more pro-poor policies and procedures.

The CBA process has made it possible to compare similar approaches for cost effectiveness and has lent a sense of proportion to softer approaches in risk reduction that tend to focus more on people rather than the hazard. The process has also highlighted the shortcomings of the tool in assessing people-centred, resilience building. Due to the lack of distributional aspects in the analysis, it is extremely important to use more qualitative tools that focus on the differential effects of various approaches on the poor and the vulnerable. If one were to focus on resilience building and number of people helped rather than the amount of capital, then such an analysis would yield even better results.

Despite its shortcomings, this CBA has established that one form of river improvement is much better than the other and also that the early warning system could have been made much more cost effective had a CBA been carried out. Use of CBA with its known limitations leads to a tangible decision support system in some cases and calls for further analysis in others.

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CHAPTER 6

Quantitative Cost-Benefit Assessment of Flood Mitigation Options:
Uttar Pradesh, India

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Country: India
Location: Select villages in Maharajganj and Gorakhpur districts in the Rohini River Basin, eastern Uttar Pradesh
Issue: The annual monsoon during the months of June through September, brings significant rainfall to the area. Low-level flooding associated with the monsoon historically was beneficial to crops. Recent widespread construction of embankments, roads and other infrastructure have seriously altered the nature of the floods, leading to higher flood water depths, persistent water logging and occasional flash floods as poorly maintained embankments burst. These types of floods now destroy crops, households and livelihoods and contribute to endemic poverty. This study assesses the costs and benefits of embankment maintenance and more 'people centered' disaster risk reduction strategies.

Key Concepts

- The two districts receive nearly 80% of their annual rainfall during the monsoon months of June through September, with the majority of that rain falling during July and August. Most of the monsoon precipitation is associated with thunderstorm (convective) activity, in which large amounts of rain falls in high intensity, short-duration events. A simple climate downscaling model for the area indicates that monsoon rainfall is likely to increase by up to 11%. It is also very likely that variability within the monsoon will increase, as will the intensity and frequency of heavy precipitation events.
- The changing nature of agriculture in the area, coupled with lack of coherent government agency coordination and practice, has led to widespread, haphazard and ill-conceived embankment construction. Ill-placed embankments frequently route flood waters to downstream villages and trap water, creating water logged agricultural fields behind the embankments. Downstream villages then request help constructing their own embankments, further exacerbating flood and water logging situations. Improper maintenance of existing embankments also contributes to the floods. Climate change is likely to worsen this largely man-made situation.
- Most households are extremely vulnerable to the now almost annually occurring floods, which destroy crops and can permanently destroy agricultural lands. Mud (*kuccha*) houses often erode in the floods and household resources (seeds, livestock, etc.) are lost. Households are then driven further into poverty by assuming debt to replace lost homes and resources.
- Embankments are a cost effective flood mitigation strategy only if they are properly maintained and if constructed in a planned manner considering upstream and downstream effects. Embankments have no benefits in non-flood years.
- People centered flood risk reduction interventions, such as raising the plinth heights of houses, early warning systems and community seed and grain banks, are also cost effective strategies. People centered interventions have the additional advantage in that they provide benefits in all years, not just those in which floods occur.
- Cost-benefit analysis is a useful tool, when used in conjunction with social assessments, for assessing whether to pursue an intervention or a suite of interventions, but is limited by data availability, people-hours and should not be used as the sole tool for deciding a project's efficacy. Cost-benefit analysis does not answer the questions of *Who benefits?* and *Who pays?* Due to the limitations described in the study, the numbers produced by the cost-benefit analysis should be considered only in terms of their magnitude, not by their actual value.

Introduction

Historic Political and Policy Environments

Strategies for flood protection within the Rohini Basin have been heavily influenced by the fluid political and policy environment of the region. The political leadership of newly independent India believed that flood control was the best way to protect people and secure agriculture. Embankments therefore gradually became the dominant flood risk reduction strategy, alongside a focus on growing crops requiring specific inputs and production techniques which are dependent on large-scale flood control and irrigation schemes and the bureaucracies created for their management.

Initial construction of embankments in the Rohini Basin created a self-propagating dynamic. Embankment construction started during the 1970s and evolved in a piecemeal and uncoordinated manner over the following 3-4 decades. Since embankments on one stretch of a river have adverse impacts on other areas, this partial approach generated further demands for embankment construction. Thus, the basin witnessed a competitive construction of embankments, with political leaders driven by short-term populist agendas often propagating the strategy when in a position of power.

Presently, any major flood event is followed the allocation of massive funds for construction of new embankments and repair of old ones. The situation is further complicated by the transboundary nature of the Rohini basin, which crosses the Nepal-India border. Both sides of the border have experienced political turmoil at various points of time and the level of cooperation on everything from data collection and sharing, to actual joint management of smaller shared rivers such as the Rohini has been minimal. Under these circumstances, relatively little attention is given to the effectiveness of existing strategies for flood control or the potential availability of alternative approaches.

Lack of Learning

Despite recommendations from several expert committees and other knowledge platforms, there has yet to be a paradigm shift from flood control to flood management. Studies conducted by the Planning Commission have questioned the role of embankments, and a number of donors and NGOs also have highlighted their adverse impacts. The political leadership, however, continues to place faith in control structures that also help gain political support in their constituencies. And while most high-level committees and task forces have flagged the importance of maintaining flood control structures such as embankments, this is seldom undertaken due to political and budgetary constraints.

The bureaucratization and centralization of water resource development in India has led to a lack of transparency of information. Most data, including river discharges, are classified. As a result, water resource management has become confined to specialists, rather than discussed openly in political and public spheres. This has reduced the ability to learn from experiences, such as those emerging from work on decentralized risk reduction strategies in other parts of the Sub-Continent, for example, Bangladesh and to some extent the Nepal Tarai.

Disjuncture between Groups, Institutions, Levels of Activity and Analysis

There is a lack of inter-sectoral coordination amongst the various government agencies involved in different aspects of flood management. Each has its own independent agenda, without taking in to account common concerns. Furthermore, administrative and physical boundaries often do not match. Flood management must be at the basin level, but most river basins fall within several administrative boundaries. Most actions directly concerned with floods thus are designed and implemented at the administrative level, but their implications are felt at the basin level.

There appears to be a disjuncture between community needs and government programmes. While a cross-sectoral approach is required to address the basic needs of communities in flood prone areas, especially on issues of communications and livelihood resilience, government flood management plans generally do not focus on the entire range of needs and potential interventions. Livelihood promotion, with the potential to address the root cause of flood vulnerability, is often not considered.

Community mobilization and capacity building require a strong network of NGOs with a long-term focus on development. In the Rohini Basin, however, very few NGOs are operating in flood-affected areas and those that are present primarily provide relief. Furthermore, long-term programmes require substantial resources.

Most rural development activities are designed at the national-level and common across the country, lacking mechanisms to respond to local contexts and specificities. There are no specific features for flood prone areas. Despite the requirement for participatory bottom-up planning approaches when preparing official disaster management plans, this is rarely realized in practice.

Major Changes due to Climate Change (to 2050)

Downscaled climate change projections to the year 2050 indicate monsoon (June to September) rainfall in the Rohini Basin will increase. Translated into potential changes in flooding, the frequency of smaller less intense events will increase, while rarer but more intense floods will remain relatively constant. What is now a 10-year flood loss in the future will be a 5-year loss, while a current 100-year flood loss will become a 60-year loss.

The embankment-driven notion of 'keeping away floods' becomes difficult to implement successfully when the thresholds needed for design, for instance flood frequencies and magnitudes, are dynamic and highly uncertain. As a result, alternative strategies such as those designed to strengthening the resilience of livelihoods and communities in flood prone areas and the ability of people to 'live with floods' need to be explored as potential alternative or complementary strategies as climate change proceeds.

Analysis of Strategies for Flood Risk Reduction

Detailed evaluation of the costs and benefits of alternative strategies for flood risk management along the Rohini Basin in Eastern Uttar Pradesh, India, highlight substantial differences in economic returns.

Construction of embankments for flood control has been the primary strategy for risk management over the last half century. Detailed analysis undertaken through the project demonstrates that this investment cannot be concluded to have been economically beneficial. When analyzed from a social welfare perspective in which all costs and benefits are considered, the benefit/cost ratio from past investments is about 1; that is the costs have equaled the benefits. Projected impacts from climate change would reduce returns further probably driving the benefit/cost ratio for new embankment construction in the future below 1. Given that investments in existing embankments represent sunk costs, investments in proper maintenance of those embankments would, however, generate high economic returns (benefit/cost ratios in the range of 2) under both current and future climate change scenarios.

In contrast to historical reliance on major structural measures for flood control, scenarios based on a more "people centered" resilience-driven flood risk reduction approach perform more economically efficiently. Benefit/cost ratios for such strategies range from 2 to 2.5 under both current and future climate change scenarios. Furthermore, since such strategies have low initial investment costs in relation to annual operation and maintenance, these returns are not sensitive to discount rates or assumptions regarding future climate conditions. Projected increases in flood risk due to climate change are unlikely to erode the overall returns from people centered strategies. Overall, economic returns from portfolios of people centered strategies appear highly resilient under a wide variety of conditions and assumptions.

Utility of Cost-Benefit Analysis

Cost-benefit analysis provides a useful support tool for decision-making and policy development for disaster risk reduction. However, the limitations in applying cost-benefit analysis need to be considered. Limitations on data availability and quality constrained the analysis. Such limitations are inherent in most risk management contexts, particularly in the developing world. As a consequence, however, the outcomes from cost-benefit analyses depend heavily on key assumptions and data. Testing the accuracy of available data and any assumptions that must be made through extensive stakeholder involvement in the analytical process is, as a result, essential. Benefit/cost ratios and other quantitative outputs are most meaningful as order of magnitude estimates rather than absolute values, especially when the inherent uncertainties in climate change projections are considered.

To complement this approach, qualitative evaluation provides insights about the perceptions and needs of diverse stakeholders, as well as varied benefits and impacts of potential disaster risk reduction strategies on different locations and communities. If undertaken in an inclusive stakeholder-based manner, the process of undertaking a cost-benefit analysis forces participants to systematically evaluate the details of risk management strategies and the assumptions underpinning them. This analytical process can ensure that the strategies ultimately selected are socially and technically viable, broadly owned and likely to generate solid economic returns. It can also ensure that the distributional consequences of strategies–who benefits and who pays–are addressed; a factor not incorporated in conventional cost-benefit analysis. Without inclusiveness, debate and iterative learning among stakeholders, cost-benefit analysis can easily be manipulated and thus misused.

Study Background

The Rohini Basin, a part of the Ganga Basin, has its headwaters in the Nepal Tarai, but is located primarily in the northeastern region of Uttar Pradesh, India. The basin is prone to annual monsoon floods, the intensity and frequency of which seem to have increased during the past 10 years. In this case study, the costs and benefits of different flood risk reduction approaches under potential climate change were analyzed and compared. In addition, the utility, applicability and limitations of cost-benefit analysis for supporting disaster risk reduction decision-making under a changing climate were investigated.

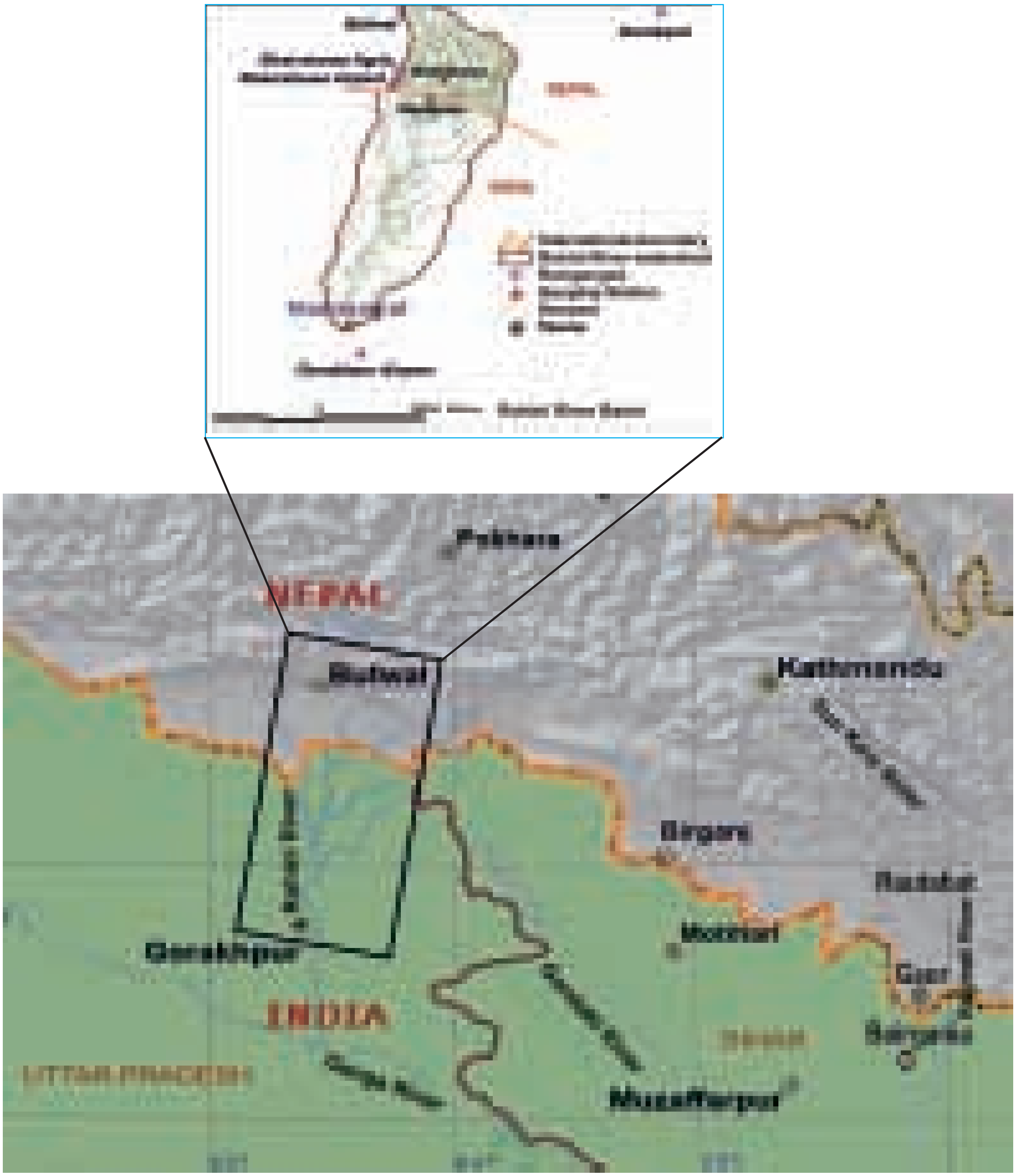
The economic performance of embankments, reflecting a historically dominant centralized flood risk reduction approach, was analyzed in comparison to a more egalitarian "people centered" basket of interventions implemented at individual, community and societal levels. These flood risk reduction strategies were evaluated through both qualitative and quantitative frameworks.

The subsequent section introduces the geographic context of the Rohini Basin study area and methodology of the study, followed by a section detailing various dimensions of vulnerability of the flood affected population. A fourth section outlines relevant policy issues for disaster risk reduction, and the process of selecting the flood risk reduction strategies for analysis. Details of the qualitative and quantitative analyses of these two contrasting approaches (embankments and people centered options) are detailed in section five. The final section summarizes key conclusions and reviews the robustness and utility of the cost-benefit analysis within the policy context.

Geographical Setting

The Rohini River is part of the Ganga Basin, located in Gorakhpur and Maharajganj Districts in the northeast Tarai region of Uttar Pradesh, India, in what is also known as the trans-Sarayu plains. Starting in Nepal, the river flows approximately north to south with a catchment area in India of about 872 km$^{2.}$ The Rohini ends at its junction with the Rapti River near Gorakhpur City. The basin location and its features are shown in Figure 1. Villages from a number of *tehsils* (sub-distirct) in both Gorakhpur and Maharaganj Districts were included in this study.

| FIGURE 1 | **Location and features of the Rohini Basin**



Agro-ecological Setting

Within India, the Rohini Basin covers elevations from 107 m in the northeast to 76 m above sea level in the southeast, resulting in a gentle slope from north to south. With a very small slope, even the smallest disruption in the natural flow of water can cause large-scale and long-term flooding.

The Rohini and Piyas Rivers traverse the case study area and merge in the middle of the basin. Many other hill streams and drainage channels join the Rohini River, which itself is a tributary of the Rapti River. These rivers and streams swell with water and debris during the monsoon, and with poorly formed banks, are prone to overflowing and erosion. This leads to frequent changes in the course of the rivers, more often in the northern reaches of the basin.

A large number of permanent water bodies (*charans*) cover the area; these developed over time due to changing river courses and abandoned channels blocked by silt. The basin also contains a vast expanse of temporary swamps and *jhils* (local water bodies), which vary from broad sheets of water during the rains to shallow marshes or even arable land during the dry season. Historically, these water bodies played an important role in flood management and provided livelihoods to a large population. In the last two decades, however, the water bodies have been heavily encroached upon.

The climate of the area is monsoonal. The temperature ranges between 5^0C to 46^0C and average rainfall is approximately 1200-1400 mm/annum, over 80% of which falls during the monsoon months of June through September. July and August are the wettest months, receiving about 60% of the monsoon season rainfall.

Numerous rivers and drainage channels transport soil and silt from the hills of Nepal. This soil plays a vital role in crop production. The low-lying lands usually have clayey soil well suited for rice paddy, while the higher lands have loam or a clay and sand mixture well suited for wheat, pulses and oilseeds. About 80% of the area is under cultivation. There are two main crop seasons: *kharif* (monsoon) and *rabi* (winter), with a third during the summer (*zaid)* in places where suitable irrigation exists. The main crops of the region are paddy in *kharif*, wheat in *rabi* and vegetables and maize in *zaid*.

About 50-60 years ago, the copping pattern was quite different.[1] Paddy was the main crop, particularly in areas having older alluvium (clayey) soil, with only a few minor *rabi* crops like pulses and oilseeds. *Madua, kerav, kodo, chana, jau, savan* (millet and legume crops) and a little bit of wheat, sugarcane and *bajra* (pearl millet) were also grown. With increasing irrigation through canals and private tube wells, wheat became more popular than minor crops. Many of the *kharif* crops like *madua* and *kodo* (millets), which had been either grown separately or inter-cropped with paddy, have almost disappeared.

[1] This summary of agricultural changes is based on interviews and surveys.

The growing popularity of 'green revolution' methods, while relatively recent in the region compared to other parts of India, has substantially changed agriculture in the area. High yield variety (HYV) seeds have replaced indigenous varieties and the use of chemical fertilizers has increased, along with groundwater irrigation. While agricultural productivity in the region has increased, it still remains low by national or state averages, primarily due to small land holdings, lack of irrigation and an absence of extension services. A lack of infrastructure for food storage and processing, communication, and electricity further limits agricultural income. There is potential for families to strengthen incomes through agricultural diversification, off-farm and non-farm employment opportunities. However, these opportunities are limited to date, and there are only some small industries in the region, primarily agriculture based, such as rice and flour mills.

Flood Hazard

Like all of eastern India, the Rohini Basin is prone to floods during the four monsoon months. About one third of its catchment lies in the Nepal Tarai where cloudbursts cause intense rainfall events. There is always some annual flooding, with major floods occurring in 1954, 1961, 1974 and 1993. In the last 10 years the intensity and frequency of floods appear to have increased and three major floods have occurred within a decade: 1998, 2001 and 2007.

In the upper part of the basin, *piyas*, or small hill streams and drainage channels, are prone to erosion and sudden course changes. In the lower part, the very low gradient causes the Rohini to meander sluggishly through the plains.

Since the 1970s, embankments (currently totalling over 113 km in length) and some spurs have been constructed for flood control. However, these embankments have frequently breached, causing more damage than if they had not been built. The structures fail primarily because they are not maintained properly, or in some cases their hydraulic designs are exceeded. Embankments have also caused the river bed to rise, decreasing the river's carrying capacity and increasing chances of flooding.

Water logging occurs because of drainage congestion caused mainly by embankments and other linear developments (roads, railways, canals, urbanization, etc.). In certain areas, including Maharajganj, the water logged area increased by 65-95% during 1971 to 1991. In many cases waterways developed across road and railway embankments drain insufficiently. Excessive rainfall can cause overflowing of low and poorly formed riverbanks, and drainage congestion is a serious problem. Siphons are either closed during high floods or do not function due to silting and clogging. The flood hazard is pronounced where drainage channels merge into the Rohini, especially lower in the basin above the confluence of the Rohini and Rapti Rivers. The overall nature of flooding therefore has changed; inundation depths have become higher and more unpredictable (embankment failures), with constant water logging in certain areas. While earlier floods were considered to have done more good than harm, they now cause immense damage to life and property, and have become an obstacle to development in the region.

An Introduction to Methods

Two contrasting approaches for risk reduction were selected for comparison:

(1) the historical centralized approach of construction and maintenance of embankments and

(2) a decentralized "people centered" basket of interventions at individual, community and societal levels.

In order to evaluate these disaster risk reduction strategies, a mix of qualitative and quantitative methodologies were used.

The team first identified data required for analyzing multiple factors that contribute to hazard exposure, vulnerability and effectiveness of risk reduction strategies. This information was sought from secondary sources such as publications, government official documents, and grey literature such as project planning documents. In order to triangulate this data, and to address gaps in information, a comprehensive survey was conducted in sample households and villages at different points in the basin. Seventeen survey villages and 208 households were selected within zones at varying distances from the river and existing embankments. Focusing on flood affected villages, about 50% of the households were below poverty line (BPL). Table 1 summarizes the zonal village distribution within the basin.

Data collected during the survey includes information on household profiles, livelihoods, assets, flood coping strategies, and perceptions of potential risk reduction interventions.

The team also employed qualitative methods included focus group discussions (FGDs) with various groups, key informant interviews, and shared learning dialogues (SLDs)[2] in survey villages in order to better understand perceptions of diverse stakeholders about potential impacts and benefits of various disaster risk reduction strategies. This approach helped capture non-tangible and non-monetary aspects of related costs and benefits.

TABLE 1 | Zonal distribution of villages in the Indian portion of the Rohini Basin

Zone	Description	Villages	% of Total
1	Between river and embankment	13	1.6
2	0-1 km behind embankment	48	5.7
3	1-3 km behind embankment	75	9.0
4	3-5 km behind embankment	88	10.5
5	>5 km behind embankment	613	73.2
Total	**All villages**	**837**	**100.0**

[2] Shared learning dialogues (SLDs) are iterative discussions with multiple stakeholders described in more detail in chapter 2 of this volume.

The quantitative evaluation framework applied a combination of backwards- and forwards-looking risk analyses to drive a stochastic cost-benefit analysis. Past flood impacts and hydrometeorological data were adapted to current conditions to determine risk, while climate and flood modelling estimated potential future risk. Field experience and estimations were used to quantify and monetize costs, benefits and disbenefits (potential negative consequences of interventions). Details of methodologies for these evaluations are provided in the section titled "Evaluating Tradeoffs" in this chapter. Finally, the methodology, experiences and results of the analysis process were reviewed for robustness and utility within the policy context.

Who is Vulnerable ?

The combination of focus group discussions, interviews, survey results and official data, provides an overview of human vulnerability in the Rohini Basin. The study specifically targeted people at flood risk.

Socio-economic Conditions

High population densities—of over 1000 persons per km^2 in some areas—puts many people at risk in these flood affected areas (see Table 2). This is significantly higher than the national average of 250 persons per km^2 in rural areas. Increasing population density is placing additional pressures on already stressed environmental and economic resources in the region.

TABLE 2 | Population density in the study area

Area	Density 1991	Density 2001
Uttar Pradesh State	548	689
Gorakhpur District	923	1140
Maharajganj District	568	734

Source: Based on the 2001 national census (Office of Registrar, 2001)

Human development indicators in the two study districts in the Rohini Basin are much lower than both national and state averages (Uttar Pradesh itself is lower than most of India). In Maharajganj and Gorakhpur, official figures report 30.8% and 28.2% of the population live below the poverty line (BPL), as compared to 25.5% for Uttar Pradesh and 21.8% for India (Singh, 2007). The incidence of poverty is even higher in scheduled caste (SC) and scheduled tribe (ST) households, with over 40% scheduled caste households BPL in 2007 (Singh, 2007). While less than 5% of the surveyed households were scheduled tribe, they were extremely poor with limited land or other assets, have low levels of literacy, and generally remain socially disempowered.

Primary sources of income are farming (65%), agricultural labour (14%), non-farm wages (14%), service (2%), business (4%) and animal husbandry (1%). While 60% of the population derive household income from local opportunities, 22% migrate to compensate for lost household income. In a significant number of cases (30%) distress migration occurs due to livelihood and productive asset losses.

It is generally accepted that a strong correlation exists between educational attainment and poverty. In India, poverty levels are almost four times higher among illiterates as compared to those with higher education (Office of Registrar, 2001). Literacy rates in

TABLE 3 | Literacy rate at state, district and survey scales (Office of Registrar, 2001 and survey)

Data scale	Total	Literacy Male	Female
Uttar Pradesh	57.4%	70.2%	43.0%
Gorakhpur	61.0%	76.7%	44.5%
Maharajganj	47.7%	65.4%	28.6%
Survey All	56.0%	n/a	n/a
Survey BPL	48.7%	n/a	n/a

Source: Office of Registrar, 2001 and Survey 2008

TABLE 4 | Household income, land owned, debt and savings (from survey)

Sample	Average Annual Household Income	Land owned (in ha)	Total outstanding loan(s)	Savings
ALL	$712	0.32	$76	$29
BPL	$550	0.22	$51	$24

Source: Survey 2008

the study area are low, particularly among women, as illustrated in Table 3.

A typical household in the rural Rohini Basin consists of 6 to 7 people (average[3] of 6.2 with standard deviation of 2.0), and earns an average annual income of USD 712[4]. Annual household income ranges from USD 90 to USD 15,300, though most household incomes are at the lower end of this range. In rural areas, poverty is strongly associated with land ownership, which is the main productive asset. On average, households own less than a third of a hectare of land (see Table 4).

Savings are generally very small for all classes. Most of the household income is used for consumption, especially food. Only a fraction is saved, or used for other purchases, as shown in Table 5.

TABLE 5 | Consumption and savings in per cent of annual income

Sample	Consumption food	Consumption medical	Consumption other	Savings	Remainder
ALL	63%	5%	18%	4%	10%
BPL	67%	6%	16%	4%	7%

Socio-economic Vulnerability

Due to flooding and poor drainage, large expanses of land remain water logged and fallow for long periods, sometimes permanently. Breaches in embankments occur regularly, causing immense and often irreversible damage to agricultural land and property, resulting in lost livelihoods for those dependent on the farming sector.

Over the past 10 years, 45% of households have had at least one death in the family due to floods, and in 65% of these households, victims were an earning member. While a significant percentage (24%) of casualties was caused by drowning, flood related deaths are caused also by other factors such as snakebites, malaria, diarrhoea and viral infection.

The type of housing structure not only determines the extent a house is damaged during floods, but also affects the risk faced by assets inside the house. According to the survey, 55% of houses in the Rohini are *pukka* (brick), which, of the common local building types, offers the greatest resilience to floods; 16% are semi-*pukka* and 29% *kuchha* (mud). During the 1998 flood, 43% of surveyed houses were devastated, while the 2007 flood destroyed 21% of houses. Housing thus provides limited protection during floods, with only 16% of people taking shelter on their own or a neighbour's roof.

[3] "Average" is reported either as the mean or the median, depending on the data. If the mean is reported, then the standard deviation is also provided.

[4] Monetary values are reported in United States Dollars (USD). Indian Rupees (INR) is converted using the average exchange rate during the period of survey (i.e. 39.5 INR/USD).

Most of the population does not have access to potable water, exacerbating their vulnerability to waterborne and gastro-intestinal diseases especially during floods. A majority of households (71%) fetch drinking water from open dug wells, which are not well maintained. Many of the un-lined *kuchha* wells cave in due to excess moisture. Privately owned handpumps provide poor water quality, especially during and after floods, because of their shallow nature and tendency to become submerged. Government handpumps generally deliver potable water during non-flood periods but they are rare.

Private sanitation facilities are limited with only 17% of households owning a toilet, and very few people use them due to cultural/religious habits. Furthermore, none of these toilets are built on elevated land or with higher plinth levels, rendering them inoperable during floods. Poor sanitation leads to an increase in cholera and gastrointestinal diseases, exacerbated during floods. Water logging leads to increases in vector borne diseases such as malaria affecting both humans and livestock.

Floods cause enormous hardships to all people, but especially to women, children and the aged. Women suffer from reproductive health problems arising from flood conditions. Their workloads are increased and they are challenged to meet basic needs of their families, such as obtaining water or food. Additionally, situations for women's personal hygiene and sanitation are compromised during flood situations.

Financial Vulnerability

The average financial losses of surveyed households due to the floods of 1998 and 2007 are shown in Table 6.

Comparing total household losses with average income reveals that income loss due to floods are most dramatic for people below the poverty line, but also significantly high for all households. Recurring droughts (among other economic shocks) also cause significant financial losses, and the impacts of the 2004 drought are included in Figure 2 for comparison to those of the 1998 and 2007 floods.

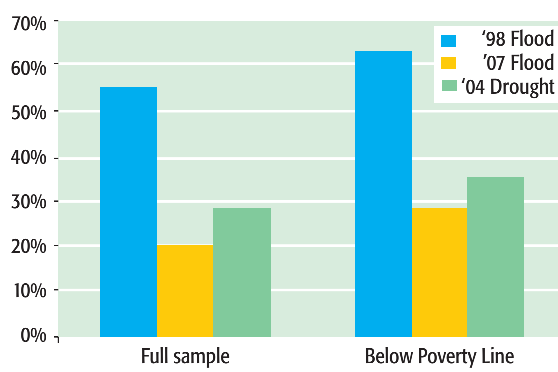
The percentage of household losses compared to average annual income were significantly less in the 2007 flood than in that of 1998. Households may have increased their resilience with improved housing (*pukka* construction), better access to early warning systems through communication technologies, and improved transport infrastructure enabling residents to move assets to safety.

Financial means to cope with floods are limited for the average household in the Rohini Basin. The initial and

TABLE 6 | Household average financial losses in USD due to floods in 1998 and 2007

	1998 Flood	2007 Flood
Crop Losses	101	76
Total Wage Losses	39	37
Additional Expenditures[5]	13	15
House Damages	160	22
Asset Damages	96	11
TOTAL	**410**	**161**

FIGURE 2 | Recent flood and drought household losses as compared to average annual income



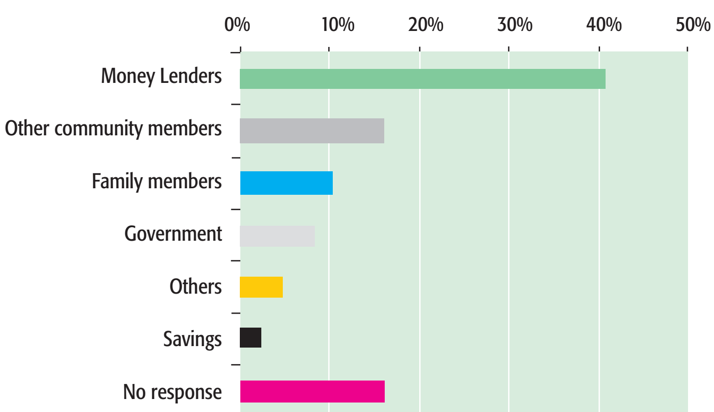
[5] This includes expenses for fodder, fuelwood and medical needs.

obvious source of disaster risk financing during and after an event is a household's own assets and income. However, only 15% of the lowest wealth classes and 50% of the highest report income sufficient to cope with flood impacts.

Livelihood diversification is generally believed to be an effective risk reduction strategy and in the Rohini Basin, 38% of households changed employment after floods. There are, however, only limited diversification opportunities in this predominantly agricultural region. Currently, only non-farm wage labour and service industries provide more income than agriculture, 10% and 83% more than farming one's own land, respectively. Agricultural wage labour (37%), business (sales kiosks, 75%), animal husbandry (33%), artisanal crafts (33%) and other income sources (25%) provide far less income than farming. As a result, most households (80%) earn their living through farming-related livelihoods, at risk to floods.

Relief, primarily governmental and not dependable, is often perceived as the primary source of disaster risk financing for poor and/or marginalized communities. Despite this, in the Rohini Basin, only 29% of households received relief after floods, and 19% receiving compensation payments after droughts. In both cases, payments were made long after the event (on average 1 month for flood relief, and 4 months for drought).

FIGURE 3 | Sources of household funding during floods



As household savings are insufficient to cope with disasters, the primary sources of funding during and after floods are local money lenders (who charge extremely high rates of interest), followed by other community members and family (Figure 3). Repayment of these debts adds significantly to households' financial burdens during disasters, with only 6% reporting that loan providers show some flexibility in repayments during droughts.

Spatial Vulnerability

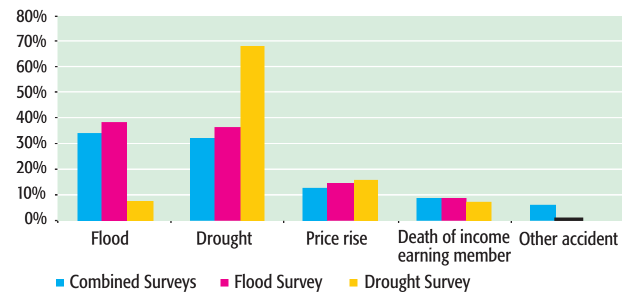
Villages located close to the Rohini River or the embankments are vulnerable to erosion, sand deposition, river flooding and water logging. Thirteen villages are trapped between the river and the embankment, suffering increased flooding and sand deposition. It is generally the poor and low caste whose land and homes are situated in low-lying areas close to the rivers, especially in flood prone areas. People in these villages tend to shift their houses onto the embankments during floods, living in temporary shelters that sometimes become permanent housing. These villages lack the most basic infrastructure, such as roads, and due to water logging and/or regular deep flooding, most of their lands have become unfit for cultivation.

There are 48 villages located within 1 km behind the embankments. Here, large tracts of land remain water logged due to flow and drainage obstructions caused by embankments. The embankments block water from local rainfall from flowing into the river. In addition, water seeps through the embankments, inundating or causing water logging in adjacent land. *Kharif* paddy is either partially or fully destroyed and even *rabi* wheat cannot be sown or suffers from lower productivity. Incidence of vector borne diseases has also increased in these villages. An additional 75 villages, 1–3 km from the embankments also suffer in years of high floods, especially when embankments breach in the vicinity or inundation is caused by water backing up from blocked drains. Siphons are frequently either closed during high floods or have become useless due to silting and clogging. Therefore about 136 out of 837 villages in the basin are directly affected by flooding, which is often exacerbated by the embankments. Another 267 villages lie within 2 km of the river, mostly in the upper reaches of the basin. Here numerous hill streams and drainage channels cause much flooding and sand deposition, and the villages are unprotected by embankments or other structures.

Summary

Eighty per cent of survey respondents consider flood impacts on their families to be high.[6] The greatest natural disaster risks in the Rohini Basin are perceived as flood and drought; however, the importance of commodity price shocks should not be ignored (Figure 4). The high dependence of the population on agriculture and the sensitivity of this livelihood to external factors are clear, as is currently being experienced with global price rise impacts in India[7].

| FIGURE 4 | Greatest perceived disaster risk in the Rohini Basin



The entire population in the Rohini Basin is vulnerable to floods, with certain locations and villages at higher risk than others. As this is one of the poorest areas in India with approximately 50% of the population below the poverty line, the population does not have the financial means to cope with floods, and barely any resources to spend on livelihood investments, much less flood risk reduction. Centralized flood risk reduction approaches have led to a strong dependency on the government for disaster management. Over 90% of those surveyed feel that the government should have primary responsibility and is the most trusted entity for preventing and responding to hazards.

[6] Considering the thematic nature of the surveys and associated discussions, these results could be biased. On the other hand, losses in terms of income indicate that impacts of hazards are indeed very high.

[7] The high rate of inflation in India is a recent phenomenon and from the beginning of 2008, there has been a dramatic rise in the price of rice and other food staples, as in other parts of the world. However, the survey was completed before this increase; hence, it is likely the perceived risk is based on past experience.

Community to Policy Context

Recognizing the intensive and negative impacts of floods in the Rohini Basin, and elsewhere in India, various organizations and agencies have developed strategies and actions to reduce flood risk. Some involve national-level policy and institutional development, while others specifically target communities and households at risk. In most cases, programmes have been developed in response to flood hazards and impacts, as opposed to addressing the underlying factors such as poverty and marginalization that contribute to risk and vulnerability.

Flood Risk Reduction Programmes

Initiatives of the Government of India (GoI)

The 2005 Disaster Management Act guides national government risk reduction activities. This Act represented a paradigm shift from an approach of "disaster relief" to a more proactive strategy of prevention, mitigation and preparedness. A National Disaster Management Authority (NDMA) was constituted as the apex body under the Ministry of Home Affairs (MHA) for establishing policies, plans and guidelines for disaster management, particularly of central government ministries and departments. The Prime Minister chairs the NDMA, and corollary state (SDMA) and District (DDMA) level authorities also have high-level leadership, chaired by a Chief Minster and District Magistrate, respectively.

BOX 1
Responsibilities of the NDMA

- Approve plans of central government ministries/ departments as per the national plan.
- Establish guidelines for SDMAs for drawing state Action Plans,
- Establish guidelines for central government ministries/departments for integrating, prevention and mitigation measures as part of their developmental plan and projects,
- Coordinate enforcement and implementation of policy and plan for disaster management,
- Recommend provision of funds for disaster management, and
- Establish policies and plans for National Institute of Disaster Management (NIDM) which is mandated with research, capacity building and creation of information repository on disaster management.

In the Eleventh Plan[8] of the Government of India, INR 80 billion have been allocated for flood management (Government of India, 2008). After extensive consultations with a wide range of stakeholders, the NDMA recently issued guidelines for flood management (NDMA, 2008) to assist government bodies, from national to district levels, to develop flood management plans. The guidelines outline both structural and non-structural

[8] The Indian Government issues plans for the Indian economy on a five-year basis. They are currently on the 11th five year economic plan.

measures for flood management. Structural measures include embankments, drainage and channel improvement, while non-structural measures include flood plain zoning, flood proofing of public utility structures such as hospitals, early warning and adoption of integrated water resources management (IWRM). The guidelines also highlight building capacities and raising awareness of various stakeholders.

Uttar Pradesh was one of the initial states to implement the Act (third after Gujarat and Madhya Pradesh), constituting the SDMA and DDMAs. However, state flood management in Uttar Pradesh continues to concentrate on the structural measures of embankments and siphons for drainage, and relief programmes. The Central Water Commission (CWC) has begun issuing early warnings of floods based on inflows to reservoirs. However, these forecasts are based on manual observation, i.e. rivergauge stations, which do not function effectively during floods and are of insufficient number to adequately gauge probable flood inflows to the reservoirs. As a result, the CWC often releases water suddenly from the reservoirs, causing floods in downstream areas.

In the past, several committees, high-level working groups and task forces[9] have been appointed to investigate flooding problems and suggest remediation measures. Unfortunately, few of the recommendations have been implemented, due to a range of social, financial, administrative and political reasons. The main areas identified for action requiring compliance by the Government of Uttar Pradesh (GoUP) are:

- Undertaking realistic and scientific assessments of flood damage at basin or sub-basin levels (the reported damage data by GoUP currently is not by basin or sub-basin).
- Assessment of existing and future flood control measures, including collection of quantitative data on performance and long-term socio-economic conditions. (GoUP has accepted the recommendations to perform such studies).
- Flood plain zoning be legislated and enforced.
- Water storage as part of flood management, including flood space in reservoirs to the extent feasible against competing uses of irrigation and hydropower. (GoUP has agreed to this recommendation).
- Funds made available for construction and maintenance of structural measures. (A lack of funds has led to poor maintenance in Uttar Pradesh)
- Implementation of flood proofing measures such as raising villages and construction of appropriate flood shelters. (The performance of GoUP has not been satisfactory).

Overall, the Government of India has renewed its efforts to mainstream flood management in development initiatives. It has developed stronger mechanisms for coordination (including monitoring and review) amongst central ministries/ departments and state governments. It has also stepped up scientific assessments of flood risk using advanced modelling, remote sensing and GIS and of the performance

[9] Policy statement, 1954; High Level Committee on Floods, 1957; Policy statement, 1958; Ministers' Committee on Flood Control, 1964; Working Group on Flood Control for Five-Year Plans; Rashtriya Barh Ayog, 1980; Pritam Singh Committee Report, 1980; Report of Flood Management in the States of Bihar, Uttar Pradesh, West Bengal and Orissa, 1988; Regional Task Forces, 1996; Expert Group on Flood Management in Uttar Pradesh and Bihar, 1999; Report of the Committee on Silting of Rivers in India, 2002; Expert Committee to Review Recommendations of Rashtriya Barh Ayog, 2003; and, the Task Force on Flood Management/ Erosion Control, 2004.

of flood control measures. However, political, social, administrative and financial challenges continue to constrain the implementation of flood management plans at state levels.

Programmes of other organizations/agencies

The United Nations (UN) system

The United Nations in India has dedicated resources to disaster risk reduction. This has included incorporating disaster risk reduction into the Millennium Development Goal (MDG) plans; developing analytical tools for identifying vulnerable groups and targeting development cooperation funds; and addressing the underlying factors contributing to disaster impacts. A flagship initiative is the UNDP Disaster Risk Management (UNDP-DRM) programme described in Box 2.

BOX 2 **GoI-UNDP Disaster Risk Management (DRM) Programme**

A comprehensive programme to reduce vulnerability to all types of hazards is being implemented in 169 districts in 17 multi-hazard prone states, including Uttar Pradesh, with assistance from UNDP, USAID and the European Union. The project has implemented prevention and mitigation measures and preparedness for rapid response to disasters, and focused on building the capabilities of communities, voluntary organizations and government functionaries at all levels.

The project is assisting Uttar Pradesh (and other states) to develop state, district and block level disaster management plans. Village disaster management plans are being developed in conjunction with the *Panchayati Raj Institutions*, or PRIs (local governing bodies). The UNDP-DRM programme is training institutions and disaster management teams consisting of village volunteers in preparedness and response such as search and rescue, first aid, relief coordination, and shelter management; establishing multi-hazard resistant Emergency Operation Centres at state and district levels; and training masons, engineers and architects in disaster resistant technologies and construction.

