From Risk to Resilience

Working Paper 8

Moving from Concepts to Practice : A Process and Methodology Summary for Identifying Effective Avenues for Risk Management Under Changing Climatic Conditions

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Cover: On August 18, 2008 the Kosi embankment north of Kosi Barrage breached causing widespread devastation in Nepal and North Bihar. Photo of boats being used to navigate breached section of East-West Highway at Laukahi, eastern Nepal. Photo by Anil Pokhrel.

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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 summary note 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 or CBA 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 in an objective manner. 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 seen as 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;
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 a series of key elements and the methodologies associated with them for understanding risk and vulnerability within communities, identifying potential response strategies and evaluating the qualitative and quantitative costs and benefits associated with them. The approach is based on a shared learning process that moves iteratively from initial scoping through systematic vulnerability analysis, identification of potential risk reduction options to qualitative and quantitaive evaluation of their costs and benefits as a basis for decision-making. In addition, in order to incorporate evaluation of the 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 going through 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 has invested heavily for decades in building dams and embankments as the cornerstone of flood mitigation efforts. Similarly, where drought is concerned, 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, attention is increasingly 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 more 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. The situation in August 2008 when an embankment breached along the Kosi River that affected over three million people in Nepal and the Indian state of Bihar is a prime example of this. Similar conflicts between community incentives and larger-scale initiatives can be made in the drought case, 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 higher-level enabling conditions in a variety of ways 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

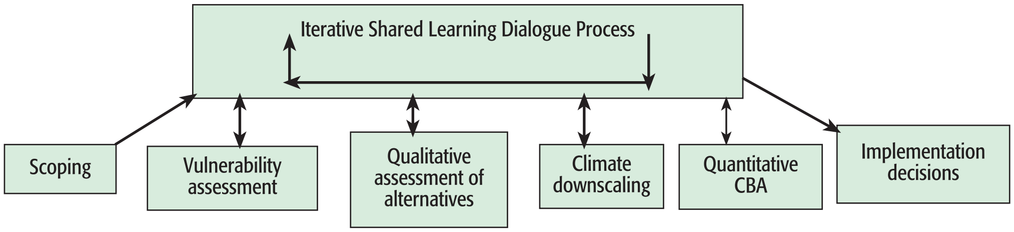
Working with communities often necessitates investing time and resources to determine:

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 actually respond to 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 is, however, 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 Risk to Resilience Working Paper No. 7). In this case, women represent a key group of stakeholders and the strategies they support would be quite different from the structural measures implemented by governments.

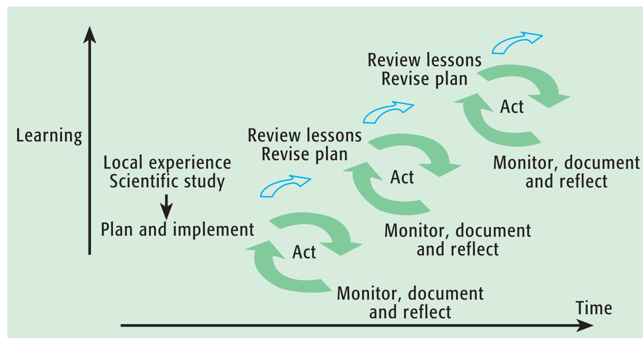
Thus, *processes that enable the integration of knowledge from different sources are essential*. Our ISET partners and field teams used a combination of methods including broad scoping activities and shared learning dialogues (SLDs) with a range of stakeholders to identify different DRR interventions and their broad cost and benefit areas, as well as 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 ultimately, 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 the 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

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



quantitative assessment of costs and benefits>ultimate implementation decisions) as diagrammed in Figure 1 should be recognized as iterative.

| FIGURE 2 | Iterative learning and action research



Following Lewin (1946)

More generally, SLDs for climate and disaster risk reduction grow out of itertative 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.

Scoping

In virtually all situations some degree of initial scoping is useful to structure later, more detailed, processes leading toward the identification of points of leverage for reducing disaster risks. Where external actors are unfamiliar with conditions and communities in target areas scoping is essential as a first step to gain a 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 types of information collected through scoping processes can serve as a critical mechanism for cross-checking assumptions and information.