The programme seeks to institutionalize DRM planning and interventions widely throughout the country, thereby reducing vulnerability and ultimately make disaster prevention and mitigation a part of normal day-to-day life.

International humanitarian organizations

Organizations such as the Indian Red Cross Society, OXFAM, CARE-India, CARITAS-India, Christian Aid, World Vision India, CASA and ECHO provide disaster aid in the flood affected areas of Uttar Pradesh. These relief agencies supply food, clothing, and medicine, and increasingly are supporting preparedness programmes. However, most of these initiatives do not yet link to long-term development programmes.

Private sector

Although private sector organizations are increasing support to disaster management activities nationally, this private support remains limited in Uttar Pradesh. In addition, they have focused primarily on emergency relief, recovery, and reconstruction, but not on addressing underlying causes of risk. ICICI Lombard and TATA AIG have provided general crop insurance. There is potential for the business sector to invest in monitoring and surveillance of hazards through promotion of technologies (such as cell phones) as well as mechanisms for sharing risk (such as insurance).

Details of other people centered flood risk reduction strategies at the individual and community levels are discussed in the section “Evaluating Tradeoffs”.

Disjuncture between Institutions and Communities

A number of challenges exist, however, with current disaster risk reduction and flood management activities. One prominent issue is the lack of inter-sectoral coordination among the various government agencies/departments involved in different aspects of flood management, which is hindered by a lack of communication and competition for budgetary allocations. For example, the state irrigation department constructs and maintains flood control and drainage projects, while central agencies manage rain and discharge observation stations. Each department follows its own independent agenda without consideration of how its activities may affect those of other departments, or influence flood management. Also, administrative and physical boundaries do not match. Flood management must be at the river basin level, but most major basins fall within many different administrative boundaries. Thus, most actions directly concerned with floods are designed and implemented at the administrative level, but their implications are felt at the basin level.

While there appears to be flood risk reduction efforts at many different levels, it is not clear if these are meeting the needs of those most vulnerable, i.e. poor and marginalized people at high risk to flood impacts. Top-down programmes often are driven by the assumption that broad based risk reduction and/or economic growth will contribute to the resilience of individual households, which may or may not be the case. Instead, there appears to be a disjuncture between community needs and government programmes. While a cross-sectoral approach is required to address the basic needs of communities in flood prone areas, especially on issues of communications and livelihood resilience, government flood management plans generally do not focus on the entire gamut of needs and potential interventions. Livelihood promotion, with the potential to address the root cause of flood vulnerability, is often not considered by governmental agencies.

Most rural development activities are designed at the national-level and common across the country, thus lacking mechanisms to respond to local contexts and specificities. There are no locale-specific features for flood prone areas. Furthermore, despite the requirement for participatory bottom-up planning approaches when preparing official disaster management plans, this is rarely realized in practice, due to constraints in budgets and capacities. As noted by Dr. NC Saxena, Former Secretary, Planning Commission (GoI):

> The other implication of sectoral scheme orientation is that the concept of district planning has remained a non-starter, despite several efforts since the V Plan period to operationalize it. The fact that states have little discretionary funds to allocate to the districts and most plan funds to the districts originate from the central Ministries have further worsened prospects for decentralized multi-sectoral planning emerging out of the felt needs of the local bodies and the people.[10]

The local governing bodies, the *Panchayati Raj Institutions* (PRIs), have been underutilized and completely left out of planning and implementation of most government initiatives for disaster management. While concerns have been raised about their limited capacities, there is an urgent need to involve PRIs in environmental governance (Ramakrishnan et al., 2002).

[10] N.C. Saxena's inputs on Solution Exchange (an egroup run by UNDP, New Delhi)

Community mobilization and capacity building require a strong network of NGOs with a long-term focus on development. In the Rohini Basin, however, very few NGOs operate in flood-affected areas and those that are present primarily provide disaster relief, rather than focusing on risk resilient development. Furthermore, long-term programmes require substantial resources and time that the few locally operating NGOs cannot currently provide.

Identifying Flood Risk Reduction Strategies

The reviewed vulnerabilities and disjunctures in current flood risk reduction efforts provided insight in identifying disaster risk reduction strategies in the Rohini Basin. Specific different risk reduction approaches for evaluation were identified and selected through shared learning dialogues with various community stakeholders. The traditional highly centralized and hierarchical (in terms of decision-making and implementation processes) strategy to control rivers through embankments was analyzed for its past as well as projected future economic performance. A contrasting decentralized and more egalitarian "people centered" basket of interventions, was also analyzed. Interventions in this strategy at the household, community and wider societal level that were evaluated included:

At the individual level:

- raising of house plinths,
- raising of fodder storage units,
- a water and sanitation package (rainwater harvesting, raising existing private handpumps, toilets).

At the community level:

- an early warning system,
- raising community handpumps and toilets,
- building of village flood shelters,
- establishing community grain banks,
- establishing community seed banks,
- local maintenance of key drainage bottlenecks,
- development of self help groups, and
- purchasing of community boats.

At the societal level:

- promotion of flood adapted agriculture (pre-flood cultivation, deep water crops, post-flood cultivation)
- strengthening overall health care system (immunization of people and livestock, distribution of mosquito nets, increased access to medical services)

Evaluating Tradeoffs

Qualitative Analysis

The qualitative evaluation aimed to better understand diversity within the basin and assess the varied impacts of existing and potential disaster risk reduction strategies at different locations. The quantitative analysis (reviewed later), driven by stochastic cost-benefit analysis, viewed the basin as a single homogenous "community." Little attempt was made to capture distributional aspects of who "benefits" and who "pays". The qualitative evaluation explored these issues, as well as the finer nuances of the perceptions of diverse stakeholders, disaster risk reduction efforts at the local level, and local capacity to adapt. Non-quantifiable elements like issues related to equity and gender, as well as historical perspectives, also are better understood through qualitative methods.

Methods used were focus group discussions (FGDs) with various groups (small and big farmers, women) and key informant interviews with *panchayat* leaders and village elders. At least two FGDs were conducted in each selected village, not only with different social and economic groups, but also at different locations to understand how vulnerability varied within the villages. Social and resource maps, as well as seasonality charts, were created in collaboration with villagers, and transect walks implemented. Care was taken to include one woman in each team of researchers to facilitate the capture of women's perspectives.

Embankments

At present the entire reach of the Rohini River—from its confluence with the Piyas to its junction with the Rapti—has been surrounded either by river embankments or roads. While these 113 km of embankments provide some protection to the area, they also contribute to adverse impacts. As more embankments were added, drainage congestion increased and the basin continues to experience disastrous floods. Embankment breaches, due to limitations in design and poor maintenance, have exacerbated floods. The nature of floods has changed with this artificial re-structuring of the basin: floods come suddenly and with force (especially when embankments breach), their duration and intensity has increased, and heavier sand rather than fine silt is deposited in the flooded areas.[11] The change in river regime has also led to changes in habitation (newer *tolas*–small clusters of habitations–have developed closer to the river) and in cropping patterns (*kharif* paddy is now grown in areas protected by embankments), which have further increased the risk to people living in the area. The impacts of floods are different depending on location within the basin. Table 7 summarizes local perceptions about flood impacts and embankments of villages located at varying distances from embankments. More detailed discussion of viewpoints in each area follows.

The livelihoods and agriculture of villages trapped between the river and embankments have been completely destroyed. While only a few villages along the Rohini River fall in this category as the embankments are not very far from the river and most villages have shifted to other locations, in the case of the Kosi River, about two million people remain trapped between the embankments and the river (Mishra, 2008a). Embankments constrict floods to smaller cross-sectional areas, resulting in higher

TABLE 7 | Perceptions about flood impacts and embankments

Location of village	Impacts	Perception about embankments
Villages trapped between the river and embankments	Higher and longer duration floods; agriculture completely destroyed; sand deposition; shifting of houses permanently or temporary	Embankments should be shifted closer to the river so that their villages also get protection
Stretches where there are no embankments	Higher and longer duration floods; sand deposition in some places and good silt deposit in others; no *kharif* crop, except early variety; constant danger to life and property during flood	Embankments should be built to protect their villages
Villages close to the river (within 3 kilometres) and behind embankments	Acreage under paddy crop increased due to protection; increase in water logged area; no silt, hence decline in land productivity; increase in vector borne disease; bad sanitation; large damage to life and property when embankments breach	Embankments should be maintained properly and drainage siphons constructed for water to drain off quickly
Villages living far (more than 3 to 4 km) from the embankments	No major impact except in villages close to a drainage channel; there is backflow in these channels because of the obstruction by embankments causing higher floods, water logging	No apparent concerns about embankments
Upper reaches of the basin, especially in the area between the Rohini and Piyas Rivers, where there are no embankments	Flash floods and sudden change in course of rivers; sand deposition	Some protection (embankments and spurs) should be provided
Confluence of streams and rivers	Higher and longer floods; water-logging problem serious; complete destruction of life and assets when embankments breach; unprotected villages suffer	Strengthening of embankments and construction of drainage mechanisms (siphons)

[11] The recent floods in north Bihar due to breaches in Kosi River embankments are a testimony to the devastation that can be caused by embankment failures (Mishra, 2008 b).

water levels. Trapped villages are submerged completely, standing crops destroyed, agricultural lands suffer sand deposition, and houses collapse. This occurs almost every year, even during "normal" flood years.

Most villagers have shifted their houses to safer locations, primarily on top of the embankments. They seek alternative livelihoods to cover the losses from abnormal floods. In the two *tolas* of Sona Tikar, the people were rehabilitated after the floods of 1984: each household received about 3 decimals (roughly 0.012 ha)[12] of homestead land elsewhere. But most of their agricultural land remains uncultivable due to sand deposition or water logging. Further, the health and sanitation conditions in these villages (or in the new locations over the embankment) are poor due to an absence of latrines, proper drinking water supply and water logging. These problems become worse during and after floods.

Strikingly, the people in these villages want the embankments shifted closer to the river so that their land and habitation is protected from river floods. This is not very surprising considering the disproportionate dependence of the majority of the households on agriculture, and an absence of alternate livelihoods and places for rehabilitation.

Embankments may cause higher and more destructive floods in stretches where there are no embankments. For example, the two *tolas* of Aaraji and Suvain on the right bank of the river suffer because of embankments on the opposite side. Last year temporary spurs constructed on the left bank to prevent bank erosion—although saving habitation on that side—diverted floods to the right bank, leading to the destruction of the two *tolas*. Though they have permanently shifted their huts and *kuccha* houses on top of the embankments, most of their agricultural land is uncultivable due to sand deposition. Rehabilitation requires high investment in order to level the land, which the inhabitants cannot afford, nor would it be worthwhile due to continued flood risk. Some villages do not even have high ground to take shelter during floods; they move with their valuables and some necessities to other locations (roads, relatives in other villages, etc.). Poverty levels are higher in these locations, evident in the prevalent housing construction (mostly *kuchha*).

Sanitation in these villages is poor, becoming even worse during and after floods. The only places to defecate above water level are the embankments and road, and these are the places where they live. A lack of privacy and security makes it more difficult for women. Potable drinking water is limited during floods.

The people in these villages want the embankments on their side of the river to be extended further upstream so that they too are protected from river floods. Additionally they desire better roads and drinking water. They feel the government should not only compensate them for house damage, but also build pukka houses for them. Further, they complained that because of their relative inaccessibility during floods, they do not receive relief.

[12] A **decimal** (also spelled **decimel**) is an obsolete unit of area in India and Bangladesh approximately equal to 1/100 acre (40.46 m). After metrication in the mid-20th century by both countries, the unit became obsolete.

Embankments are mostly beneficial for villages close to the river (within 3 kilometres) and behind embankments. Earlier, these villages had to bear with the disruption of life during floods, with the intense period lasting only a few days before the flood subsided and rain water drained back into the river. River floods deposited silt on agricultural lands, helping to reduce the need for fertilizers, as well as improving soil moisture content. An early *kharif* variety, followed by a *rabi* crop was normally grown. In addition, the embankments have enabled the cultivation of crops that could not be grown earlier, such as long duration paddy.

However, in some areas very close to the river, water logging disrupts agriculture. For instance in Aaraji Suvain, the embankment does not allow draining of rainwater to the river. This not only destroys standing *kharif* crops, but also delays sowing of *rabi* crops, reducing productivity. Over 10 ha of agricultural land have become uncultivable in the village. Similar agricultural impacts occurred in Sona Tikar, where a siphon on the embankment was blocked by silt, and most of the village was water logged for about three months during the floods of 2007. An old drainage channel has also been blocked by silt and encroached upon some landholders.[13] In some places, for instance in the two western *tolas* of Satguru, excessive moisture delays sowing of the *rabi* crops; the villagers believe that this will reduce wheat productivity by at least half. Interestingly, in Brahmapurwa, a village situated next to the embankment, people reported that in low rainfall years their paddy crop is saved because embankments obstruct drainage, thereby providing water storage and irrigation. An example of water logging is shown in Figure 5.

FIGURE 5 | **Example of water logging on the Kosi River, upstream of Bhaptiahi, Bihar, India. While the embankment (running from bottom left to top right) protects the village, the water logged fields–area encircled with a white dotted line–can be seen just behind the embankment.**

Source: Google Earth, accessed July 2008

People in these villages desire the continuation of embankments but with drainage schemes. They also wish for higher compensation for their crop losses due to water logging, as existing compensation covers less than 10% of productivity losses.

When embankments breach (every few years), the devastation is enormous even in villages 2 to 3 km away from the embankments.[14] The high intensity floods arrive due to breaches, quickly and without warning, not allowing the inhabitants

[13] A local NGO, GEAG (a part of this consortium), mobilized the people to clear the channel. The funds for this 'food for work' program were routed through the NREGA scheme (a poverty alleviation scheme of the Governmnet of India). The water logging situation has improved as water drains off more quickly. The villagers now desire another siphon to be constructed to eliminate all water logging.

[14] Breaches in embankments can cause huge devastation, as again witnessed in the Kosi Basin in August 2008. These can reach catastrophic proportions if rivers shift their course, which is normal in eastern India, as they carry large water and silt loads (Mishra, 2008b).

enough time to save their property or even lives. This occurred in the western *tolas* of Satguru, which flooded a through drainage channel when embankments breached in 2007. Lives were saved in these *tolas* only because people received news of the breach by mobile phone. While natural floods come gradually and left a thick layer of fertile silt, floods caused by breaches arrive quickly and lead to sand deposition and physical disruptions in agricultural fields. Large investments are required to render the land cultivable again.

Though these villages appreciate the benefits of floods from earlier times (no embankments), they desire embankments to be strengthened and raised in order to reduce the chances of breaching. Cropping patterns have changed in these villages; they now grow mostly long duration paddy and wheat. Banana cultivation has also increased because of the artificial protection provided by the embankments.

For villages living far (more than 3 to 4 km) from embankments, there has been no major flood impact except for villages close to a tributary of the Rohini, which takes longer to drain because of embankments and failures of siphons. Thus, land in these villages near the tributary is flooded for longer periods.

In the upper reaches of the basin, especially in the area between the Rohini and Piyas Rivers, where there are no embankments, flash floods in the hill streams and drainage channels occur frequently. These streams do not have well formed banks and often overflow during intense rainfall events. They carry heavier sand loads, which deposit on the river bed, resulting in frequent and sudden changes in stream courses. Bank erosion is also a serious problem in the area. Stagnant pools in the abandoned stream beds make the area prone to malaria and other vector borne diseases. While floods are typically short, lasting only until the end of the rainfall event, they cause heavy losses to standing crops and agricultural lands.

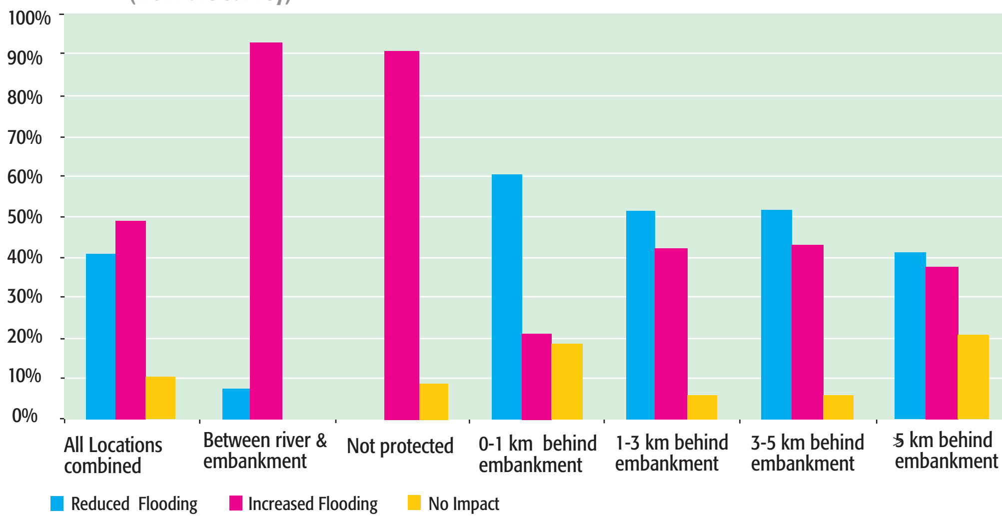
People living far from embankments appear to feel little impacts from them, positive or negative, while those in the upper reaches of the basin suffer from flash floods.

The problem is more intense and slightly different at the confluence of streams and rivers, where floods are higher and of longer duration. In some cases, embankments have been constructed to channel rivers and protect areas between them. Unprotected villages in this area face more intense flooding and damage because of the combined sedimentation loads and water backing up on land from the rivers. Embankments in these locations are most prone to fail, and the destruction in the 'protected' villages is immense when this happens. The devastation is because of not only the higher intensity of flooding, but also due to increases in exposure and vulnerability as people have started living with a false sense of security, despite past breaches.

People living at stream and river confluences generally experience high flood impacts, and although frequent breaches occur, continue to feel a false sense of security created by embankments.

Figure 6 summarizes household perceptions of embankment performance, depending on household location. While overall there is a tendency for people to feel that

| FIGURE 6 | **Household perceptions of embankment performance, depending on household location (from the survey)**



embankments have actually increased flooding, perceptions depend heavily on the individual experiences and location.

Embankments have changed not only the nature of floods but also the manner in which people live in the region. While in some areas, embankments certainly provide flood protection, this often is negated by water logging and drainage congestion in large areas, rendering agricultural land uncultivable. In embankment 'protected' areas, people feel a sense of security that has led them to change their lifestyle and agricultural practices, increasing their exposure and vulnerability. However, past experience has demonstrated that this protection is not guaranteed and the devastation caused in 'protected' areas after breaches or overflows likely cancels out any benefits. Furthermore, embankments that provide protection and benefit some areas may come at the cost of other areas that become more exposed to higher intensity floods and erosion.

While the presence of embankments has led to increased acreage of higher value crops and thus increased incomes, this has been negated by increases in fallow land due to water logging. Water logging has also led to a higher incidence of vector borne diseases, increasing health expenditure.

People centered flood risk reduction

Governments and NGOs in flood prone areas have also implemented decentralized and non-structural flood risk reduction measures. The effectiveness and reach of some of these were evaluated through qualitative methods with the villages.

NGO facilitated risk reduction activities

While there are many NGOs working in this basin on issues such as HIV/AIDS, human trafficking, education, and women's empowerment, very few focus specifically on disasters (floods and drought) or sustainable agriculture. Of those NGOs concentrating on disasters, most focus more on relief than on decentralized risk reduction. A few NGOs work on promoting and demonstrating long-term adaptation activities, but their reach and impact is minimal. Climate change and its link to natural disasters and livelihoods are poorly understood among most of these NGOs and development workers. However, given the poor reach of government programmes in the study area, some of the NGOs do provide needed relief to a large population. Table 8 lists the work of some of the more prominent NGOs and the areas they operate in the basin.

TABLE 8 | **Activities and areas of operation of certain NGOs in the Rohini Basin**

NGO (headquarter location)	Operational Area Village/Block/District	Nature of Activity
Vikalp	42 villages in Laxmipur and Nautanwa blocks of Maharajganj, Campierganj block of Gorakhpur	Land rights, relief, health and sanitation, agricultural activities, promotion of non-farm based livelihood activities
Grameen Development Services (Pharenda, Maharajganj)	115 villages in Dhani, Pharenda, Brijmanganj blocks of Maharajganj	Agricultural activities: promoting new crops, techniques etc.; promotion of SHGs; health and sanitation, drinking water
Shree Bhardwaj Gramodyog Sewa Sansthan (Belwa Quazi, Maharajganj)	10 villages in Nautanwa block of Maharajganj	Education, advocacy, liaising with government departments for relief, sanitation
SHASHWAT, Vill.-Nandana, Post-Belwa Khurd, Maharajganj	15 villages in Pharenda block of Maharajganj	Agricultural activities, advocacy, liaising with government departments, women empowerment
Gorakhpur Environmental Action Group (Gorakhpur City)	4 villages in Campierganj block of Gorakhpur and 15 villages in Paniyara block of Maharajganj	Eco-agricultural activities: promoting new crops, techniques etc.; promotion of SHGs; advocacy of rights of small, marginal and women farmers; liaising with government departments on related issues; promotion of non-farm based livelihood activities for farmers; developing adaptive capacities for floods, climate change and sustainable agriculture
GNK Plan	Some villages in Nautanwa	Training children on rearing goats, sanitation (building latrines), health, environment, organic composting, formation of *babu bahini manch*, running a *balwadi*; non-farm livelihoods; relief distribution; SHGs

The project did not attempt to evaluate the work of each NGO, but rather aimed to develop a picture of the types and reach of interventions implemented. A rapid survey in some of the villages revealed that the NGOs generally employ participatory methods, and in some cases supported long-term development activities. For instance, emphasis on raising awareness about disasters and how to manage them through relevant community institutions has helped people better deal with flood risk. In an innovative initiative, GNK Plan, an NGO working in Trilokpur village, has trained children on life skills and disaster preparedness.

People in the villages argued that local disaster management committees could better co-ordinate and implement government activities, especially in selecting beneficiaries of relief and its distribution. However, currently few community groups for disaster management exist, and existing groups are not mobilized for this purpose. For example, SHGs, mainly facilitated by NGOs, are designed mainly as savings and lending groups, which are able to access loans from public sector banks, providing women from poor households with credit at lower interest rates (than from money lenders, for example). However, there seems to be little attempt to use these institutions as vehicles for entrepreneurial promotion or to raise sanitation and health issues, as has been experimented with in parts of Bangladesh (Singh and Paranjape, 2007).

NGOs also support livelihoods through promotion and training of innovative agricultural strategies. For instance, the Farmer's School facilitated by GEAG has helped farmers access information and management practices on different crop varieties. The promotion of a number of early harvesting varieties of crops has helped farmers avoid having standing crops during floods. GEAG also introduced a new higher value variety of banana in Satguru after farmers had already started shifting to this crop.

Other NGOs in the region have tried to popularize late rice varieties (*bodo*) in areas perennially waterlogged. Though these new varieties are of lower value than the usual *kharif* rice, it has helped farmers cultivate land that would otherwise be permanently fallow. For farmers with small land holdings, this might also aid in food security (GEAG/Novib, 2008).

Innovative practices implemented in other flood prone regions such as grain and seed banks, community flood shelters and rainwater harvesting have not yet been introduced in the Rohini Basin. Local NGOs hopefully will apply lessons learned from these experiences to design and implement new programmes.

Though these decentralized DRR interventions—together or individually—cannot greatly reduce flood hazard, they can decrease the socioeconomic vulnerability of a large section of the population. Through participatory approaches, these interventions promote more equitable access to options that may reduce flood risk. However, only one or two interventions in a few villages will not generate large-scale impact. Processes to widen the reach and accessibility of these options are needed. This cannot be done by NGOs alone (Menon et al 2007). State and civil society organizations need to use lessons learned from these pilot interventions to support effective replication over a larger area.

Government supported risk reduction activities

Although the primary focus of the government has been on structural measures for flood control, the state has initiated some decentralized programmes in flood prone areas. Many of these programmes, however, have been relatively ineffective, for reasons discussed in the next sections.

Latrines, drinking water and health

Although the government has provided sanitary latrines, housing to the poor, and drinking water supply, there have been several limitations in the way these interventions are conceived and implemented. Insufficient subsidies and lack of awareness raising activities has resulted in very few people taking advantage of the programmes. Furthermore, these programmes do not involve any special design for flood prone areas. Elevated toilets and handpumps or higher plinth levels for houses potentially could reduce many of the health and sanitation problems for people affected by floods.

This requires not only higher subsidies for people living in flood prone areas, but also a change of the mindset of both policy makers and implementers.

Some government programmes have limited reach because of standard problems of delivery through a large bureaucracy. For instance, although budgets exist, villages often do not have access to health care. In Brahmapurwa, a village of extremely poor households seriously affected by floods and water logging, no health camps were organized and the nearest primary health centre was 15 km away.

Key weaknesses in these government programmes are insufficient subsidies, lack of transparency in delivery, and limited reach. The same set of challenges plagues agricultural extension services, although state scientific and agricultural research institutes invest in the development of improved varieties of crops that give higher yields and are more resilient in flood conditions.

Relief

Relief during and after floods is helpful if appropriate quantities of quality material are delivered quickly. However, this rarely occurs in the Rohini Basin, particularly with relief distributed by the government. Assessing the extent and level of damage, selecting beneficiaries and distributing relief are the responsibility of the revenue branch of the district administration. However, the process becomes delayed due to bureaucratic processes at local and district levels.

Key issues that arose during the evaluation of relief include:

i. Lack of representation of the *panchayat* or civil society in any stage of the assessment or distribution. As a result, relief seldom reaches those most in need,
ii. Extensive time required delays arrival of relief. For example, one may have to open a bank account just to receive relief in the amount of 1 USD,
iii. The high level of poverty in the Rohini Basin has already stressed existing budgets, hence funds available at times of disaster are less than that required, and
iv. State level politicians often use their clout to have their electoral constituency declared as "disaster affected". Because of this, the most affected areas in need of support—but politically weak and under-represented—are unable to obtain assistance.

Early warning

Though public early warning mechanisms such as flood forecasts exist, these frequently do not reach local populations because of inadequate communication or translation of this information in formats accessible to local villages. Alternatively, private warnings of impending disasters have been facilitated by the popularity. For instance, some people reported that relatives in the upper part of the basin (Nautanwa) warned them of heavy rainfall and rising water levels. Similarly, people living in the low-lying eastern *tolas* of Satguru (about 2 km from the embankments) received calls from friends living close to the river about an embankment breach. This provided them with about an hour to get to a safer location; they were still, however, not able to save many of their assets.

Raising homestead land

After the floods of 1981, the government raised homestead land in villages close to the river, by as much as 1.8 m in some places. However, during large events such as the 2007 flood, this elevation increase was still not enough to rise above the flood waters in many locations. In Manoharchak, floods caused by an embankment breach entered homes built on raised land, which was only a small area occupied by houses and cattle sheds. Thus, all cropped areas, including crop nurseries and vegetable gardens, are still exposed to flooding and water-logging.[15] In the Rohini Basin, the total number of villages and area of land raised is quite low.

Household flood risk reduction and adaptation activities

Households employ a number of adaptation and risk reduction activities, which appear not to be driven by external factors, but rather evolve over a period of time in response to adversity. Some of the more prominent actions include:

Migration: A cursory look at labour and semi-skilled workers in any urban area in north and west India will reveal that many come from eastern Indian states like Uttar Pradesh. In most of the surveyed households in the Rohini Basin, one or more members migrate to urban or agricultural rural areas to supplement income. The type of migration and its duration is broad: those from higher caste backgrounds or artisanal castes have better employment prospects in urban areas; those from lower and agriculture-based castes obtain mostly low paying manual work, dependent on the agricultural season.

Rehan is a very common practice in villages in this region. The poor must give land as collateral when borrowing money. While no interest is charged, the borrower must give crops from this land until the debt is paid, or at times work in the field or household of the lender.

Share-cropping, locally known as *adhiya*, is not very common as there are not many farmers with large land holdings. However, *adhiya* is very common in goat-rearing: a poor person manages a goat for a better well off person for 1 to 2 years, and they share the proceeds when it is sold.

A number of people have **raised plinth levels** of newly constructed houses. Many feel it is worth the higher cost, and this generally occurs more in villages where people have been able to save. In villages close to the river where the depths of floods are higher, people do not see any advantage of raising plinths, although some poor households raise levels of *kuccha* houses and cattle-sheds. Unlike other flood prone areas, there is no raising of latrines and handpumps in the Rohini Basin.

Conclusions

Embankments clearly have provided flood protection benefits to some communities, while increasing flood impacts on others. When embankments are constructed, they block flood waters from entering low-lying areas that, in natural systems, buffer flood

[15] In some parts of Bangladesh enough lands are raised to accommodate houses, latrines, cattle sheds, nurseries and vegetable gardens. This has ensured not only the safety of the people, but also protects income generating activities (Singh & Paranjape 2007).

levels by serving as storage areas within the flood plain. As a result, the waters that would have been stored in such areas are diverted to any areas that remain unprotected; thus increasing flood levels in those areas. Overall, partial embankment systems create inherent tradeoffs; reduced flooding in protected areas comes at the cost of increased flooding in those areas that are unprotected. Some communities have even been trapped between the river and embankments, rendering them uninhabitable during the monsoon season. Embankments have increased water logging, with local rainfall and tributary flows unable to properly drain. This makes certain areas unusable for monsoon (*kharif*) crops, and often delays planting of winter (*rabi*) crops, reducing yields. In some areas, the land has become totally unusable and is now a source of waterborne diseases.

The benefit of embankments to households and communities depends on location. Although central agencies bear the costs of embankments (construction and, in theory, maintenance), many communities experience "disbenefits", or negative impacts. The communities themselves have no input in embankment design or implementation, and are disempowered from decision-making processes.

People-centred flood risk reduction interventions so far are limited in the Rohini Basin. Whether implemented by government, NGOs, SHGs or households themselves, their impacts (in terms of costs and benefits) are difficult to quantify. These interventions contribute to overall resilience, reducing household vulnerability not only to floods, but also to other economic shocks (droughts, commodity price fluctuations, etc.). However, these approaches are piece-meal and not coordinated within an integrated flood risk reduction approach.

As the name would suggest, people centered approaches have included more stakeholder involvement in their design and implementation. Yet there appears to be a general inconsistency between those most in need and those able to access benefits. While some programmes specifically target the poor and marginalized, others only are accessible to better off or well-connected households. Adaptive actions that may reduce risk such as changing cropping patterns, building more resilient housing, and early warning through mobile phones, are more accessible to those with resources. Hence, better designed flood risk reduction programmes are needed to reach those who are most in need of the benefits, but who can pay only very little or none of the costs.

Quantitative Analysis

Cost-benefit analysis was performed to quantitatively evaluate under several potential changing climate scenarios, two contrasting flood risk management approaches in the Rohini Basin, based on existing as well as potential interventions. In addition, the use of cost-benefit analysis under complex and dynamic conditions was investigated. By applying a highly data–and resource-intensive stochastic cost-benefit approach, a detailed modelling approach was reviewed and evaluated for applicability, robustness (especially under uncertain conditions), and utility for the disaster risk reduction decision-making process.

As described in the methodology chapter of this volume, a combination of backwards- and forwards-looking risk analyses was applied to assess current and future flood risk. Review of past flood impacts and hydrometeorological data provided estimates for current risk, while climate/weather and flood modelling, combined with projected changes in exposure and vulnerability, were used to estimate risk for the period 2007-2050. Current and projected Rohini Basin-wide loss frequency relationships were developed. Benefits of flood risk reduction options were quantified through their differing impacts on the loss frequency relationships and ultimately included in the cost-benefit analysis as reductions in annual expected losses. Intervention costs were estimated from past and current projects, and potential disbenefits were also quantified and incorporated in the analysis.

Despite considerable data collection and modelling efforts, the ultimate cost-benefit analysis is considered to be of a “pre-project appraisal” level of complexity. The past performance of Rohini Basin embankments were also analyzed through a post-completion evaluation. This work represents a middle level of resource and time commitments in the range of potential complexities of cost-benefit analysis (see Chapter 2).

Climate and weather modelling

This section summarizes the weather and climate change analysis relevant for the flood risk analysis in the Rohini Basin; a more detailed review is provided in Chapter 3.

Climate change is projected to influence river flow patterns through changes in the amount and timing of rainfall in the basin. The IPCC (Christensen et al., 2007) projects an approximate 11% increase in precipitation during the monsoon months for the entire Ganga Basin. The IPCC projections, however, are based on the geographic resolution of the general circulation models synthesized on the order of 100 to 200 km, which is too large a geographic range to support targeted climate change adaptation interventions in the Rohini Basin. Therefore, a statistical downscaling model was developed to investigate potential climate change impacts on precipitation patterns in the Rohini Basin and to be used in flood models.

Statistical downscaling models work by finding a relationship between large-scale climate variables (e.g. wind, pressure or air temperature) and a local variable, such as the rainfall in the Rohini Basin. The particular downscaling method used is a robust, analogue method that looks for similarities in large-scale climate variables across a period for which historical observations are available (1976-2006) to replicate historical rainfalls. Projections of potential climate change impacts on precipitation are made by comparing future projections of large-scale climate variables (in this study obtained from the Canadian Third Generation Coupled Climate Model or CGCM3) with historical observations of large-scale climate variables and then resampling the rainfalls of the most similar historic years.

Climate change projections for the Rohini Basin are based upon two climate change scenarios: A2 and B1. The A2 scenario refers to a world with continued high reliance on fossil fuels and high population growth. The B1 scenario assumes that carbon dioxide levels in the atmosphere stabilize around 550 ppm. The A2 and B1 scenarios were each comprised of five simulations, resulting ultimately in 10 different scenarios.

Rainfall projections were fairly similar for the runs within each scenario. Each of the model runs is equally probable under that given climate change scenario, and due to flood modelling resource limitations, 4 representative scenarios were chosen. The results are shown in Table 9. Each model run of scenario A2 or B1 indicates the potential for an increase in drought conditions the majority of the year, which might lead to overpumping of groundwater resources and greater crop failure. During the monsoon months, rainfall amounts are projected to increase, leading to increased flooding and water logging. There is also a shift in the timing of rainfall, with smaller amounts happening in July and greater rainfall in August and September.

TABLE 9 | Median rainfall projections under select A2 and B1 scenarios, in mm of rainfall

	Historic	A2R1	A2R5	B1R3	B1R4
January	18	9	5	8	7
February	16	6	6	6	6
March	21	3	5	6	3
April	41	4	4	4	4
May	127	87	153	82	188
June	367	410	410	389	471
July	648	569	512	568	604
August	476	503	503	505	501
September	322	347	353	365	293
October	87	36	27	20	24
November	8	1	2	1	2
December	19	117	9	9	8

Flood modelling

Flood modelling utilized common methods for statistical analysis, rainfall-runoff assessment and flood inundation modelling to estimate flooded areas, both with the current embankments and assuming no embankments. In order to test the potential impacts of climate change on flooding, rainfall projections were run through the flood model, which took several days of computing time per rainfall projection. It was therefore decided to use only the runs from each climate change scenario A2 and B1 representing the highest and lowest annual rainfall projections: A2Run1, A2Run5, B1Run3 and B1Run4. These results are shown in Tables 10 and 11, given as percentages of the Indian portion of the Rohini Basin flooded during different return period events.

It can be seen that more frequent floods are expected to increase substantially in magnitude due to projected climate change impacts. Less frequent floods will also increase in magnitude, however not as drastically. People at risk therefore will have to contend with more frequent flooding, with larger events still occurring but only on a somewhat increased scale. When comparing Tables 10 and 11, it can also been seen that the embankments only have a limited impact in reducing overall flood hazard risk at the basin level.

TABLE 10 | Portion of Rohini Basin area inundated with existing embankments

Return Period (years)	Flooded Area (km²)				
	Historical (1978-2006)	Future (2007-2050)			
		A2R1	A2R5	B1R3	B1R4
2	0.8%	12.5%	12.2%	12.0%	12.2%
5	2.0%	13.4%	12.9%	13.1%	14.0%
10	3.5%	13.9%	13.4%	13.6%	15.7%
25	6.2%	15.6%	13.9%	15.2%	16.4%
50	7.4%	16.1%	14.2%	15.7%	16.9%
100	11.7%	16.6%	15.7%	16.2%	17.3%
200	14.8%	17.1%	16.1%	17.0%	17.8%

TABLE 11 | Portion of Rohini Basin area inundated assuming no embankments

Return Period (years)	Flooded Area (km²)				
	Historical (1978-2006)	Future (2007-2050)			
		A2R1	A2R5	B1R3	B1R4
2	0.0%	14.4%	15.0%	15.6%	16.6%
5	3.9%	15.6%	15.3%	16.3%	18.3%
10	8.9%	17.9%	16.3%	17.2%	19.0%
25	11.6%	19.1%	17.4%	19.1%	20.2%
50	14.0%	19.9%	18.5%	19.8%	20.7%
100	16.5%	21.3%	19.8%	20.4%	24.5%
200	19.1%	24.1%	20.8%	21.7%	25.8%

Data collection

Overview

Data was collected from secondary sources and through a detailed survey. Listing and prioritisation of data required for a stochastic cost-benefit analysis of disaster risk reduction, including information on spatial and temporal data specifications and sources, guided the data collection. Secondary data sources included official documents and published data from various ministries and departments of the Governments of India and Uttar Pradesh. The spatial resolution was limited to the district level (Gorakhpur and Maharajganj districts), and the temporal resolution varied from a one-off data point to time-series of years. It quickly become clear that the available secondary data would not be sufficient for a detailed stochastic cost-benefit analysis, hence great investment in collecting primary data (through the survey) was made.

There are over 837 villages with over 200,000 households in the study area. Survey villages were selected across zones of different distances from embankments, and in upper, middle, and lower reaches of the basin. 28 villages were initially selected and basic social-resource maps[16] were generated. Preliminary visits were used to verify the distance of villages from embankments and collect information on decentralized, community driven interventions implemented by NGOs. The final 17 villages were selected in consultation with local governing officials, with 10% of households in each village surveyed, resulting in a total of 208 households surveyed. Households were selected to capture diversity across landholding size, caste, women-headed households and engagement in different risk reduction activities. Drawn up through extensive consultation with field teams during a pre-survey visit and testing, the survey questionnaire was designed to collect specific disaster-related loss, coping, exposure, vulnerability, preference and cost-benefit data.

TABLE 12 | **Data requirements and issues for the Rohini Basin flood risk analysis**

Key Data Required	Issues
Past flood losses	Secondary data incomplete, survey data likely not representative of full basin. Only two events available.
Maps of flooded areas	Some satellite photos available, insufficient resolution for analysis.
Basin topography	Topographical maps of insufficient and mismatched resolution. Only one cross-section available for the entire river.
Hydrometeorologic time-series	Rainfall data was available only for the Nepali side of the Rohini Basin, but its validity was unknown. Significant gaps exist in the streamflow data of the Rohini River and the record is short. Both rainfall and streamflow datasets had to be corrected and estimates used to fill significant gaps.
Embankment details including past performance	Failure data limited, specific maintenance information not available.
Demographic information	Recent census at village level but projected future trends only available at state level.
Ongoing flood risk reduction activities (explicit and/or autonomous)	Very limited information, some trends on autonomous risk reduction could be inferred from surveys (primarily housing dynamics).
Climate change projections	Downscaling of regional climate model results and transformation into changes in flood regime highly uncertain.

[16] These maps show general physical features (roads, schools, etc.), natural features (river, drains, etc.) and spatial settlements of various caste groups

Limitations

Despite this intensive data acquisition effort, data availability and quality remained key issues in determining not only the specific analysis structure, but also the robustness of the results. Table 12 summarizes the key data elements required for a stochastic cost-benefit analysis, and issues that arose specifically in the Rohini Basin.

Stochastic cost-benefit analysis

A combined backwards-looking and forwards-looking approach was applied to assess current and future flood risk. Review of past flood impacts provided estimates for current risk, while projected climate and exposure changes were used to estimate risk for the period 2007-2050.

Backwards-looking risk analysis

Past flood losses

Data on past flood impacts and losses were collected from surveys and secondary sources, focusing on the 1998 and 2007 flood events. Comparison of basin-wide loss estimates from the data indicated that the secondary information was incomplete for the 2007 flood, and under-estimated real impacts for the 1998 flood in Maharajganj District. In both cases, considering that data had been collected shortly after the event, it is not surprising that the full impacts had not yet been captured.

Basin-wide flood losses for the large 1998 and 2007 floods were estimated primarily using household averages from the survey, calibrated with secondary data. However, these losses were not calculated simply by pro-rating the survey results since the survey focused on high flood risk areas, and was not representative of average basin conditions. Rather, differences between the average risk profile of the survey sample and the overall basin population (determined by location in the basin and losses over embankment zones) were thus taken into account. It was assumed that crop losses were the most accurate secondary data, as this requires primarily estimates of flooded area and average crop values, as opposed to specific location and damage ratios of other loss categories such as private housing. Basin-wide loss calibration was thus driven by Gorakhpur District crop losses in 1998.

Cost-benefit analysis of different risk reduction interventions requires information on various categories of household financial losses due to floods. The survey yielded direct loss information for housing, assets, crops, livestock, wages and health/medical expenditures. Fodder losses were estimated indirectly based on crop damages and normal fodder purchases, while food and grain losses were developed from household's reported flood food aid needs. Increased debt-servicing loads due to floods were estimated by computing total interest paid for loans covering consumption losses and at high post-disaster interest rates. Due to the static nature of the analysis, multi-year reconstruction loans could not be considered. Seed losses were assumed based on local expert assumptions.

Secondary data were used to estimate public infrastructure losses including public buildings. While it is hoped that these data are robust, there are concerns about accuracy given different capacities in state, district, and local governing units to estimate losses. Further complications arise when attempting to isolate data solely for the Rohini Basin, considering the non-alignment of administrative zones and basin boundaries.

It should be noted that while data on relief were available, relief is a response to losses in the above categories (for example crops, livestock, fodder, health, food, etc.) and therefore is not considered a loss category in its own right.

Update for current conditions

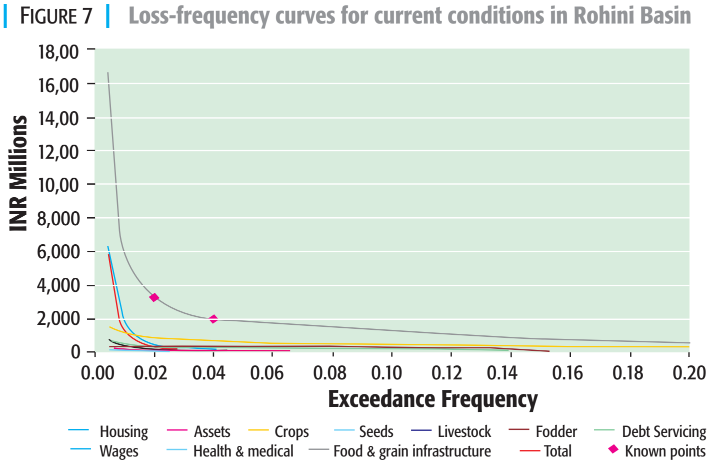
As cost-benefit analysis must be performed under present conditions, losses from past floods were adapted to present conditions. Observed regional population dynamics were used to account for changes in exposure. Due primarily to a trend of switching from mud (*kuccha)* to brick (*pukka*) construction, housing vulnerability has decreased by about 40% over the past 10 years. Enhanced rural communication (particularly the advent and rapid expansion of mobile telephones) has also led to better early warning, allowing for increased evacuation response time. After considering these exposure and vulnerability dynamics, as well as economic inflation, the estimated total flood losses in present value terms for the 1998 and 2007 events were INR 3.3 billion and INR 2.0 billion respectively.

Loss-frequency relationships

Stochastic cost-benefit analysis requires loss-frequency estimates for a full range of return periods. Based on anecdotal evidence, overall monsoon descriptors and general loss trends, it was estimated that the 1998 flood was approximately a 50-year event, and 2007 a 25-year event. Using these two events, as well as an assumption that floods up to 2-year return periods do not cause losses, statistical distributions for each of the loss categories were developed. These three points (1998, 2007 and "no loss") were used to fit truncated Pareto distributions to each of the loss categories ("truncated" meaning all losses below the 2-year event were set to zero). In some loss categories, particularly wage and infrastructure, the fit Pareto distribution resulted in unrealistically high losses for high frequency events. Based on field observations, these distributions were set to no loss below 10-year event. Figure 7 shows the loss-frequency curves for current conditions in the Rohini Basin.

Final outcomes of the cost-benefit analysis are highly sensitive to recurrency periods (exceedance probabilities) assigned to the two flood events. If the 1998 flood were considered a 25-year instead of a 50-year event, and the 2007 flood a 10-year instead of a 25-year event, the curve in Figure 7 would shift up and to the right. The area under the curve, representing average annual expected losses, would approximately double, thereby changing annual benefits. Depending on the way a specific intervention impacts the loss frequency relationship, annual benefits could be halved, drastically reducing the economic efficiency of the intervention.

FIGURE 7 | Loss-frequency curves for current conditions in Rohini Basin

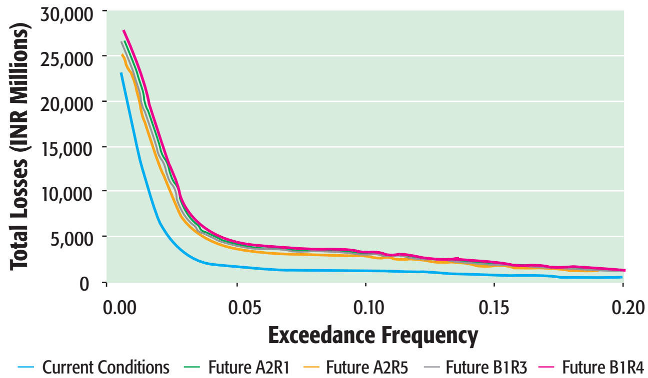


Considering the uncertainty of recurrency periods assigned to past floods due to lack of sufficient historic flood data, and the high sensitivity of annual losses and potential benefits, an inherent uncertainty in the results of the cost-benefit analysis must be acknowledged. This is, however, only one of many uncertainties challenging such an assessment. Sensitivity analysis, as reviewed later, helps to determine the robustness of the results.

Forwards-looking (risk-based) risk analysis

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 analysis to project future climate conditions. Figure 8 shows the results, representing best estimates of current and future monetary 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 in the future will be about a 5-year event, a current 100-year loss will become a 60-year loss.

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



Forwards-looking risk analysis focused primarily on hazards resulting from climate change. Changes in vulnerability were captured during the actual cost-benefit analysis; where appropriate, benefits and costs in future years were adjusted to reflect changes in the population exposed based on projected population growth. Changes in future fragility,[17] another aspect of vulnerability, are considered explicitly only in the future scenario loss-frequency curves for changes in mud to brick housing. Reduced fragility is the main objective of the people centered flood risk reduction strategy and therefore considered in the assumptions made by the analysts regarding how much this strategy would reduce losses (loss-reduction assumptions).

The primary outputs of the risk analysis for the static cost-benefit analysis are the expected annual losses for the different loss categories and climate scenarios. These are determined by integrating under the developed loss-frequency curves, the results of which are shown in Table 13.

| TABLE 13 | Total annual expected flood losses for the Rohini Basin (INR million)

Item	Current Conditions	Future A2R1	Future A2R5	Future B1R3	Future B1R4
Housing	113	192	175	188	201
Assets	94	151	139	148	158
Crops	164	386	344	376	406
Seeds	10	23	21	23	25
Livestock	17	42	37	41	44
Fodder	24	57	51	55	60
Debt servicing	8	18	16	18	19
Wages	46	108	97	106	114
Health & medical	15	34	30	33	35
Food & grain	25	53	48	52	55
Infrastructure	47	106	94	103	111
TOTAL	**564**	**1169**	**1052**	**1141**	**1226**

[17] The impact an event of any given magnitude has on structures, systems or assets. In this case, mud houses are much fragile when subjected to flooding than brick houses.

Annual expected flood losses are projected to approximately double during the next 50 years due to climate change. This massive impact is again due to projections that losses from smaller, but more frequent events will greatly increase. As this occurs, the annual average loss burden increases, such that these "small" floods become more important in terms of long-term economic impacts. With this increasing importance, the lack of real loss data for such events becomes more prominent. Estimates of small event losses based on statistical distributions could over- or under-estimate reality, greatly impacting the final results.

Key Assumptions

Review of the risk analysis has identified a number of key assumptions driving the cost-benefit analysis design and results, summarized in Table 14. Further key assumptions in terms of costs, benefits and disbenefits are also listed in Table 14, and discussed in the following section.

TABLE 14 | Key assumptions driving the cost-benefit analysis

Assumption	Basis	Issues
District level secondary data representative of basin	Can pro-rate based on per cent of area in basin	District outside basin includes other rivers, regional major city.
Survey data representative of entire basin	Secondary data incomplete, no other choice	Although upscaling considered risk profiles, could still misrepresent basin.
Return periods of past events	Anectodal, overall monsoon descriptors and general loss trends	Inconsistent with hydrologic analysis, has major impact on estimated loss frequencies.
Pareto distribution best represents loss frequencies	Commonly used extreme value distribution, based on two loss events and no loss below 2-year event	Statistical fit based on 3 points is weak, has major impact on estimated loss frequencies. Estimates of high frequency flood losses a driving factor.
Rainfall and large-scale climate data are valid and accurate	Standard practice–no other choice.	Significant gaps and uncertainty in the geographically limited historic rainfall data adds uncertainty.
Relationships between rainfall and large-scale climate will remain valid in future	Standard practice–no other choice.	Monsoon rainfall has historically been linked to ENSO (El Niño) and other large-scale climate features. These relationships are changing and breaking down.
GCM (General Circulation Models) climate change projections are sufficiently dependable	Standard practice–no other choice.	Climate change appears to be happening much faster than the GCMs predict, e.g. the melting of Arctic and Greenland icesheets is faster than predicted. Actual climate change could be much different than model projections.
Basic hydrologic and hydraulic analysis sufficiently dependable.	Data limitations and desire to keep analysis simple.	In relatively flat basins with large anthropogenic alterations like the Rohini (embankments, land use changes, etc.), hydrology and hydraulics become dynamic and multi-dimensional.
Flood losses linearly related to flooded area	Simplification of modelling	Over-simplifies a complex issue, particularly for small events and economic flow (versus stock) losses.
Future exposure represented by projected populations	Nothing else available	Does not consider all autonomous adaptation.
Shifting of larger loss frequencies to reflect embankment failures	1998 and 2007 floods	Not calibrated with observations of flooded areas.
Intervention costs	Field experience	May not be appropriate for basin/programme specifics.
Intervention benefits	Modelling, field experience, expert judgement	Monetized values generally unproven, based on multiple small assumptions.
Intervention disbenefits	Modelling, field experience, expert judgment	Monetized values often unproven.
Discount rate	Standard "best practice"	Has major impact on results.

While the uncertainty inherent in each of the above assumptions is ultimately reflected in the uncertainty of the cost-benefit analysis results, it is difficult, if not impossible to quantify. Although there is likely some "cancelling" of errors by various components pulling the results in opposite directions, it is unclear what inherent biases may dominate. In any case, this cost-benefit analysis is considered complete, and followed the best practices possible given time and resource constraints.

Embankment analysis

Estimated costs

Available historical construction cost and timing data for the 113 km of embankments present in the Rohini Basin was limited, while state and national-level cost data proved inconsistent. As such, costs from an embankment project[18] completed in 2003 in Maharajganj District were used as a basis. When distributed over the 5.2 km of the project and inflated to 2007 values, embankment capital costs are approximately INR 5 million per kilometre.

These project costs, however, were not reflective of the real societal costs. In project calculations, the area lost to the embankments themselves (a strip of land approximately 25 m wide) was compensated at about INR 250,000/ha in 2007 values, while conservative estimates of real, current land prices are double this amount. Further, the land lost to borrow pits (where material was removed to construct the embankments) was compensated only for one year of crop loss, at about half of normal paddy production and price. The reality is, however, that the area of the borrow pits is permanently lost; crops can never again be grown on them, at least not without great reclamation efforts. To reflect this in project costs, all land and crop reimbursement costs were removed from the original estimate and replaced by full compensation of land lost to embankments and borrow pits at the above market price, effectively doubling the estimated capital cost per kilometre of embankment. Furthermore, while the project estimates annual operations and maintenance costs as 4% of capital costs, historical data shows actual spending in the basin was only about one quarter of this.

Estimated benefits

The benefit of embankments is determined as the difference between expected annual losses with and without embankments. The backwards-looking risk analysis provided estimates of these for the with-embankment or "real life" situation. The hydrologic/

TABLE 15 | **Theoretical reduction of flood losses by embankments (in per cent)**

Flood Return Period (years)	Current Conditions	Future A2R1	Future A2R5	Future B1R3	Future B1R4
5	47	20	21	22	20
10	61	40	42	42	40
25	46	18	20	20	19
50	48	19	23	20	19
100	29	22	21	20	29
200	22	29	23	22	31
Annual Average	**17.2**	**8.5**	**9.0**	**9.0**	**8.6**

[18] Bhagwanpur embankment in Pharenda *tehsil* (Maharajgunj District)

hydraulic analysis produced flooded areas with and without embankments for the historical time period as well as future scenarios. Assuming losses to be linearly dependent on flooded areas, theoretical, without-embankment expected annual losses were determined by pro-rating the with-embankment losses by the ratio of without- and with-embankment modelled, flooded areas (Table 15). While a standard practice, the assumption that flood losses are linearly dependent on flooded areas is an over-simplification, but are, however, often due to data and time restrictions necessary.

Cost-benefit analysis compares situations with and without a given project or intervention. The forward-looking cost-benefit analysis of existing embankments in the Rohini Basin must therefore consider the current reality that the embankments have already been built. As the immediate removal of all embankments is not realistic, the comparison is therefore not with versus without-embankments, but rather with versus without proper maintenance (thus impacting performance). Under the without-maintenance scenario, the embankments lose effectiveness over time. Utilizing a typical engineering project lifespan of 30 years, the analysis assumes an annual decrease in performance leading to complete failure after 30 years. Benefits over time are expected to further increase due to increased exposure based on demographic trends.

Disbenefits

While costs specifically reflect the financial investments necessary for implementation of an intervention, the concept of "disbenefits" refers to the possible negative consequences of an intervention. Low intensity flood events, while causing damage, are also beneficial because they provide nutrients and water to the flood plains. With the construction of embankments, however, this natural nutrient and soil water recharge cannot occur. Hence, in the analysis, it was assumed that up to the 5-year flood, the benefits of crop flood protection are approximately equal to the disbenefits of cutting off nutrient and soil water recharge. There are therefore no benefits for embankments in reducing crop losses up to the 5-year flood event.

It is also well known that embankments cause water logging on land immediately behind them, due to the inability of local rainfall and tributary flows to adequately drain into the main river. This water logging causes both losses in crop production and increases in waterborne, vector-based diseases. These disbenefits were monetized and included in the analysis.

Crop disbenefits due to water logging were calculated based on the assumption of 50% annual paddy production loss for a 200 m wide strip of land behind the embankments and borrow pits, using average annual paddy production rates and prices. It also was assumed that 50% of malaria incidence in the Rohini Basin is due to water logging caused by embankments. Using conservative Uttar Pradesh estimates of average annual malaria incidence (3% of population) and the assumption that households experiencing malaria lose 20 days of work, annual average days of work lost due to malaria were estimated. These were multiplied by surveyed average wage rates (about 32.5 INR/day) to estimate lost wages per year. Combined with secondary data on the costs of waterborne, vector medical programmes, it was estimated that in the Rohini Basin about INR 5.5 million was lost to waterborne vector diseases caused by embankment water logging.

People-centred disaster risk reduction analysis

Costs and benefits of the various interventions comprising the people centered flood risk reduction strategy were determined on a per-serviced ("benefiting") household level, then scaled up for the full Rohini Basin. Final costs and benefits accumulations consider the portion of the population serviced by each intervention.

Estimated costs

Table 16 lists cost estimates for the people centered interventions for the entire basin, reflecting assumptions as described in the annex (e.g. plinth raising only occurs after a house has been destroyed by floods, hence no initial costs in the first year). For given interventions, costs are probabilistic depending on flood intensity and frequency. In these cases, an average annual value was computed. Annually recurring costs are relatively high, about two-thirds of capital costs (as opposed to 4% for embankments). This reflects the more systemic resilience-driven approach of the strategy, which requires constant and consistent resources rather than massive up-front investments. Ideally, financial management of people centered interventions should be left to local communities, with a focus on activities that generate returns on investments. These activities would be more sustainable over the long term and not require external support.

TABLE 16 | Cost estimates for implementing people centered flood risk reduction interventions in the Rohini Basin

Type	Intervention	Capital Costs (INR million)	Annual O&M (INR million)
Individual	Raise plinth, build *kuccha* house	0	11
	Raise plinth, build *pukka* house (previously *pukka* house)	0	102
	Raise plinth, build *pukka* house (previously *pukka* house)	0	19
	Raise fodder storage unit	88	44
	Water and sanitation package	148	0
			2
Community	Early warning	6	20
	Elevated handpumps and toilets	28	1
	Flood shelters	419	2
	Community grain bank	5	1
	Community seed bank	2	10
	Maintain key drainage points	151	2
	Self help groups	5	4
	Purchase community boat	46	
Society	Flood adapted agriculture	0	440
	Strengthen overall healthcare	56	24
TOTAL		**954**	**684**

Estimated benefits

Benefits for each intervention were considered individually for each loss category defined in the risk analysis. Table 15 provides an overview of the assumed loss categories reduced by each intervention.

In many cases an intervention provides benefits only for one or two loss categories. At the other extreme, the maintenance of key drainage points was considered to reduce losses for all categories, as it would reduce the actual flooding hazard.

TABLE 17 | Financial loss categories reduced by the various people centered interventions

Interventions	Housing	Assets	Crops	Seeds	Livestock	Fodder	Debt servicing	Wages	Health/medical	Food & Grain	Infrastructure
Individual Level											
Raise house plinth	■	■			■	■				■	
Raise fodder storage unit					■	■					
WatSan package							■		■		
Community Level											
Early warning		■									
Elev. handpumps & toilets					■				■		
Flood shelters		■			■				■	■	
Community grain bank							■				
Community seed bank							■				
Maintain key drainage points	■	■	■	■	■	■	■	■	■	■	■
Self help groups							■				
Purchase community boat								■			
Societal Level											
Flood adapted agriculture			■								
Strengthen overall healthcare							■	■	■		

Ultimately the various interventions combine to reduce losses. As a simple modelling approach, loss reductions from different interventions are added, but not allowed to exceed full loss prevention. In some cases, the total sum would far exceed total flood losses, indicating that there are either benefits beyond flood reduction, or inefficiencies in the strategy design. Benefits beyond flood reduction, such as an increase agricultural productivity, are considered separately in the cost-benefit analysis, but the issue of strategy design efficiency (avoiding duplication of efforts) must be considered during planning.

Disbenefits

Disbenefits identified for the people centered strategy include:

- Lower economic value of some flood adapted crops;
- Community toilets becoming disease sources because of difficulties in maintenance due to social pressures,
- Self help groups on group loans, leading to financial burdens on their members,
- Shifting to 100% reliance on groundwater for drinking, a source which could also become contaminated, for example by improper private toilets, and
- The question of how the poorest really benefit from community interventions.

Such disbenefits were not considered in the cost-benefit analysis, however, as they were considered unlikely to occur. Most flood adapted agriculture crop values are higher than standard crops, hence it was assumed that households will optimize their use.

Discount rate

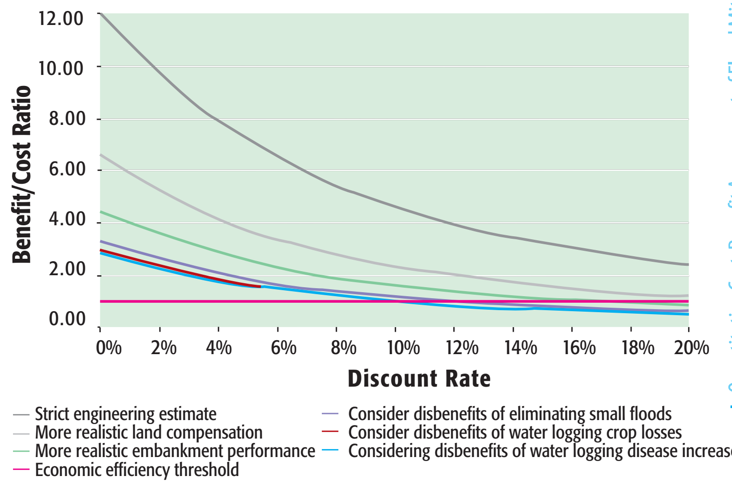
In economic calculations, future benefits are discounted in relation to current benefits to reflect the cost of capital. This is justified on the assumption that the current value of future benefits from investments should be compared to existing secure alternative investment alternatives for the same funds. Applying high discount rates expresses a strong preference for the present while potentially shifting large burdens to future generations. Standard practice in developing countries assumes a discount rate of 10-12%, while sensitivity analysis covering the full range of 0-20% is useful to understand the implications of the chosen rate.

Main results

Historical embankment performance

In the cost-benefit analysis of the Rohini Basin's embankments' historical performance from the beginning of development (1973) to present, costs and benefits develop over time based on the previously described embankment construction pattern. At the same time annual benefits, based on the difference between the 2007 with–and without–embankment loss-frequency curves, were adapted to exposure dynamics. Travelling backwards in time, benefits were therefore reduced based on historically lower populations in the basin.

| FIGURE 9 | Results of CBA for historical performance of embankments



Inconsistencies arise in that, while the current with-embankment loss-frequency curves are based on actual embankment performance, the adaptation of the curves to the theoretical, without-embankment situation is based on technically modelled flooded areas. Although the without-embankments modelling can be considered relatively accurate, the with-embankments modelling assumes perfect embankment performance (sufficient maintenance and no breaches/failures during floods), which historically has not been the case. The with-embankment model therefore underestimates the reality experienced in terms of areas flooded.

Since theoretical, without-embankment losses are simply with-embankment losses pro-rated based on modelled, without–verses with-embankment flooded areas, an increase in modelled with-embankment flooded areas results in a decrease in theoretical without-embankment losses. This in turn decreases embankment benefits, as they are the difference between without- and with-embankment losses. Logically, embankment breaches and failures lead to reduced embankment benefits.

To capture this, based on observed embankment performance during the 1998 and 2007 events, it was assumed that, historically for the with-embankment condition, a 50-year flood actually experienced 100-year losses. Further shifting the loss-frequency relationship to reflect realistic embankment performance, it then follows that a 100-year flood actually would have experienced 200-year losses, and a 200-year flood would have experienced 250-year losses.

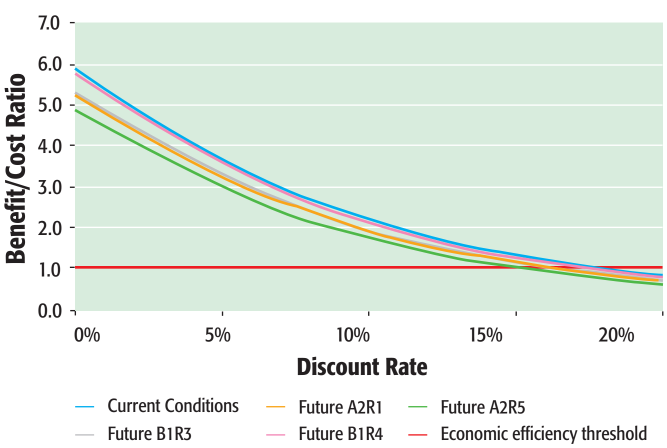
Maintenance costs were set based on real practices (as opposed to 4% of capital costs) as previously discussed. Figure 9 shows the results of the analysis, in the form of the benefit/cost ratio, under multiple modelling assumptions and a range of discount rates.

Traditional engineering analysis of infrastructure projects tends to ignore disbenefits and often does not capture all societal costs. Such an approach based on official embankment costs and hydrologic engineering analysis yielded, at a discount rate of

10%, a benefit/cost ratio of about 4.6, indicating high economic efficiency. It could therefore be concluded that the embankments have been "worth it." When refining the analysis, however, the economic efficiency reduces greatly. By considering real land compensation costs, the benefit/cost ratio is about halved. Further adding to the analysis a better reflection of real embankment performance, that is insufficient maintenance (as also reflected in the costs) leading to failures, the benefit/cost ratio further reduces to about 1.6 (again at discount rate 10%). When these disbenefits are explicitly taken into account, the embankments become economically inconclusive (benefit/cost ratio of 1.0 at discount rate of 10%). Considering that all disbenefit assumptions and computations were conservative, and reflecting on the many uncertainties within this stochastic analysis, it cannot be concluded with any confidence that the embankments of the Rohini Basin have been economically effective since 1973.

Also to be observed in Figure 9, due to the high level of capital costs versus annual costs and benefits, the chosen discount rate can be seen to have a large influence on the overall results.

| FIGURE 10 | Results of CBA for future embankments maintenance



Future embankment performance

Figure 10 shows the results of the cost-benefit analysis of proper embankment maintenance under different climate projections.

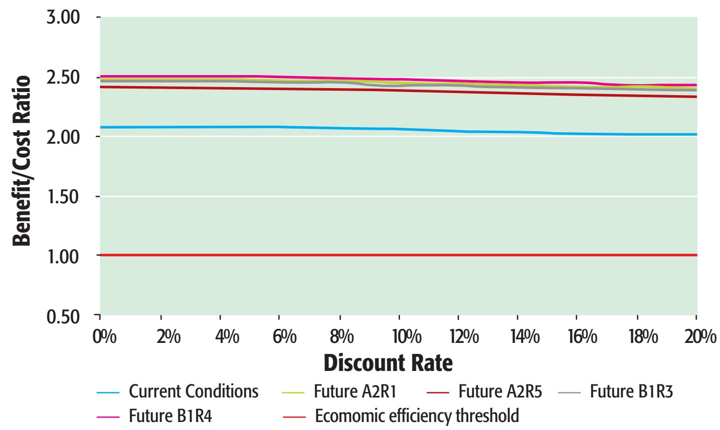
Not surprisingly, the benefit/cost ratios for practicing proper embankment maintenance are above 1.0. Even with their disbenefits, it is economically efficient to maintain existing embankments. The benefit/cost ratios for all scenarios are however not greatly above 1.0. Considering that already incurred capital costs are not included in this analysis, a much higher benefit/cost ratio for simply maintaining the embankments may be expected. Maintenance costs were set at 4% of the revised capital costs, taking into account real land compensation, resulting in annual maintenance costs of just over INR 400,000 per km of embankment. If original capital costs were used, reducing annual maintenance costs to INR 200,000 per km, the benefit/cost ratios shown in Fig. 4 double. These not-too high benefit/cost ratios point to the importance of proper embankment maintenance, which implies higher costs but also more effective performance.

Projected climate change impacts lead to reduced embankment performance. While the embankment designs and implementation remain the same, with an increasing intensity of floods, they become less effective.

People-centred strategy

The results of the cost-benefit analysis of the people centered strategy for 2007-2050 considering different climate change projections are shown in Figure 11.

FIGURE 11 | Results of CBA for people centered flood risk reduction



Benefit/cost ratios for the people centered strategy are above the economic efficiency threshold of 1.0. The discount rate has a limited impact on the results, with benefit/cost ratios barely changing over the spectrum of tested 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 11.

As opposed to the embankments, the economic efficiency of the people centered strategy increases when climate change is considered. Due to the resilience-driven approach of the strategy, increases in flooding result in increases in benefits (while the flooding may be greater, their impacts are still reduced, leading to greater benefits). The actual flood risk reduction of the people centered strategy, in light of climate change is admittedly difficult to quantify. However, even if the current assumptions of future risk reduction are overly optimistic, sensitivity analysis shows that with a 50% reduction in the assumed benefits, the benefit/cost ratios under climate change projections are still around 1.2. While due to uncertainties and the probabilistic nature of the analysis a benefit/cost ratio of just over 1.0 does not guarantee economic efficiency, considering that this represents a worst-case scenario, a certain robustness of the results can be inferred.

Comparison of Strategies

While cost-benefit analysis of classical engineering solutions like embankments is considerably easier than for more community/household based approaches, the results appear to be less robust. 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 annually, benefits are greater than costs, than 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 clearly lose efficiency with increased flood risk.

Estimating the costs and benefits of the embankment strategy proved more straightforward than the people centered strategy. Embankments are engineering constructions with specific dimensions and thus costs, as well as threshold driven designs that make it relatively easy to estimate benefits. These are, however, challenged by the primary assumptions that embankments will always be perfectly maintained and subsequently perform as planned, and that all flood losses including those involving financial flows and regional supplies, are reduced proportionally to the reduced area of flooding.

People centered benefits are more difficult to assess. Assumptions must be made on intervention impacts at the household level, also varying by flood intensity. Further, the combining of benefits of multiple interventions, while performed linearly in this study, is in reality, likely not a simple sum of benefits. As different interventions provide benefits, behaviours and risk choices may change, leading to dynamic starting points for other benefits. Non-flood related benefits, while clearly of importance to people centered strategies, may also be difficult to quantify.

In theory, the resource management of a people centered strategy, defined by relatively high annual costs, should be left to the served communities and include self propagating resource mobilization (return on investments). It also, however, begs the question of securing guaranteed long-term outside support as opposed to one-off "donations."

Cost-Benefit Analysis Issues

Evaluation

Intense data collection efforts in the Rohini Basin provided very useful insights into household flood impacts and coping strategies, particularly through the survey. At the same time, however, the collected data still provided only an incomplete picture of flood losses for two large and recent events. Broad assumptions were needed to estimate various categories of losses, both at the household and basin levels. In light of the multitude of uncertainties introduced during other stages of the cost-benefit analysis, the data collection effort, while indeed increasing confidence in assumptions, cannot be considered to have been worthwhile in terms of improving the cost-benefit analysis results.

Given the vast uncertainties in the collected data, risk analysis and cost, benefit and disbenefit estimations, the results of cost-benefit analyses are racked with compounded uncertainty. Final numbers must therefore be treated in terms of order of magnitude to draw reasonable conclusions, and a benefit/cost ratio of over 1.0 cannot without hesitation be accepted as an indicator that an intervention is "worth it."

While the absolute results may not always be robust, the process of developing the analysis itself was quite useful. Beyond the fundamental challenge of risk analysis, assumptions about disaster reduction strategies were developed in a transparent and logical manner. Particularly for people centered approaches, the compounding of benefits had to be considered, possibly also contributing to the optimization of limited resources. Without transparent and detailed discussions between the involved stakeholders, however, cost-benefit analysis can be easily manipulated and thus misused.

For the people centered, flood risk reduction strategy, cost-benefit analysis was used to provide an aggregated economic analysis of the full strategy. It could just as easily be applied individually to each intervention to provide component evaluations. This would, however, lead to incomplete results as some more coordination driven actions, while contributing to the overall strategy impacts, may on their own provide little monetizable risk reduction benefits (for example, the development of self help groups).

A known drawback of cost-benefit analysis is that it does not consider distributional aspects, that is "who pays?" and "who benefits?" This continues to be a challenge when analyzing centralized disaster reduction strategies like embankments, but is somewhat better handled through the inherent designs of people centered risk reduction strategies.

Possibilities for improvement

Provided the necessary data were available, the hydroclimatologic hazard analysis could well be refined by utilizing more complex analysis methods. Given the intense data acquisition required for this, as well as current limitations on climate modelling, such an effort is likely not worth the effort in terms of improving overall results. This conclusion is further supported by the identified analysis limitations: results should be considered in terms of orders of magnitude with the process being more important than the exact values.

As discussed, the cost-benefit analysis did not explicitly consider who loses and who benefits from disaster reduction interventions ("distributional aspects"). Such information is particularly critical for specifically targeting assistance to the poor and vulnerable. It is thus important to simultaneously consider more qualitative vulnerability, preference and risk reduction analyses. These should help guide not only strategy design, but also support assumptions used within the cost-benefit analysis. Less tangible and therefore difficult to monetize costs, benefits and disbenefits would be given due consideration, unlike in the current approach.

The analysis as performed has captured only benefits with regards to reductions in immediate asset losses. Flow effects, such as dynamic impacts on household income, savings and consumption over many years, are better indicators for individual and societal welfare and changes therein, due to shocks such as disasters. In our case, asset effects were used as a proxy for the flow effects, which may be sufficient given the scope of the analysis. A more comprehensive, yet more complex analysis such as conducted in the Uttar Pradesh Drought case (Chapter 7) in this volume, would better reflect long-term welfare issues.

Conclusions

Flood Risk Reduction Strategies

This study projects that flood impacts in the Rohini Basin will increase in the future (to 2050) due to climate change. Smaller floods will occur more frequently (about twice as often as they are now experienced), while rarer but more intense floods will remain relatively consistent. This will result in a twofold increase in future average annual economic loss due to floods.

Historical analysis of embankments following a strict engineering cost-benefit analysis shows a high benefit/cost ratio, indicating economically efficient performance. However, when conservative estimates of disbenefits, more realistic costs and actual structural performance are incorporated, the ratio reduces substantially. Given the many uncertainties involved, it cannot be concluded that the Rohini River embankments have been, in overall economic terms, cost-effective. Future analysis indicates that proper embankment maintenance, even under climate change projections, is economically efficient. Projected climate change, however, will reduce embankment 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 overall benefits, whereas the threshold-driven embankments depend upon certain design floods to optimize benefits.

Disaster Risk Reduction Policy

Pilot projects that demonstrate optimal design, implementation and performance of a decentralized, resilience-driven package of interventions need to be initiated. While proper maintenance of existing embankments is important, additional state resources should be directed towards piloting and scaling up "softer" flood risk reduction strategies that enhance the resilience of vulnerable populations.

In order to ensure local relevance and applicability, a people centered approach requires decentralized approaches, with local level stakeholder participation in the development of disaster management plans, including identification and implementation of the most appropriate interventions. Most of the financial management of these interventions should be left to communities. Interventions providing sufficient returns on investments will likely be the most viable and sustainable over the long term. Decentralized management however, is difficult to put into practice, particularly given limited local capacities and inflexibility of a highly bureaucratic state.

As a result, there is a need to strengthen the capacity of local level institutions. State institutions are often ill-equipped, or potentially unsuitable to implement these local level options. While civil society organisations have experience of working with communities and facilitating innovative approaches, they may not have the reach or capacity to operate at a larger scale. Furthermore, these organizations must shift from the existing "relief" focus, to one of long-term sustainable development.

Local governing bodies (such as the *Panchayat Raj Institutions*), in part because of financial dependence, are sometimes more accountable to higher levels of state than to the people they represent. This may hinder their ability to respond to local stakeholder priorities and needs. These local level bodies also generally lack capacity for planning and implementation of large-scale interventions. Local level resource management (e.g. water user groups) and credit institutions (e.g. self help groups) may facilitate implementation of interventions, but lack political legitimacy. Ideally, processes that bring together *Panchayat Raj Institutions* and NGOs to facilitate people centered risk reduction activities will be most effective.

Supporting Decision-Making and Policy Development

Cost-benefit analysis provides a useful support tool for decision-making and policy development for disaster risk reduction. However, the limitations in applying cost-benefit analysis should also be considered. In this study, a simplified estimation of the costs and benefits of embankments was relatively straightforward, but challenged by issues of proper embankment maintenance and vast loss assumptions. People centered cost and benefits are even more difficult to assess, with assumptions required not only at the household level, but also with regards to compound impacts of multiple interventions. Add to this vast uncertainty in the risk data, assumptions and analysis, as well as intervention disbenefits, the results of cost-benefit analyses themselves are highly uncertain. This is even more pronounced when climate change is taken into consideration. To draw reasonable and reliable conclusions, final numbers must be treated in terms of order of magnitude.

Furthermore, quantitative cost-benefit analysis does not capture distributional (Who benefits? Who loses?) and non-monetizable aspects of disaster risk reduction interventions. It should thus not be used as a standalone decision-making metric, but rather in conjunction with vulnerability-based, stakeholder-driven processes. To complement this approach, qualitative evaluation provides insights about diverse stakeholder perceptions and needs, as well as varied benefits and impacts of potential disaster risk reduction strategies on different locations and communities. Non-quantifiable elements such as issues related to equity and gender, as well as historical perspectives, are best understood through qualitative methods.

The real benefit from cost-benefit analysis lies in the framework and process used. The approach provides a logical and transparent framework for organizing and reviewing assumptions. It also provides a clear basis that key stakeholders can utilize to evaluate tradeoffs and implications of their own assumptions. As a result, it can help operationalize and promote dialogue and integration of policies and programmes across ministries, departments and organizations.

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CHAPTER 7

Combining Innovative Strategies for Effective Drought Risk Management:
Costs and Benefits of Insurance and Irrigation in Uttar Pradesh, India

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This chapter is a joint product of the above mentioned authors. We further gratefully acknowledge critical assistance by Sunandan Tiwari, Mamta Borgoyary and Sharmistha Bose (WII), who all provided extensive input for designing the surveys- both the quantitative and qualitative assessments- and were also involved in field work for the qualitative survey. Abhilash Srivastav and Gyaneshwar Singh (GEAG) provided important support for collecting the necessary secondary data and co-ordinating the survey operation. The quantitative and qualitative assessment would not have been possible without the vital support of many field team members of GEAG for conducting the actual field survey.

Country: India
Location: Nautanwa *tehsil*, Maharajganj district, eastern Uttar Pradesh
Issue: High frequency, low intensity drought contributes to endemic poverty in the area. High intensity, low frequency droughts also have significant negative impacts on the economic bases and livelihoods of households. Boreholes for groundwater irrigation and micro-insurance are cost effective strategies that can reduce the financial risk drought poses to poor households

Key Concepts

- The study area receives only 20-30% of its total annual rainfall outside the monsoon months of June through September. Most households support themselves through agricultural activities and are vulnerable to droughts. When rain fails, is deficient, or is untimely, crops planted during the months of October through the end of May can fail.
- Many households lack protective buffers against climate variability. A simple climate downscaling model for the area reveals that climate variability is likely to increase in all months of the year by 2050. It is very likely that rainfall during the non-monsoon months will decrease, with possible rainfall reductions ranging from -1% to -50% of the historic average (1976-2006), depending on the season and the climate change scenario.
- The study assessed the costs and benefits of two drought adaptation strategies for households below the poverty line: constructing boreholes with public resources for groundwater irrigation and risk spreading through subsidized crop micro-insurance. Both strategies yield benefit cost ratios greater than one. A combination of the two strategies provides a better cost benefit ratio than either intervention alone. The benefits of the two strategies increase when potential climate change impacts are considered.
- Pumping groundwater from boreholes for irrigation is best suited for reducing drought risk associated with high frequency, low intensity droughts. Access to groundwater irrigation is currently constrained by inadequate and insufficient electricity to drive the pumps. Instead households rely on diesel pumps, which are expensive to operate and can stretch budgets if irrigation is necessary several times a year or for long periods of time. Households below the poverty line can ill afford pumping for regular irrigation. Thus, borehole pumping is only a suitable drought risk reduction measure for a short-duration, low intensity drought.
- Crop micro-insurance, when subsidized, is an effective risk and poverty reduction strategy for poor households against high-intensity, infrequently occurring drought events. If the premium is not subsidized by at least half, poor households are, however, unable to afford this protection. The insurance scheme considers households at or below the poverty line and hence the subsidy is justified as a poverty reduction investment. Additionally, if we consider the cost of post disaster relief spending, the cost of the premium paid by the government is comparable in magnitude.
- Although theoretical in nature and somewhat simplistic in assumptions, this study demonstrates the need for ingenuity in disaster risk reduction strategies and targeting them according to specific needs for economic efficiency.

Introduction

Drought related disasters are a major factor contributing to endemic poverty, particularly in developing countries, where a large proportion of the population depends on agricultural livelihoods. Such disasters, and the associated impoverishment of large populations, are likely to grow if climate variability increases as a consequence of global change processes. Furthermore, while large-scale droughts may have the sufficient, immediate impact to draw the attention and concern of global actors, the increases in incremental losses associated with changes in the variability and unpredictability of climate conditions may have an equally great impact on vulnerable populations. Strategies for reducing this impact are, as a result, central to poverty alleviation and adaptation to climate change.

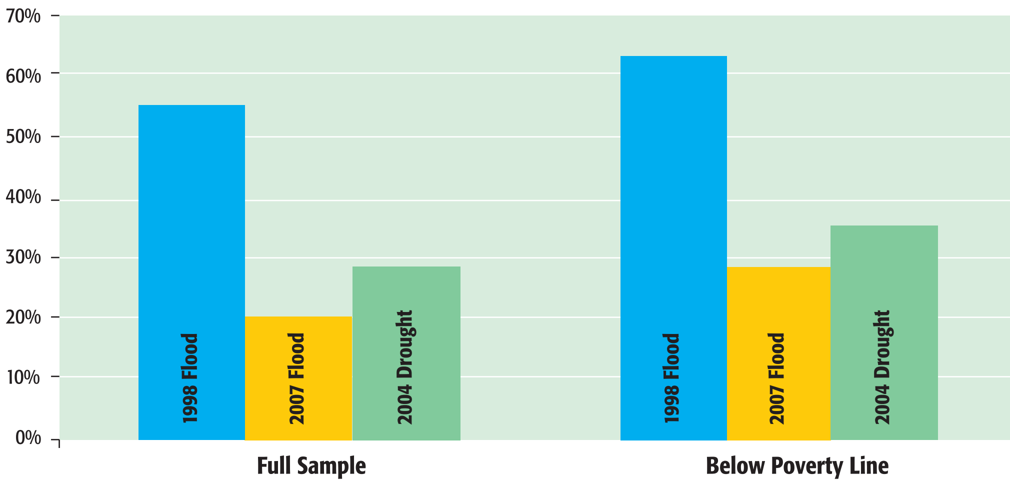
The case study presented here analyzes the costs and benefits of alternative strategies for mitigating the impact of drought on rural livelihoods in Uttar Pradesh, India. The case study explores both insurance mechanisms for spreading drought risk and, as an alternative, the development of groundwater irrigation for reducing such risk. The study draws attention toward approaches to drought mitigation that are based on integrated combinations of strategies, which may perform better than a single set of techniques or mechanisms. While the study is based on analysis within a relatively narrow case area, the results have more general implications for the development of effective strategies for responding to drought and other challenges associated with global climate change.

Our analysis indicates that a strategic combination of irrigation, plus an insurance strategy, has higher return rates than either technique practiced on its own. Specifically, the study suggests that the benefits of insurance are likely to decline in relation to the costs if climatic variability increases substantially because of climate change, thereby necessitating its use in combination with a more conventional strategy.

The Issue: Drought and Rural Livelihoods

Drought poses a considerable risk to rural livelihoods in rural Uttar Pradesh. In a survey conducted during 2007 for the Risk to Resilience project, farmers reported significant impacts on their livelihoods in the 2004 drought (see Figure 1 for reported effects for the full sample and those below the poverty line, as well as in comparison to the 1998 and 2007 floods).

| FIGURE 1 | Drought and flood impacts as reported in survey (losses as per cent of income)



In this study, using cost-benefit analysis (CBA), we assess the impact of drought on rural livelihoods and the benefits of reducing and sharing risk, thus stabilizing income and consumption. A focus on livelihoods denotes an analysis at the microeconomic level (focus on households) as compared to a macroeconomic level study (focus on economic aggregates). The unit of analysis is a farming household which mostly derives income from subsistence farming.

The Methodology and Key Findings[1]

For this case study, we conducted a detailed CBA analysis for assessing the drought risk small-scale farmers in Uttar Pradesh are exposed to and risk management interventions that can help them to reduce or share those risks. We adopted a detailed approach, which may be used for a pre-project appraisal, project appraisal, or for evaluating of accepting, modifying or rejecting projects. For this purpose, we adopted a forward looking methodology assessing risk explicitly in a risk-based modelling framework. The resource and time commitment for the analysis was large due to the need for conducting statistical analysis, stochastic modelling, and economic modelling of the household income generation process.

We assessed the costs and benefits of donor disaster risk management (DRM) support for helping farmers better deal with drought risk to rice and wheat crops and

[1] For a more in depth discussion of the CBA methodology refer to From Risk to Resilience Working Paper No.1 on cost-benefit analysis.