Objectives

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

1. <u>Outlining the array of hazards present in a region.</u> This can be particularly complex in areas that have recently been affected by high-profile disasters such as earthquakes. In this situation, 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 specific activities and report sections 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 recent scientific literature, particularly any available for the specific region under consideration, is essential. Evaluation of potential hazards associated with climate change requires approaches that focus as much on changes in the level of uncertainty regarding future conditions, as on the results of specifc 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 are literally transitioning into a new climate state which we cannot completely know. Understanding the implications of uncertainty in hazard evaluation is as important as attempts to narrow such uncertainty.

2. Identifying the core 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, for example, people living in traditional (*kuccha*) houses face far higher flood losses than those residing in adjacent brick (*pukka*) houses (Risk to Resilience Working Paper No. 4).

3. Beginning the process of exploring how hazards translate into risk of different types. Understanding different patterns of vulnerability can serve as a basis for initial analytical activities to map the relationship between hazards and the risks faced by different communities. It is important to undertake such analysis even in the scoping phase because understanding the manner in which hazard exposure relates to risk 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. Fishermen, 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 are, however, 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 projects and programmes either exist or have previously been implemented to respond to specific hazards and increasingly the potential consequences of climate change. However, information on such prior events is rarely considered in the development of new programmes and policies. As a result, regions often "reinvent the wheel." Having some level of understanding regarding what has or hasn't worked in the past and why, should be a central part of scoping exercises.

5. Beginning the process of identifying major alternative avenues for addressing risk. Although any identification of avenues for addressing risk must remain preliminary at the scoping phase, developing initial ideas on practical avenues for doing so is essential as a basis for discussion with key actors. In addition, it is important to think through at this phase 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 the disease morbidity generally associated with flood events than structural control measures. Beginning to think through 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 whatever basic information is available on impacts and their distribution (deaths, economic losses, communities affected, etc.). It should also include any information that is available on the changing nature of regional hazards whether that is 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 of particular importance for all of the above.

2. **Policy and programme reviews:** Targeted reviews of disaster related policies and programmes are essential in order to understand the institutional landscape. Where possible, such reviews should also address key elements in 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, etc.

4. **Interviews with carefully selected key informants:** This is one of the most important elements in scoping processes. Carefully targeted key informant interviews can serve as a critical guide to understanding both perceptions regarding the nature of hazards, patterns of vulnerability and potential response elements. Wherever possible, it is important to interview key actors representing a wide array of social perspectives and knowledge. The above information should be sufficient to serve as a basic starting point for the more intensive learning dialogue processes that we believe are, in most cases, 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. In addition to their partial, fragmentary nature, the insights and perspectives of local groups often lack the insights that specialized groups from the international scientific or risk management communities can bring.

Even more importantly, where patterns of vulnerability are changing, local knowledge is unlikely to reflect the types of changes that can be projected by drawing on global resources. Furthermore, where responses are concerned, knowledge is also fragmentary. Local communities often have key insights on the types of activities that could reduce the risks they currently face - but they frequently lack any understanding of processes and limitations operating 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 more globalized 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 governmental and other institutions. Overall, as a result, effective solutions rarely emerge from any one set of actors.

The core point here is that all forms of knowledge on hazards and risk tend to be partial and unless these can be brought together, risks cannot be effectively addressed. Shared learning dialogues are the mechanism we have developed for this purpose. These are essentially iterative 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 patterns they suggest.

In the SLD process we have developed, each meeting starts with a brief synthesis and critical issue presentation by the organizers. 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 points of entry 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 shared learning dialogues 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 core goal underlying the development of shared learning processes is growth of a common understanding regarding the nature of hazards and the potential avenues for responding to them. Development of a common understanding takes time - it 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 shared learning dialogue 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 evolution of understanding regarding hazards, risks and potential response strategies;
3. Mechanisms to evaluate and prioritize alternative response strategies.