TABLE 1 | 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	Forward looking, risk based methodology using projected climate and corresponding probabilistic outcomes
Utility	Pre-project appraisal or project appraisal for detailed evaluation of accepting, modifying or rejecting projects
Focus and options of analysis	Risk mitigation and sharing options considered: 1. Irrigation: Construction of boreholes for groundwater pumping - pumping to be paid for by household 2. Subsidized micro crop insurance 3. Integrated package of the options above
Benefits considered	Stabilization of income and consumption
Unit of analysis	Representative farmer household of 7 comprising 80% of the survey sample with income/person of up to INR 6570 (national poverty line in 2008: INR 4,400).
Resource and time commitment for the analysis	Several man months of professional input due to statistical analysis, stochastic modelling, and explicit modelling of the household income generation process
Key findings	• All options seem economically efficient • Irrigation benefits increase with climate change as low intensity droughts increase • Insurance benefits reduced, as high intensity events becomes less frequent with climate change • Integrated package delivers similar benefits at lower costs • For harnessing the benefits of integrated packages, cross-sectoral cooperation between different public and private actors is essential.

subsequent income effects. DRM interventions considered were (i) irrigation via the implementation of a borehole for groundwater pumping, with pumping costs paid for by the affected household, (ii) subsidized micro crop insurance, and (iii) an integrated package. Table 1 summarizes the characteristics of the Uttar Pradesh drought CBA.

The benefits evaluated in our analysis consisted of the reduction in average losses and the variability of income due to DRM interventions. As key findings of the CBA, we found that all of the interventions, including the integrated package, are economically efficient given the assumptions taken. Insurance seemed less dependent on discount rate assumptions, which can be explained by the fact 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 and an inability to pursue pumping efforts in later periods (which are more heavily discounted than the present). With a changing climate, groundwater irrigation benefits are likely to increase as average rainfall and rainfall variability increases, while insurance benefits are likely to decline as volatility is reduced. 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 explore such integrated packages in a process involving diverse public and private actors.

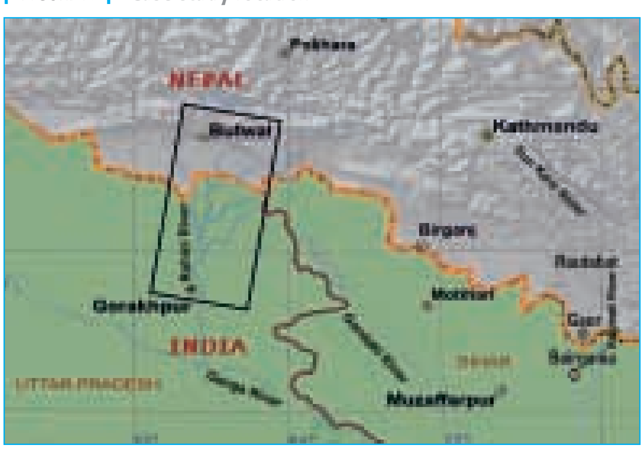
The Case Location, Issues and Responses

A large part of India is located within the semi-arid tropics characterized by low and erratic rainfall. The areas of India with high to very high climate sensitivity are located in semi-arid regions, including major parts of the states of Uttar Pradesh, Madhya Pradesh, Rajasthan, Gujarat, Punjab and Haryana. Villages in the Rohini Basin, in the state of Uttar Pradesh, face dual climate hazards of both drought and flood. The majority (70-80%) of rainfall in the basin falls during the monsoon months of June-September. The average rainfall in the Gorakhpur and Maharajganj districts has been approximately 1400 mm per annum. When rains are delayed, insufficient or sporadic, drought-like conditions harm the livelihoods of many. The recurrence period of highly deficient rainfall in East Uttar Pradesh has been calculated to be 6 to 8 years whereas in Western Uttar Pradesh it is 10 years.

The study was conducted in the Nautanwa *tehsil* (administrative sub-district), which lies in the northernmost part of the Maharajganj district of Uttar Pradesh, India (see Figure 2).

The *tehsil* falls under the Tarai region which is characterized by small undulations in the terrain, and crossed by numerous streams and drainage channels. Two rivers, the Rohini and Piyas, traverse the study area, the latter merging with the former somewhere in the middle portion of the Rohini basin. There are many other hill streams and drainage channels which also merge with the Rohini.

FIGURE 2 | Case study location



The climate of the area is strongly influenced by the monsoon, with the majority of precipitation during the monsoon months from June-September. Average rainfall is approximately 1,200-1,400 mm/annum. July and August are the wettest months receiving about 60% of the rainfall of the monsoon season. For a more in depth discussion of the basin's hydrometeorology refer to From Risk to Resilience Working Paper No. 3.

About 80% of the area is under cultivation. There are two main cropping seasons - the monsoon *kharif* and the winter *rabi* season. A third crop, *zaid*, during the summers is also sown where artificial irrigation facilities exist. The main crops of the region are rice in *kharif*, wheat in *rabi* and vegetables and maize in *zaid*. Despite its late adoption, the 'green revolution' has changed agricultural practices. High Yield Variety (HYV) seeds have replaced the indigenous varieties of seeds and the use of chemical fertilizers has increased, along with groundwater irrigation. Although this has increased cropping intensity and crop productivity in the region, productivity still remains low by national or state averages.[2] The main causes of low productivity are small land holdings, lack of irrigation facilities and absence of extension services. Absence of infrastructure for food storage, processing, communication, electricity etc. all add to the poor gains in agricultural income. There is ample scope for agricultural diversification and development of off-farm and non-farm activities.

The Risks

Although predominantly flood prone, the basin also experiences drought-like conditions which cause widespread distress. Drought occurs due to below normal, untimely or poorly distributed rainfall. Considering that rain fed agriculture is practiced in large parts of the basin, even a slight deviation in the quantity or timing of rainfall causes distress. The areas relatively more vulnerable to drought are the Nautanwa and Laxmipur *tehsils*. These *tehsils* are particularly vulnerable because large parts are located in the uplands where the soil is of an inter-mixture of clay and sand (*domat*)—which retains less water—and canal networks are limited. Although irrigation from tube wells is increasing in this area, it is not economical to use groundwater to save the rice crop, especially if rains fail during the crucial flowering stage of rice. Drought also affects *rabi* crops in the case of an early cessation of rain; this reduces the moisture content of the soil thereby decreasing the productivity of wheat.

Who is Affected and How ?

When drought hits this region, the entire population, except that falling in the canal command area, is affected, but the extent of population effected varies according to location. Those living in uplands are hit hardest as there is no moisture in their land. A number of people whose land is closer to a stream or drainage channel frequently put an obstruction in the water and pump it to their fields, while others use groundwater over a small area to protect their crops. Small and marginal farmers and landless labourers, the most vulnerable groups, suffer the effects of drought the most. They not only lose the investments they made in the sowing and other operations but also lose the food grain they rely upon for subsistence. The landless are also heavily affected as there is no agricultural work available locally and they lose employment opportunities. Households where one or more members have migrated outside can survive the effects of drought if they receive income from remittances, but others have to suffer malnutrition and exploitation at the hands of local moneylenders.

[2] The crop production is quite low as compared to national averages and the grain production is 21.4 and 25.6 quintals/ha in Gorakhpur and Maharajganj districts respectively.

The Main Strategies for Risk Reduction that are being Implemented

Historically, the main strategy employed to deal with drought and rainfall variability has been surface irrigation. Parts of this *tehsil* fall under the command of various perennial canal networks—Gandak canals, the Rohini canal and the Danda canal. The Rohini canal is the oldest. It was built in 1954 to irrigate a narrow strip of land on the right bank of the river. Although it was built to irrigate the *kharif* rice crop, it has also helped in the extension of the area under wheat cultivation. The Gandak and Danda canals were built during the 1970s. Although these canals are important, only a small area of the study *tehsil* benefits from canal waters while large stretches of it are outside the command area.

In the 1980s, and even more in the 1990s, there was an increase in the use of groundwater irrigation through borewells. Earlier, open dugwells were used only to irrigate a small area under some valuable *rabi* crops and for summer (*zaid*) vegetables. The development of groundwater irrigation started very late in eastern India (compared to north, west and south India). Although this region has about one-fourth of India's usable groundwater resources, only about one-fifth of the groundwater potential has been exploited (Shah, 2001). The growth of groundwater irrigation in the region is mainly due to private sector initiative rather than government policies. Apart from private borewells, some government group tube well schemes do exist. However, these have not been good models of efficiency or equity, and have mostly failed to deliver the expected benefits.

Whatever little groundwater irrigation exists is further constrained by the inadequate and insufficient electricity supply in the region. Tube wells have to be run on diesel pumps and the cost of irrigation is significant. This has put a limit not only on the total area irrigated but also on securing the main crop—*kharif* rice—from rainfall variability.[3] On the other hand, groundwater irrigation does help save the *rabi* wheat and also gives an option of growing vegetable crops during *zaid*. A water market has developed in this region: those who do not have tube wells buy water from neighbouring wells and rent the diesel pumps required to deliver the purchased water to their fields. Generally, the cost of irrigation from a 5 horsepower pump comes to about INR 80 per hour. So the issue is not of irrigation availability but of affordability.

Aside from irrigation, a key strategy of the government to deal with drought is the ex-post distribution of relief to the affected population. For instance, after the drought of 2004, Nautanwa was declared drought affected. All the landholders received cash relief for crops lost on the basis of their landholding size. In some cases, the relief amount was as little as INR 50. The relief amount hardly covered one-tenth of the cost of sowing the fields. The timing and/or delay in relief distribution also make it more of a politically driven event rather than a sincere attempt to cover the losses of the drought affected people. In most cases, the state level politicians use their clout to get their electoral constituency declared as disaster affected to gain popularity. Because of this areas that are affected and need support are often left out.

[3] Further, tube well irrigation for rice is possible only in the nursery preparation stage; if drought occurs anytime in the post transplantation stage then it becomes unviable to save the entire rice crop.

In contrast to relying on humanitarian relief, crop insurance could serve as an important strategy for helping farmers address drought risk. Crop insurance has not yet, however, become very common in this area. Only a few big farmers have access to financial services such as Kisan Credit Cards (KCC) and historically only some of them have taken loans for agriculture. According to responses in the survey conducted for this project, none of those surveyed are aware of the crop insurance that KCC holders have access to. They are only aware of the built-in life insurance benefit of the KCC. This is surprising, considering that in some villages, for instance Satguru, farmers are growing high investment, high-risk banana crops. In the canal irrigated villages, e.g. Koharwal, about 100 households have KCC. They all consider that it is a good scheme as the loans are provided at low interest rates (7-9%). But even here none of the KCC holders, including the village *pradhan* (the elected village leader), or are aware of the crop insurance aspect of the KCC. Obviously banks and extension agencies of the government have not done enough for raising awareness on this issue.

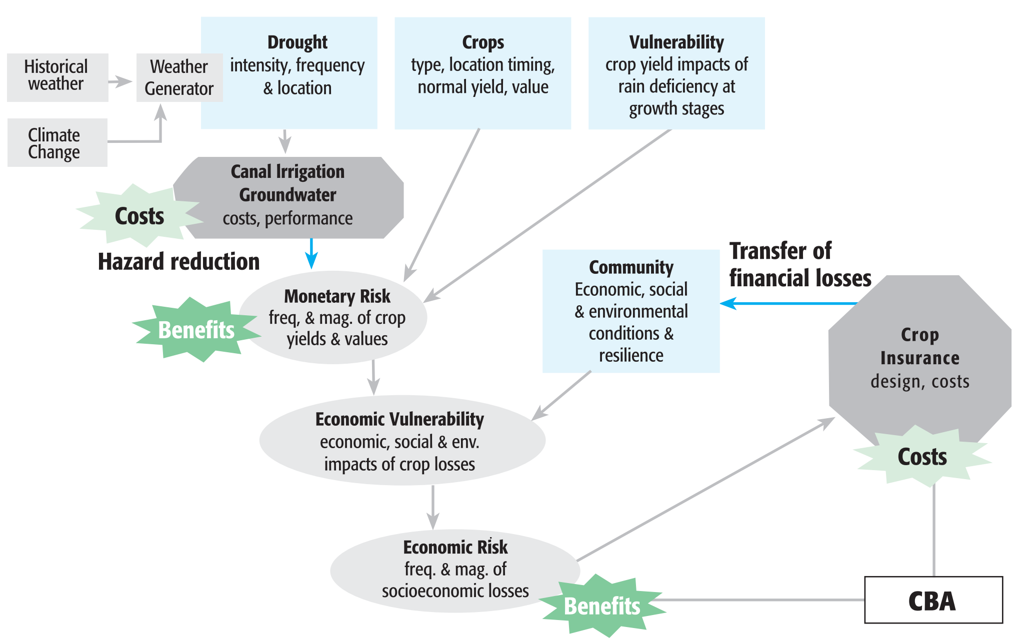
Assessing Risk: The Modelling Approach

In order to systematically assess the costs and benefits of risk management, we developed a risk-analytic modelling approach. The following steps, in line with the general methodology, are taken in the model (Figure 3). This involves:

1. Assessment of direct physical and monetary risk to crop yield as a function of rainfall
2. Assessment of economic risk to farmers' livelihoods
3. Evaluation of the costs of risk management interventions
4. Evaluation of the benefits of interventions
5. Computation of the economic efficiency of different risk management options

The model is stochastic in nature making use of Monte-Carlo simulation to generate probabilistic drought shocks to farmers.

| FIGURE 3 | **Model algorithm**



Monetary risk due to drought is modelled as a function of hazard, vulnerability and exposure. Hazard is defined as the lack of rainfall over given time periods, vulnerability is determined through a statistical model which relates total rainfall over specific dates with average crop yields in tonnes 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.

In Table 2, specific risks (impacts commonly incurred as a consequence of drought) are identified which, when avoided or reduced, create benefits. These risks, along with important changes in the future, are explicitly modelled in our analysis. Climatic changes are incorporated via a statistical downscaling model for different climate change scenarios. Changes in the variance of total rainfall over given time periods are also explicitly modelled with the help of ensemble runs. This assisted in estimating the uncertainty of climate related changes within this integrated modelling approach. In general, the uncertainties in the integrated modelling approach are substantial. These uncertainties are addressed in the ensuing discussion whenever they are considered important.

TABLE 2 | Potential impacts of drought assessed in the case

Category		Monetary Impacts		Non-monetary Impacts	
		Direct/financial	Indirect/economic	Direct	Indirect
Social	Households Farmers Farm workers Community Health Education Stability Cohesion			affected people	Food security Malnutrition Migration
Economic	Private sector Households Economic sectors Agriculture Industry Commerce Services Public sector Education Health Water and sewerage Electricity Transport Emergency spending	Crops affected or destroyed	Livelihood income Poverty Debt Production Market activity Trade with outside markets Relief expenses	Drinking water (people & livestock)	
Environmental				Natural habitats Fodder Land degradation Groundwater Water levels Water quality Fuelwoods	Biodiversity

TABLE 3 | Data and model sources

Module	Data/Model source	Approach
Drought hazard and climate change	Observations, SRES model runs	GCM downscaling, statistical relationship
Vulnerability	Observations	Statistical relationship
Exposure	Survey	Survey analysis
Risk	Combination of above	Stochastic modelling
Economic vulnerability and risk	Survey, national statistics	Microeconomic livelihood model
DRM interventions and benefits	Shared learning dialogues	Scenario-type simulation analysis

In the following sections, we discuss the drivers of risk in more detail. Our analysis starts with the level of exposure to the hazard; that is, the lack of precipitation over given areas and time horizons based on past precipitation data as well as climate modelling results coupled with an analysis of rainfall-crop yield relationships. We have done this utilizing past crop yields over two districts in Uttar Pradesh, supplemented by the outputs from statistical models for rice and wheat crop production and rainfall characteristics. The resulting rainfall-crop production relationships are translated into monetary production values (the market value of estimated crop yields), which then serve as input to the economic livelihood model. The components of the modelling approach and the sources of data utilized in the analysis are shown in Table 3.

Exposure

The level of economic exposure to drought hazards in an agricultural region is primarily a function of the cropping system. As a result, the unit of analysis is a farming household that mainly derives income from the subsistence farming of rice and wheat crops.[4] We define a representative household as characteristic of the lower 80% income stratum of the survey sample. We consider such households to be the sole beneficiaries of the DRM interventions evaluated in this study. More wealthy households would thus not be eligible for the donor supported DRM interventions evaluated here. Table 4 shows the characteristics of an average farm household according to the survey.

TABLE 4 | Farm household characteristics

Household characteristics	Values reported in 2008 INR, for year 2008
Household size	7
Income from farming	92%
Land owned	0.8 ha
Total household farming income from crop production	31,000.00 (average). The top of the sampled income range was 45,000.00 (about 1.6 times the poverty line)
National poverty line for household	28,500.00
Debt	2,500.00
Savings	600.00

Data source: Survey conducted by project team.

[4] In order to estimate poverty of subsistence farmers, the poverty line is measured in terms of the caloric intake necessary to sustain a living, and the monetized value of the food consumed. The income metric measures a potential income to be achieved when selling crops in the market after the minimum nutritional requirement has been met (here defined by the national government of India as the national poverty line).

Hazard

TABLE 5 | Projected seasonal per cent changes in median precipitation for the years 2007-2050

Season	A2	B1
Pre-monsoon (JFMAM)	- 46%	- 45%
Monsoon (JJAS)	1%	2%
Post-monsoon (OND)	- 40%	- 71%

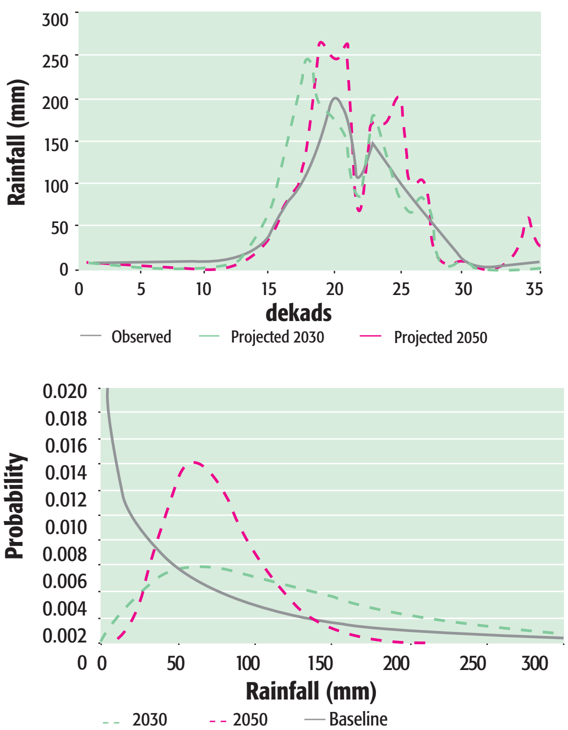
A large part of India is located within the semi-arid tropics characterized by low and erratic rainfall. The areas with high to very high climate sensitivity are located in the semi-arid regions, including major parts of the states of Uttar Pradesh, Madhya Pradesh, Rajasthan, Gujarat, Punjab and Haryana. Villages in the Rohini Basin face the both the climate hazards of drought and flood. The majority (70-80%) of rainfall in the basin falls during the monsoon months of June-September. The average rainfall in the Gorakhpur and Maharajganj districts has been approximately 1,200-1,400 mm per annum. When the rains are delayed, insufficient or sporadic, drought-like conditions harm the livelihoods of many. The recurrence period of highly deficient rainfall in Eastern Uttar Pradesh at present has been calculated to be six to eight years whereas in Western Uttar Pradesh it is ten years.

The IPCC (Christensen et al., 2007) broadly projects an overall change in annual precipitation range of -15% to +20% for South Asia by 2099. This projection though, is for an extremely large geographic area, long time scale, and too broad to be of use in deciding the benefits and costs of specific disaster risk reduction and adaptation strategies "on the ground." Furthermore, there are large discrepancies in the amount and timing of rainfall in many areas of South Asia that simply are not captured in the IPCC projections. To this end, a statistical downscaling model was developed for the Rohini Basin to project potential climate change impacts on rainfall patterns in the basin. Using a statistical downscaling method, we estimated the distribution and probability of rainfall in the study area for current and expected future climates. We utilized two representative climate change scenarios (A2 and B1) run by the Canadian Third Generation Coupled Climate Model (CGCM3) (see Flato, 2005). In terms of possible rainfall conditions for the basin, the downscaling climate model made the following broad projections (Table 5). We considered a total of 5 different model runs for the A2 and the B1 scenarios each, and picked the two most representative, the A2R1 and B1R3 scenarios. A complete description of the downscaling model methodology and its limitations can be found in From Risk to Resilience (Working Paper No. 3).

Predictions of median rainfall for the A2 and B1 scenarios indicate significant drying for the pre-and post-monsoon seasons and a slight increase in monsoon rainfall. The B1 scenario would lead to stronger post-monsoon drying. Climate projections do not estimate daily, weekly or monthly weather variability. As a result, the next step in our analysis involved examining observed "on the ground" data on local rainfall patterns in order to link to the climate predictions. We assessed observed rainfall data for 5 different stations for 1976-2006, and finally picked the station of Bhairhawa Airport in Nepal as the only station leading to satisfying relationships with average crop production in our two study districts.

We examined accumulated rainfall over *dekads* (10 day periods, which is the standard time period used for studying crop phenology). On the top panel of Figure 4, we show

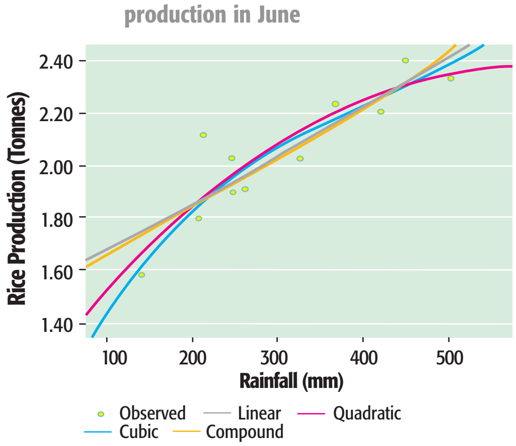
FIGURE 4 | Observed and projected mean precipitation of *dekads* based on observed data and climate change projections for the years 2030 and 2050 (Top panel), and fitted Gamma probability distributions (Bottom panel)



mean rainfall for each *dekad* for observed as well as future rainfall in the years 2030 and 2050 for the A2 model scenario run. The possible effects of climate change are evident. Compared to the historical trend, the timing of heavy precipitation shifts from *dekad* 20 (middle of June) to *dekad* 17 (end of May) in 2030. There are also shifts in the magnitude and variance of precipitation. Furthermore, in other months, rainfall totals are projected to decline in 2030 in comparison to the historical period of record. For the more distant future, e.g. 2050, the magnitude of precipitation during the monsoon months is projected by the model to be higher. The model also suggests that heavy precipitation would be more likely at the end of December, while in other *dekads* mean rainfall totals would decline in relation to the past.

As a next step, we fitted probability distributions for each of the *dekads* to the empirical and projected rainfall data. Generally for rainfall totals, a heavy tailed probability distribution like the gamma distribution is used. Based on the given data, we estimated gamma distributions using maximum likelihood techniques for each *dekad* for current conditions, 2030 and 2050. The top panel on Figure 4 shows distributions for *dekad* 16 (beginning of June). These distributions served as the basis for representing the risk due to lack of rainfall in the study period 2008-2022. We used one distribution for each of the years of our study period. We find effects for B1 similar to A2, yet especially in the non-monsoon months, rainfall effects in B1 are more pronounced than in the A2 scenario. As a result, for the drought analysis we use the A2 scenario leading to a more conservative estimated climate effect as the modelled drying effect is less pronounced.

FIGURE 5 | Observed and estimated curve for rice production in June



Vulnerability

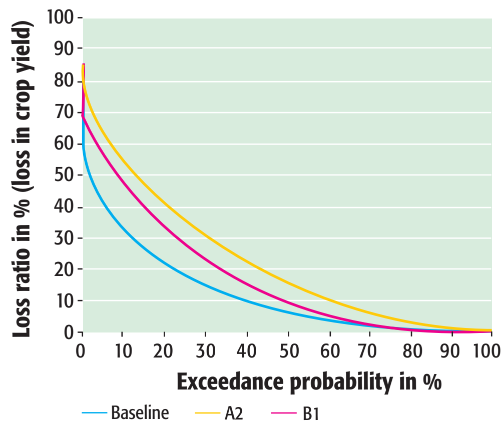
In a next and important step, we assessed physical vulnerability in terms of crop production and loss due to lack of rainfall. We used a nonlinear statistical model based on the rainfall data and time series for wheat and rice production for the two districts for 1990-2006. Only two types of crops were considered, wheat and rice. While there are two growing seasons for rice there is only one growing season for wheat. For rice the most important growing season is during the monsoon months from June to October, the other season from March and June is less important and it is not included in the analysis. Winter wheat is usually grown between October and March. The values for rice and wheat are normalized according to the total land area used for the crop. To determine drought vulnerability of the crops, data on production and rainfall are correlated using multi-variate regressions. Various curves were used to represent the distribution of historical data. Curves with quadratic and cubic fit showed good fit and hence we used the quadratic function. Figure 5 shows the scatter-plot and the fitted curves for rice as estimated using maximum likelihood techniques.[5]

Monetary Crop Yield Risk

Combining exposure, vulnerability and hazard leads to an estimate of monetary risk in terms of crop production lost. The monetary risk is determined by multiplying the crop yields for rice and wheat in tonnes by the average market price, which is fixed by the government. We calculated loss-frequency distributions (representing direct risk) indicating the probability of monetary crop losses for current climate conditions (as well for future scenarios).

Figure 6 displays the loss-frequency schedule for rice for 2008 (baseline) and future A2R1 and B1R3 climate scenarios with year 2020 chosen for illustration purposes. It indicates that probabilities of a given loss ratio (such as a 10% yield loss) increase under future scenarios; i.e. events that cause losses occur more frequently. According to our analysis, losses of this type have a probability of about 40% today, and this probability may increase respectively to more than 60% or 70% in the future under the two climate scenarios. As the A2R1 and B1R3 climate scenarios appear to be rather similar (the signal being stronger for the latter scenario), in the following we only focus on the A2R1 scenario and we use this as a "marker" scenario for future climatic changes in the study area.

| FIGURE 6 | Loss-frequency curve for crop yield for baseline (2008) and future A2R1, B1R3 climate scenarios



Economic Vulnerability and Risk

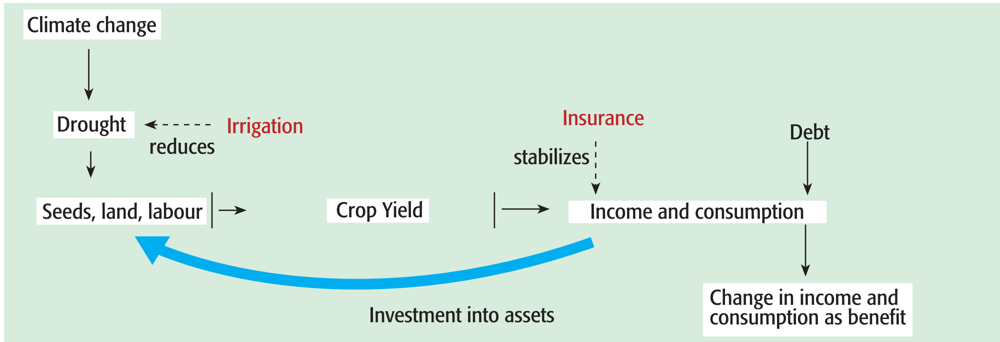
We now turn to assessing the livelihood and income consequences of crop risk to households. As discussed, the unit of analysis is one representative of a subsistence farming household.

The "livelihood" model

Livelihoods and income are generated and determined by a host of factors. For example, the sustainable livelihoods framework, a well known conceptual framework, defines assets, policies, institutions, as well as vulnerabilities, to critically determine livelihood outcomes such as income, wellbeing and improvements in these outcomes (DFID, 2000). Our model and approach focuses on vulnerability to drought (and flood) and physical, natural and financial assets. Particularly, the latter is a key determinant of

[5] Using a quadratic function, rainfall in June approximately explains 83% of the annual variation of rice yields, and rainfall in October 65% of wheat yield variation.

FIGURE 7 | Direct and indirect drought risks and risk management interventions



the analysis, which is based on dynamic debt, investment and income relationships. Conceptually the relation between crop risk (direct) and economic risk to income and consumption (indirect risk) is shown in Figure 7.

BOX 1

Model algorithm

Mechanics of the model are illustrated here for any of the 15 years of the time horizon.

1. At the beginning of the year, given household's initial savings and debt, a minimum savings buffer is determined for
   - smoothing income in case of an event to guarantee a minimum level of consumption;
   - to be used in a drought to implement the backstop option of water pumping.
2. The residual savings may be invested
   - in income generation: seeds, technology etc., or
   - into risk management in order to stabilize income.
3. Stochastic rainfall is calculated determining a possible crop loss
   - Pumping mediates crop loss during event,
   - Income is derived from selling yield,
   - Income in drought event is derived from the insurance claim payment.
4. With total income obtained, a critical subsistence consumption level determined by the poverty line needs to be achieved (for 2008 INR 28,470 per household)
5. If income falls below this level, a loan needs to be taken out with local money lenders creating debt dynamics, as the loan has to be paid back in following years. This reduces savings and thus the ability invest and conduct risk management.
6. Pumping has additional benefits by increasing productivity during the non-monsoon *rabi* and *zaid* seasons.
7. Finally savings and debt are determined forming the initial conditions for the next year.

The model is based on dynamic debt, investment and income relationships, is informed by our survey and refers to the literature on debt-poverty dynamics (see, for example, Carter and Barret et al., 2006). Crop yield (rice and wheat) is a major source of a farmer's income and is a function of weather and prior investment decisions. The model assumes a critical subsistence level (calorie-based) that needs to be achieved with annual income or additional debt if income falls below this critical level.

Given initial debt and wealth, the farmer faces the following investment decision:

1. Invest into income generation: Farmer increases income by investing into land, labour, technological progress (fertilizers), or buying improved seeds; or
2. Invest into income stabilization: Physical and/or financial risk management, of which a large portion is sponsored/subsidized by donor or government.

This is the key trade-off for assessing the viability of risk management. The costs and benefits of risk management are

- **Cost:** Due to limited savings and the need to consume the necessary calories, risk management done by the farmer takes away from income generating investment, thus depressing income;
- **Benefit:** Risk management reduces the losses and stabilizes income.

This trade-off may be fully relaxed or weakened by donor or government intervention. For example, donors may sponsor a borehole, subsidize insurance or support any other development or DRM intervention. The trade-off is not a complete one, e.g. water pumping may be used in normal, i.e. non-drought, years as well. The costs and benefits of risk management examined in this report are the costs of an outside sponsor for this risk management. Benefits arise due to an increase in income and increased stability (reduced volatility) in income and consumption. Additionally, benefits arise to the government due to a reduction in relief payments required (this only in the insurance case). The endpoint in our analysis is indirect risk and changes in investment and consumption and we model the dynamics over a 15 year time horizon based on the assumed viability of the irrigation borehole.

Ideally, a model would be comprised of detailed asset-flow relationships using a production function relationship. This would require the representation of technology, land, labour and capital use, as they determine the generation of income. Yet, similarly to the crop modelling, we take a reduced form approach, and relate income statistically to crop yields, then study the financial consequences of crop risk on households.

FIGURE 8 | Income and debt dynamics with and without a drought shock

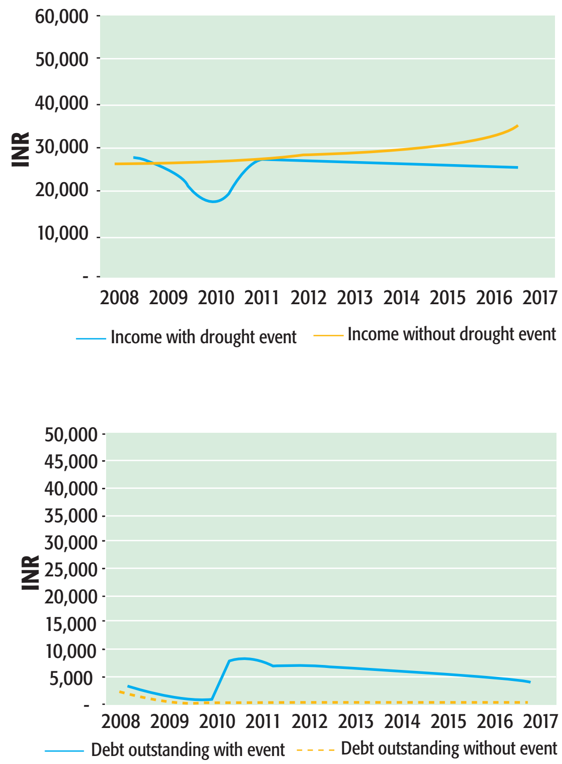


Figure 8 illustrates the effects of a drought on farm income and debt with and without a loss of crop production of 30% in 2010 for a time horizon of 10 years. Starting from initial income and debt levels in 2008, without a drought event, the household would achieve modest income growth and, as a priority, be able to slowly repay debt with the savings generated. After repaying debt, productive investments would be fostered and income would increase over time.

In contrast, a drought event would severely affect crop income and hamper the ability of the household to achieve the critical income level defined. This would cause income to fall below the critical consumption level. Per model assumption, the remedy chosen would be for the household to incur debt quickly post-event from local money lenders at high rates. This substantial debt would have to be paid back consequently over time with savings otherwise earmarked for productive investment. Thus, in our model—as in the survey—ex post coping with the drought to maintain subsistence consumption levels diverts from future consumption opportunities. The key question we address in this study is how and whether those future income, debt and consumption effects can be avoided and reduced by DRM interventions.

Risk Management Interventions: Identification and Costs

Overview

Based on shared learning dialogues conducted with local populations under the Risk to Resilience project we identified two DRM interventions for the purposes of quantitative evaluation.

- Risk reduction with irrigation via groundwater pumping: Construction of a borehole that can be used by drought-affected farmers for pumping water and reducing the water deficit.
- Risk financing via (micro) crop insurance: Crop insurance can be used to transfer crop risk for a premium payment. We examine the establishment of a new micro scheme by a sponsor including technical assistance and premium subsidies.

Table 6 summarizes the costs and benefits of the interventions.

TABLE 6 | Summary of costs and benefits of groundwater irrigation and insurance interventions

Categories of impacts	Irrigation	Insurance
Activity	Groundwater imigation	Parametric micro-insurance
Costs to government	Construction of borehole	Premium subsidies
Costs to farmer	Costs of pumping water	Non-subsidized premium portion
Direct Benefits	Reduces hazard	Compensates direct losses
Indirect Benefits	• Smoothes food supply, consumption & income (farmer) • Reduces relief expenses (government)	• Smoothes consumption & income, reduces variability (farmer) • Reduces relief expenses (government)

BOX 2

Key assumptions for irrigation

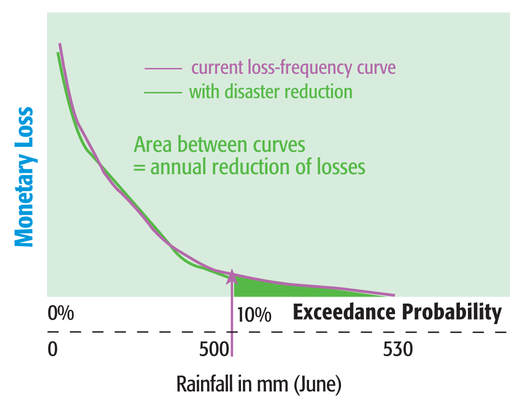
- Construction of borehole by a sponsor,
    - to be used in drought years as an option for pumping water to alleviate the water deficit,
    - reduces water deficiency, thus rice and wheat crop loss risk is reduced.
- In normal, non-drought years additional benefits due to increased productivity during non-monsoon harvests in *rabi* and *zaid* seasons (productivity increases by 1%/year.
- Total cost of drilling a borewell (60 feet deep): INR 10.000, no maintenance assumed
- Lifetime 15 years
- One such borewell can irrigate about 10 acres or 4 hectares
- Average land owned by farmer households: 0.8 hectares, so borehole serves 5 families and cost/family is INR 2,000
- Cost of pumpset is INR 22,000. Poor households do not have pumps. The cost of renting the services (including diesel) are INR 80 per hour
- 10 mm of water can be pumped per hour

Irrigation

The lack of large- or small-scale irrigation is a key constraint to agriculture in Uttar Pradesh and in India more generally. As groundwater depletion is not an issue in this study area, we identified groundwater irrigation using boreholes and pumps as an intervention to reduce risk. The borehole would be drilled by the sponsor (fixed costs), and the pumping would be undertaken during a drought by the affected farmer (variable costs). Key assumptions used to evaluate this intervention are listed in Box 2 and a schematic illustration of these benefits is shown in Figure 9. The purple line is the unmitigated drought loss curve without pumping and the green line shows risk and risk reduced with pumping.

In this illustrative example, pumping would help to mitigate up to a 10-year drought event (probability 10%) associated with an accumulated rainfall in June of 500 mm, which is a deficit of 30mm. For providing the additional 30 mm required, about 3 hours of pumping would be necessary at a total cost of INR 240. Given the establishment of a borehole, risks could thus be reduced assuming sufficient savings are available for pumping water.

FIGURE 9 | Mechanics of irrigation intervention



10% = "10-year event" associated with 500 mm rainfall

Insurance

In contrast to irrigation, insurance does not reduce risk, but it spreads out risk by pooling it across a larger population in exchange for a premium payment, and thus providing indemnification against losses. People affected by a disaster benefit from the contributions of the many others who are not affected and thus, receive compensation that is greater than their premium payments. Micro-insurance is distinguished from other types of insurance by its provision of affordable cover to low-income clients. By providing timely financial assistance following extreme-event shocks, it helps to reduce the long-term consequences of disasters. Affordable insurance can provide low-income farm households with access to post-disaster liquidity, thus

BOX 3

Calculating the insurance premium

Generally, the basis for the premium calculation is the expected losses, the losses that can be expected to occur on an annual basis. These are also called the pure premium. On top of the expected losses a risk premium will be charged by the insurer consisting of transaction costs, profit margin and loading factor as follows:

Insurance premium = Expected losses + risk premium (loading factor + transaction costs + profit margin)

Natural disasters are low-frequency, but high-consequence events, and the volatility of losses is also taken into account by insurance companies in order to be properly prepared for an event. This is done by charging a loading factor accounting for the variability of losses. Transaction costs arise such as personnel costs for risk assessment and contract delivery. These have to be included in estimating premiums. Last but not least, insurance companies will also charge a profit surcharge.

securing their livelihoods. Moreover, insurance can improve their creditworthiness and allows smallholder farmers access the capital required to engage in higher-return crop practices. (See Box 3 for a description of calculation of insurance premiums).

Insurance does not reduce the average losses to be expected, but helps with the variance. Another way of paraphrasing this is that insurance helps with the larger, yet more infrequent events, which potentially may have debilitating consequences; it is not a useful mechanism to reduce frequent or even annually-occurring losses.

Uptake of insurance in developing countries has been miniscule owing to its high cost in relation to the low incomes of those at risk, as well as a lack of "insurance culture." Recently, novel micro-insurance instruments have been emerging to address these problems and cater to the poor and vulnerable. Innovation is related to product delivery and claim settling (Hess et al., 2005). Based on achievements and institutional structures set up for providing microfinance, donor supported, public-private partnerships for providing sustainable and affordable insurance are emerging, involving insurers, rural development banks, NGOs, public authorities and international sponsors. A key aim is to provide insurance catered to the needs of the vulnerable and poor at low costs using established delivery channels. The second innovation is related to the claims settling process, where the claim payment is based on physical parameters, such as rainfall measured at a local weather station. This compares with indemnity-based insurance, where the actual loss experience establishes the basis for a claim payment. By using representative indexes for a group of people, the transaction costs of issuing contracts and settling claims can be drastically reduced. The downside to index insurance is the potential lack of correlation of the index with the actual loss ("basis risk"). Insurance can be costly and the premium charged may be considerably higher than expected losses, sometimes amounting to several times the expected losses.

BOX 4

Key assumptions for insurance

- A novel micro-insurance scheme is set up potentially involving an insurance company, NGO, local or state government or a donor, and the insured
- Technical assistance for risk and premium calculation and scheme set-up is assumed to amount to INR 5,000 per household (assuming 1000 farmers are insured, the technical cost would be INR 5 million which corresponds with anecdotal information.
- Based on a survey of micro crop insurance, the (unsubsidized) premium is ca. 3.4 times the expected losses. Given expected losses for the baseline of 1.8%, the full premium would amount to 6.4% of insured value (i.e. monetary crop production).
- The premium subsidy is 50%
- The scheme is based on rainfall, with a claim layer defined by lower (exit point) and upper (exit point) thresholds for rainfall
- Reinsurance is not considered explicitly, but considered to be organized by the insurance scheme
- The government will prorate relief payments in proportion to its premium subsidy provided; maximum relief according to Uttar Pradesh statistics was INR 400. For example, If the subsidy is 50%, then maximum relief would be INR 200 per year. We are studying this scenario.

In order to simplify the analysis, we have made the insurance assumptions shown in Box 4 based on a review of crop insurance in India and elsewhere (see Manuamorn, 2005; Mechler et al., 2006).

Table 7 lists the costs and benefits of the insurance intervention considered.

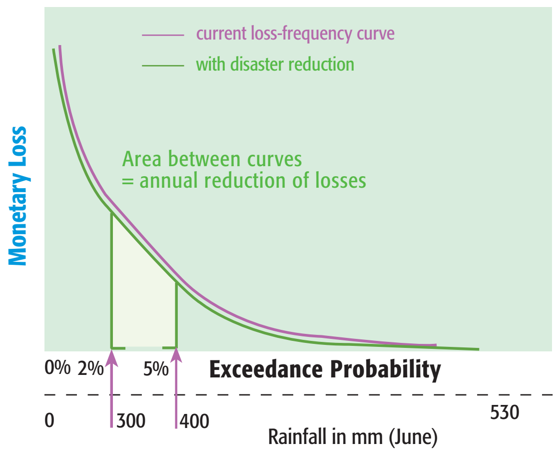
TABLE 7 | Insurance intervention considered

Scenario	Costs to Government (=costs in CBA)	Costs to HH	Benefits in CBA
50% subsidy	50% of premium, technical assistance	50% of premium, leads to substantial diversion of income	Reduced income diversion by the farmer from productive activities, reduced relief expenditure

In the following illustrative example shown below, insurance may protect from losses from 20 year (5% probability) to 50 year (2% probability) droughts, and there would be no compensation for smaller (more probable) or bigger (less probable) events. Generally, it will not be cost-efficient to cover all possible events and purchase full insurance, particularly for disaster risk, due to a high premium mark-up, which can be multiples of the annual average losses.

Compared to pumping, where risk reduction (and the income loss effect) would be limited by savings available to meet the cost of pumping, an insurance claim would guarantee a certain payout. This payout would be determined by the entry and exit points, here the 20 and 50 year droughts respectively. On the other hand, for insurance an annual premium payment would be required, while with pumping for irrigation, costs are only incurred (i.e. the pump is switched on) when a drought or water deficit is actually experienced.

FIGURE 10 | Mechanics of insurance interventions



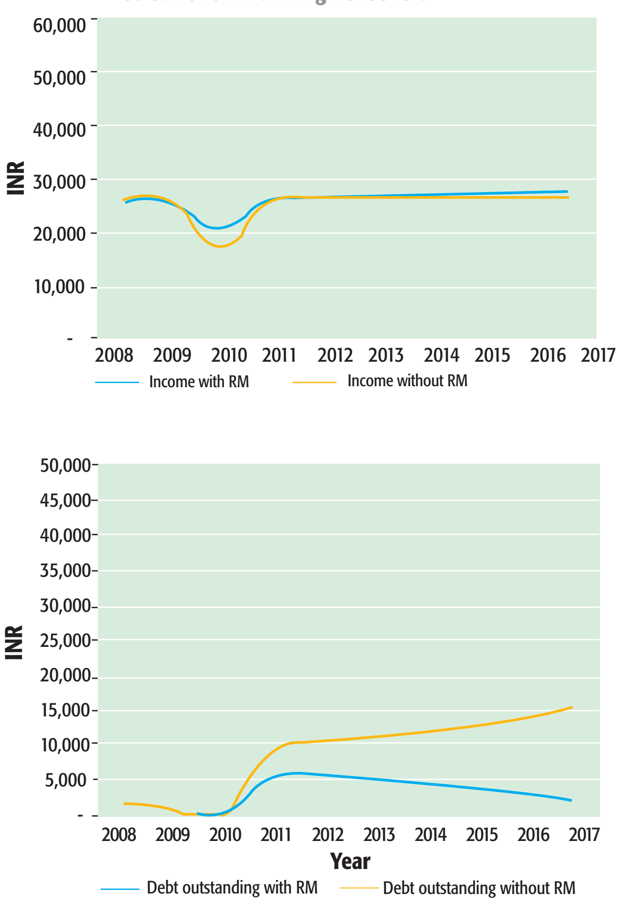
Insurance may protect from 20-year (5% probability) to 50 year (2% probability) drought

Risk Management Interventions - Assessment of Benefits

Irrigation

Figure 11 illustrates the mechanics of the two interventions by modelling a 30% crop income shock in 2010. This is a shock of the size of the drought that actually occurred in 2004 and is considered to be about a 50 year event. Based on our approach, such a shock would cause income to fall for both scenarios. Yet, for a household with the ability to pump, the risk could be partially reduced depending on the (limited) savings available for pumping. While pumping comes at a cost for the household in terms of drawing down and diverting savings from investment into production improvements, the effect here would be that the debt burden to be taken out to guarantee the subsistence level of income is smaller with irrigation. Additionally, there are benefits to irrigation in normal years. For example, during the non-monsoon, rainfall-deficient seasons, irrigation in the early cropping stages would increase productivity. Overall, over time, in this deterministic illustration with one drought event occurring, there would be a small increment to income.

FIGURE 11 | Effects of irrigation intervention on income and debt streams for a farming household

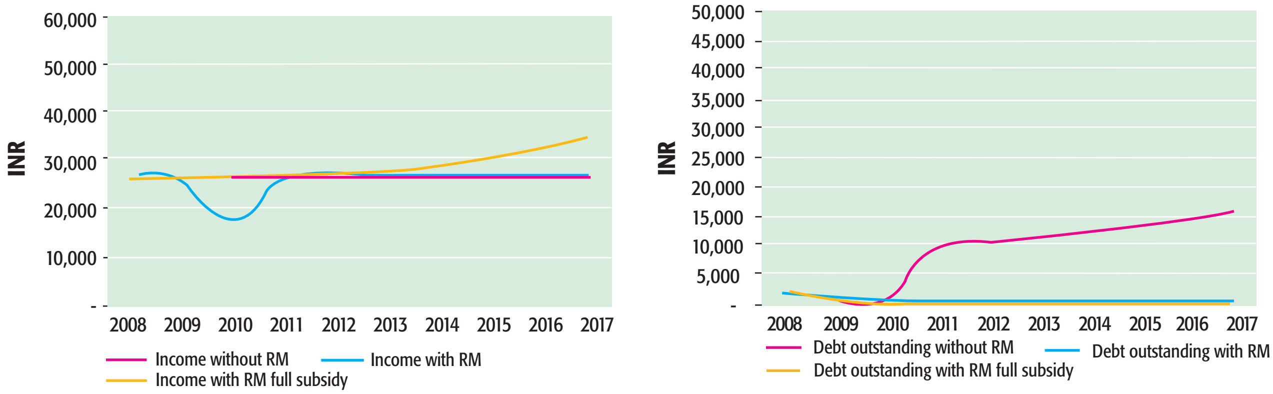


Crop Insurance

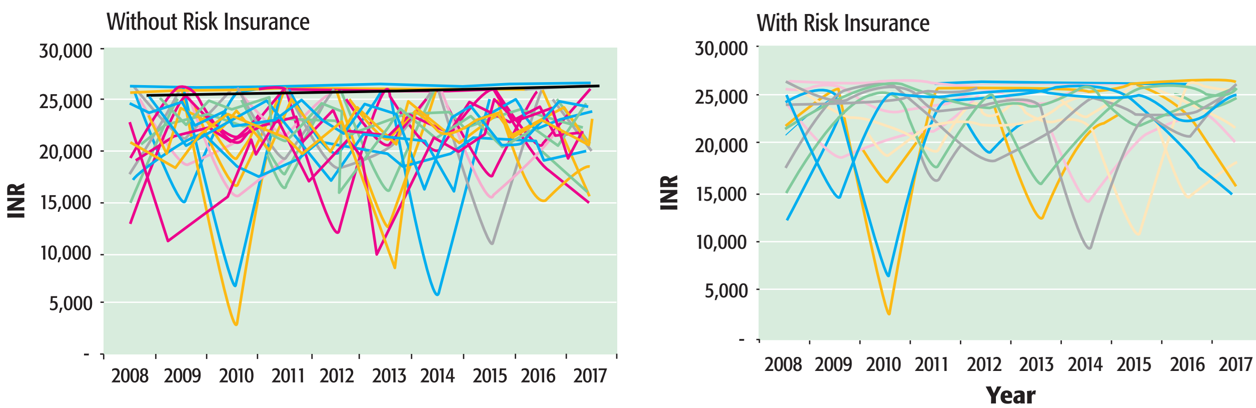
Similarly we now deterministically illustrate the benefits of financially managing risk via insurance. In case of insurance, the risk is not reduced, but a claim is received post event in exchange for a fixed annual premium payment.

The benefit of insurance is the extra income received after the event and the income stream is

| FIGURE 12 | Effects of insurance option on income and debt streams with full insurance



| FIGURE 13 | Comparison of stochastic income trajectories without and with risk insurance



smoothed out; also, no new additional debt is necessary. In the less subsidized case, however, premium payments are large and future income stagnates in a similar manner as in the uninsured case, where livelihoods are affected by the large debt repayments. For the case of full premium subsidy, there is no income effect of the premium payment and income can increase (although there are no relief payments by the government).

Stochastic Representation of Interventions

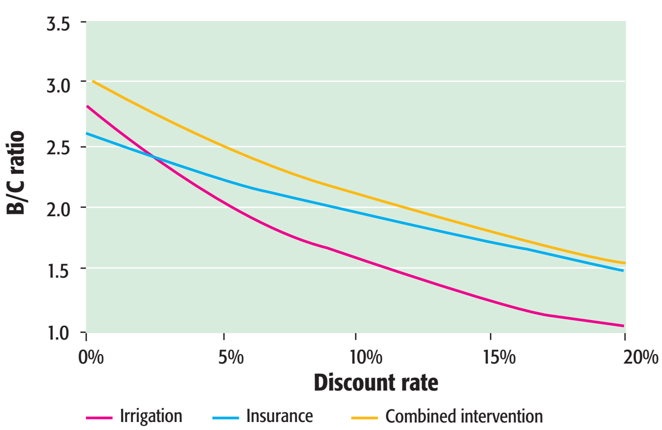
Nature is not deterministic and droughts may occur frequently or may not occur at all. Accordingly, benefits of DRM will materialize only in a drought and those benefits are probabilistic. In order to capture the vagaries of nature, we had to simulate the system stochastically and ran a large number of possible "futures." For example, when conducting stochastic analysis for insurance and running the simulation 1,000 times for a time horizon of 10 years (2008-2017), the income stream is smoothed out as its variability is reduced.

Essentially, insurance cuts out a large number of bad "years" with severe income effects, as the income loss is reduced due to the claim payment received. Although this is difficult to see visually, the effect is illustrated in the greater variability of income stream trajectories shown in the top panel in Figure 13 in contrast to the lower panel.

Economic Efficiency of Risk Management

As a last step in our analysis, we calculate economic efficiency of the interventions using CBA. We present results for the interventions discussed under baseline (constant) climate and changing climate conditions, as well as for different discount parameter assumptions.

| FIGURE 14 | B/C ratios for interventions considered given constant climate



Constant Climate

All interventions were considered economically efficient given the assumptions taken (see Figure 14). The B/C ratio for irrigation, which mainly helps to reduce the impact on income of high-frequency, low-magnitude events, is well above the threshold of 1 for the range of discount rates considered. The total cost calculated per household, is assumed to be financed by the government or development bank as the sponsor, would be about 0.4% of a farmer's income for baseline and future climates. In contrast, insurance helps to reduce the variability of income when higher magnitude, but less frequent events occur. We find B/C ratios to be high for the 50% subsidy scenario. For a less subsidized premium (not shown here), benefits are reduced, as more household income is necessary to pay for the premium by diverting income from productive investments. Compared to the model farm household's income, the total cost to a sponsor (including technical assistance–the fixed costs for setting up the system as well as the 50% subsidy) for funding insurance over the time period considered would sum up to a value in the range of 1.5% of the farmer's income, while the household's own cost for paying the other 50% of the insurance premium would amount to 0.9% of farmer's income.[6] Insurance is less dependent on discount rate assumptions, which can be explained by the fact that it offers a secure, guaranteed payout over the whole time horizon, while

[6] As explained, in order to avoid double-counting these private costs do not figure in the CBA, as they are already included via the investment-income relationship, where the premium payment diverts money from productive investment and thus reduces income.

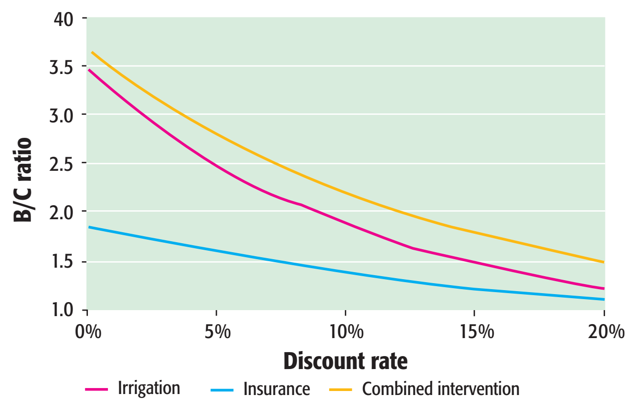
irrigation and its benefits are dependent on the ex-post ability of the household to pay for pumping water. As the low-income household is generally constrained in its financial ability, multiple events over the study period can lead to accumulation of debt over time and the inability to conduct the pumping efforts in later periods (which are further more heavily discounted than the present).

According to our analysis, the greatest benefits would be achieved with an integrated strategy combining both irrigation and insurance. In such an adaptive strategy, a more efficient insurance layer structure could be implemented; as irrigation reduces the higher-frequency events (irrigation, in effect, cuts off the initial portion of the risk curve), insurance could be adapted to cover more of the lower frequency events. We studied different interventions while keeping the premium constant, and found that a 20 to 80 year event insurance layer, instead of a 10 to 50 year event insurance coverage would cost the same if the 0 to 20 year layer were to be covered by irrigation. Therefore, combination of the two risk management strategies could offer more protection at the same cost.

Changing Climate

In a changing climate with low-magnitude, high-frequency drought events increasing, (as modelled by the A2R1 scenario) the benefits of irrigation would increase, while the insurance benefits would be reduced when low-frequency/high-magnitude events become less common (see Figure 15). Again, a combined package, where the insurance contract is linked to the irrigation intervention and adapted to changing conditions, would reap the highest benefits.

| FIGURE 15 | B/C ratios for interventions considered given a changing climate



Conclusions

We conducted a detailed forward looking, risk based cost-benefit analysis on the economic benefits of two risk management interventions suitable for a typical poor, farming household exposed to drought in rural Uttar Pradesh. Benefits were assessed in terms of income and consumption smoothing for current and future climates. Cost of both risk reducing (irrigation) as well as risk-sharing instruments (micro crop insurance) were evaluated.

We found that both of the options and the integrated package are economically efficient within the assumptions. Insurance seems less dependent on discount rate assumptions, as 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. A typical household as modeled in our case study is financially vulnerable. Multiple adverse shocks over time lead to accumulation of debt and to an inability to afford pumping in the future (leading to higher discount rate).

With a changing climate, irrigation benefits increase as average rainfall and rainfall variability increases, while insurance benefits are reduced, as high intensity events decrease. Finally, integrated physical (irrigation) and financial (insurance) intervention packages return higher benefits at similar costs. This is a result of strategically targeting higher frequency events (with irrigation) and lower frequency events (with insurance) with different approaches to disaster risk management. Consequently, it seems highly important to foster the exploration of such integrated packages in a process involving different public and private actors.

Using this data and model intensive framework, we encountered a host of methodological hurdles, which introduced considerable uncertainty into the assessment process. One of the biggest challenges was to incorporate the different types of information and estimation methods within one comprehensive modelling approach. For example, rainfall variation pattern analysis requires statistical methods, while the generation of future scenarios has to be dealt within a simulation programming framework. Further, while assessing the risk and the net benefits of risk management, results should be based on many possible risk factors, which also involves considerable mathematical complexity. For example, our crop yield model is based on rainfall only. Detailed crop simulation modelling (accounting for soil conditions, cropping patterns etc.) was not used in this analysis due to significant data and resource limitations and unsatisfactory calibration of results.

Like any CBA, information on the costs and benefits of risk management strategies by itself is not sufficient for decision makers to make an informed decision. Use of CBA is often useful as a key input within a more *process-oriented* framework. There are always limitations to using a modelling approach for determining and assessing risk and risk management strategies, and finally calculating the desirability of interventions, as done for example, by a cost-benefit analysis. Models do not and cannot capture everything. Systematic assessment and estimation of risks, however, provide important decision-making support, as it requires a process of identification and quantification of the effects of various DRM strategies in reducing and sharing those risks. Such analysis conducted in collaboration with stakeholders and decision makers is likely to lead to better-informed, equitable and eventually decisions that are acceptable to wide array of stakeholders.

The study conducted may be useful for promoting stakeholder dialogue on investments and the design of schemes. Departments, agencies and NGOs working on groundwater irrigation, crop insurance and drought relief in Uttar Pradesh and India can initiate a transparent and coordinated dialogue with the results of this case study. We suggest the DRM strategies discussed can be put to use for the following applications:

- Organizing data for assessing and monitoring the evaluated DRM strategies by the Crop Weather Watch Group (CWWG) and State Planning Department of Government of Uttar Pradesh;
- Systematically assessing investments needs and tradeoffs in crop insurance and groundwater irrigation management by *Grameen* (Rural) Banks, primary agriculture cooperatives (PACs), Agriculture Insurance Company of India, private bodies such as Birla Sunlife; departments of rural development—watershed development, agriculture and minor irrigation—groundwater recharge);
- Promoting micro-finance activities through non-government organizations with government support (NABARD) in the form of matching funds;
- The Uttar Pradesh government may consider shifting its existing focus and investment away from minor (surface) irrigation to funding and supporting an intensive groundwater programme because of the huge groundwater potential. It may also benefit from experience from other states (for example, the *Jyotirgram* scheme in Gujarat), which provide a dedicated electricity connection at non-subsidized rates for groundwater pumping.

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8

CHAPTER

Moving from Policy to Practice:

The Role of Cost-Benefit Analysis in Pro-active Disaster Risk Reduction

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Key Issues at the Policy Level

It has been mostly in the wake of large disasters that disaster management policy has developed in India, Pakistan and Nepal. All three countries have had a reactive approach to natural disasters in which rescue and relief has been the key objective. Over time, various concerned government departments such as irrigation, water and power, as well as local government have become involved in devising approaches to disaster management as a part of their larger mandate. In recent years, and especially after the massive earthquakes of 2001 and 2005 in Gujarat and Kashmir, very specialized apex level institutions have been set up for disaster management in India and Pakistan.

Both India and Pakistan have constituted national disaster management authorities under the aegis of their prime ministers. Nepal adopted the National Action Plan on Disaster Management in Nepal in 1996. These apex agencies are entrusted with all that is related to disaster management, including the establishment of disaster management agencies at the regional and local levels. Despite elaborate plans and documentation, no disaster management framework has, however, reached the local or even the regional level pervasively enough to have effective risk reduction potential. Although there are elements of risk reduction, the thrust of their activities is on post-disaster relief. Although all of these agencies are placed high in the government and have access to resources, their ability to perform during disasters is questionable. Communities in all three countries still believe that they have to fend for themselves and are solely responsible for risk reduction and relief.

These specialized hierarchical agencies, with little downward accountability, are not well suited to reducing vulnerability. They have little contact with communities at risk and specialize in providing large structural solutions, solutions that suit the political economy of countries with weak governance. The case studies reveal that the causes of vulnerability span many sectors. Building resilience, then, means changing the way we use water, practice agriculture, build houses and provide other social services. These changes are best done by responsible local authorities with access to communities. Disaster risk reduction needs to filter down into the everyday working of local authorities. The sectoral policies currently practiced seem to be untouched by such concerns and sometimes even undermine vulnerability reduction. As an example, the Drought Emergency Recovery Assistance programme in Pakistan was designed to reduce drought-induced poverty through public works and by providing diesel pumps for irrigation. In the long run, however, such a water management practice will contribute to the lowering of water tables, which will in turn increase vulnerability during future droughts. There is a great need to evaluate such sectoral policies to understand their contribution to risk reduction.

In particular, there is a need to determine which package or combinations of strategies are most effective for disaster risk reduction. The expected climate change complicates this demarcation. The cost-benefit analysis method, with its probabilistic risk, is well suited for this purpose, but there do not seem to be enough resources or skills or wide enough mandates to compare strategies that span many sectors for it to be effectively utilized at the local level. Complete cost-benefit analyses, like those performed for India's flood and drought cases, need to be undertaken and advocated by apex level institutions such as planning commissions and other economic policy-making agencies.

Cost-benefit analyses are particularly effective if they started at the local level using shared learning dialogues to identify both the array of less commonly quantified benefits and costs from strategies that have been implemented by governments and are already known as well potential local risk reduction strategies to evaluate. Shared learning dialogues were used in this Risk to Resilience study both specific new strategies to evaluate (many of which had not been recognized as playing a role in risk management) and also key factors to evaluate within existing strategies. For example, where new strategies are concerned, in several locations local authorities that establish and enforce building codes had not realized that they play a concrete role in disaster risk reduction. They also need to be involved in the process of developing strategies. Similarly, where identification of potential costs and benefits are concerned although communities in the Lai River basin could not fathom the massive infrastructure costs associated with government flood control projects, the communities in Nepal were able to use pluses and minuses to rank the risks and benefits of both flood control structures and community level approaches. Qualitative methods used to measure vulnerability are also necessary to target interventions, as cost-benefit analysis alone does not capture distributional aspects. Yet cost-benefit analysis can be one of the criteria for choosing risk reduction strategies.

Generally, a major risk with cost-benefit analysis lies in the fact that analyses conducted for project preparation are not of great quality and do not capture many of the external social and environmental costs. Cost-benefit analyses are usually pieced together as a formality for project approval and can only rarely be challenged by the affected populations. Unless the process is inclusive and transparent and project developers are held accountable, a cost-benefit analysis is not an effective tool for policy development. It is also difficult to undertake cost-benefit analyses of risk reduction strategies that are affected by climate change due to lack of solid data on the implications of such change at local levels. In some cases, such as donor-sponsored risk reduction programmes where both financing and global technical support can be made available, it may be possible to have all the conditions present to undertake a properly designed probabilistic cost-benefit analysis using future climate change scenarios as a starting point for identifying strategies. Since a lot of adaptation related activities are externally funded, cost-benefit analyses can be used extensively for such strategies.

The case studies also indicate that formal mechanisms for continuous learning are either very weak or missing in India, Pakistan and Nepal. Academic institutions and public and non-profit research organizations do not seem to be prepared to undertake research. Not only do current policies and practices need to be analyzed and compared but ingenious mechanisms for risk reduction also need investigation. The study of drought responses in Uttar Pradesh (Chapter 7), for example, showed that providing a combination subsidized micro-insurance and boreholes for irrigation during periods of drought can have economically beneficial outcomes for vulnerable populations living at the poverty line. More research into such mechanisms is needed and climate-based cost-benefit analysis is a good tool to start with.

National Cases

The following sections delineate the development and practice of disaster risk reduction policies in India, Pakistan and Nepal. The history and development of the various institutions involved in disaster risk management and the current practices and key issues in their implementation are discussed in some detail.

India

This section sketches the landscape of policies and institutions with specific reference to disaster management in the flood context in India in order to determine how to undertake the cost-benefit analysis of flood risk reduction strategies. The aim is to understand the role of various institutions and sectoral programmes of relevant ministries in flood risk reduction and to identify effective points of entry for catalyzing disaster risk management. We begin with the general national context and follow it with descriptions of key programmes and institutions. Then we examine the understanding, potential use and application of cost-benefit analysis. The findings are based solely on secondary literature and on the results of the scoping exercises undertaken for a detailed cost-benefit analysis of risk reduction strategies in India (see Chapters 6 and 7).

Key Characteristics of the Indian Context

The "Top-down" Planning Process

India is one of the largest democracies in the world. Though the Planning Commission promotes a bottom-up planning process, it is often constrained by the inability of low-level agencies to address local development concerns. The process is further constrained by a lack of comprehensive data on ground realities, and by budgets and time. As a result, planning is, in fact, often top-down. This situation holds true for disaster management too.

Disjointed Institutions: Lack of Coordination

The government accords great importance to large-scale disaster management. Its Disaster Management Act of 2005 represented a paradigm shift from a "relief centric" to a proactive approach of prevention, mitigation and preparedness. This act provided for the constitution of the National Disaster Management Authority (NDMA) as apex body for laying down policies, plans and guidelines for disaster management under the aegis of the Ministry of Home Affairs (MHA) with the prime minister as chair. State and district-level disaster management authorities are chaired by the chief minister and district magistrates respectively. Although various central ministries and departments and state governments should function in a coordinated manner under the NDMA, budget constraints and entrenched sectoral approaches have hampered their efforts, resulting in a disjointed approach overall.

Mismatch between Physical and Administrative Boundaries

Administrative and physical boundaries seldom match. Flood control management has to be dealt with at the basin level, but each basin, especially the bigger ones, lies within many different administrative boundaries (block/*tehsil*, district, state and national). As a result, most actions with a direct impact, especially on floods, are taken at the administrative level but their implications are at the basin level.

Mismatch between Community Needs and Government Programmes

There is a disjuncture between community needs and government programmes. Community needs for prevention, mitigation, communication, and resilient livelihoods are cross-sectoral and interventions combine individual, community, and higher-level actions, but the government's flood management plans generally do not focus on entire gamut of interventions. In particular, they neglect livelihood promotion, despite its potential to address the root cause of flood vulnerability.

Capacity Gaps at the Local Level

Community mobilization and capacity building programmes demand long time frames. Government-supported programmes of this nature are difficult to sustain, partly because of inadequate resources or time constraints. The mobilization, educating and training of community institutions, including *gram panchayats* (the lowest level of government), requires a strong network of NGOs with a long-term commitment to area development. Unfortunately very few NGOs work in flood-affected areas and most of them provide only relief.

Ineffective Follow-up and Integration of Learning into Practice

Several committees, high-level working groups and task forces[1] have been appointed to look into flood-related problems and suggest remedial measures. The implementation of recommendations has been rather slow and for social, financial, administrative and political reasons at best partial action has been taken on the majority of them. Some areas the government of Uttar Pradesh needs to follow-up on are listed below:

- Undertake a realistic and scientific assessment of flood damage at the basin and sub-basin level. Currently available data is not by basin and sub-basin.
- Assess the performance of existing and future flood control works. The expert committee which reviewed the implementation of the recommendations of the

[1] Policy statement of 1954, High Level Committee on Floods-1957 and policy statement-1958, Ministers' Committee on Flood Control-1964, The Working Group on Flood Control for Five-Year Plans, Rashtriya Barh Ayog-1980, The Pritam Singh Committee report-1980, Report of FM in the state of Bihar, Uttar Pradesh (UP), West Bengal and Orissa-1988, The Regional Task Forces -1996, The Expert Group on FM in UP and Bihar – 1999, Report of the Committee on Silting of Rivers in India-2002, Expert Committee to Review Recommendations of Rashtriya Barh Ayog-2003, and the Task Force on Flood Management/ Erosion Control-2004.

Rashtriya Barh Ayog (National Flood Commission) and produced its report in 2003 recommended collecting data systematically so that there will be quantitative and dependable information on performance and long-term socio-economic factors. The state government has accepted this recommendation.

- Legislate and enforce flood plain zoning. The government considers the legislation necessary and is taking administrative measures.
- Provide storage in various forms, like flood space in reservoirs as far as it is feasible given the competing uses of irrigation and hydropower. The government has agreed to this recommendation.
- Make available the requisite funds for the construction of new works and maintenance. Maintenance suffers because of a lack of funds.
- Implement flood-proofing measures such as raising villages and constructing appropriate flood shelters. The performance of some of the state governments has not been satisfactory.

Key Features of the Policy Environment

Disasters in India[2]

India is vulnerable to multiple disasters on account of its unique geo-climatic conditions. Floods, droughts, cyclones, earthquakes and landslides are recurrent phenomena. Perhaps the most telling measure of India's exposure and vulnerability is the human death toll, defined as killed and missing people in a disaster. Over the period 1996 to 2000, various catastrophes claimed more than 45,000 victims across South Asia, with the majority of these fatalities occurring in India.[3]

About 55% of India's land is vulnerable to earthquakes, 8% is vulnerable to cyclones and 5% is vulnerable to flooding. The long coastline of India, especially the eastern coast, is exposed to tropical cyclones almost every year. Around 85 cyclones from the Bay of Bengal and the Arabian Sea have affected the country over the past 35 years. In November 1996 over seven million people were displaced when a major cyclone hit Andhra Pradesh.

Over the past five decades, the frequency of disasters in India has increased. About twice as many events were reported in the 15 years from 1981 to 1995 (181 events, or 15 per year) as in the preceding 15 years (1965-1980). Just in the more recent five-year period between 1996 and 2001, 75 events causing approximately US$ 14 billion worth of losses occurred (see Table 1).

TABLE 1 | **Disaster losses by major hazard in India, 1996-2001**

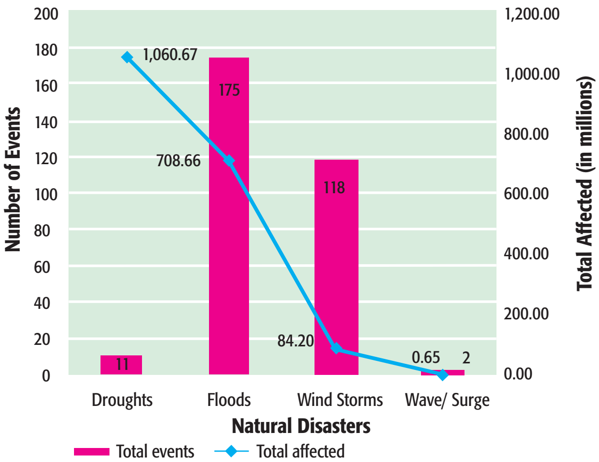
Hazard	No. of reported events	No. of reported deaths (thousands)	People affected (thousands)	Reported losses ($million)	No. of loss reports submitted	Per cent reported	Average loss per report ($million)
Windstorm	15	14.6	25,213.7	5,619	15	100	374.6
Flood	29	8.9	150,980.3	2,928	18	62	162.7
Earthquake	3	20.1	16,367.0	4,707	6	200	784.5
Drought	4		90,000.0	588			
Other	24	5.9	356.9		3	13	
Total	**75**		**282,917.9**	**13,842**		**56**	**329.6**

Source: CRED, International disaster database, Université catholique de Louvain, Belgium

[2] This section draws heavily from World Bank Report 2003, Disaster Management Status, Ministry of Home Affairs

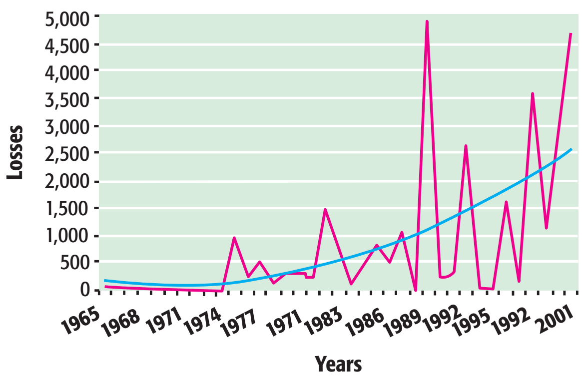
[3] Sources: Swiss Re, Natural catastrophes and man-made disasters 1996-2000; CRED, International disaster database, Universite Catholique de Louvain, Belgium; World Factbook.

FIGURE 1 | Number of disaster events and total population affected from 1960-2006.[4]



Adapted from: Swiss Re, Natural catastrophes and man-made disasters 1996-2000; CRED, International disaster database, Universite Catholique de Louvain, Belgium; World Factbook.

FIGURE 2 | Reported Catastrophe Losses in India, 1965-2001 Nominal US$ Million adjusted for changes in exchange rates



Adapted from: CRED, International Disaster Database, Université catholique de Louvain, Belgium

These recurrent disasters have caused huge direct losses of public and private economic infrastructure in India. It is estimated that on an average direct losses attributable to disasters constituted about 2% of India's GDP and consumed up to 12% of the central government's revenues between 1996 and 2001. It is alarming that the reported direct losses from natural catastrophes during the 15-year period from 1981to 1995 ($13.4 billion) were more than four times those registered during the previous 15 years ($2.9 billion).

Disaster Management Policies and Programmes in India

The government's response to disaster has traditionally been limited to calamity relief and has largely been implemented through the five-year fiscal planning cycle. This more or less reactive response to disaster management can be broadly categorized into three types:[5]

Rescue and relief: The disaster management plans developed by state and national authorities have emphasized the prevention of loss of lives through rescue and relief efforts and the provision of food, clothes, safe water and proper medical treatment.

Infrastructure restoration: The government accords priority to the restoration to normal operating conditions of basic infrastructure, like roads, public buildings, airfields, ports, and communication networks.

Communication: Government authorities communicate the impact of the disaster and the specific activities that are being (or need to be) undertaken to the larger community.

Disaster management has been the responsibility of the state, with funding support from the central government. Three distinct categories of support have been provided from the centre: direct relief (including emergency water, food and shelter, drainage works and seed); relief coupled with productive activities, such as work on planned projects; and the repair and reconstruction of government assets.

While there have been numerous *ad hoc* changes in the government's approach to disaster funding over the last five decades, particularly with regard to the nature of central supplementary transfers, the primary mechanisms for disaster funding, which

[4] CRED database
[5] WII- Review of Policies, 2005

are gradually shifting now as the paradigm shift outlined in the next section proceeds, can be briefly summarized as:

- The Calamity Relief Fund (CRF) meets the immediate relief needs of the victims of cyclone, drought, earthquake, fire, flood and hailstorms. Under this arrangement each state receives funds, 75% of which come from the central level in the form of non-planned grants. The state has to provide the remaining 25%. States may also draw on up to 25% of the central funds due in the following year, subject to subsequent adjustment.
- State CRFs are administered by committees of officials associated with relief work or experience in the natural calamity field. CRF funds may be applied to existing capital works, but only if required for the provision of immediate relief, such as the restoration of drinking water and shelter.
- Following a severe disaster, the central National Calamity Contingency Fund (NCCF) meets relief expenditures in excess of a state's CRF fund, subject to oversight by the National Centre for Calamity Management (NCCM) constituted by the Ministry of Home Affairs.

The Paradigm Shift in Disaster Management in India

The last decade has witnessed a paradigm shift in the government's approach to disaster management. The calamity relief approach has been replaced by a disaster preparedness approach integrated into the development process itself. This new strategy proceeds from the conviction that development cannot be sustainable unless disaster mitigation is built into development strategies. This new approach also stems from the belief that investments in mitigation are much more cost effective than expenditure on relief and rehabilitation.[6] The Tenth Plan (2002 to 2007) included a number of schemes that deal with the prevention and mitigation of the impact of natural disasters.

The new approach has been translated into a national disaster management framework that serves as a broad guide to be referred to at the state and district levels. In this framework, the Ministry of Home Affairs is the apex body for disaster management for all natural disasters except droughts for which the Ministry of Agriculture is the apex body. The central government provides financial and logistical support to state governments. The new approach has involved:

> BOX 1
> **Community Involvement in Disaster Management**
>
> The tsunami of 26 December 2004, which hit Samiyarpettai village in Cuddalore District of Tamil Nadu, showed that adopting a strategy of community involvement is very effective in saving lives. Villagers from Samiyarpettai were trained under the UNDP-GoI Disaster Risk Management Programme that includes developing survival skills, establishing search and rescue teams, conducting mock drills, and promoting general disaster awareness. Only 22 lives were lost in the disaster, while in neighbouring villages, like Pudukuppam, the death toll was much higher.
>
> Source: Comprehensive Disaster Risk Management Framework, End of the Course Project, Aanchal Garg 5/8 6/14/2005

1. The set-up of a national disaster management authority (NDMA) at the central level
2. Promotion of the integration of disaster preparedness and mitigation into the development process though the reorientation of existing rural development schemes
3. Development of early warning systems, vulnerability maps, safe building by-laws, and other preventive measures
4. Promotion of community participation in designing and implementing programmes and building the skills of communities

[6] Source: GoI Status Paper

5. Increasing awareness by using information and communication technologies and targeting the education sector
6. Exploration of new mechanisms such as crop insurance for disaster risk reduction

In the following sections, we examine key institutional developments that demonstrate the existing approach to disaster management in India.

National Disaster Management Authority

The NDMA is the nodal agency for disaster management in India. It's establishment was mandated under the 2005 National Disaster Management Act. It is mandated to coordinate policies and relief and rehabilitation programmes on disaster management and to promote disaster preparedness at all levels from state to district. NDMA is responsible for all kinds of disasters. It is responsible for coordinating five areas:

1. Policies for and approaches to disaster reduction
2. The promotion of preparedness at all levels - state, district and block
3. Response
4. Relief and rehabilitation
5. The amendment of existing laws and procedure

In its approach to pre-disaster activities the government puts an equal effort into developing institutional and human capital and investing in the strengthening of physical infrastructure (see Box 2)

BOX 2
NDMA's Approach to Disaster Management

Institutional capital
- Develop a multi-disaster surveillance system
- Liaise with the Ministry of Home Affairs/Emergency Operations Centre
- Conduct vulnerability assessment through multi-hazard risk zonation
- Develop guidelines for earthquakes, flood and warning manuals
- Produce a safety housing atlas

Human/social capital
- Conduct social mobilization and awareness campaigns
- Increase participation in decentralized planning
- Enhance community capacity in multi-hazard prone districts (through DMCs and DMTs by training communities to prepare village inventories, build safe shelters, stockpile relief materials and make evacuation plans

Physical capital
- Build cyclone shelters, dams, barrages and flood shelters

Mainstreaming Disaster Management into the Development Processes

The government of India has adopted mitigation and prevention as essential components of its development strategy and each state is supposed to prepare a plan for disaster mitigation in accordance with this central-level strategy. Existing development schemes are being reoriented in order to mainstream disaster preparedness either by preparing communities to cope with disasters by enhancing their ability to use available resources to meet basic needs during times of adversity or to adapt to disasters through bringing about long-term changes in livelihood and economic systems, such as changing cropping pattern or land use. The main institutions responsible for mainstreaming disaster preparedness into the development process are described here:

Ministry of Agriculture (MoA): Endorses projects focusing primarily on the technical aspects of developing rain fed agriculture. These include the National Watershed Development Project for Rain fed Areas (NWDPRA), the Indian Council of Agricultural Research's model watershed projects, and the World Bank-assisted pilot project for watershed development in rainfed areas.

Ministry of Rural Development (MoRD): Oversees projects focusing on water harvesting through the construction of percolation tanks, contour bunds, and other structures. These fall under the Department of Soil and Water Conservation's Projects (Jal Sandharan) and the Drought Prone Area Project (DPAP).

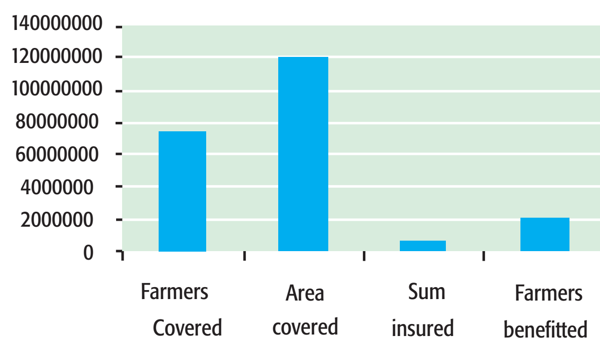
Non-government organizations (NGOs): Implement projects, which typically place greater emphasis on social organization than on technology compared to government programmes.

NGO-government collaboration: refers to projects operated jointly by government and non-government organizations (like the Indo-German Watershed Development Programme (IGWDP) and Adarsh Gaon Yojana (AGY)) that combine the technical approach of government projects with the orientation toward social organization generally found in NGOs.

Agriculture Insurance Company Limited

The Agriculture Insurance Company Ltd. (AICL) was formed by the government of India, to offset the impact of crop losses due to uncertain risks, including droughts and floods, by strengthening the financial base of agriculturists to recover from the shock of natural disasters. AICL has a national agriculture insurance scheme that covers both farmers who have taken a loan and those who have not. The new insurance scheme covers food crops and oilseeds, as well as annual commercial and horticulture crops such as sugarcane, potato and cotton. The coverage is compulsory for farmers who have taken a loan and optional for those without. It provides a 50% subsidy to farmers as an incentive for adopting the scheme. It is clearly a social scheme with no profit orientation. As payments are made only to bank accounts, the scheme encourages farmers to open bank accounts, thus providing them with opportunities to save. Premium rates are decided based on the coefficient of variation in the yields of a particular crop over 10 years. The greater the fluctuations are the higher the premium. AICL has a rainfall insurance scheme, too, but few farmers have adopted it (see Figure 3)

FIGURE 3 | NAIS - Business statistics of 12 seasons from *rabi* 1999-2000 to *kharif* 2005



AICL is also trying to develop schemes tailor-made for farmers (e.g. to cope with fluctuating prices) as well as package insurance schemes that simultaneously insure life, livestock and crops. The company has recently come up with new products that will help cope with natural disasters. (see Box 3).

BOX 3
New Products Offered by Agriculture Insurance Company Limited

- *Sookha Suraksha Kavach.* This is a rainfall index for *guar*, *bajra*, maize, *jowar*, soyabean and groundnut crops in Rajasthan.
- Coffee rainfall index and area yield insurance for Karnataka. This covers damage due to a shortfall in the actual rainfall index and/or yield losses due to other non-preventable natural factors.
- Poppy insurance for Madhya Pradesh, Rajasthan and Uttar Pradesh for licensed growers by the Bureau of Narcotics.
- Wheat crop vigor and temperature insurance for a few districts of Haryana and Punjab, a risk-combination insurance based on biomass crop vigor and temperature.
- Mango weather insurance. For a few districts of Andhra Pradesh, Maharashtra and Uttar Pradesh.
- Micro-level marketing strategy. Though rural entrepreneurs to market crop insurance products.
- Re-insurance. Provided on a quota share basis for all new products by the General Insurance Corporation of India and other public sector units general insurance companies.

Current Operational Environment

Key Actors in Government

The Planning Commission is evolving a long-term strategic vision and deciding on priorities for the country. It also envisages playing a key role in policy formulation in critical areas of human and economic development in an integrated manner. It plans to focus on increasing the efficiency and utilization of allocations.

In January 2008, as mandated, the NDMA issued guidelines for flood management prepared though extensive consultations with various stakeholders, including representatives from the government, international humanitarian organizations, multilateral and bilateral organizations, academics and private organizations. These guidelines will help both central government ministries and departments and state governments draw up flood management plans under the nodal agencies for flood management, the Ministry of Home Affairs, the Ministry of Water Resource and the Central Water Commission. These plans will be formulated and implemented by central government bodies, state governments and local bodies, including *panchayats* and urban bodies, while compliance and enforcement of the same will be ensured by communities and other organizations. The plans will be reviewed and monitored by the State Disaster Management Authorities (SDMAs) and the NDMA at the state and national levels, respectively.

The UN system in India

A major emphasis of the UN in India has been on incorporating drought risk reduction into the Millennium Development Goal plan developing an understanding of the analytical tools necessary for identifying vulnerable groups and targeting drought risk reduction, development cooperation funds as well as addressing the immediate, underlying and root causes of the impacts of disasters. Simultaneously, the focus is on increasing credit in order to disaster-proof livelihoods and on livelihood diversification in order to protect against disaster losses. An illustrative example is the GoI-UNDP-Disaster Risk Management programme (see Box 4).

International Humanitarian Organizations

Organizations such as the Indian Red Cross Society, Tearfund, Oxfam, CARE-India, Eficor, Caritas-India, Christian Aid, World Vision India, CASA and ECHO have focused on providing disaster aid in flood affected areas. These relief agencies provide food, clothing, medicine and other necessary items to affected populations but they are increasingly

BOX 4
GoI-UNDP DRM Programme

With the assistance of UNDP, USAID and the European Union, a comprehensive programme has been introduced in 169 districts in 17 multi-hazard prone states: Assam, Arunachal Pradesh, Bihar, Delhi, Gujarat, Maharashtra, Meghalaya, Mizoram, Manipur, Nagaland, Orissa, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, Uttarakhand and West Bengal.

The states are assisted in drawing up state, district and block-level disaster management plans. Village disaster management plans are being developed in conjunction with *Panchayati Raj* Institutions and disaster management teams consisting of village volunteers are being trained in preparedness and response functions such as search and rescue, first aid, relief coordination and shelter management. State and district-level multi-hazard resistant Emergency Operation Centres (EOCs) are also being set up under the programme state nodal agencies have identified equipment district and state EOCs need and are in the process of providing them. Orientation trainings for masons, engineers and architects in disaster resistant technologies have been initiated in these districts.