The ultimate outcome of shared learning dialogue processes should be the identification of avenues for responding to the specific risks faced by different communities that are:
1. <u>Practical</u> - 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 the core sets of 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 actually 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 identifying avenues for responding to risk that reflect the above are the ultimate objective of SLD processes, at initial stages of engagement, objectives can be much more limited. Prior to more detailed work on vulnerability or the prioritization and economic evaluation of potential options for responding to risks, shared learning dialogues should produce:

1. A fairly detailed understanding of hazards, including those likely to emerge as a consequence of climate change, and their likely implications for different groups (communities, economic groupings, geographic regions);
2. A fairly detailed understanding of the factors that local groups see as mediating the impact of hazard events and strengthening the resilience of society when events occur;
3. A fairly detailed understanding of the 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 the more detailed vulnerability analyses and qualitative and quantitative evaluations of avenues for responding to risk that are discussed in the sections that follow below.

Vulnerability Analysis

Why is vulnerability analysis important? In virtually all situations, different groups face different levels of risk in relation to specific hazards. Perhaps the most tangible case of this relates to the tendency of poor populations to cluster in high risk areas such as urban and rural floodplains. 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 but in many cases interventions that might "benefit" the larger society as a whole actually increase the risk some groups face. This duality, the fact that interventions often have differential effects or may not reach specific groups, is common across most hazards and contexts. Furthermore, in many situations the factors causing vulnerability aren't 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 don't 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 some of the 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 - indexes and other elements that can be mapped and disaggregated - 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 focus here primarily on 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 the policy-makers' concern with aggregate populations at the meso and macro national scales and the vulnerability analyst's general bias towards socially differentiated household and community levels at the micro and meso scale (Mustafa, 2002 and 2004);
- Policy-makers' social position as representatives of the prevailing political and economic structures and many vulnerability analysts' concern 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 vulnerability researchers. Anderson and Woodrow (1989) proposed the Capacities and Vulnerability Analysis (CVA) matrix, which came to be one of the more influential schemas, largely qualitative, for monitoring the vulnerability of communities and households and was primarily used by many influential NGOs (ActionAid, 2005; Davis, 2004). Drawing on this, we developed a quantitative Vulnerability and Capacities Index (VCI) which is applicable at the household and community level, 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, and 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 Luers et al. (2003) and Luers (2005), for example. 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 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) of 20% for economic wellbeing and stability, 20% to demographic structure, 40% to institutional stability and strength of public infrastructure, and 10% each to global interconnectivity and natural resource dependence for measuring vulnerability of African countries. Since we are operating at the micro scale, our material vulnerabilities category encompasses the first and the last two of her categories, while the demographic structure category is not as applicable at the micro scale or household and communities. 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 for households in rural areas. For detailed analyses on the rationale and scoring 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. Data to compile the VCI can either be drawn 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 disaster risk reduction interventions. Before undertaking data collection, there has to be thorough discussion of the scoring amongst field team members, and scoring must 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, where 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 approximation of reality and not *the* reality and therefore its use should ideally be supported by a narrative on the complex social and institutional context underlying the measurement of vulnerability.

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% dependent on a local level productive asset, e.g., fishing, land, shop, etc. • Lower vulnerability score by 1 for every 10% 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, jewelry (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. floodplain • Lower the score by 1 for the equivalent of every 10-yr. floodplain 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

	Types of Vulnerability and Indicators	Vul.	Cap.
8	Proportion of dependents in a household:		
	If the proportion is greater than 50%	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
	Membership of disadvantaged lower caste, religious or ethnic minority	5	
	Attitudinal Vulnerability	**15**	
10	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**	

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 being identified as more or less vulnerable than others. When used in shared learning dialogues, the results from this type of analysis provide a solid basis for identifying the specific factors that appear to contribute to risk and their relative importance or weight. This, in turn, provides a very 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, shared learning dialogues and vulnerability analysis, these options need to be evaluated in relation to their effectiveness and sustainability as a basis for prioritization and ultimately decision-making. At a minimum, the types of qualitative evaluation described in this section should be undertaken. If it is seen as important and sufficient resources (data, financial and human) are available this can provide the basis for a full cost-benefit analysis.

Initial Evaluation

Once a suite of potential options for reducing disaster risks have been identified, these need to be evaluated in a relatively systematic manner to understand tradeoffs, and potential costs and benefits for different vulnerable groups. Qualitative evaluation of alternative strategies consists, in essence, of subjecting those alternatives that have been identified on a preliminary basis to a number of critical questions, such as:

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 elements to consider in answering this question 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 does it affect risk through systemic changes in vulnerability (e.g. by encouraging livelihood diversification or improving communications)?
   - If the strategy directly targets specific hazard events, evaluators need to consider whether or not they are the most important hazards and whether or not targeted interventions will 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, care may be required in relating interventions 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? In many cases there are clear gainers and losers when DRR strategies are implemented. This is particularly clear in the case of embankments for flood protection - those living in areas between the levies lose (e.g. they are subject to more flooding) while those living in areas protected by the levies gain. Similar distributional effects also often exist with mechanisms such as insurance or zoning that tend to benefit wealthy groups, in some cases at the expense of less well off groups.

3. Is the strategy accessible to the intended beneficiaries? Insurance, for example, may not be affordable for the poorest sections of society 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 can be demonstrated that will ensure risk responses remain alive between events, then the viability of such responses is highly questionable. This is an area where 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 to be maintained in the absence of sustained public demand for the service.

5. Is the strategy consistent with emerging and projected social or other trends? As illustrated in the cases that are part of the Risk to Resilience working paper series, climate change may, for example, reduce or increase the effectiveness of different strategies. It is important to recognize, however, that the effectiveness of strategies can also 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 governmental 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, for example, 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. It is important to recognize that the effectiveness of some types of interventions (the embankment case just given, for example) depends heavily on specific assumptions while others are much more robust under uncertainty. This is particularly important to recognize in the case of weather related disasters since recognition of climate change processes undermines the reliability of many basic projections regarding flood, storm and drought frequency, intensity and duration.

7. Are the capacities for implementing a given strategy available within the society or can they be developed with relative ease? In many situations, strategies are developed based on the assumption that either technical or institutional resources are available. Such issues can range from data availability to enforcement of laws.

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 virtually all situations additional criteria should be added to the list above.

Qualitative comparison of potential strategies in relation to key tests such as the above can be achieved relatively simply through construction of a matrix listing all the potential interventions and flagging where each scores well and where major questions or concerns exist. In general, the evaluation process should be done with direct input from participants in shared learning dialogues. It is precisely in the process of discussing different perspectives on potential options with communities, technical specialists and other key actors that key advantages and constraints associated with each option - i.e. the answers to the above test criteria - will become clear. In the example below, areas where clear answers exist that support the strategy are shown in green, areas where major questions exist are marked in blue and answers that do not support the viability of a given strategy are marked in red. The net result should provide, at minimum, a clear indication of strategies where numerous indicators suggest they are likely to be viable and other strategies where major concerns or questions would need to be resolved.

Prioritization and Ranking

Results of the above types of qualitative evaluation of potential DRR interventions should provide 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. This type of evaluation does not, however, provide much indication regarding the relative benefits of different strategies in relation to their financial or other costs, or even their dis-benefits.

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 floodplains	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)								

As with the qualitative evaluation, mechanisms for prioritizing alternative strategies that reflect social perceptions of their relative costs and benefits can be achieved using relatively simple matrix-based ranking techniques in focus group and shared learning dialogue processes. The method simply involves having groups rank the benefits and costs of potential interventions in relation to their impacts on both hazard specific and more general risks on a scale of 1 to 10. The reasons behind these initial rankings are then probed in the discussion with questions focusing on the reasons different interventions were ranked as higher or lower cost and higher or lower benefit. Discussions of this type rapidly focus down on sets of interventions that are perceived as high-benefit/low-cost. They can also be used to draw out why specific interventions are perceived as having higher or lower costs and benefits.