The mission of the programme is to reduce vulnerability to all types of hazards, be they natural or man-made. Significant steps towards vulnerability reduction have already been taken, including putting in place prevention and mitigation measures and preparing for a rapid and professional response. With its massive awareness-generation campaign and its capacity building as well as the institutionalization of the entire mechanism through a techno-legal and techno-financial framework, the programme is gradually moving in the direction of sustainable development. The various prevention and mitigation measures outlined above are aimed at building up the capabilities of communities, voluntary organizations and government functionaries at all levels.

Particular stress is being laid on ensuring that these measures are institutionalized in a manner appropriate for handling the vast population and the geographical area of the country. This is a major task. The ultimate goal is to make prevention and mitigation a part of everyday life.

supporting preparedness programmes. As of yet, however, these programmes are not linked to long-term development programmes.

Private Organizations

In the recent past, especially after the 2005 tsunami, private organizations have shown greater interest in disaster management activities, but their role has focused primarily on emergency relief, recovery and reconstruction but not on addressing the underlying and root causes of disaster impacts. Private organizations already play a significant role with respect to insurance and catastrophe bonds. By providing technological support, they have the potential to also invest in the monitoring and surveillance of hazards and preparedness programmes. Catalyzing substantial investment in risk reduction by the private sector, however, requires improved understanding of the associated costs and benefits. Such assessments can, as a result play a critical role toward involving the private sectors. In addition, the assessment process can assist private organizations in understanding the trade-offs involved between alternative interventions and thus assist them in prioritizing and targeting the disaster risk reduction activities they undertake more effectively.

Perceptions & Behavior of Communities in Flood Areas

In addition to government interventions and those by the private sector, communities often undertake a variety of actions to reduce their risk from floods. These actions and the perceptions could form a cost-effective basis for strengthening formal risk management programs if, using CBA, they were consistently incorporated in the overall development and economic evaluation of such programs. While the range of strategies and perceptions is too great to discuss in detail here, the examples below illustrate the value they could add:

- Historically, people in eastern Uttar Pradesh and in other parts of India stored seeds to barter for grain after a disaster. Currently, however, only small farmers store seeds, whereas large farmers purchase seeds from the market. Improvements in seed storage at the local level could be a very cost-effective strategy for reducing flood risks.
- The people of Lakshmipur village in Maharajganj District of Uttar Pradesh believe that if they receive information about water levels during the flood season then they can take preventive actions. The information newspapers and the radio currently provide is not specific enough for them to gauge if their village is likely to be affected or not, so they monitor water levels on their own. As a result, devolving early warning systems for floods from the region, district or block-level to the village level could be a cost-effective DRR strategy.
- Farmers in eastern Uttar Pradesh were interested in learning about suitable alternative crops that they could cultivate in order to minimize crop damage due to floods and droughts. These could include:
  - Early-sowing, short duration crops that can be harvested before the onset of the flood prone season (July-August)
  - Crops that can survive in waterlogged conditions
- Seasonal migration is a common strategy that helps local communities that are regularly affected by floods to cope with the losses they incur. Strategies for supporting migrants could be a highly cost-effective approach to flood risk mitigation.

Stakeholders' Perceptions of Insurance Issues

Perceptions are also highly important in the evaluation of new strategies. In eastern Uttar Pradesh, for example, local perceptions regarding insurance raise fundamental questions that need to be evaluated in order to determine the effectiveness and benefits such schemes might have. Key perceptions that require evaluation include:

- Farmers in eastern Uttar Pradesh and Orissa know little about crop insurance. A few farmers take loans against their Kisan Credit Cards, which have an in-built crop insurance mechanism, but they are more interested in the amounts of these loans than the insurance component
- Payment for insured crop loans is made to farmers through often very politically driven official declarations. Compensation and exemptions from loans are not often provided to those farmers who have been most affected by floods or droughts
- Because insurance agencies are generally unwilling to insure assets in areas that are highly prone to disasters, the risk-spreading capabilities of communities in these areas are minimal.
- Changing climatic scenarios throw related insurance mechanisms out of gear because it is difficult to estimate event probabilities and thus either losses or appropriate premiums. It is problematic for insurance agencies to keep rescheduling their schemes.
- Demand-side structures and mechanisms for managing credit and insurance need to be promoted more than supply side structures and mechanisms.
- Existing insurance companies have not taken the initiative to raise the level of awareness
- Payment procedures are complicated: It requires numerous investigations and farmers have to present certificates, which consumes time and money, and they sometimes have to mobilize influence to get the papers required.
- People interviewed were reluctant to go continue paying premiums without any interim benefits against their premium.

Data gaps

There are gaping holes in the data needed to do a complete hydrological analysis and a cost-benefit analysis of flood risk reduction strategies, though rainfall data can be bought by any agency in India. Because the density of rainfall stations is very low, it is impossible to develop a true picture of the distribution of rainfall at the basin level. Individuals or non-governmental agencies cannot access river discharge data; the Central Water Commission fiercely guards these. Even when one does get this data, it is not very useful as it is collected in just one point in the entire basin and, in the case of the Rohini basin of Uttar Pradesh the only discharge gauging station has been closed since July 2006. Because relevant data from various agencies and departments is not available all in one place or in a usable form, the cost and time required to conduct a cost-benefit analysis is high.

Lack of Holistic Framework for Integration, Decision-making and Advocacy

In the current context, when all primary stakeholders seem to be in favour of embankments, the attempts of some civil society groups to force a re-think of the strategies adopted to deal with floods have had little success. The reasons for this failure are many. Such groups are unable to show convincingly the disaggregated impacts of embankments and other disaster risk reduction strategies, they cannot engage effectively with relevant government departments, they are very critical of the government strategy but have no scientific baseline study to prove their assertions and they promote a single disaster risk reduction option rather than a package of options. There is a need for an overarching framework that can highlight the trade-offs for each disaster risk reduction option, (or a package of them) and allows for clear-headed policy formulation.

Potential Role of Cost-Benefit Analysis in Disaster Risk Reduction Efforts in a Flood Context

A comprehensive cost-benefit analysis can help address many of the problems and constraints outlined above. It can serve as a framework for organizing and analyzing data in a manner that promotes a multi-stakeholder process in identifying and prioritizing various disaster risk reduction strategies. In particular, it has potential for being used in making decisions about investments in ministries and departments working on flood management.

A cost-benefit analysis can also help international humanitarian and private organizations in making decisions about appropriate disaster risk reduction options by promoting dialogue with stakeholders.

Pakistan

This section reviews Pakistan's policies for disaster risk reduction in order to ascertain the potential application of information from risk-based cost-benefit analysis.

Key Characteristics of the Pakistan Context

Fluid Politics

More than sixty years after Independence, Pakistan still does not have a stable democratic political system characterized by multi-party representation, and smooth successions of leaders and changes of governments. The government that took office after the general elections of 2008 has initiated a constitutional reform package that seeks to restore the supremacy of the Parliament. In the previous eight years of military-dominated government, a number of institutions were set up for disaster management, such as the National Disaster Management Authority (NDMA) and the Earthquake Relief and Reconstruction Authority (ERRA). The mandates and roles of these organizations will change under the new regime, but at present it is uncertain precisely how. As a result, the context is extremely fluid.

Disjointed Institutionally

Progressive Centralization of Disaster Management

Pakistan is a federation of four provinces – Punjab, Sindh, North West Frontier Provinces (NWFP) and Balochistan - and three federally administered territories – Islamabad Capital Territory, Federally Administered Tribal Areas, and Northern Areas. Azad Kashmir has its own state government.

For the first few decades after Independence, disaster management was considered a provincial subject. The army was called in to carry out emergency flood protection and rescue, for example, but operational command remained in the hands of the deputy commissioner (district chief executive) and supervisory command was largely with the provincial relief commissioner. The centralization of disaster management started in the 1960s and accelerated in the 1970s. A federal Kohistan Development Board (KDB) was established to absorb the huge international donor assistance after the Kohistan earthquake of December 1974. The government of NWFP was deemed not to have the capacity to undertake the scale of rehabilitation that was made possible by donor support (Nadir, 1983). After the large floods of 1973 and 1976 in Punjab and Sindh provinces respectively, the Federal Flood Commission (FFC) was created

With the establishment of the FFC, flood mitigation planning was centralized, but relief operations remained at the district and provincial levels. In 1983 the NWFP Cabinet rejected a proposal to replicate the KDB model as it implied a continued upward delegation of rehabilitation functions (Nadir, 2007), but two decades later, after the catastrophic earthquake of October 2005 in Azad Kashmir and NWFP, relief and rehabilitation planning and operations were centralized under the ERRA.

Operational rescue command has moved from the deputy commissioner in the field to the Chairman of the NDMA in the federal capital. To an extent, the centralized management of all the stages of disasters - from preparedness to rehabilitation - has been made possible by more and better communications and transport. Some would argue the scale of recent disasters has also necessitated it. But these institutional arrangements are out of joint with a *de jure* federal state. Researchers have documented the disempowering impact of federal government and army interventions on provincial and local disaster management capacities (Khan et al., 2007).

Sector-Based Institutions in a Multi-Hazard Reality

Although people face multiple hazards, only some of which are natural, over the past several decades, separate organizations have emerged for each main type of natural disaster and specific disaster events, such as the FFC for flood management and the ERRA for the 2005 earthquake in Azad Kashmir and NWFP. Furthermore, sector agencies and territorial units manage the preparedness, mitigation, relief and rehabilitation aspects of disaster management separately. Realizing that such arrangements are flawed the government established the National Disaster Management Authority (NDMA) in 2006. The NDMA however is a new organization, which exists largely on paper. At the field level, disaster response is still organized by sectors and segments.

There are different organizational entities to manage different aspects of a single natural hazard. For example, for rainstorms and for floods, both water-related disasters there are two separate organizations for early warning and for preparedness and mitigation planning. The Pakistan Meteorological Department (PMD), the Water and Power Development Authority (WAPDA) and the FFC all have distinct institutional histories and mandates, but only the FFC has a mission that focuses directly on disaster management.

On paper, there are adequate protocols for cooperation between the involved organizations, but deficiencies have been repeatedly exposed when a heavy rainstorm causes a fast-rising flood, particularly in minor catchments. Such flaws were clear the case of the Lai River basin flood in 2001 and also more recently in the 2006 and 2007 floods in several hill torrents in the North West Frontier Province. The PMD radar in Sialkot is useful for forecasting rainfall and run-off events in the watersheds of the main tributaries of the Indus River but not for the hill torrents in the northwest. Pakistan Space and Upper Atmosphere Research Commission (SUPARCO) satellite imagery is useful only for forecasting large sea storms. While the Meteorological Department does issue flood-warning circulars on the basis of more general information, the UNDP and Rural Development Policy Institute (RDPI) forum in Jhang District documented in 2003, there are several conceptual gaps in district flood fighting plans (Box 5).

BOX 5

Critique of District Jhang, Flood Fighting Plan 2003

A paper, "Alternative Perspective of Disaster Management: A Policy Framework for District Government Jhang", by Amjad Bhatti, Journalists Resource Centre Islamabad was presented at the UNDP and RDPI forum. The author presented critical observations on the Flood Fighting Plan of Jhang district which included dominance of an emergency and relief management approach. The paper recommended that disaster management, particularly flood management in the district should be linked with the process of annual district development planning within the ambit of district assembly. The author recommended capacity building training workshops for flood prone communities and district departments and suggested preparation of five-year disaster preparedness plans for Jhang district.

Source: District policy workshop on disaster management, Jhang District, Punjab, Pakistan

Old Flood-Fighting Plans for Disasters that Cross Jurisdictions

District Flood-Fighting Plans (FFPs) are better on paper than in reality. Frequently, FFPs are just routine revisions on the previous year's plans, merely updating the names of contact officials, for example. This approach can result in serious omissions. For example, the WAPDA commissioned the major Chashma Right Bank Canal (CRBC) in D.I. Khan District in 2001. This canal cuts across the paths of several major seasonal streams and has resulted in flooding along its west bank in several years since 2001 but WAPDA is not a part of the district's flood-fighting plan sponsored by the FFC (ADB, 2006). Overall, the FFP is just a reproduction of a document produced routinely on an annual basis since the 1980s.

A similar issue exists with relief. The territorial units for rescue and relief are returned to their bases when flood waters pass to the downstream district or province. The responsibility for relief then passes to the NDMA which then commissions other organizations for the actual delivery. This was demonstrated in the case of flooding after cyclone Yemyeni in 2007, as the huge flood passed from Balochistan province to wreck havoc in Sindh. The NDMA only complicated matters by quite arbitrarily allocating districts for relief operations to designated NGOs.

Absence of Learning Environment

Formal Institutions Are Highly Hierarchical

In theory, a highly hierarchical culture is neither a necessary nor sufficient impediment to learning. Witness the lack of learning in some markets. On the other hand, quite a lot of learning goes on in some universities, colleges and schools, most of which are hierarchically arranged. In the government of Pakistan, however, with its strict procedures and hierarchy, there is very little scope for inter-disciplinary or inter-sectoral learning as any interaction between departments has to be initiated at the apex level and all communication has to be conducted along the same "proper channel." As a result, various organs remain airtight and there is little room for the cross-fertilization of knowledge and experience at the operational level.

Infrastructure Led Development

The idea that development is good in each and every way and its corollary that investment in infrastructure is the key to development, have been successfully sold in Pakistan. Leading political and executive decision-makers accept it as fact that mega-projects yield the most bang for the buck. In this paradigm, there is little room for learning. Conservation is seen as an impediment to development. Institutional development is neglected or thought to emerge naturally from the process of change. Mega-projects that mesh well with a command-and-control style of management do have their opponents, but the motives of those opponents are questioned. Opportunities for corruption align well with this pattern of thinking.

Corruption and Avoiding Documentation

Corruption is pervasive and entrenched in Pakistan. Corrupt institutions have developed policies and instruments that reinforce and perpetuate corruption. Low government salaries, lavish perks and privileges for selected elites, a plethora of directly regulating rules for industry and commerce (many of which are mutually inconsistent), and non-transparent tendering processes are just some elements of this tainted system, while bribery and nepotism are its products. In this setting, managers avoid consistent documentation in order to escape accountability. It is nearly impossible to find maps that depict Pakistan's entire developed infrastructure. Since each project has its own separate plan, questions like why the same drain has been built so many times are avoided. Without objective documentation, there can be little learning.

There are no systems for monitoring the outcomes or for evaluating the impacts of projects. In fact, traditional systems of supervision have decayed. For example, the use of the Planning Commission form (PC-IV) for project completion and satisfactory operation has largely been abandoned.

Weak Universities and Research Institutes with little Knowledge Management Capacity

In the first half-century after independence, Pakistani universities decayed as places of learning for several reasons. Recently, however, along with a growth in the number of universities and research institutions, there has been a concerted government and private sector effort to revive excellence in some universities. Some NGOs, such as FOCUS Humanitarian, PATTAN, RDPI and SCOPE, are working in disaster management and drawing lessons from their experiences, but there is still no research institution with an explicit mission for disaster risk research or a university with the subject of disaster management as part of its curriculum.

Disaster management agencies need to acquire a knowledge management orientation. There are a number of requirements for capitalizing on experiential learning. These include establishing linkages between university departments and research institutions for database development, monitoring outcomes, evaluating impacts, and documenting institutional histories.

Policy History and Key Features of the Policy Environment

Pakistan has a well established macro-economic and development planning tradition. Prospective and medium term development frameworks are approved at the highest levels of government with the intent of providing the basis for all development planning in the country. Currently, the long-term Vision 2030 released in 2007 and the Medium-Term Development Framework (MTDF) 2005-2010 are the key macro-policy documents of the government in power. Pakistani's Poverty Reduction Strategy Paper-II (PRSP-II) is being finalized. These macro-policy documents make little mention of disaster management in general, and disaster preparedness and resilience in particular.

Pakistan has also framed policies for specific sectors, such as communications, education, energy, and environment, and health and water, which have implications for disaster management, but the linkages are not explicit in most cases. For example, the policy of subsidizing tube well operations through a flat rate electricity charge has lead to the lowering of the water table in desertification-prone areas. Sector policies and legislation need to be reviewed in order to align them with National Disaster Management Ordinance (NDMO) 2006, and, more generally, with sustainable development.

Cost-Benefit Analysis in Project Formulation

Pakistan's public sector development policy has become increasingly project-driven over time. In fact, has been observed that the MTDF and the Association for the Development of Pakistan are no more than bundles of projects (Hunnam and Saeed, 2007). Projects that cost more than a stipulated amount are required to prepare cost-benefit analyses, but this component of the PC-1 form is met quite mechanically. Costs are narrowly defined in terms of direct financial outlays. Externalities such as social and environmental costs are ignored. The estimated outlays on a project are compared with notional benefits down the years at a standard discount rate (usually 12%), and a crude benefit-cost ratio is presented to decision-makers. Any ratio over 1 is taken as a signal that the public sector project in question is feasible. There is a tacit understanding that most of the benefit numbers are developed in the absence of (any intention to levy) user charges.

History of Disaster Management Institutions & Policies

Before the October 2005 earthquake, the government was not organized in a manner for addressing prevention and response to disasters. The Calamity Act of 1958 was the first significant piece of Pakistani legislation designed to address disasters, but in practice it only addressed disaster response, not the prevention of disasters, and no systematic plan or organization was created to tackle a host of other issues concerned with disaster management. In addition, the authority to respond to disasters was assigned to the provincial level since it was believed that disasters primarily created problems at that level and below. Until 1970, Pakistan Civil Defence was assigned the task of responding to disasters, but this institution[7] consisted only of volunteers who received limited training a mere two times each year.[8] Following a cyclone in 1970 an Emergency Relief Cell (ERC) in the Cabinet Secretariat became responsible for organizing the federal response to disasters.[9] However, little change actually occurred in the management, preparation or planning for disasters.

[7] NDMA National Disaster Risk Management Framework Pakistan, Government of Pakistan, March 2007.

[8] Qazi, Muhammed Usman, UNDP, personal communication, August 2, 2007.

[9] National Disaster Management Authority, National Disaster Risk Management Framework Pakistan, National Disaster Management Authority, Government of Pakistan, March 2007.

Current Operating Environment

This section seeks to relate policies concerning what is actually happening on the ground: Who are the key actors? What really makes a difference in terms of disaster risk reduction implementation and flow of funds? It looks at large-scale government institutions and the role cost-benefit analysis could play as a decision-making tool within them.

National Disaster Management Commission and Authority

Following the 2005 earthquake, the government of Pakistan passed the National Disaster Management Ordinance 2006 to be implemented by a National Disaster Management Commission (NDMC). This body was established in February 2006. It has made a five year plan to address disaster preparation and management, with an indicative budget of $15 million.[10] In addition, the NDMC published a National Disaster Risk Management Framework to guide the system of disaster risk management. It envisages coordinating the national response to national-level disasters via a National Emergency Operations Centre (NEOC) and requires that the government make available people and resources to engage in emergency responses.

The National Disaster Management Authority (NDMA) is assigned the task of implementing this framework. This mandate includes the establishment of disaster management authorities at the provincial, regional, district and municipal levels.[11] While the document itself is commendable, the current focus on the ground remains on response and relief after disasters. The plans for vulnerability mapping have yet to be implemented.

The NDMC and NDMA are attached to the Prime Minister's Secretariat. The NDMA's powers and functions duplicate to some extent the duties previously assigned to the Emergency Relief Cell of the Cabinet Division and the National Crisis Management Cell in the Ministry of Interior. These units have not been disbanded nor their residual functions been specified. Indeed, the actual operational framework for disaster management is not transparent at all. The allocation of long-range responsibilities for the programming and coordination of disaster management capacity building and extension across the country is even more unclear.

What is NDMA doing on the Ground?

NDMA is a "small outfit" with 17 staff members, including a chairman, senior officer, advisor, Information Technology and Communications expert and technical advisor. It does not have any disaster risk reduction experts. The Chairman of NDMA insisted on a "small outfit" as, according to him, there is no need of NDMA during "normal times". NDMA has a huge mandate for a handful of technical staff. NDMA and its associated organizations need to adopt a highly pragmatic and efficient (non-bureaucratic) management style to accomplish their mission.

Provincial disaster management authorities (PDMAs), district and municipal disaster management authorities (DDMAs) and *tehsil* (sub-district) and town management

[10] Abbas, Hyder, "When Disaster Strikes," Dawn Islamabad, Sci-tech World, August 4, 2007, p. 1.

[11] National Disaster Management Authority, National Disaster Risk Management Framework Pakistan, National Disaster Management Authority, Government of Pakistan, March 2007.

authorities (TMAs) have been conceptualized, but they have not been made operational in the two years since the launch of NDMA. In Sindh, a PDMA was set up without first creating a provincial disaster management committee (PDMC) for legislation. The consequence is an ineffective and dormant PDMA unable to design and implement provincial disaster risk management policy. All sub-authorities are linked to NDMA through a linear chain of command. The federal government, subject to approval of their disaster risk reduction plans, grants funds for these sub-authorities. Only the lowest tiers of DDMAs and TMAs have been conceptualized in a framework of multi-stakeholder partnerships. No multi-stakeholder partnership has materialized yet.

Other elements of NDMA's mission include capacity building, training and awareness sessions at the community, district, provincial and national levels. A few workshops on urban search and rescue (USAR), and pre-flood preparedness have been conducted and some PDMA staff trained, but NDMA has not managed to train a single rescue team in two years. (Source: www.ndma.gov.pk)

NDMA is developing projects in each of its nine policy areas. One of the projects is titled "Vulnerability Mapping of Pakistan". For this and some other projects, risk-based cost-benefit analysis could provide an important tool for analysis and policy communications.

Can Risk-Based Cost-Benefit Analysis Help NDMA?

The NDMA Framework does not explore the multiple dimensions of vulnerability such as social and political marginalization, lack of communication infrastructure, gender and ethnic discrimination, landlessness, all of which exacerbate the risks for vulnerable communities. Nor does it have space for the concept of development-induced disaster (RDPI, 2006). NDMA focus is on major national disasters and, either deliberately or through oversight, it ignores emerging threats, such as climate change, saline water intrusion in the Indus Delta, and urban flooding (Comments during NDMA Launch Event, December 2006).

At present, NDMA has little use for a risk-based cost-benefit analysis approach. It does not have the in-house capacity to undertake or to absorb the outputs of a cost-benefit analysis exercise. The fact that its mandate for major natural hazards risk reduction ignores social vulnerability could bias the terms of reference for an outsourced risk-based cost-benefit analysis assignment. It is not required to share the results of a cost-benefit analysis with community stakeholders either.

BOX 6
Observations of Auditor-General, ERRA

Communities are having trouble reconstructing their houses owing to the absence of proper construction guidelines the complexity of the building methods specified and the rising prices of construction materials. In an interview with the Risk to Resilience Study Team, the Auditor General of ERRA said, "Millions of dollars are presented to ERRA presuming that work will be done. It is not being done! There is an absence of disaster risk reduction capacity building through media. The DIY (do-it-yourself) Policy of ERRA is good. However, there is an urgent need for a toll-free helpline for self-construction to be successful. A call centre with facilitators giving advice in Pashto or Kashmiri is necessary. Many ERRA schemes have failed and several million rupees of funds have lapsed owing to the lack of co-ordination among experts, implementers and end users."

Source: PIEDAR Shared learning dialogue, 22/8/2007

The Earthquake Relief and Reconstruction Authority (ERRA)

The mission of ERRA is to plan, coordinate, monitor and regulate activities for the reconstruction and rehabilitation of earthquake-affected areas; encourage self-reliance via private public partnerships and community participation; and ensure financial transparency. ERRA is primarily relief-focused. Since its charter does not include reducing vulnerabilities and building capacities it cannot "build back better".

The eleven sectors that ERRA has chosen to "build back better" are housing, livelihoods, health care, environment, tourism, telecommunications, education, transportation, agriculture, water supply and sanitation, and governance. But its focus is on cash grants and compensation rather than on building capacity and developing resilience. For example, five billion Pakistani rupees have been disbursed as compensation for the loss of livelihoods, but little attention has been given to building linkages to markets and providing training in livelihood opportunities. (Source: ERRA Progress Report, www.erra.gov.pk, 2007)

Could ERRA use Risk-Based Cost-Benefit Analysis?

Given ERRA's focus on the construction of quakeproof houses, schools and other physical infrastructure, there was an opportunity to establish construction standards based on a risk assessment of costs and benefits, but this opportunity has been missed. Over-designed structural specifications have been imposed, and environmental issues and challenges ignored.

Financial transparency and accountability have not been maintained at the standards promised when international donors pledged over six billion U.S. dollars (Box 6). Rather, the charter of ERRA states: "…no suit, prosecution, {or} other legal proceedings shall lie against the authority, the council, the board, the Chairperson, or any member, officer, advisors, experts or consultants in respect of anything done in good faith". For the financial provisions of ERRA, internal audit control has been adopted to ensure financial accountability. Nonetheless, NGOs and communities have made charges of corruption and poor administration. Some 80,000 applications were received in the offices of deputy commissioners from claimants who had failed to receive even the first instalment of building compensation grants (Cheema. M, 2006).

ERRA has no mandate for effective disaster risk reduction. It missed the opportunity for land use planning and urban planning in Muzaffarbad, Bagh and Balakot based on environmental factors and risk-based analysis of economic choices. There is no requirement for it to a present the economic rationale of its decision-making to the public. As a result, it has no need for a forward-looking risk-based cost-benefit analysis tool. (ERRA Progress Report, www.erra.gov.pk, 2007)

Drought and Drought Emergency Recovery Authority (DERA)

Pakistan does not have institutions dedicated to drought monitoring and drought risk reduction. The government has focused on crisis management and relief-based policies for coping with droughts. Dr. Shahid Ahmed argues for formal, effective, efficient and transparent linkages between drought monitoring and mitigation agencies (Ahmad, 2007). In his report, "Institutional Arrangement and Policies for Drought Mitigation in Pakistan," he identifies drought-monitoring institutions (such as the Pakistan Metrological Department (PMD), the Drought and Environment Monitoring Centre, the Water and Power Development Authority and the Provincial Irrigation Drainage Authorities), drought research and development institutions (such as the Arid-Zone Research Centre and the Pakistan Agriculture Research Centre) and drought-implementation agencies (such as the Department of Agriculture in Sindh and the Irrigation and Power Department in Balochistan). At present, their linkages are informal, reactive, and unaccountable. Actions materialize long after drought impacts have become irreversible, at least during any realistic planning horizon.

Pakistan launched a federally administered drought mitigation programme called The Drought Emergency Recovery Authority (DERA) in 2001 in response to the severe drought of the late 1990s. From its inception DERA has been a reactive, relief-oriented programme which focuses on infrastructure development, temporary employment, and irrigation. It has not worked as a national apex organization for coordinating drought risk reduction activities with a clear vision and strategies for building drought resilience by focusing on reducing vulnerability and developing the capacities of livestock grazers although the loans from international financial institutions did request that such an authority be set up.

Even the most basic elements of drought risk reduction, such as the consequences of lowering of the water table have not been considered by DERA (IWRM, 2004). Balochistan Resource Management Programme (BRMP) has concluded that the current programme of DERA is environmentally unsustainable owing to the mining of groundwater and the lowering of the water table; technically unsound owing to inappropriately designed and located delay action dams; operationally unviable owing to the lack of participation of water users and financially costly owing to the high overhead and management costs of its schemes (IWRM, 2004).

The draft final report of BRMP recommends that any long-term strategy must include the key disaster risk reduction practices listed below:

- Water harvesting and conservation through traditional methods, such as *karezes* (lateral underground channels that tap the groundwater table), *sailaba* (flood water conservation), and *khuskhaba* (rainwater harvesting).
- The establishment of year-round drought monitoring and early warning systems, the building of community awareness and the active participation at all levels of NGOs and water users in drought mitigation schemes.
- Herd management and livestock extension services for adaptation.
- Soil and water conservation.
- Insurance, re-insurance and income diversification schemes.

Can DERA Benefit from Risk-Based Cost-Benefit Analysis?

Risk-based cost-benefit analysis can help inform a holistic, integrated and well-defined disaster risk reduction policy. The results could be used as a policy advocacy tool for setting up an organization dedicated to drought preparedness, mitigation and adaptation. A well-conducted series of cost-benefit analysis exercises could be used to demonstrate the risks of groundwater mining to both decision-makers and communities. Such cost-benefit analysis exercises could be a component of an integrated water resource management (IWRM) toolkit and programme. They could also help create links with private insurance and re-insurance sectors. They could be adapted to run with downscaled climate models for the drought-affected regions of Pakistan.

Flood and the Federal Flood Commission (FFC)

The FFC was formed in response to the massive floods of 1973 and 1976. It prepares and plays a major role in coordinating, financing and implementing the National Flood Protection Plans (NFPP). NFPP-IV, for the decade from 2007 to 2016, is being reviewed by the Ministry of Water and Power (MOWP).

The government, ADB loans and project-based donor contributions fund the FFC. It has a highly centralized decision-making structure with a uniform template for district flood-fighting plans. Having evolved from the Office of the Chief Engineering Advisor, it has a technical and engineering approach to flood management. Most of the professionals in FFC are engineers. There are no disaster specialists, geomorphologists or hydrologists.

The mission of the FFC is “effective flood management on a country wide basis with reference to main river systems of Pakistan” (Kamal, A. Superintending Engineer FFC). The aim is to develop integrated and standardized flood management plans. Most of its plans are structural and based on increasing flood resistance through technological improvements. Chief Meteorologist Shaukat Ali Awan, FFD, PMD, thinks that FFC does not possess a complete flood hazard assessment of Pakistan. FFC has never carried out vulnerability and capacity assessments. In fact, Pakistan does not even possess mechanisms for risk monitoring and risk mapping. Systematic socio-economic and environmental loss analysis is not carried out after major or minor flood disasters. There are no educational programmes related to disaster risk reduction in government schools and flood protection training programmes are not provided to the public. Large government organizations behave as though there is no indigenous knowledge about flood coping mechanisms (interview by ISDR accessed on 6/16/2008).

Since 2004, there has been some realization of the importance of community participation and awareness in the formulation and implementation of flood protection plans. A national NGO named PATTAN serves as a countrywide link between communities living in the flood plains of Punjab and the FFC. However, multi-stakeholder partnerships in the NFPP are negligible. In fact, all provincial flood plans are approved or rejected at the discretion of FFC (Bari, S., personal communication, 4/7/2007).

Can Risk-Based Cost-Benefit Analysis Help FFC?

The government should review the mission and strategy of FFC in view of the annual recurrence of flood disasters and the massive havoc caused by cyclone Yemyeni in July and August 2007. The change must centre on developing a disaster risk reduction policy. FFC could follow up by making action plans which bridge the gaps between policy and practice, create better linkages among flood management institutions, and develop and implement best practices for flood risk resilience with the active participation of communities at risk. The concept of risk-based choices has a role in the formulation of policy, while cost-benefit analysis could be used to refine the action plans.

Climate Change and Disasters in Pakistan

Comparative Assessment of Disasters in Pakistan

The records of natural disaster events since 1926 that have killed more than ten or affected more than one hundred people are relatively complete. A UN Technical Working Group using the EM-DAT database of Center for Research on the Epidemiology of Disaster (CRED), Belgium, has attempted to collate the number of people killed or otherwise affected by natural disasters and the monetary damage caused by them. These estimates are conservative, controversial and incomplete. For our purposes, it is sufficient to use the estimates to rank natural disasters by frequency, deaths, number of affected persons and damage.

Climate Change and Variability: Adaptation and Resilience

For Pakistan, GCM models forecast increased flooding, rock avalanches, and water resource disruptions as Himalayan glaciers melt. Floods could destroy the capacity-constrained irrigation infrastructure on which agriculture depends. The risk of hunger will also increase because of the decline in crop productivity owing to heat stress. Other areas of concern include more saline water intrusion in the Sindh coastal zone owing to the acceleration in the rise of sea-levels; more and stronger cyclones owing to rising sea surface temperatures and impacting Karachi and other coastal settlements; heat stress during summer temperature spikes, and the spread of disease vectors because of stagnant water ponds and mild winters (ADB, 1994).

It is possible to adapt to climate change by devising anticipatory response strategies to minimize adverse impacts. The challenge begins with understanding just how climate change may affect Pakistan's uplands and rivers, its agro-ecological zones and sub-zones in the Indus Plain, and its coastal lands. A starting point for more regional and ecological-zone specific analysis is improved information on the dynamics of climate change at the regional level.

Over the past decade, there has been significant advancement in the development of regional climate models (RCMs). They provide data with greater spatial resolution than GCMs. They take general information from GCMs and refine its precision at the regional level. RCMs are full climate models based on the physical processes, interactions and feedback of the climate system, but provide climate change information on a 50 km grid for domains of 5000 km by 5000 km rather than on a global scale. As a result, impact and adaptation researchers have a great interest in the results of RCMs.

TABLE 2 | Comparative Assessment of Natural Disasters in Pakistan (1926-2006)

Frequency	Deaths	Persons Affected	Economic Damage
Ext. temp. events	Earthquakes	Floods	Earthquakes
Landslides	Floods	Earthquakes	Floods
Floods	Windstorms	Droughts	Droughts
Windstorms	Ext. temp. events	Epidemics	Windstorms
Epidemics	Landslides	Windstorms	Epidemics
Droughts	Epidemics	Landslides	Landslides
Earthquakes	Droughts	Ext. temp. events	Ext. temp. events

Note: Ext. temp. events = Extreme temperature events
Source: UN TWG on DRM, 17 May 2007 derived from EM-DAT, CRED

TABLE 3 | Frequency & Magnitude of Natural Hazards by 2040-49

Natural Hazards	Frequency	Magnitude
Extreme temperature events	More frequent	Higher summer peak temperatures
Landslides	More frequent in northern Pakistan	More hillsides or bigger landslides
Floods	More frequent	Higher peak flows
Windstorms	More frequent	Stronger winds
Epidemics	More frequent	Variety/virulence
Droughts	More frequent in southern Pakistan	Longer duration
Earthquakes	No change	No change

Source: Thought-experiment based on climate scenarios for 2040–49 using Model RegCM3

What are the implications of climate change for natural hazards? We conducted a scoping thought-experiment with model outputs for changes in the frequencies and magnitudes of the main natural hazards in Pakistan. The results are presented in Table 3.

Table 3 suggests that the natural hazards that already occur frequently in Pakistan are likely to become even more frequent and more intense. This hypothesis needs to be tested and validated by detailed empirical studies. Nonetheless, it indicates the need for a national review of disaster risk reduction policy.

The review should re-assess the changing risks from natural hazards over the coming decades. It should assess who is likely to be more vulnerable. It should provide direction to national climate change adaptation and resilience building strategies. A probabilistic cost-benefit analysis could be a tool in the studies leading to such a policy review. The cost-benefit analysis component may play an important role in communicating to the global community the risks and costs of climate change to Pakistan and also forcing regional institutions to evaluate alternative approaches to risk management much more systematically.

Can Cost-Benefit Analysis Help in DRR in Pakistan?

Can probabilistic cost-benefit analysis serve as a credible tool in the Pakistan context? This depends, in essence, on whether or not it is used as part of an open participatory process of evaluation or, as unfortunately has historically been the case, by small groups of experts as an easily abused tool to justify projects where decisions to proceed have already been made.

In Pakistan, a large federal country with multiple social realities and multi-dimensional hazards, the question of process has no ready answer. In some cases, participatory approaches to cost-benefit analysis could easily be implemented. In other cases, however, such processes could with equal ease be captured and used to justify the desires of a specific group. As a result, a key question concerns the scaling up of cost-benefit analysis for disaster risk reduction. Major questions exist regarding how micro to macro connections could be made and how cost-benefit analysis would meet the needs of potential users. Cost-benefit analysis could, in theory, be used to promote negotiation, involve people in the political debate, and build consensus. Whether or not this can be achieved in practice requires the development and testing of simplified methodologies in a wide variety of contexts with different groups of users. While there are no ready answers, the potential applications are widespread.

Nepal

Climate induced disasters are a regular phenomenon in Nepal. In 2008, Nepal experienced two major water related disasters. The first was the breach of Kosi embankments that affected 70,000 Nepalis and 3.5 million Biharis. Monsoon floods led to massive devastation in the Mid and Far Western region. In both these and past flood events, individuals and households adjusted to the hazards in several ways depending on their economic conditions, education levels and social standings. The impacts on marginalized groups, including low-income families, widows, women headed households, the elderly, children, the disabled, families dependent on daily wages, those in debt and communities who were without access to basic services and infrastructure, were largely negative. Their responses were similar to those made by many other communities who have faced similar hazards. Their efforts at coping were aimed at diversifying sources of income, including migrating, drawing upon a common pool of resources, using social networks, drawing upon household savings of food and fuel, and exploiting other assets.

On August 18, 2008 the eastern embankment of the Kosi River in Nepal Tarai was breached. Notably, the failure occurred when flow in that river was lower than 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 (See Box 1 in Chapter 1). According to the preliminary results of the inter-agency Kosi River Flood Impact assessment, a total of 66,500 individuals were displaced by the flood of which 42% were Indian nationals.[12] The detailed damage assessment of the Kosi 2008 disaster was not available at the time of writing this report.

In another example, flash floods generated by monsoon rains between the 19th and 21st of September, 2008, affected more than 200,000 people in Nepal's Mid and Far western Regions. More than 40 persons died and three months after the disaster more than half of the population remains displaced. Though the flood water receded in a few days, irreversible damages to crops, houses and cattle resulted. Families joined hands to carryout those repairs that were within their capacity. They helped each other to repair houses and roofs and to improve drainage around the settlements. The response of the state remained negligible. A few non-governmental organizations provided relief.

In both cases, hardships continued even five months after the disaster. Most of the affected families from Kosi floods live in tents in relief camps established on embankments, canals banks and roads because these spaces were dry. Some people also lived on neighbour's rooftops. In many cases people sought help from local leaders, but support provided by such leaders was far too little. The response was better in Kosi flood compared to that in the Mid and Far western floods.

Our research shows that in response to these events some families migrated to other places in search of employment and some came back having developed skills like carpet weaving; making plastic bags, buttons, brooms, switches or bangles; and repairing bicycles. A few acquired skills in handling machines. Although local conditions did not encourage it, they also established local units and tried to earn a livelihood

[12] OCHA situation report No. 5, 19 December 2008

outside of agriculture. Many others who were unable to obtain jobs ended up borrowing money and falling into the debt trap. Individuals in low-income brackets and those without education were particularly vulnerable. Because of a lack of education and a low level of awareness, many individuals develop fatalistic tendencies—*jasto parchha testai tarchha* (whatever happens in the course of time will be tackled as per one's capacity). Some families suggest that God will protect them from the scourge of floods.

People point to the following four causes of flooding: (1) the disturbance of natural drainage by roads and canals (2) the breaching of embankments and spurs (3) the increase in river discharge, including changes in river course and (4) the use of specific local measures that do not take the larger picture into consideration. Villagers consider frequent and prolonged rainfall, thunderstorms and strong winds as signs of potential flooding. Those living along riverbanks watch flow and water levels. When early monsoon floods wash away crops or damage farmland, farmers replant. Unless there is substantial harm to the standing crops, farmers do not worry about standing water in their plots. They consider the fine sediment deposited by the river to be beneficial. Bank erosion and land cutting on the other hand are harmful and sand casting severely reduces land quality and agricultural productivity.

A family that loses its house normally takes shelter with a neighbour or relative. During floods many affected families shift to schools or Village Development Committee (VDC) offices, which are built on higher lands. To earn a livelihood they work on others' farms. Some families remain in their villages waiting for external help. When flood waters do not drain quickly, villagers dig ditches to drain the stagnant water. They even take drastic measures like breaching embankments and sections of roads. Such a response is not unique. In North Bihar too, communities affected by water logging occasionally cut embankments to drain stagnant water. In August 1998, some villagers in Parasi deliberately breached the Nepal-Gandak canal and a section of the road along the canal because both had constrained drainage and prolonged inundation.

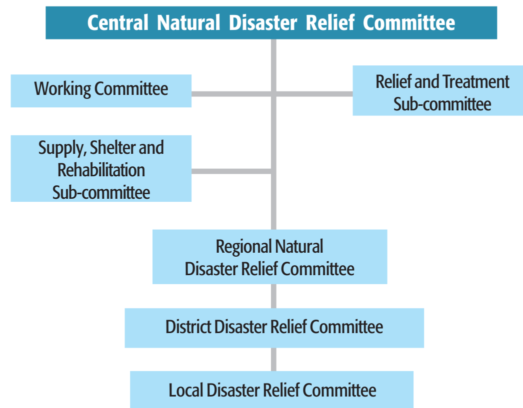
Safe storage of food, fuel and fodder before the onset of the monsoon is a common precautionary measure. The lack of safe drinking water and proper sanitation is a major problem during and immediately after floods. To cope, families keep water in pots and store them in a place safe from flood water. Because the vessels are small and only a little water can be stored, difficulties arise even so. Women often refrain from eating to avoid defecation.

Actors and Activities: Fragmentation and Dysfunction

Families face many difficulties due to floods. Responses by state agencies are still relief-based and similar to those during earlier flood hazards. This is especially true in Nepal because of the institutional vacuum and dysfunction it has faced in recent times. Indeed, the state is conspicuous by its absence and its policies do not cater to individual needs. The institutional erosion following the Maoist insurgency has worsened the situation even since this study began. As of the end of 2004, the insurgency had caused the deaths of more than 10,000 people. Violence, along with a political vacuum, has undermined the social context as the national parliament, VDCs, District Development Committees (DDCs) and municipalities were dissolved. Even after the Constituent Assembly Election in 2008, uncertainty remains.

Three types of organizations are involved in flood disaster mitigation: governments, NGOs and funding agencies and donors. The first type includes governmental departments, whether central of district-based. These departments can be classified into those that are directly involved in with disaster mitigation and those that have policy roles. They provide financial, material and technical support and also implement projects. Those directly involved in disasters provide relief and distribute materials and funds voluntarily contributed to the affected communities. Central departments dominate the terrain; the role of both local governments and community based institutions is limited.