Example of Cost and Benefit Matrix Exercise

1. List possible courses of action to reduce climate risks in the first column. As a scoping exercise, suggestions by non-project members should be listed first, then project members should list the potential interventions they view as possible. This can be done on a white board or flip chart.

2. Rank these 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. Rank 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. Probe: why are certain interventions likely to be more or less effective? Why do you think they will be more or less cost?

While ranking ratio between benefits and costs based on the above ranking does not actually reflect economic returns, the ratios do indicate social perceptions of the types of intervention that are likely to be most effective in relation to the level of investment required. At minimum they can be used to identify the types of interventions that are broadly perceived to be beneficial in relation to overall investments required. In combination with the other analyses and shared learning dialogue outputs, this may provide sufficient information to choose effective strategies. For large investments, however, more systematic quantitative evaluation of costs and benefits are important. This is particularly true because more quantitative measures may highlight information or the scale of specific costs and specific benefits that are different from the perceptions that emerge from community dialogues. In the Pakistan case study, for example (Risk to Resilience Working Paper No. 7), the specific early warning system implemented was shown to have a very low benefit to cost ratio, quite different from the ranking ratio shown in Table 3.

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 floodplains	9	10	0.9
Building small protected areas and structures	8	6	1.3
Improve banking and financial systems	6	3	2.0

Qualitative evaluations such as the above can be combined with other techniques to identify the distribution of perceived costs and benefits across areas. In the Nepal case study (see Risk to Resilience Working Paper No. 6) ranking exercises using a simple +/- system were used along a series of transects to assist local populations in identifying the costs and benefits of specific risk mitigation measures across flood-affected areas. At regular points along the transect, shared learning dialogues were held to identify the major benefits and costs associated with each risk reduction measure. Local groups then weighted each of the costs and each of the benefits using between one and three +/- symbols to indicate their view regarding relative magnitudes. This enabled development of a systematic, although qualitative, picture of perceived benefits and costs of each set of interventions for the region as a whole. The approach also provides a foundation that could be used for more quantitative evaluation of the costs and benefits should that be desired.

Quantitative Methodologies

Moving beyond qualitative approaches to evaluation, such those described in the preceeding 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. The decision to proceed with quantitative analysis should, as a result, be based on careful evaluation of the degree to which such information would actually inform the choice of risk management strategies and whether or not the types of information desired can actually be produced. As the India and Pakistan case studies (Risk to Resilience Working Papers Nos. 4, 5, and 7) 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. In consequence, even following substantial data collection, such analyses are best viewed as semi-quantitative evaluations. This said, however, 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 be necessary to generate the types of 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 and and so on. Cataloguing and discussing all these methodologies is beyond the scope of this summary. Instead, we focus here on methods for projecting future climate conditions (the main source of uncertainty in projecting future weather-related disasters) and cost-benefit analysis. The climate change element, although highly technical, has become essential for any analysis of the role risk reduction could play under different potential climate futures with regard to weather-related hazards.

Projecting Climate Change Impacts on Smaller Geographic Scales

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 Intergovernmental Panel on Climate Change (IPCC) in its reports are very general. They discuss trends and broad patterns of change. They also identify areas where available information points toward the potential for substantial change, but little scientific consensus exists regarding the directions of change, and as a result uncertainty is high. Moving beyond general projections requires both familiarity with the scientific literature on climate change - which is evolving rapidly - 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. This latter element, involving the downscaling of model results, is the crux of developing scenarios regarding future climate risks.

The downscaling methodology described in this section was developed to undertake detailed case analyses in India and Pakistan (Risk to Resilience Working Paper Nos. 4, 5 and 7). For a variety of reasons, mostly related to data and hydrologic system dynamics, it was however not possible to use the results to analyze changes in flooding in the Pakistan case (Risk to Resilience Working Paper No. 7). The discussion below, as a result, is drawn from the Indian cases. Because climate science is evolving rapidly, appropriate downscaling methods may also develop quickly. The discussion here, however, illustrates the issues and challenges that are likely to remain relevant to any organization seeking to estimate the impacts of climate change on hazards and risk reduction measures.

Why Climate Downscaling?

The majority of climate change projections are made using general circulation models (GCMs) on a global scale, with a geographic resolution of 100-200 km. The GCMs' resolution is too broad to be of use in developing specific disaster risk reduction and adaptation measures. As seen in Risk to Resilience Working Paper Nos. 4 and 5, the flood and drought models used for estimating weather related hazards within river basins require climate information at a much smaller geographic scale. The ability of CBA and other techniques to assess the economic viability of DRR investments requires probabalistic information (frequencies and magnitudes) of potential events such as floods and droughts.

The Risk to Resilience project assessed the viability of current DRR investments and investigated their continued relevance under various climate change scenarios for Eastern Uttar Pradesh. A robust statistical downscaling technique was developed for relating large-scale climate information, such as wind or atmospheric pressure, to rainfall patterns in the Rohini Basin. We must caution, however, for reasons which are explained here and in greater detail in Risk to Resilience Working Paper No. 3, while the method presented here can provide key insights into potential climate change impacts in the basin, the projected changes in basin rainfall patterns (timing and magnitude) exhibit a high degree of uncertainty. Understanding the source of this uncertainty is central to understanding the uses and limitations of any analysis based on outputs from downscaling attempts.

A large part of the uncertainty inherent in climate change projections is due to an increase in variability away from the previous long-term climatological mean. The systems are literally transitioning into a new climate state which cannot completely be known. The numerial and statistical climate models rely on data from the near past (~last 100 years) and knowledge of current physical climate dynamics to make guesses of the new system states. The picture is incomplete because recent climate regimes have been fairly stable. This underlies recent research on paleoclimatic conditions to get information from further in the past when climate regimes were a lot more variable in order to supplement the knowledge of possibilities and constraints. It could turn out that it will not be possible to reduce uncertainty in certain parts of the world, simply because those systems are becoming more variable. An additional difficulty is that there can be sudden transitions or snaps into new climate states, without any nice, gradual transitions. As a result, the outputs from GCMs and attempts to downscale those results represent scenario generation exercises rather than actual projections of future conditions.

Furthermore, there are multiple downscaling methodologies in existence, ranging from numerical methods to stochastic methods. The choice of which method 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 stochastic methods, ranging from neural networks, weather generation schemes and non-parametric, K-Nearest Neighbor schemes. Stochastic models rely on relationships between the variable to be predicted (often precipitation or temperature) and other climate variables. All of the downscaling methods are complex. Therefore, we focus only on the downscaling method we developed for use in the Rohini Basin. Although this methodology and most other climate downscaling techniques would not be possible to implement without expert support, we've included discussion of it here in order to give readers an idea of the issues and steps involved. This section, as a result, provides less insight on "how to" implement the techniques than other sections in this summary. For those interested primarily in the mechanics of methods they can directly implement, a detailed reading of this section is not necessary.

Climate Downscaling Methodology

There is significant disagreement between GCMs about current and future precipitation and temperature estimates for South Asia (Kripalani et al., 2007; Christensen et al., 2007). Global temperature projections are however fairly robust; most agree that temperatures are increasing and will continue to increase (IPCC, 2007). Global precipitation projections vary widely in timing, geographic distribution, amount and variability between all the GCMs. However, GCMs are able to simulate large-scale climate fields, such as wind, specific humidity and geopotential height (atmospheric pressure) quite well and are generally in agreement (Trigo and Palutikof, 2001; Osborn et al., 1999).

Utilizing the GCMs' ability to more reliably simulate large-scale climate fields, basin-scale rainfall forecasts were derived. A non-parametric, statistical downscaling approach based on the K-Nearest Neighbour (K-NN) algorithm was employed (Yates et al., 2003; Gangopadhyay et al., 2005). The algorithm was modified to forecast monthly precipitation ensembles, based on various climate change scenarios, which were then disaggregated to daily precipitation estimates.