FIGURE 3 | Disaster response structure Nepal



Government

The most important actor in flood disaster mitigation is the government. Ministry of Home Affairs (MoHA) is at the apex as mandated by the Natural Calamity Relief Act (NCRA) promulgated in 1982. A section within this ministry is the *Daibi Prakop Uddhar Sakha*, which co-ordinates the activities of the various task force groups formed to advise ministerial level committees. The ministry produces data and records of those affected by eight different kinds of disasters: earthquakes, floods, fire, storm, landslides, heavy rains, drought, famine and epidemics. This data gathering process began in 1983. In each district there is a district disaster relief committee, which is chaired by the chief district officer (CDO), and includes the highest-ranking army officer in the vicinity, as well as representatives of other governmental departments. Such a committee is formed or activated when monitoring and supervision of disasters relief work is needed.

While the MoHA has direct responsibility for providing relief, many other departments are directly or indirectly concerned with flooding and the amelioration of its impact. The framework of operation for governmental agencies is the National Development Council (NDC), which was constituted in 1993: it approves the country's development goals, including its plans and programmes (including the water resource development plan and the disaster mitigation plan). The Prime Minister heads the council, on which representatives from all sectors serve. Though created to discuss national development issues and secure a consensus on national development, the council has not met.[13]

In 1993, Nepal Environmental Policy and Action Plan (NEPAP) was promulgated. This plan focuses on the following five areas: (1) sustainable management of natural resources; (2) population, health and sanitation, and poverty alleviation; (3) safeguarding national heritage; (4) mitigating adverse environmental impact and (5) legislation, institutions, education and public awareness. The plan brings in the notion of sustainability in to the development agenda.

[13] In 1993, the government formed the National Water Resources Development Council (NWRDC) under the chairmanship of the prime minister with the objectives of developing a national policy framework for the development and management of water resources and of securing consensus among various political parties about its utilization. The committee has an inherent institutional limitation: the Prime Minister, who heads the council, is also the executive head presiding over the delivery function. The same person is designated to provide oversight on the policy that he/she is to implement. The situation creates moral hazards.

With support from UNDP and other donors the government is working on earthquake disasters mitigation. The UN agency also provided support to strengthen disaster preparedness capacities in the Kathmandu valley. The project's major objective was to build capacity of the valley's communities and municipalities to cope with earthquake risk, and thus reducing the impact of a potential disaster.

In February 2008 a disaster management policy for Nepal was proposed. The 'National Strategy for Disaster Risk Management' (NSDRM)[14] was submitted to the MoHA for approval. Based on the Hyogo Framework for Action (HFA) and the Millennium Development Goals NSDRM proposes a road map until 2015.

In the water sector, the policy formulating body is the Water and Energy Commission (WEC) and its Secretariat (WECS), which are together meant to provide policy input to the Ministry of Water Resources. The WEC's mandate was defined in January 1999, when it was entrusted with a wide range of policy tasks. WECS was designated the central water planning and coordinating agency. The Water Resources Strategy of 2001 suggested that 'the WEC/WECS mandate needs to be further strengthened and the organizational set up changed'.

Two departments of GoN are concerned with water-related activities, including floods: the Department of Hydrology and Meteorology (DHM), and the Department of Electricity Development (DoED). DHM plays an important role in mitigating flood disasters: it maintains a network of rainfall and flow gauging stations. The database compiled serves as a basis for the analysis of hazards. The department helped to co-ordinate a project supported by the Dutch government that lowered the water level of the Tsho Rolpa Glacier Lake to minimize the possibility of its breach. The lack of sophisticated instruments needed to collect hydro-climatic data, and an insufficient budget, are the main problems the department faces. The DoED issues licenses to hydropower projects and is concerned with their safety. Another concerned agency is the para-statal Nepal Electricity Authority (NEA), which repaired the Kulekhani hydropower plant, damaged by the 1993 flood. Apart from this specific responsibility, the NEA plays no role in disaster mitigation.

The Department of Soil Conservation and Watershed Management (DSCWM) within the Ministry of Forest and Soil Conservation (MFSC) is also involved in disaster mitigation. Its main objective is 'to maintain the ecological balance by conserving the important watershed areas by reducing the incidence of natural disaster such as soil erosion, landslides and floods.'[15] The DSCWM has a mandate to help people manage watershed resources and meet their basic needs for forest and food products through enhancing land and agricultural productivity. The programme's aim is to integrate forestry, agriculture, livestock, water, and land use practices in its effort to help communities conserve and manage land and water. Its policy of forming user groups accords importance to mobilizing local communities and raising their level of awareness about the need to implement conservation measures. Since its inception in

[14] http://www.undp.org.np/pdf/NSDRMFinalDraft.pdf

[15] For discussions about the mandate of this department, see HMG (1991).

1974, the Department has implemented many water conservation projects. Their contribution to flood mitigation, however, has not been examined.

The Ministry of Local Development (MLD) is responsible for formulating strategies regarding local development and for assisting in the institutional development of local governments. The MLD coordinates with the Rural Community Infrastructure Works (RCIW) Programme, which provides technical, financial, and material support to selected communities in twenty districts to build small-scale infrastructure. The MLD does not directly implement disaster mitigation activities but development local governments in infrastructure provisions, including river training activities.

Activities related to water issues are of the Ministry of Water Resources. At the operational level, it is mandated as the agency for carrying out planning and policy-making and projects related to the country's water resources strategies. Two departments under its aegis are concerned with mitigating flood disaster: the Department of Irrigation (DoI) and the Department of Water-Induced Disaster Prevention (DWIDP).

Department of Irrigation (DoI): Nepal's DoI celebrated its fiftieth anniversary in 2003. The Department consists of five divisions, six central-level project offices, five regional directorates and 75 district-level offices. The DoI's five major divisions are the Planning, Design, Monitoring and Evaluation Division; the Surface Water Irrigation Division; the Groundwater Irrigation Division; the Irrigation Management Division; and the Flood Control, Environmental and Mechanical Division (FEMD). The DoI manages its river training activities through the last. The organization has two types of river training projects: national-level ones handled by the FEMD and local-level projects that district irrigation offices handle.[16] The River Training Division of DOI undertakes flood control works such as the construction of small embankments and riverbank protection using gabion the mattress.

The DoI implements local-level flood mitigation activities through the District River Training Coordination Committee (DRTCC). This committee used to be headed by the District Development Committee (DDC) chairman, and its members include representatives of major political parties as well as district-level representatives of the Ministry of Local Development (local development officer), and the Ministry of Home (chief district officer). The director-general of the DoI serves as a member-secretary of the DRTCC. Under this arrangement, local communities are expected to submit their requests to the DRTCC, which then considers supporting them, so that the DoI's resources can be linked to local demands and activities suitably prioritized. Establishing such a link is essential because one feature of the monsoon season is lobbying for implementing river training works: delegations from many flood-affected villages lobby government agencies before the onset of the monsoon, asking to have river control activities implemented in their locality. In response, district irrigation offices (DIOs) survey stretches of river proposing rudimentary river training works

[16] As of 1998, the Department of Irrigation had executed six river training projects: a) Rajapur Irrigation Project, b) East Rapti Irrigation Project, c) Bagmati River Training Project, d) Banganga, e) Extension of Right Embankment along Lalbakeya and f) Bakra Flood Protection Project. They all involved construction activities. See JICA (1999) for details.

that use gabion nets. Because these structures are built without a proper understanding of local hydraulics, the end result is often failure and unhelpful changes in river regimes.

In 1999 the DoI proposed a draft River Training Policy to serve as a basis for the MoWR to take forward its flood mitigation strategies. The policy emphasized the need for a more comprehensive approach to flood mitigation through (a) the use of local materials instead of gabion wire boxes, (b) the incorporation of bio-engineering in river training facilities (c) a combination of structural and non-structural measures, and (d) capacity building of community organizations for flood mitigation. The draft policy stresses the need to adopt a more systematic approach to river training in the Tarai, to specify design criteria, and to prepare a database. However, the policy has yet to be reviewed within the MoWR for formal approval. Furthermore, detailed damage and inundation surveys are not carried out and plans focus on structures.

Department of Water-Induced Disaster Prevention (DWIDP): In 1992, the Disaster Prevention Technical Centre (DPTC) was established as a joint undertaking of various concerned government agencies. The MoWR was named the lead agency. The centre received technical and financial assistance from the Japanese government. DPTC was reorganized as a Department in 1999 and its new objectives set to strengthen the capability of the government to respond to water-induced disasters. DWIDP focuses on conducting research on disasters, including study of landslides, as its contribution to strengthening the country's capacity for flood disaster mitigation. It also organizes training, conducts experiments with developing technology, and maintains a database in the fields of land erosion control, landslide prevention, and river training.[17]

TABLE 4 | Support agencies and types of assistance provided

Agencies	Status	Nature of support
District Development Committee	Elected body	Activates Disaster Relief Committee and mobilizes government resources following the disaster.
District Administration Office	Lead government office	Coordinates government offices including police and mobilizes them as recommended by the Disaster Relief Committee.
District Irrigation Office	Government	Identifies water logging and submerged areas and keeps its records. Also builds very limited drainage works. Undertakes river training activities.
District Drinking Water Supply Office	Government	Rehabilitation of damaged drinking water supply systems.
Municipality and Village Development Committees	Elected body	Re-construction and rehabilitation works within their jurisdictions.
Nepal Red Cross Society	INGO	Provides emergency and technical help with food, shelter and clothes.
Reyuikai Nepal	INGO	Mobilizes volunteers for rehabilitation works as and when needed.
Action Aid, Oxfam, Lutheran world Service, Practical Action, CARE, Mercy Corps	INGO	Works with partner organisations for awareness and capacity building for local people in disaster prone areas.
Water Users' Association	CBOs	Rehabilitation of damaged canals and irrigation management.
Nepal Food Corporation (NFC)	Parastatal	Distributes food as per the quota of government.

[17] The DWIDP has prepared a draft mitigation policy, but it has not been formalized.

Local Level Institutions

In the past the State's interests were expressed, realized and maintained through statutory decrees, most of which provided for the utilization of land resources as the main source of revenue.[18] Embedded within this practice was the culture of "rent seeking," wherein the state used its authority to maintain order by creating scarcity and continued to enhance its patronage-dispensing function. Its approach to decentralization and popular participation was bureaucratic. It perpetuated feudal practices rather than fostering elements of good governance, a democratized society, decentralized economic (and consequently political) power, and uplifting the productive features of society. The 1991 Constitution, while it provided a framework for democratic governance at the macro level, was silent about many aspects of local governance and the devolution of political power (HDR, 1998). Following the principles set forth in that Constitution, the parliament passed the Local Self-Governance Act of 2055 (1999), which devolves power to local bodies so that they can mobilize local resources for development.[19] This act authorized DDCs, VDCs and municipalities to plan, make policies concerning, and implement local-level projects and programmes[20] and made them responsible for coordinating development activities in their own jurisdictions.

Despite this provision, many district offices still function as extensions of central ministries and departments, which implement activities mostly through project offices. Externally funded projects are handled directly by donors or by central government agencies. The various organizations at the district level have no effective mechanism to come together, discuss issues, share experiences and provide each other the assistance and co-operation needed for implementation of flood disaster management. As indicated by MLD's experiences in small-scale infrastructure development, local institutions can play a significant role in facilitating community mobilization and in coordinating different organizations operating within their jurisdiction. Water user associations, community based organizations, INGO and NGOs are other types of organizations involved at the local level.

[18] Before the unification of Nepal, all land belonged to the state, and farmers had to pay one half of the produce they grew to the government. After the rise of Gorkha, land was distributed as *jagir* and *birta* to maintain the army and revenue offices. After the advent of the Ranas, the distribution of land to private individuals became commonplace. By 1950 about one third of the total forest and cultivated land was under *birta* tenure, and of that, 75% belonged to members of the Rana family. Land is still in the hands of those who control the state and its bureaucracy. Since 1950, it has been this group which exercises control over resources made available through foreign aid.

[19] The 1990 Constitution of the Kingdom of Nepal included directive principles of the State in Article 25. Clause 4 states that it shall be the main responsibility of the State to maintain conditions suitable for enjoying the fruits of democracy through the wider participation of the people in the country's governance and decentralization. But the Constitution did not include provisions for decentralization; for this, the Local Self-Governance Act was promulgated only in 2055 BS. According to this act, the government shall pursue the following principles and policies for the development of a system of local self-governance.

a) Devolution of such powers, responsibilities, and means and resources as are required to make local bodies capable and efficient in local self-governance;
b) Building and development of institutional mechanisms and functional structures in local bodies capable of considering local people and bearing responsibilities;
c) Devolution of powers to collect and mobilize such means and resources as are required to discharge the functions, duties, responsibility and accountability conferred on local bodies;
d) Having local bodies oriented towards establishing a civil society based on democratic process, transparent practice, public accountability, and people's participation, in carrying out the functions devolved on them;
e) For the purpose of developing local leadership, arrangement of effective mechanisms for making local bodies accountable to the people in their own area; and
f) Encouraging the private sector to participate in local self-governance in the task of providing basic services for sustainable development.

[20] There are 75 districts, 3,912 villages and 58 municipalities. Elected representatives, who form development committees at each level, namely, district development committees (DCCs), village development committees (VDC), and municipalities, head these units.

Civil Society Groups

In this milieu the experience of citizens and citizen groups in collective civic and political actions has been limited. Consequently, Nepali society's response to mitigating hardships caused by natural hazards was and still is limited to kinship arrangements; informal institutions provide immediate relief in the aftermath of a disaster.[21] The engagement of non-state actors such as NGOs did not flourish in the aftermath of the 1951 political change. In fact, the Panchayat system of the 1960s focused on centralization though decentralization was one of its tenets. A limited number of social service organizations began functioning, but individuals close to the ruling establishment headed them.[22] A few citizen organizations played the role of civil dissent but these groups were perceived to be a political threat to the Panchayat polity.[23]

Most NGOs are involved in the fields of education, health, income generation and skill development, and help provide drinking water and sanitation, promote agriculture, and uplift children and disabled persons (Hossain, 1998). Though local NGOs did not work in disaster mitigation, international non-governmental organizations such as the Red Cross Society, Oxfam, Action Aid and the Lutheran World Service did. Initially, these agencies focused on relief and rehabilitation because of the immediate needs in the aftermath of a natural hazard. They have now recognized that their focus needs to shift to events between disasters rather than to the events after a disaster. This recognition is reflected in the fact that Oxfam was one of the members of the regional initiative *Duryog Nivaran* that began in 1994 as a network of individuals and organizations in Bangladesh, Nepal, India, Pakistan, and Sri Lanka which focus on research on and the dissemination and advocacy of disaster-related themes promoting an alternative perspective on disasters and vulnerability.[24]

At present, a few indigenous NGOs work in the field of disaster mitigation in Nepal. Agencies such as Oxfam, Practical Action and ActionAid have begun emphasizing the importance of understanding linkages between societal vulnerability and natural hazards.[25] In 1995, Oxfam began supporting NGOs based in the Nepal Tarai to begin working at the interface between vulnerability and natural hazards. This support coincided with the inception of its River Basin Programme that aims at flood disaster mitigation. In 2001, the Disaster Preparedness Network (DPNet), a network of organizations involved in community based disaster relief was formed.[26] The member

[21] One characteristic of Nepalis is a sense of voluntarism in providing support to people affected by natural disasters. Manandhar (1985) recounts two instances of voluntary action by local groups who responded to communities affected by landslides in Hyumat, Kathmandu, and by a fire in a village in Gorkha. Other institutional arrangements include *guthis.* While humanitarian support is crucial in the immediate aftermath of a hazardous event, long-term support needs to be based on organized institutional input.

[22] Some INGOs, like the T. B. Eradication Association, Rotary Club, Nepal Family Planning Association, Nepal Red Cross Society and Nepal Children Association began working in Nepal during the *panchayat* years (Hossain, 1998). For a detailed and critical discussion of the role and responsibilities of NGOs, see Bhattachan et al. (2001)

[23] The proceedings of the seminar in 1983 provide interesting insight into this particular line of thinking. Banskota (1983) suggested that 'local non-governmental bodies and organizations are major alternative…. They will not only help the *panchayat* to get more done, but will help them to function more effectively in other activities like identifying needs, planning and managing other local affairs.' His paper seemed to hint that NGOs could serve as catalysts and social auditors. But in the discussion session following the presentation, among the many questions raised was, "Are the NGOs, however, envisaged as a countervailing force to the *panchayat* bodies?' See floor discussion, pp. 92, Foreign Aid and Development in Nepal, Proceeding of a Seminar October 4-5, 1983, Integrated Development System, Kathmandu.

[24] The five themes are: understanding linkages with society, myths of science and technology, accountability, regional co-operation, and understanding vulnerability and capacity (Duryog Nivaran, 1995). The National Society for Earthquake Technology (NSET) has been engaged in earthquake disaster mitigation since 1997. It produces scenarios, helps retrofit schools, and increase public awareness about safety during earthquakes.

organizations of the network attempt to address the causes of vulnerability and come to a better understanding of natural hazards and preparedness.

Multi Lateral and Bilateral Agencies

The 1951 political change in Nepal marked a change in the function of the centralized authority. Though the decades of 1950 and 1960 were marked by uncertainty in internal politics, the period did see the emergence of the institution of foreign aid in a world polarized between two ideological camps led on one side by the United States and on the other by the former Soviet Union. The government of Nepal worked in cooperation with the institution of foreign aid to dole out development projects—a task necessary to neutralize the political dissatisfaction stemming from the aftermath of the 1960 coup, to buy loyalties and to gain political mileage. The result was the usurping of the customary land and water management practices of Nepali villages on the one hand and the erosion of the state as an institutional resource on the other. The influence of donors increased over time.

Many donor agencies are involved in disaster mitigation within sectoral development programmes. The UNDP, for instance, co-ordinated distribution of international relief to victims in the aftermath of 1993 floods. More precisely it is the UN Disaster Management Secretariat (UNDMS) located within the UNDP country office that assists in coordinating the international response to disasters, including floods. During emergencies, the UNDMS acts as an information clearing house, receiving and disseminating situation reports, needs assessments, donor pledges, and other pertinent information, to facilitate the coordination of emergency operations by different government agencies and donors. The Japanese government has provided support to the DWIDP. In addition, the Office of Foreign Disaster Relief (OFDA), under the aegis of USAID, has provided support for some disaster mitigation activities since 1999.

Building Resilience

The earliest state organized response to flood disaster mitigation in Nepal was in 1954, when families affected by landslides and floods in the mid-hills were encouraged to resettle in the Chitwan valley. The same year, the Chitwan Valley Development Board was created to establish an institutional basis for resettling the affected families. This response was the outcome of several factors, not simply the occurrence of landslides and floods in 1954. The government had already identified the valley as ideal for major land reclamation and development efforts. In 1953, one year before the landslides, USAID had planned to conduct aerial, topographical, and soil surveys of the Rapti Valley (Skerry et al., 1991). The 1954 initiative fitted well into this plan.

The three decades from 1950 to 1980 were marked by the absence of an organized response to mitigating disasters, including those caused by landslides and floods. As early as 1954, academic and journalistic writings recognized landslides and floods as a major problem for Nepal. Gurung (1993) cites an expatriate forester working in Department of Forest who wrote that sediment-laden rivers washed away the basis of life-soil in Nepal. According to Khanal (1991), from 1955 to 1981, the national

[25] Duryog Nivaran (1995) *Ibid.*

[26] DPNET receives support from agencies such as Action Aid, Care Nepal, Caritas, Japan Medical Association and Oxfam.

vernacular newspaper *Gorakhpatra* reported that 156 landslides had result in the loss of property and human lives.[27] Although this 30 year period coincided with six of the government's national plans, none contained any programme to mitigate flood disasters. Instead, a committee for disaster mitigation was constituted after each event, treating disasters on a case-by-case basis.[28] The DoI did implement river training works in response to mitigating flood, but these efforts involved the building of river structures like spurs and embankments and made little attempt to mitigate flood disasters. It was not until the Ninth Plan that disaster relief was incorporated and country's first disaster-related act was promulgated only in 1982.

The period from the early 1970s to early 1980s also coincided with the emergence and consolidation of the theory of Himalayan environmental degradation, which suggested that upland deforestation was the reason behind lowland flooding. During this period the government focused on mitigating the harmful impacts of erosion by implementing watershed conservation projects. The first effort in this respect began in 1968, when, with support from UNDP and FAO, the government began the pilot-scale Torrent Control Project in Trishuli watershed in central Nepal.[29] Six years later, in 1974, the government established the Department of Soil Conservation with the objective of minimizing the degradation of watersheds. Although the department focused on minimizing the impacts of landslides and floods, disaster mitigation did not figure into its responses. Furthermore, its efforts were biased towards the building of check dams for controlling hill torrents.[30]

In the 1980s the social and economical challenges that Nepal was facing began to receive greater academic attention. Blaikie et al's *Nepal in Crisis* published in 1980 highlighted this crisis. The book implicitly referred to disasters thus: "There are frequent famines and the processes of erosion and ecological decline, coupled with continuing population growth will contribute to an increase in apparently 'natural' disaster in the future." Two years later, in 1982, the Natural Calamity and Relief Act was promulgated in order for the government to be more organized in its efforts to mitigate the impacts of disasters. Though it is difficult to pinpoint the exact reason for its promulgation, it seems clear that several events including the earthquake of 1980 led to its formulation.

In the years immediately preceding the passage of the National Calamity and Relief Act Nepal had faced a number of disasters. In 1980, there was a major earthquake in Bajhang in the Far-West. One year later in 1981, south Kathmandu faced a cloudburst that devastated the Lele Valley, and floods washed over Dauretol Butwal. Though many communities all over the country were hit by disasters, the response of the state was at best *ad hoc* and sporadic. An indication of how the government in Kathmandu responded to disasters in far away parts of the country is captured in geographer Harka Gurung's account in *Vignettes of Nepal* published in 1980. Gurung reminisces

[27] Karmachrya (1989) found that from 1970 to 1990 an average of 78 landslides occurred annually in the Central and Western development regions

[28] According to Russel et al. (1991) 'no information is available on how much has been spent on disaster mitigation. No single authority is responsible for monitoring disaster mitigation activities.'

[29] See Toutscher O. G. (1970) Erosion Control Surveys and Demonstration for the Management and Development of Trishuli Watershed, Project Report No 13, HMG/UBDP/FAO

[30] An indication of this focus is reflected in a paper by Toutscher (1979) that deals mainly with the science of dealing with the design of torrent control measures.

TABLE 5 | Five Year Plans: Objectives, policies and programmes on disaster mitigation

Plan Period	Objective	Policy	Programme
Seventh (1955-1990)	No specific objective on the issue	None	None
Eighth (1992-1997)	Not specifically stated regarding the disaster issue	Measures will be undertaken to preserve the forest in Chure range and *bhabhar* region for controlling ecological conservation, and controlling landslide and river cuttings. Incentives will be provided for promoting community or leasehold forests in marginal land of all citizens.	Not available
Ninth (1997-2002)	To protect developmental infrastructure and national heritage and provide security to life and property of the public by minimizing effects of natural calamities; and To promote national capacity in disaster control and management by developing necessary institutional infrastructure for the management of natural calamities.	Coordination policy will be adopted by reviewing existing legal provisions related with national resource protection. A Natural Disaster Management Information System will be developed. National and international resources will be mobilized for mapping of areas prone to earthquake, flood, landslide, etc., for integrated disaster mitigation, control and management.	In order to control the heavy loss of land by erosion and landslide in hilly areas and by flood in lower flat land of hills and Tarai, watershed will be protected, after identifying such areas. Existing laws and regulations relating to land use will be amended. New regulations will be enforced, where necessary.
Tenth (2002-2006)	Formulate Policy, Act, Rules and Guidelines on water induced disaster management. Point out and categorize the disaster prone area, and draw map and sketch of them. Operate sample projects for minimizing/preventing damages of flood, landslide, sediment flow and erosion, and develop appropriate technology. Provide disaster management training to technicians of concerned government agencies. Operate appropriate programs to collect and transmit information, and to increase public awareness, about flood and water flow. Provide assistance to rehabilitate damaged infrastructures (by water induced disaster), and provide emergency relief to affected persons. Maintain coordination among concerned bodies engaged in disaster management. Make Nepal-India Committee/Sub-committee on Inundation Problems more effective.	National and international information about water-induced disaster will be collected and exchanged. Risk map of possible flood, landslide, sediment flow and GLOF will be prepared, and disaster prone area categorized. Nepal-India Committee/Sub-committee on Inundation Problems will be made effective. Action plans will be formulated for controlling flood and landslide. Concerned bodies engaged in water induced disaster management will be strengthened. Capacity of resettlement and rehabilitation activities will be increased making coordination among government agencies, NGOs and communities. Flood control activities will be operated coordinating with agriculture, forest and soil conservation activities.	Formulate policy, acts, rules and guidelines. Prepare maps and sketches of disaster prone area. Continue Disaster Management Support Program. Develop and expand appropriate technology through constructing and operating sample projects. Make public informed about damages to be triggered by flood and landslide providing them prior information, and increase public awareness on disaster minimization. Provide relief materials to disaster-affected area and rehabilitate damaged infrastructures. Maintain coordination among related agencies that are engaged in disaster management. Make Nepal-India Committee/Sub-committee on Inundation Problems effective, and implement action plans to minimize disaster effects.

about his travel to the country's Far-West development region to provide relief to the victims of the 1966 earthquake thus: "It was a Pilatus Porter plane chartered by Nepal Red Cross Society for the delivery of medicine and clothes that took me and Ramesh Sharma, as members of the [Red Cross] Society's Disaster Relief Committee, to the Far West on 26th January 1967". Gurung goes on: "The worst affected areas by the previous year's earthquake were in the hills and we left… for Doti…We had the task of estimating the requirements of food aid to the affected population in addition to what had already been airdropped the previous autumn". This, the first visit of the Red Cross, took place a full year after the disaster.

Typically, the support in 1967 was relief based, and the practice had not changed 13 years later when a major earthquake hit the region again in 1980. According to Manandhar (1985), "the first cartel of help in the form of food, clothing, and tents had arrived with the help of the Red Cross. The local officials and the politicians were given the responsibility of these materials. While relief itself was received with support of the Society, the challenge was more with distribution of the materials to the needy." Manandhar continues: "Favouritism was perhaps unavoidable and those who sided with the local politicians received the gift handsomely than others.… The poor, of course, almost always got the worst deal." Citing a local resident, the author notes, "We found some blankets, received as a form of relief for the victims, being sold across the border in India." The relief was used to solicit political and other types of support. This practice continues. It could be hypothesized that news of the embezzling of relief materials did reach the corridors of powers in the capital, thereby creating incentives to make more organized arrangements for distributing relief. The 1982 Act mentions both disaster relief and disaster preparedness and provided for the establishment of the Central Disaster Relief Committee under the Home Ministry. It was amended three times, in 1986, 1989 and in 1992. The amended version covers the preparedness and rehabilitation aspects of disaster management and broadens its scope to include all disasters, including industrial accidents. The Act has envisaged an organizational hierarchy for dealing with natural disasters: a central level committee consisting of the Home Minister, Defence Minister, Supplies Minister, Finance Minister, the secretaries of these ministries, representatives from the army, NGOs, and representatives from affected districts. The hierarchy of committees included a regional committee, a district committee, and an *ilaka*-level committee. In its vision, depending upon where a disaster occurs, committees at appropriate levels are activated. The Act can be operationalized before or during a calamity to prevent or mitigate its effect or to provide relief and rehabilitation after a disaster occurs. A special disaster unit was created to function as the committee's secretariat and long-term plans for disaster mitigation were prepared. At the same time, a Natural Calamities Assistance Fund was established under the chairmanship of the Home Minister.

A major earthquake that struck Nepal in the mid-1980s underscored the need for a comprehensive disaster mitigation policy. In 1988 the heads of state and governments of the SAARC countries at their meeting in Islamabad decided to undertake two studies, 'The Causes and Consequences of Natural Disaster' and 'The Protection and Preservation of the Environment'. As a part of this study, Nepal's national report was published in 1990. Two years later, in 1992, Nepal's revised Relief Act was amended again. Following the United Nation's declaration of the International Decade for Natural Disaster Reduction (IDNDR) in 1994, Nepal established a national committee for the IDNDR under the convenership of the Home Minister. Subsequently, a national action plan for disaster mitigation was formulated but the lack of consistent co-ordination in its implementation suggested that it had serious teething troubles.

A year later, in 1995, the plan was modified. The following year, the government approved it, naming it the 'National Action Plan on Disaster Management in Nepal'.

The plan actually comprised four plans: a disaster preparedness action plan, a disaster response plan, a disaster reconstruction and rehabilitation plan, and a disaster mitigation plan (Rana, 1996). Each prioritized activities, delineated responsibilities, and stipulated time frames for monitoring and evaluation. Overall, the action plan specified (a) priority activities to be undertaken in the field of disaster management (including flood mitigation), (b) responsible agencies, and (c) time periods for completion.

In theory, Nepal has laws, policies, and departments to respond to floods and their impact, although its approach is the dominant, reactive one, executed only after an event has occurred. There are two strands of response to flood disaster mitigation: the provision of relief and water resource development and management. By and large both occur within the rubric of political governance and public policy formulation. Responses to flood disaster mitigation are top-down, bureaucratic and *ad hoc*. Conventional approaches have failed to deliver: because they fail to acknowledge differences in social, economic, administrative, cultural, legal, and technological environments. Until the Ninth Plan (1997-2002), the government was silent on flood disaster mitigation, as Table 5 shows.

There is a discrepancy between the stated and actual roles of departments and between the promised and provided support that victims receive in the aftermath of a flood. At a fundamental level, these responses conceive of relationships among social, economic, administrative, cultural, legal, and technological environments in a linear and mechanistic sense, though in reality interactions among knowledge, resource bases and social organizations are equally important because the context itself is changed by their interactions. Recognizing these dynamics leads to a broader understanding of institutions as distinct from organizations.[31] Institutions, in contrast to organizations, demonstrate a pattern of values and behaviour within a socio-system and their functioning is sustained over a period of time. In other words, human institutions and physical components interact and influence each other through feedback loops over time.[32]

Conceiving of institutions in a broad sense results in a better understanding of the social dynamics that underlie responses to mitigating flood disasters. This is because institutions increase of benefits communities and families affected by floods by building on internal societal reliance and by negotiating with external support organizations or the market. The success of communities also depends on how they collectively exercise civil power, and that, in turn, depends on their access to information, knowledge, and, above all, the availability of alternative courses of actions. Access to information or knowledge is crucial, but much work is needed to transform information into usable forms of knowledge and to make it available to communities.

The combined result of the processes described above is that responses to flooding have not been effective. Flood-affected families, especially the poor, are left to fend for themselves in the aftermath of floods. At the same time, the failure of governance has

[31] This approach to institutional study acknowledges the interrelationship among knowledge, values, social organization, technology and the natural resource base. For detailed discussions see Gyawali, et al. (1993)

[32] Pelling (2003) refers to the concept of co-evolution by Norgard (1994) while discussing paradigms of risk in natural disaster discourse.

further exacerbated vulnerability. The response of state agencies to the 1998 disaster was predictable: it was a one time, relief-based response. The ongoing political crisis in Nepal has made the challenges of flood disaster mitigation even more daunting. Responses need to bring synergy between the macro and the micro. Flood disaster mitigation efforts must be anchored on the processes of empowering rural poor to move beyond poverty. In this effort, the issues to consider are (a) a blend of political devolution and actions for ensuring that there will be participatory decision-making about flood disaster mitigation measures; b) a mechanism for delivering services to poor families to enable them to access and rebuild household assets after a flood; (c) initiatives for natural resource management; and (d) the development of linkages with social auditors and catalysts who can facilitate and empower a community, building its capacity to demand services from state agencies and negotiate with the market to its advantage.

The devolution of responsibility for the management of common property resources to local levels is a key component of this process. Local participation must be fostered so that the social capital created, particularly among poor families, is linked to the dynamic sectors of the economy. Participation needs to create space for the poor to express themselves, and the devolution of decision-making authority to give them the power to determine ways to improve their lives. Empowering the poor is the foundation of rural poverty alleviation and, by extension, of overcoming the ills of flood disasters in a meaningful way. By engaging with civil society institutions, communities can access information that will be crucial to help them build their assets in the long-term.

Decentralization may reduce poverty where there is a reasonable level of concurrence between local leaders and their community as a whole in setting goals to raise incomes and build assets. These initiatives can be effective if social auditors actively question the role of the market and the approaches of state agencies. In the absence of contestation, however, the ability of poor rural families to overcome hardships is limited because the bureaucratic exigencies of state agencies hinder responsive mitigation. The dominant approach to flood disaster mitigation has serious problems with accountability. And unless the state introduces favourable policy measures, market institutions will have a very limited role in disaster mitigation.

Institutional innovations are prerequisites to helping the poor; but introducing a shift in approach is a daunting task. One challenge comes from the fact that the non-poor may monopolize institutions designed to meet the needs of the poor and influence the policies of the state of the market and even of NGOs to their benefit, at the cost of the poor. Often, those who control one institution also control others. For instance, even after land redistribution, large landholding farmers may continue to enjoy better access than the ex-landless not only to land but also to production, credit facilities, information and marketing networks, and because their livelihoods are more developed they have more insurance against disaster risks.[33] The central question is how the poor and the weak can benefit from institutional processes in the first place and sustain those benefits in the long-term.

[33] See IFAD (2000)

This question is a part of a long-term problem: even when decentralization and local governance structures do exist, political exigencies threaten to dismantle them and leave political voids. The dissolution of Nepal's elected local bodies (DDCs, VDCs and municipalities) has had serious political as well as procedural ramifications for resource management approaches, including flood disaster mitigation. On May 22, 2002, the government of Sher Bahadur Deuba dissolved both district and local-level governments because their terms had expired. The dissolution of elected local bodies was one of several quagmires Nepal faced at the time: a constitutional crisis, no possibility of immediate elections to the national parliament and the ongoing insurgency of the Maoists. In the absence of elected local bodies, even the relatively straightforward distribution of relief was seriously hampered during the floods of the 2002 monsoon.[34]

In 2003, the government of Prime Minister Surya Bahadur Thapa nominated mayors, chairpersons of DDC and other officials. Though it brought politicians in the place of bureaucrats to manage local bodies, these representations lacked the democratic legitimacy elections provide,[35] the process reflects deep challenges for institutionalizing representative local democracy in the country. Unlike the central government, which faced major dysfunctions in the decade following the restoration of democracy in 1990, local-level institutions had seen two cycles of elections and seemed, until they were dissolved, to have acquired some stability. Though the term of the local bodies expired in 2002, a provision to extend their tenure by one year did exist, but it was not used. Whatever the outcome of the impasse, Nepal must make provisions for devolving political and administrative powers to local institutions if governance is to be accountable and representative.

Decentralization can make access to information easier, and turn the institution more suitable to the local context and more sensitive to the needs of the community. As a result, decision-making comes closer to local communities. Unfortunately, information is very context specific.

In an ideal situation, as decentralized institutions become attuned to local needs, they become more transparent and accountable. In actual practice, however, the things play out very differently: the outcome of decentralization depends upon its context. Before 1990, for example, during the Panchayat Period, decentralization became synonymous with administrative de-concentration, a process that saw a several-fold expansion of the central bureaucracy rather than devolution of political power.[36] Massive amounts of external funds were channelled through DDCs and VDCs, but the majority of such interventions did not deliver, and their sustainability was fundamentally in question. Politically, the Constitution of 1990 is silent on the critical domains of the devolution of power and local self-governance. As a result, local government bodies such as DDCs and VDCs existed as extensions of the central

[34] In the monsoon of 2002, many hill districts of Nepal faced disaster due to cloudburst. The print media reported shortcomings in the provision of support to the victims beyond a one-time relief package See NWCF (2003) for a compilation of news reports about the relief provided.

[35] The Ambassador of the Federal Republic of Germany to Nepal in a public speech said that in the absence of elected representatives, foreign aid could not be utilized. He added that nominated members are not true representatives of the people *'Prajatantrik Soonyata ma sahayog ko auchitya chhaina*" See *Kantipur Daily* November, 22, 2003.

[36] See Martinussen (1993) and Blaikie et al. (1980) for discussions on the growth of bureaucracy in Nepal in the post 1950 period.

administration rather than as autonomous institutions of local self-government accountable to the electorate (HRD, 1998).

Nepal's Local Self-Governance Act (LSGA) promulgated in 1999 did include a discussion of local responsibilities, but is lack of political institutionalization, because continuity has been broken, the question of how to institutionalize local bodies question is particularly stark in the aftermath of the dissolution of the local governments.[37] Despite the break in the electoral process, there are ongoing initiatives in managing forests, irrigation systems, community-level micro hydro plants, drinking water supply systems and, more recently, electricity distribution that bring to the fore certain aspects of substantive democracy. In a theoretical sense, these initiatives provide a basis for pursuing community based flood disaster mitigation.

The involvement of flood-affected people, particularly the poor and marginalized, in local decision-making can make a difference in the distributional outcomes of flood mitigation activities within a village. Perhaps even the otherwise double-edged sword, relief, can become more humane and more effective, as arrangements for preparedness against floods can become responsive to local needs. While decentralization does have many benefits, local bodies will not necessarily be more accountable to the poor than centralized ones because the relationship between a local-level government and the community is a difficult one.[38] If centralized agencies are removed from the poor, decentralized organizations face the risk of being taken over by local elites unless safeguards are introduced. Independent social auditors can serve as vanguards, hence the emphasis that they contest the policy terrain and help mediate a balance of power in society.

While conceiving of institutional measures to mitigate flood disasters, it is necessary to examine interactions among governments, social auditors and markets as well as their proposals for interventions. The key questions are whether the suggested arrangements for mitigation reach, benefit and empower the poor and the affected communities, and, in the process, enhance their capacity to benefit from macro-level policies and whether participation in local institutions enables local communities to increase their general wellbeing and acquire the capacity to negotiate with external actors, whether they be NGOs, departments of state or the market. The role of such inter-linkages has not been investigated systematically or woven into approaches to flood disaster mitigation. Doing so is the new challenge.

[37] The government headed by Surya Bahadur Thapa in 2003 began nominating past elected representatives to the posts of mayor and district government chair. Though nominating political figures may have circumvented the void in local governance, it reflects a deep crisis facing Nepal's body politics as elected representation is non-existent.

[38] The following arguments by Iyer (2003) encapsulate this difficulty: "In a parliamentary democracy people elect their representative to local level bodies, legislative assemblies, and parliament and their interest can be presumed to be taken care by these representatives. In this case, there is no question of any conflict between the state and the people, and there would be no need at all for any movement to empower the people." But reality is main different. On a reflective note it can be suggested that parliamentary governance approaches focus on balancing power among the executive, judicial and legislative functions. In South Asia, however this structural triad has not been successful in yielding a power balance among social relations and particularly between the state and civil society (Moench et al., 2003). This contradiction is particularly clear in the case of providing water-related services and flood mitigation. Only by introducing a balance of power among different interests as a key feature of governance will the process of flood mitigation become effective.

Summary and Key Findings

The above sections elaborated the trajectory of institutional development in India, Pakistan and Nepal with regard to disaster management. All three countries are currently susceptible to natural disasters, and climate change scenarios predict that the incidence of natural disasters in the region will increase. Although the three share a geographical area, the political scenario in each country is quite different. India is the world's largest democracy, Pakistan has just returned to civilian democratic rule after a long spell of military dictatorship, while Nepal has just put an end to its monarchy and is moving towards democracy. Despite these huge political differences, the countries' approaches towards natural disaster management are quite similar. Their similarities are highlighted in the key findings arranged by country in the next and the last sub-section.

Most of the disaster-related institutions in each country were formed in the wake of large events. Being home to the world's largest river basins has forced each to address the risk of flooding. Departments such as irrigation, water and power are at the forefront of disaster reduction activities and have focused on constructing large infrastructure to harness the natural risk. Pakistan did devise specialized provincial-level organizations for flood control, but with time, these were converted to the Federal Flood Commission. With each progressive disaster, there was a tendency to create new organizations with even more centralized power and funding.

At the same time there was a realization that calamity acts that dealt with the post-disaster situation needed to be replaced with policies that also help avert disaster and mitigate their impact. Nepal started developing such legislation after a massive earthquake in the early 1980s. In 2005, with the help of international agencies, India and Pakistan established agencies, national disaster management acts, and frameworks. These institutions are still nascent and it will take some time before they can be effective on the ground.

In the meantime, the strict departmental/sectoral focus regarding various forms of disasters continues. There is a general disjunction between the functions of these departments and the need for risk reduction. Issues remain in terms of administrative and geographic jurisdictions, sectoral approaches to multi-hazard scenarios and the general lack of coordination of disaster risk reduction. A rising sense of political and humanitarian urgency with regard to disasters is leading towards a centralization of disaster risk management. For policy and resources, this may be the correct action, but to be effective, disaster risk reduction has to be managed at the local level.

There is also a shared lack of mechanisms for incorporating learning from experiences into future policies. Whenever there are lessons to be learnt, they are conveniently ignored. Government institutions at the planning level and other public, private or non-profit organizations of learning have not yet turned their attention towards research into proactive risk reduction.

Our cost-benefit analysis of some of the common risks across India, Pakistan and Nepal shows key lessons that can be learnt by making such an analysis. One needs to be able to identify and compare different approaches to risk reduction and recognize that each case is unique. In one case we found that soft community based approaches can be more cost effective than hard, structural approaches. This is primarily due to the side effects associated with embankments, such as loss of land due to water logging. When such costs are included in the analysis, it substantially reduces estimates of the net economic benefit. In contrast, in that case many of the softer measures generate consistent benefits and have few negative side effects. Net returns can also be low with softer measures. For example, in the case of early warning on the Lai River in Pakistan, the existing investment in early warning has a low economic return because it provides insufficient advanced warning (about 15 minutes) to enable people to move or otherwise protect economic assets and the system was designed with a heavy focus on expensive hardware.

We found that both the process and the results were very useful in deriving cost-effective, pro-active disaster risk reduction activities. Identifying and analyzing options with all stakeholders not only increased the range of options but also lent transparency and trust to the process. It allows for inter-sectoral dialogue and drew attention to strategies that were not traditionally discussed. In one hypothetical case we discovered that the costs and benefits of the combination of a micro-insurance scheme and borehole irrigation would be more cost-effective than either one of them alone.

The new national frameworks of all three countries do include national disaster management institutions that could easily incorporate cost-benefit analysis and thus devise effective pro-active disaster management. In fact, these institutions could become home to such methods and tools. There is a dire need to evaluate the current sectoral strategies to make sure they do not actually increase vulnerability. In particular, increasing use of groundwater in parts of Pakistan and constructing embankments in India and Nepal may actually be reducing the resilience of communities. On the other hand, introducing some innovative financial products and decentralized household-level strategies may be economical than providing the traditional hard resilience to everyone.

With climate change impending and the frequency of natural hazards projected to increase there is a great need to further explore risk reduction strategies. In the discussion at international level, policies related to climate change are increasingly emphasizing adaptation, and new funding is being allocated to developing countries for this purpose. With this new development, there is an increasing need to collectively and transparently devise strategies that will help poor nations deal with future scenarios. Risk-based probabilistic cost-benefit analysis just may be one important tool for making headway in this new field.

Very few mainstream interventions are being made to help countries cope with impacts of climate change and the inherent risks that it may bring. All three countries have nevertheless managed to move toward disaster management from reactive disaster relief, at least in the policy arena. Below are the key policy findings about each country:

India

- India passed the National Disaster Management Act in 2005 in the wake of the Gujarat earthquake and other natural disasters in the recent decades. It is in the process of rolling out different components of this framework, but is still far from reaching any degree of functionality at the local level.
- This act calls for pro-active disaster management instead of the relief-centric approaches in practice. It foresees that the central apex body and sectoral state departments work make a coordinated effort in risk management. To implement this approach will require massive resources, especially as even the sectoral approach to relief provision currently employed finds it difficult to work across administrative boundaries and the new approach requires much more coordination.
- At the local level, it is important to develop the capacity for disaster risk reduction through NGOs, local institutions by pursuing capacity building programmes. With the exception of a few areas the means to build local capacity are lacking.
- There have been formal government led efforts to review past practices in flood control and to improve disaster management approaches, but the findings and recommendations of such exercises have not been incorporated and business proceeds as usual.
- The Agricultural Insurance Company of India Limited has started weather-related risk pooling through a crop insurance scheme that is mandatory for farmers who take out agricultural loans and optional for others. Since the premium is subsidized at 50%, it is more a social security scheme than a market based instrument. Knowledge about and uptake of this risk-sharing instrument seemed very low in our project areas because of a lack of awareness about such opportunities.
- Foreign actors such as UNDP have started massive disaster risk reduction activities at the local level. One such programme covers 169 districts in 17 states. Although good results are expected from this programme there is no indication who will continue this programme in these states and replicate it in other state in the future.
- The weather-related data needed to project climate change is rarely available as weather stations are so sparsely placed. In additions, state policy puts restriction on non-governmental individuals and entities from accessing river discharge and other data.
- There is no framework for integrating and evaluating various approaches to disaster management. For example, there is no platform for promoting alternative to the current infrastructure-based solutions.

- A comprehensive cost-benefit analysis can help address many of the problems and constraints outlined above. It can serve as a framework for data organization and analysis that can promote a multi-stakeholder process in identifying and prioritizing various disaster risk reduction strategies across ministries, departments and international humanitarian and private organizations. A process-oriented approach can also promote dialogue among stakeholders.

Pakistan

- Pakistan has undergone a progressive centralization of disaster risk reduction due to the creation of national level bodies such as the Federal Flood Commission (FFC), the Drought Emergency Recovery Authority and the National Disaster Management Authority. The latter is to be established at the provincial and local levels in the future but remains focused on the national level for now. The role of existing disaster-related organizations and linkages at the local level is still not clear for effective DRM.
- Pakistan has followed a sectoral approach to disaster management although hazards are multi-dimensional and often require multi-sectoral solutions. For example, in the Lai basin it is as important to prevent health risks from polluted waters as it is to manage the flood risk. Unfortunately, hierarchical government structures prevent cross-sectoral approaches from being adopted.
- Devolved risk management organizations face jurisdictional issues, as disasters do not follow administrative boundaries, whether we refer to large floods that cross provinces or to those that occur at a very local level. To cite an example, storm water drainage from Islamabad floods the old city of Rawalpindi few kilometres downstream, but the well-resourced Capital Development Authority does not consider it a local issue and the municipalities in Rawalpindi do not have the wherewithal to deal with such large-scale hazards. There are no mechanisms to overcome such jurisdictional overlaps and decide on an appropriate scale of management depending on the nature of the risk.
- For several reasons, Pakistan has not developed a learning environment and simply continues to implement past practices regardless of their ineffectiveness. First, there is little exchange or analysis of the limited information and data available. Data and development planning documents are kept well guarded to prevent public censure. Second, few organizations have the ability to carry out research on the effectiveness of various approaches to and competing strategies for disaster management. No university and no public, private or non-profit research institute caters to multi-disciplinary research into disaster management though the National Disaster Management Framework of 2005 envisages this.
- The result of the above gap is that Pakistan continues to focus on mega projects, whether they cater to overall development activities or those focused on disaster risk reduction. The concept of soft, resilience-enhancing non-structural strategies for vulnerability reduction has yet to enter the formal planning process or documents of Pakistan.
- In the wake of the 2005 earthquake and growing awareness about the impacts of climate change at the global level, future planning documents like Pakistan's Poverty

Reduction Strategy Paper (PRSP) and other prospective plans are likely to include disaster risk reduction as an explicit part of programming.

- There is much scope for the application of probabilistic cost-benefit analysis in disaster risk reduction in Pakistan. With climate change likely to result in chains of impacts within and across sectors of the economy and society, there is a need to prioritize impacts and risk management strategies to address them. Various policy options can benefit from using cost-benefit analysis to decide on their prioritization and adoption.

Nepal

- Although disaster relief is organized down to the district level, the management of risk is spread across various line agencies, these ranging from the DoI to the DWIDP to local governments. At the policy level, the Water and Energy Commission (WEC) is meant to provide policy guidance, but the Water Resource Strategy (2001) that the WEC needs to be strengthened and reorganized if it is to play an effective role in water resource and risk management.
- Although the Local Governance Act of 2055 (1999) provides for the devolution of the power to plan and formulate policies to local bodies, most local offices act as subsidiaries of the central government because of the abundance of vertical programmes that are financed locally and through donors. Previous experience in the local governance of natural resources show that there is a great potential for effective disaster risk management at the local level.
- International NGOs such as Oxfam, Practical Action and ActionAid have started working in disaster risk reduction. Their efforts led to the development of a Disaster Preparedness Network, which involves local organizations in disaster relief activities.
- In times of disaster, the UNDP's in-house Disaster Management Secretariat has served as an information clearinghouse, undertaking needs assessments, seeking donor pledges, and coordinating of relief operations between government and donor agencies.
- The Natural Calamity and Relief Act was promulgated in 1982 and revised in 1986, 1989, 1992 and 1996 because of problems in its implementation. In 1995, it was renamed the National Action Plan on Disaster Management in Nepal. This plan includes disaster preparedness and mitigation along with plans for monitoring and evaluation. In reality, disaster became part of national planning for the first time only in the Tenth Plan (2002-2006).
- Decentralization and local governance of natural resources, especially common pool resources, is essential for reducing the vulnerability of poor communities affected by disasters. These steps will not only result in better management and growth in non-disaster situations but also lay the foundation for making risk reduction policies that protect those who are most affected.
- Further stronger linkages need to be forged with state departments, the market and NGOs so communities can benefit from their activities.

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CHAPTER 9

Reflections on the Value of the Cost-Benefit Analysis Process

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Conclusions

The analyses presented in the chapters above clearly document that disaster risk reduction can generate economic returns that are both positive and competitive with other channels for public investment. All forms of risk reduction do not generate equally high returns, however. In fact, when indirect costs and negative impacts (disbenefits) are considered, some forms of risk management, such as the construction of embankments for flood control, may not be economically efficient at all. The fact that the cost of an embankment may outweigh its benefits does not imply that infrastructure-based flood control strategies are inherently inappropriate. Instead, it points toward the need for selecting strategies carefully and for implementing them in ways that both respond to local conditions and reflect the costs, benefits and disbenefits associated with them. As the Pakistan case study demonstrates, even strategies that generally have high benefit-cost ratios, such as early warning systems, can generate negative returns if they are not carefully designed in ways that minimize costs and account for the maintenance and operational inputs required to ensure sustainability.

The Value of the Cost-Benefit Analysis Process

As many of the chapters in this report have emphasized, much of the value in conducting a cost-benefit analysis lies in the process. If a cost-benefit analysis is carried out appropriately (that is in a transparent and participatory manner) the process of conducting it forces analysts, policy-makers and other actors involved to do two things: *first*, specify the precise links between an intervention and the reductions in risk it is intended to generate; and, *second*, to evaluate whether or not the data available substantiates those links. Furthermore, because the data on hazards and the benefits of risk reduction are generally insufficient to fully quantify those links, the process of conducting a cost-benefit analysis makes participants consider and reach a common understanding about the assumptions made. These points highlight the fundamental importance of the process of the cost-benefit analysis.

A second key value in conducting a cost-benefit analysis relates to the identification of tangible interventions and their relationship to specific risks. Groups, such as policy-makers, development actors, and academics, often talk in broad terms of the need for "adaptation" to climate change or of the role of "disaster risk reduction" without really considering the complex relationship between an intervention or set of interventions on the ground and the risks they are intended to mitigate. The technical and economic effectiveness of a project designed to control flooding by constructing embankments, for example, depends heavily on a wide variety of factors including: (1) the frequency and magnitude of actual flood events and how they relate to the types of events anticipated in the project design; (2) the operational lifetime of the embankments and its relationship to the design lifespan; (3) the actual cost of constructing the system and how it relates to the cost projected at the time the system is designed; (4) the degree to which externalities, such as water-logging behind embankments, were effectively identified and addressed in the design; (5) the nature and cost of the systems of maintenance and whether or not they are implemented regularly; (6) the nature of the assets in both protected and otherwise affected areas and how they evolve; and (7) what reductions in assets and other losses are actually incurred with the embankment system in place as opposed to what losses would have been incurred had the system not been constructed.

Evaluating the technical and economic effectiveness of an embankment system requires understanding and evaluating each of the above seven factors. Since, in virtually all cases, particularly in developing country contexts, there simply is not enough data to accomplish such an evaluation in a fully quantitative manner, important assumptions must be made. How accurate these assumptions eventually prove to be determines the validity of the analysis and, ultimately, the technical and economic effectiveness of the intervention.

In general there will be no basis for understanding cost-benefit relationships—and thus for informed decision-making—unless these assumptions are transparent and subject to intense scrutiny. Conducting cost-benefit analyses in an open and transparent manner enables assumptions to be evaluated and helps lay out clearly the relationship between proposed interventions and their intended impacts. This is fundamental to informed decision-making.

A closely related point is the need early in the process to clarify and agree upon the objectives, information needs and data situation among the stakeholders. The type of envisaged product is closely linked to its potential users. A cost-benefit analysis may be conducted for informational purposes, as a pre-project appraisal, as a full-blown project appraisal or as an ex-post evaluation. Purposes, resource and time commitments and expertise required differ significantly for these products. For example, information required is substantially different between cases involving a development bank or a municipality, between small-scale and large-scale investments, planning physical infrastructure or capacity building measures, and between mainstreaming risk in cost-benefit analysis versus cost-benefit analysis for disaster risk management. At a very early stage, interested parties need to achieve consensus on the scope and breadth of the cost-benefit analysis to be undertaken. In our project, we pursued this for our case studies through a combination of scoping exercises, shared learning dialogues and qualitative assessment prior to any decision on undertaking a more comprehensive cost-benefit analysis. Furthermore, even after quantitative analyses were completed, it was essential to review results in the light of qualitative information that cost-benefit analysis is not designed to consider. Such information may relate to cultural values or the distribution of benefits between different groups within society. As a result, approaches that start with qualitative forms of evaluation before proceeding to more quantitative forms and then return to qualitative analysis are, we believe, central the role cost-benefit analysis could play as a decision support tool.

Challenges and Limitations of Cost-Benefit Analysis for Assessing Disaster Risk Reduction

Estimating risk and the costs and benefits of disaster risk reduction is inherently complex. Disaster events are in essence probabilistic events; consequently, benefits due to risk management arise only when disasters occur. Benefits should be assessed in terms of probability multiplied by the consequences, leading to an estimate of risk. However, the treatment of risk in cost-benefit analysis (and disaster risk management generally) is often ad-hoc and assessments focus on past events rather than potential future disasters, possibly resulting in an underestimation of damages and an underinvestment in preventive measures.

The need to account for climate change when assessing future hazard intensity and frequency adds considerable complexity and resource demands. Climate modelling and downscaling are key input requirements but the results of models are inherently uncertain and depend on numerous assumptions. In many cases, this may make projections of future event probabilities highly uncertain, undermining the analytical basis for estimating the costs and benefits of investments in risk reduction. At minimum, assumptions and uncertainties must be sufficiently communicated and understood in order to properly interpret results derived in a cost-benefit analysis.

Furthermore, general methodological challenges affect the analysis. Valuation of health, environmental, cultural and many other aspects is extremely difficult. In some cases, such as human life, challenges in the assignment of monetary values are compounded by inherent ethical issues. An additional challenge is accounting for indirect impacts of disaster (e.g. increased prevalence of diseases post-disaster, higher transport costs due to loss of infrastructure, increased costs due to business interruption) and how they may be reduced through interventions. Indirect damages can be substantial and sometimes even exceed direct impacts, yet due to methodological limitations, social and indirect economic effects are rarely included in the analysis. As a result, assessments primarily focus only on direct impacts, leading to a partial picture of potential disaster impacts to be avoided and an incomplete cost-benefit analysis.

Vulnerability and Distributional Analysis

The fact that conventional approaches to cost-benefit analysis do not address distributional issues is an additional significant limitation in the cost-benefit analyses of disaster risk reduction options conducted for this report. As Chapter 5 on the qualitative analysis of the costs and benefits of different strategies for flood risk reduction in Nepal illustrates, some strategies have major distributional implications. In the case of flood control structures, for example, individuals living within protected areas often benefit while those who live in adjacent unprotected areas suffer. In fact, such discrepant impacts are part and parcel of flooding since water prevented from flowing in one area still needs to drain somewhere. While, in some cases, the benefits may still exceed the costs, clear winners and losers generally exist.

Similar, although somewhat more subtle, distributional effects may be present with other disaster risk reduction strategies as well. In the case of drought mitigation strategies, for example, it has often been argued that constructing wells for groundwater irrigation disproportionately benefits the relatively affluent because they have more land and can afford to purchase pumps and fuel. The case of insurance is similar. The history of financial service institutions in India suggests that skill in negotiating with bureaucracies and knowledge of rights are critical factors in obtaining insurance payouts. Such subtle distributional impacts were not documented in the case studies conducted for this report but the potential is important to recognize and highlights the inadequacies of conventional cost-benefit analyses. It is necessary to introduce complementary processes that address the differential dimensions of vulnerability and the distributional implications of strategies in order to generate a more holistic basis for decision-making.

The vulnerability analyses conducted as part of the case studies documented in this report, along with the vulnerability index developed by several of the project participants as part of our overall methodology (see Chapter 2 in this volume and Risk to Resilience Working Paper Number 2), represent an initial step in this direction. However, additional research is needed to develop tools that enable us to integrate vulnerability and economic analysis. Since the objective of most investments in disaster risk reduction and adaptation to climate change is to assist vulnerable communities, *tools that clearly identify who benefits and who bears the cost of interventions to reduce or spread risk are critical to inform decision-making*. Such tools may enable decision-makers to understand how the costs and benefits of different strategies are distributed in relation to any key target group (women-headed households, wealthy, hazard exposed, etc.). Consideration of distributional issues requires a substantial expansion beyond the conventional focus of cost-benefit analysis, which is only on the economic returns of an intervention to society as a whole.

The Policy Context

The policy context across South Asia highlights the importance of processes that enable the costs and benefits of alternative approaches and their distributional implications to be evaluated transparently.

Detailed analysis of the policy context in India, Nepal and Pakistan clearly shows the centralized policy-making environment as far as disasters and climate change are concerned. There is substantial rhetoric about the need for community participation in disaster risk reduction but, in most cases, actual participation is limited. Initiatives to reduce disaster risk, particularly when implemented in response to specific disaster events, are often influenced by populist or other considerations rather than by their true role in risk reduction. Another limitation is that the policy environments in all three countries limit learning. As discussed in more detail below, key points from analysis of policies in each of the involved countries confirm these observations and point toward the role participatory approaches to cost-benefit analysis could play.

Pakistan

Pakistan's approach to disaster risk reduction has become progressively centralized since it created several national-level bodies such as the Federal Flood Commission, the Earthquake Rehabilitation and Reconstruction Authority, and the National Disaster Management Authority. The latter is eventually to be established at the provincial and local levels, but it remains focused on the national level for now. A lack of clarity regarding the role of existing disaster-related organisations and their linkages at the local level still exists and needs to be resolved if disaster risk management is to be effective. The effects of centralization are compounded by the government's sectoral approach to disaster management despite the fact that hazards are multi-dimensional and often require multi-sectoral solutions. The Lai Basin case study highlighted the importance of preventing the health risks associated with polluted flood waters rather than simply managing the direct risk of flooding. However, since cross-sectoral approaches are not implemented, doing so has proved difficult. With devolved risk management organisations, jurisdictional issues arise as disasters do not follow administrative boundaries. This applies to floods across provinces and as well to those that occur at a very local level. For example, storm-water drainage from Islamabad floods the old city of Rawalpindi just a few kilometers downstream, but the well resourced Capital Development Authority does not consider it a local issue and the Rawalpindi municipality does not have the wherewithal to deal with such large-scale hazards. Mechanisms to overcome such jurisdictional issues are limited, so rarely is there an appropriate scale of management, reflecting the nature of the risk.

Where Pakistan is concerned, several factors contribute to the lack of learning and the continuation of past practice, however flawed. First, there is little exchange or analysis of information and data, whatever little is available. Data and even future development planning documents are kept well-guarded to prevent public censure. Second, few organisations have the capacity to carry out research on the effectiveness of various approaches or on competing strategies for disaster management. No university and no public, private or non-profit research institute caters to multi-disciplinary research on disaster management. A National Institute for Disaster Management is envisaged in the National Disaster Management Framework of 2005, but has yet to be established and it is far from clear how it would effectively transmit learning across sectors and scales. Consequently, Pakistan continues to emphasize mega projects, whether they promote overall development activities or focus on disaster risk reduction. The concepts of soft resilience and non-structural strategies for vulnerability reduction are limited in the formal planning process or documents of Pakistan. There have been some recent efforts towards risk pooling of farmers through the "Crop Loan Insurance Scheme" approved by the Government in July 2008. This plan supports small farmers to mitigate risk from natural disaster-related damage to major crops including wheat, rice, sugarcane and cotton. However, this initiative is recent, and has yet to yield results.

In the wake of the 2005 earthquake and growing awareness on climate change at the global level, there is potential for Pakistan to include disaster risk reduction as an explicit part of its national planning and related documents, such as the Poverty Reduction Strategy Paper. The application of probabilistic cost-benefit analysis may support this fiscal planning. At the same time, as discussed extensively above, it may also contribute to learning and provide a framework for cross-sectoral and cross-scale learning. With climate change likely to result in chains of impacts within and across sectors of the economy and society, it is necessary to prioritize impacts and risk management strategies.

India

In the wake of the Gujarat earthquake and other recent natural disasters, India passed a National Disaster Management Act in 2005. It is slightly ahead of Pakistan in rolling out different components of the framework, but still far from functioning adequately at the local level. The Act calls for proactive disaster management instead of the relief-centric approaches that have dominated past practice. It foresees coordination of risk management by its central apex body and sectoral state departments. Implementation of this approach will require massive effort and resources. Even with the current practice of sectoral approaches to relief provision, it has been difficult to work across administrative boundaries. At the local level, it is important to have developed the capacity for disaster risk reduction through NGOs, local institutions and capacity building programs but, with the exception of few areas, little effort has been made to scale up or replicate. One exception is the work of the UNDP: the global agency has started major local level disaster risk reduction activities in 169 districts in 17 states. Although good results are expected from this initiative there is no indication of who will continue this programme in these states and replicate it elsewhere in the future. Decentralisation is being attempted but the ability to sustain the effort is open to question.

India has made some progress in fostering a learning environment. The National Institute of Disaster Management (NIDM) established over a decade ago has played a major role in training disaster managers at the state and central levels, but it is relatively small in relation to the scale of training and knowledge management needed. Furthermore, its main focus is on disaster management organisations rather than on the many organisations in other sectors whose activities are equally central to disaster risk reduction. Limitations of state efforts toward learning in disaster risk reduction are evident in the case of floods. There have been formal government-led efforts to review past practices in flood control and to improve disaster management approaches, but the findings and recommendations of such exercises have not been incorporated. It generally has been "business as usual", particularly within sector-specific agencies. Furthermore, there is a lack of framework for integrating and evaluating different approaches to disaster management.

Organizations working in India have identified and are working with the government to pilot major alternative approaches to disaster risk management. The UNDP-supported programme mentioned above is a case in point. A variety of programmes to manage risk through the development of innovative financial mechanisms are also emerging. The Agricultural Insurance Company of India Limited, for example, has started weather-related risk pooling through a crop insurance scheme that is mandatory for farmers who take out agricultural loans and optional for others. The premium is subsidized up to 80%, and as such, it may be considered more of a social security scheme than a market based instrument. The uptake of and knowledge about this risk-sharing instrument seemed very low in the Uttar Pradesh case study area. Even in these pilot efforts, the ability to learn is hindered by the absence of a platform and framework for promoting or systematically evaluating alternatives to current approaches. Learning is also affected by the limited availability of and access to data. Weather-related data to be used for predicting climate change, for example, is rarely available at the local level in vulnerable areas such as eastern Uttar Pradesh because it is sparsely recorded. In addition, non-governmental individuals and entities are restricted from accessing river discharge and other data.

In addition to inadequate attention to learning, the Uttar Pradesh flood case study also highlights a number of other limitations in the policy environment. First, there is a lack of coordination amongst the sectoral government agencies involved in different aspects of flood management. Each has its own independent agenda which does not take into account common concerns. Second, administrative and physical boundaries often do not match: flood management must be at the basin level, but most river basins fall within several administrative boundaries. Most actions directly concerned with floods thus are designed and implemented at the administrative level though their implications are felt at the basin level. Third, there appears to be a disjuncture between community needs and government programmes. While a cross-sectoral approach is required to address the basic needs of communities in flood prone areas, government flood management plans generally do not focus on the entire gamut of needs and potential interventions. In particular, livelihood promotion, which has the potential to address root causes of flood vulnerability, is often not considered. Most rural development activities are designed at the national level and are common across the country, lacking mechanisms to respond to local contexts and specificities. For example, there are no specific features of rural development activities for flood prone areas. Despite the need for employing participatory bottom-up planning approaches when preparing official disaster management plans, in practice local people are rarely involved. Fourth, capacity of local level institutions is weak and needs to be strengthened. State institutions are often ill-equipped to implement local-level options and may not always be the most appropriate body. While civil society organisations have experience of working with communities and facilitating innovative approaches, they may not have the reach or the capacity to operate at large scales. Both civil society organizations and state must shift from their existing "relief" focus to a focus on long-term sustainable development.

A comprehensive participatory approach to cost-benefit analysis can help address many of the problems and constraints outlined above. It can serve as a framework for data organisation and analysis that can promote a multi-stakeholder process in identifying and prioritizing various disaster risk reduction strategies across ministries, departments and international humanitarian and private organizations. A process-oriented approach can also promote dialogue among stakeholders.

Nepal

Although disaster relief in Nepal is organized down to the district level, the management of risk is scattered across various line agencies which range from the Department of Irrigation to Soil Conservation and Water Management to local governments. National policies have been revised to better consider disaster risk management. For instance, the Water Resource Strategy (2001) called for strengthening and reorganizing the Water and Energy Commission (WEC), which is supposed to provide policy guidance, so that it can play a more effective role in water resource and risk management. The Natural Calamity and Relief Act was promulgated in 1982 and revised in 1986, 1989, 1992 and 1996. After many implementation problems, it was renamed in 1995 as the National Action Plan on Disaster Management in Nepal. This plan includes disaster preparedness and mitigation, along with plans for activities including monitoring and evaluation. Despite these acts, disasters have not received substantial attention at the highest policy levels until relatively recently. Disaster-related issues were incorporated for the first time in the Tenth Plan (2002-2006).

Where implementation of disaster risk management and related activities is concerned, the Local Governance Act of 2055 (1999) provides for the devolution of powers to local bodies to plan and formulate policies. Despite this legislation, most local offices act as subsidiaries of the central government because programmes are financed vertically whether financed by the government or donors. The role of international organizations in supporting disaster risk management in Nepal is much larger than it is in either India or Pakistan. International NGOs such as OXFAM and Action Aid have established a Disaster Preparedness Network involving local organisations in disaster relief activities. In times of disaster the UNDP's in-house Disaster Management Secretariat has served as an information clearinghouse by undertaking needs assessments, seeking donor pledges, and coordinating relief operations.

Experience in the local governance of natural resources shows that there is a great potential for effective disaster risk management at the local level but at present this potential is not effectively reflected in the policy environment. As the array of strategies for risk management documented in the Nepal case study illustrate, decentralisation and the local governance of natural resources, especially common resources, is essential for reducing the vulnerability of poor communities affected by natural disasters. Local governance will not only result in good management and growth in non-disaster situations but also lay the foundations for making risk reduction policies that protect those who are most affected.

At present, consistent frameworks for evaluating alternative approaches to disaster risk management are limited in Nepal. As in the India and Pakistan contexts, the adoption of participatory processes for the cost-benefit analysis of different risk management strategies could contribute substantially to strengthening the policy environment at both local and national levels in several ways. For instance, the results generated will highlight returns to different strategies in ways that draw attention at policy levels. In addition, the process of conducting participatory cost-benefit analysis should in itself draw actors together and help to identify points of entry for action at different levels in ways that help organisations cross sector boundaries and encourage the devolution of responsibility to those levels with the greatest comparative advantage for actual implementation.

Insights from Cases

Each of the case studies conducted for this project generated key insights that are directly relevant to the management of disaster risks under changing climatic conditions. These insights are summarized briefly below.

Uttar Pradesh Flood Management

The Uttar Pradesh case study on flood management suggests that decentralized, people-centred approaches to managing flood risk are likely to be more economically robust and to generate more widespread benefits for local populations than centralized flood control structures. While flood control structures will remain important in some contexts, the core need is to invest much more heavily in decentralized, people-centred approaches and in the maintenance of existing structures rather than to construct new ones.

The case study projects that flood impacts in the Rohini Basin will increase in the future (to 2050) due to climate change. Small floods will occur more frequently (about twice as frequent than present), while the rare but intense floods may remain relatively consistent. These changes will result in a two-fold increase in future average annual economic loss due to floods.

An historical analysis of embankments following a cost-benefit analysis based primarily on direct structural engineering costs shows a high benefit-cost ratio, indicating economically efficient performance. When conservative estimates of disbenefits, more realistic costs and actual structural performance are incorporated, however, the ratio decreases substantially. Given the many uncertainties involved, it cannot be concluded that the Rohini River embankments have been cost-effective. Furthermore, the benefits from constructing new embankments depend heavily on the accuracy of future climate change projections. If the floods that actually occur exceed the maximum threshold flows for which embankments are designed, then major disasters are likely to occur. Since with climate change the magnitude of future floods is highly uncertain, the economic efficiency of embankments and other strategies that depend on similar design thresholds is equally uncertain. This said, analysis indicates that proper embankment maintenance, even under climate change projections, is economically efficient although economic performance will decline.

In contrast to embankments, the economic efficiency of the people-centred strategy does not decline due to projected climate change impacts. Moreover, due to the lack of a large upfront investment as is necessary for embankments, the results are not particularly dependent on the discount rate because benefits are greater than costs every year and even accrue in non-flood years. The resilience-focused approach of the people-centred strategy means that the increased flood risk projected as a consequence of climate change does not reduce overall benefits.

Uttar Pradesh Drought Management

Key conclusions from the study on drought management in Uttar Pradesh indicate that climate change may cause an increase in the frequency of droughts. In Uttar Pradesh, the non-monsoon eight months receive only 20-30% of the total annual rainfall. Model result suggests that non-monsoon rainfall will decline by as much as 40% as climate change proceeds. This change in rainfall will likely have significant adverse consequences on the rural livelihoods in the state.

Our analysis shows that reducing drought risk by constructing borewells for groundwater irrigation and by spreading risk through the introduction of a hypothetical subsidized crop micro-insurance programme both yield benefit-cost ratios of greater than one. Although most groundwater development in India has been through private sector initiatives, in the case we evaluated, borewell construction would be subsidized by public resources in order to target particularly poor and vulnerable communities, yet pumping activities, as is current practice, would be paid by the households themselves. However, the lack of disposable income on the part of poor households reduces the benefits of groundwater irrigation as people cannot afford to pump regularly; they only irrigate if rain fails at critical stages of crop growth.

The hypothetical insurance scheme is hardly affordable by those at risk and would be beneficial only if about half of the premium is subsidized. However, if we look at the substantial cost of government disaster relief post event vis-à-vis the cost of insurance premium to be paid by the government for both household and state level financial security, it is comparable in magnitude. Since the insurance scheme considers households close to the poverty line, the subsidy is justified as a poverty reduction investment.

Returns would be particularly high if a combination of both the evaluated strategies were implemented simultaneously reducing and transferring risk. In this case, borewells would cover the risk of high-frequency, low-intensity droughts while insurance would cover part of the losses from crop failures caused by large, less frequent droughts. This combination gives a better cost-benefit ratio than either of the two interventions alone. In the case of climate change, when drought becomes more frequent, this third strategy will intensify benefits. It is, however, important to recognize that the benefits of insurance (relative to the cost) decline under the climate change scenarios evaluated.

That is, because of difficulties in projecting the probability of loss events and the likelihood that such events will increase in frequency, the viability of insurance as a mechanism for addressing drought risks appears likely to decline as climate change proceeds.

Although complex in nature due to a fully probabilistic approach and the requirement for numerous simplifying assumptions, the Uttar Pradesh drought study reveals two main conclusions. First, achieving economically efficient returns to investments requires ingenuity in formulating disaster risk reduction strategies. Second, strategies must be targeted according to specific needs.

Rawalpindi–Lai Basin Flood Management

All four interventions considered for flood risk reduction in the Lai Basin generate favorable benefit-cost ratios. This finding reflects the high value of almost any intervention to reduce disaster risks in urban contexts. Even so, different strategies generate very different returns. For instance, concrete paving of the channel in the midsection is far less beneficial than channel improvement in the lower reaches of the Lai. Because the Lai is short and the equipment expensive, the early warning system implemented is less beneficial than improving basic services such as health, water and sanitation. Although it is not cost effective, the low level of investment required made the early warning system the most viable project for the government. A more effective and cheaper strategy might be to provide early warnings using short messaging services on cell phones.

Many conservationists and Rawalpindi locals would like to see the Lai River restored to its natural state. The cost-benefit analysis shows that although the results are positive, the cost of ecological restoration of the Lai flood plain (which would require relocation of people out of the flood plain and opening up space around the river for vegetation growth) is the most expensive of all four strategies. The issues of untreated sewage from both Islamabad and Rawalpindi and solid waste from the localities around the Lai also need to be investigated. Moreover, Pakistan's archaic land acquisition laws tend to benefit the rich and discriminate against the poor. Most people living along the Lai rent their houses, but tenants are not compensated for flood-related damages. In addition, many of the houses encroach on public property, making them illegal; the owners of these houses cannot claim benefits. In terms of the cost of land, the Capital Development Authority has a mandate to develop new housing and, in fact, owns large tracts of land for low-cost housing. If the houses along the Lai were exchanged for units upstream, the prospect of relocation would become very feasible as the authorities would only have to pay for land development and not for the cost of the land. This would have to be done, though, under a special project with more pro-poor policies and procedures.

Overall, the Lai Basin case study documents the economic value of most interventions to reduce risks in urban contexts. Such investments generate strong returns due to the high density of people and assets found in urban areas.

Nepal Qualitative Case Study

The assessment conducted in the Nepal case study area along the lower Bagmati River clearly demonstrates that there are both winners and losers from current investments in addressing flood risks by constructing embankments. Structural measures such as embankments and spurs provide short-term benefits to a few communities but have negative consequences downstream and in other unprotected areas. People-centred investments such as early warning, raising the plinth level of housing, boats, and so on have fewer costs to offset benefits they generate and appear far more resilient to changes anticipated as a consequence of climate change. It is unclear, however, if these strategies will be able to mitigate flood risks sufficiently to reduce losses as climate change proceeds.

In a context where embankments, spurs and other structural measures are the focus of government and policy-making organisations, our qualitative methodology for evaluating the costs and benefits of alternative strategies provides new insights. It helped to identify (1) the types of costs and benefits associated with different flood management techniques; (2) the relative magnitudes of these costs and benefits; and (3) their distribution. While the method does not provide sufficient information to evaluate the overall economic viability of different strategies, it does provide critical information to indicate major areas where additional analysis is needed for informed decision-making.

The information generated while conducting a qualitative benefit-cost assessment provides many of the same insights that would be generated by a more quantitative approach. It highlights both the direct and indirect costs and the benefits associated with each type of risk reduction intervention. In addition, unlike the quantitative cost-benefit analysis, this methodology allows us to evaluate the differential distribution of costs and benefits to different sections of the population in a data-deficient environment. However, the magnitude of the costs and benefits identified are difficult to compare. In many ways, a qualitative analysis can lay the groundwork for a more quantitative evaluation without replacing it. If a full cost-benefit analysis is required for project purposes, this methodology strongly complements it by identifying and thus enabling the inclusion of many costs and benefits that are often excluded as externalities in standard economic techniques.

Evaluating the Impacts of Climate Change

Down-scaling outputs from general circulation models (GCM) as a basis for estimating the costs and benefits of different risk reduction strategies under different climate change scenarios is a challenging process. It is, however, essential for any approach to cost-benefit analysis that requires probabilistic information on the frequency and intensity of future drought, storm or flood events. Chapter 3 outlines the innovative methodology developed under this programme for down-scaling GCM scenarios to local basins in South Asia where data are limited. We employed a simple, analogue-type statistical down-scaling technique to examine potential precipitation changes in the Rohini Basin up to 2050. We utilized output from the Canadian Third Generation Coupled Global Climate Model (CGCM3-T47), because a study by Kripilani et al. (2007) found this model to be one of six that proved capable of replicating key historical features of the South Asian monsoon system and because accessing data from this model was relatively easy. We chose the A2 and B1 scenarios to drive our down-scaling model because these represent the upper and lower boundaries of estimates of greenhouse gas emissions. The CGCM3 is run in ensemble mode, with a total of five model runs each for the A2 and for the B1 scenarios publicly available, and we utilized output from each run to drive our model. The outputs were used in both the Uttar Pradesh drought and flood analyses. Down-scaling was also attempted in the Lai Basin. Data at the local level, however, were insufficient and of too uncertain quality to allow for the results to be incorporated in the cost-benefit analysis in this case.

Incorporating down-scaled results from different climate change scenarios in analysing the costs and benefits of different risk management strategies has both major advantages and major limitations. In general, our model's down-scaling projections show similar trends to the broad IPCC (2007) projections for the South Asian region. We project an increase in precipitation during the monsoon months from June to August and a decrease in precipitation from December to February. Our projections differ from the IPCC projections for the periods from March to May and from September to November in that we see decreases in precipitation in these seasons while IPCC projections foresee increase. The scenario of increase in climate variability we generate is consistent with IPCC projections. Table 1 summarizes our down-scaling scenarios.

TABLE 1 | **Comparison of the interquartile IPCC projections for the South Asia with the down-scaled interquartile projections for the Rohini Basin**

	IPCC - South Asia			Rohini Basin					
	A1B			B1			A2		
Season	25th	50th	75th	25th	50th	75th	25th	50th	75th
Dec - Feb	-9	-5	1	-104	-89	-59	-37	-24	-1
March – May	-2	9	18	-59	-52	-28	-60	-55	-35
June – Aug	4	11	16	-4	1	11	-3	0.5	10
Sept – Nov	8	15	20	-19	-13	-1	-15	-9	2
Annual	4	11	15	-12	-7	4	-10	-6	5

There are significant differences in the methodologies and resultant meanings of the IPCC projections and the Rohini Basin projections, as explained below.

We stress that caution be exercised when utilising our downscaling projections. While we do believe the precipitation trends (up or down) to be correct for all seasons, the magnitudes of our projections are probably high. We recommend utilising the 75th *percentile ensemble member as more representative of probable future conditions. We also recommend caution in comparing the IPCC projections with our projections for the following reasons:*

1. The IPCC projections run for the period from 2010 to 2099 and our down-scaled projections are for the period from 2007 to 2050. Furthermore, the IPCC projections take a longer time to converge (reach agreement between models);
2. IPCC projections are based on a summary of results from a minimum of 14 out of 22 different GCMs, while ours are based on the output of a single GCM. GCMs are numerical models that take into account physical processes between the land, ocean and atmosphere, but downscaling models look at the statistical relationship between large-scale climate features and rainfall;
3. The IPCC projections cover an extremely large geographic area. Ours are basin specific and there are significant differences of scale; and
4. The most crucial difference is that the IPCC projections mentioned in the report are for the scenario A1B, while we chose A2 and B1. The A1B scenario is based on carbon dioxide emissions stabilizing at about 720ppm.

The primary source of uncertainty in our down-scaling methodology is the lack of rainfall data of a sufficient duration for the basin, particularly on the Indian side. Through verification of the testing phase of the model, we were able to quantify that our data sets are of insufficient duration. During the testing phase, the model exhibited a slight wet bias during the months of November and December and a slight dry bias during the monsoon period. This is one reason for our recommendation to utilize the 75th percentile 2008-2050 projections. Despite the model bias, the agreement of trends of the interquartile spread point to drier conditions much of the year except during the monsoon season. In addition, variability is expected to increase. Both of these factors will have significant impact on the cropping patterns, weather-related vulnerability, and livelihoods of the people living in the basin.

Despite the uncertainties involved and the limited amount of data available at the local level, the results of down-scaling helped estimate the costs and benefits of risk reduction in the Rohini Basin, with implications for the identification of appropriate strategies. In the Rohini Basin drought case, the economic viability of insurance mechanisms appears likely to decline as climate change proceeds. Hence, other strategies such as increasing reliance on groundwater irrigation or other physical courses of action for risk reduction are likely to be increasingly important. In addition, when incorporated in cost-benefit analyses of flood management options, down-scaling scenario results suggest that people-centred strategies are more likely to generate robust economic returns than long-term structural measures for flood control.

Summary

As the cases presented in this report clearly illustrate, disaster risk reduction can "pay". Whether or not disaster risk management generates returns that justify public investment, however, depends on the details of the specific strategy implemented. In order to generate positive economic returns at a level that competes effectively with other avenues for public investment, risk management strategies need to be tailored to specific contexts. They also need to reflect the best possible knowledge regarding the impacts of climate change on regions. These impacts can fundamentally change the returns to different strategies and their resilience as conditions change. As a result, despite the inherent uncertainties in projecting the impacts of climate change at local levels, evaluation is essential.

Overall, when conducted though an open and transparent process cost-benefit analysis provides a useful tool for supporting decision-making and policy development for disaster risk reduction. However, the limitations and complexities in applying cost-benefit analysis should also be considered. This is particularly true for weather related disasters where climate change processes make it difficult to characterize future conditions.

In the Uttar Pradesh flood study, the simplified estimation of the costs and benefits of embankments seemed relatively straightforward, but it was challenged by issues of lack of proper embankment maintenance and assumptions needed to estimate categories of losses (e.g. housing, crops, wages) under changing climatic conditions. The costs and benefits of people-centred strategies are very difficult to assess, as assumptions are made not only at the household level but also with regard to compound impacts of multiple interventions. Add to this the great uncertainty in the data, in the assumptions and analysis, as well as in the intervention disbenefits, and it is clear that results of cost-benefit analyses are themselves highly uncertain. This uncertainty is even more pronounced when climate change is taken into consideration. To draw reasonable and reliable conclusions, final numbers must be treated in terms of order of magnitude.

In addition to helping evaluate the economic returns to different strategies, if conducted in a participatory transparent manner, cost-benefit analysis can make a substantive contribution to the identification, the evaluation and ultimately to the implementation of approaches to disaster risk management under changing climatic conditions. In particular, the process of conducting an open and transparent cost-benefit analysis can enable the organisations involved to clearly identify the assumptions underlying proposed strategies and the degree to which available data actually substantiate their effectiveness. By bringing multiple stakeholders to the table around a tangible, policy relevant activity, the process can also serve as a catalyst and provide a framework for different organisations and sectors to contribute substantively to the evaluation of different strategies. This process begins to address the challenges inherent in coordinating activities across sectors and scales. It could also contribute to the creation of a learning environment particularly because cost-benefit analysis outcomes—that is, the returns estimated for different strategies—have direct relevance for the allocation of public finances either at a national level or within organisations. As a result, unlike in many other arenas where coordination is needed, organisations and sectors should have a strong incentive to participate and to learn from past experience.

A major limitation of conventional approaches to cost-benefit analysis is that it historically has not been designed to capture distributional issues of who benefits and who loses, nor non-monetisable aspects of disaster risk reduction interventions. For this reason, it should not be viewed as a stand-alone decision-making metric, but instead be used in conjunction with vulnerability-based stakeholder-driven processes. Conventionally, cost-benefit analysis focuses on evaluating the overall economic returns to an investment at a societal level. It does not assist in the targeting of activities toward particularly vulnerable or at-risk communities. As a result, to complement conventional approaches, qualitative evaluation provides insights into the perceptions and needs of diverse stakeholders as well as the varied benefits and impacts of potential disaster risk reduction strategies on different locations and communities. Elements such as equity, gender, and historical perspectives are best understood through qualitative methods. The inclusion of vulnerability analysis in our methodology and in each of the case studies presented here represents an initial step in this direction. However, the development of techniques that clearly illustrate the distribution of costs and benefits according to wealth, hazard exposure, gender and other factors is essential if cost-benefit analysis is to become more generally useful as a tool to support decision-making.

The real benefit from cost-benefit analysis for the analysis of disaster risk reduction and climate adaptation options lies in the framework and *the open, transparent, participatory* process used. The approach provides a logical and transparent framework for organizing and reviewing assumptions. It also provides a way for key stakeholders to evaluate trade-offs and the implications of their own assumptions. This is particularly important for evaluating the implications of climate change for local areas. Cost-benefit analysis combined with the down-scaling of results from climate change scenarios can help operationalize and promote dialogue between ministries, departments and organisations to promote the integration of their policies and programmes. The process of conducting a cost-benefit analysis is particularly effective when it proceeds systematically from initial qualitative evaluation to quantification and then returns to qualitative analysis. This sequence enables: *First* the identification of potential risk management strategies and the likely cost and benefit areas: *Second,* the production of detailed quantitative estimates of those costs and benefits; and *Third,* the systematic evaluation of quantitative estimates in the light of the often many and important factors where the data required for quantification are lacking or where quantification is inherently impossible.

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