The steps taken to perform the downscaling are described below:

STEP 1: Data Collection

The Rohini Basin straddles the border of Uttar Pradesh (India) and Nawalparsi (Nepal) with approximately 70% of the basin lying in India. The basin receives the majority (70-90%, depending on location) of its annual precipitation during the monsoon months of June-September. With some difficulty, daily rainfall data for five weather stations on the Nepal side were acquired, with 1976-2006 being the most complete. No information exists about how the data were collected or steps taken to ensure validity. Unfortunately, due to budgetary constraints, we were not able to purchase data sets for the Indian side of the basin. Thus, information on rainfall patterns for the majority of the basin is missing in this study.

After collecting rainfall data, selection of the large-scale climate fields commenced. Selection of large-scale climate fields is governed by two sets of assumptions which determine the physical relationship between the local variable (rainfall) and large-scale variables. The first set is based on the necessary atmospheric conditions that allow for convective activity, which drives most of the Rohini's rainfall:

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 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 capture the climate change signal.

We selected the large-scale climate variables - geopotential height, zonal or meridional winds, specific humidity and air temperature, based on the two sets of conditions. Large-scale variables from the historical period of 1976-2006 were obtained from the NCEP/NCAR Reanalysis datasets (Kalnay et al., 1996) and were also used to test the ability of the model to replicate past rainfalls. The better the ability of the model to replicate past occurrences, the higher the confidence in its ability to project possible climate change futures.

A second set of large-scale climate variables was acquired from the Canadian Third Generation Coupled Climate Model (CGCM3). This represents potential climate change scenarios and is used to simulate future rainfall in the basin. The CGCM3 was selected after a literature analysis to determine which GCM is best able to model the South Asian Monsoon. Kripilani et al. (2007) analyzed the ability of 22 GCMs (the same the IPCC utilizes) to reproduce historic key features of the monsoon and found that only six models performed well. Out of the six possible GCM candidates Kripilani et al. identified, data from the CGCM3 proved easiest to access. The project team agreed that the A2 and B1 climate change scenarios would be applied.[1] Due to great uncertainty in climate change processes (e.g. Artic and Greenland icesheets melting faster than GCMs are predicting), only climate change scenarios for the years 2007-2050 were utilized.

Finally, a rescaling of the large-scale climate variables was conducted. Both the NCEP and CGCM3 datasets cover the geographic range of 25°N-30°N, 80°E-90°E, but the resolution of the datasets is different. The NCEP observations are of a higher resolution (2.5° × 2.5°) than the CGCM3 projections (3.75° × 3.75°). Thus, the NCEP dataset had to be rescaled to match the grid spacing of the CGCM3 data.

STEP 2: Final selection of climate variables

The physical relationships between the large-scale climate indices and basin rainfall can be established through correlation analysis. Correlation analysis between each month's total rainfall (1976-2006) with various large-scale climate indices from the NCEP dataset was performed. Correlations were tested for significance and the climate indice that had the highest correlation with the month's rainfall was identified to form the predictor set.

STEP 3: Testing the model over the historic period 1976-2006

During the testing phase, the model is run in drop-one, cross-validation mode. This means that the year for which the model is trying to predict rainfall is dropped from the rainfall and large-scale climate datasets. For instance, in trying to estimate the rainfall for May 1980, the rainfall and large-scale climate indices of May 1980 are dropped from the datasets. The model then makes the rainfall prediction using the remainder of the data.

The model works by finding a relationship between the rainfall/large-scale climate variables of the month (say May) and year (1980) to be projected and all data for that same month for the whole historic period (all Mays 1976-2006, except May 1980), again minus the year to project. The years with the most similar large-scale climate features to May 1980 are retained (the K-NN years). The rainfall values from the K-NN years are then resampled, based on a weighting scheme, to make the rainfall projections for May 1980. The resampling process generates multiple rainfall values (ensembles) to give a range of possible rainfalls under the large-scale climate conditions. This the ensemble approach also provides a range of uncertainty (variability) in rainfall projections.

The smaller the range of rainfall projections (say 100 - 130 mm) and the accuracy of projections to the actual, historic rainfall observations, determine, the certainty of the projections. The model's accuracy can thus be tested, and whether or not the large-scale climate variables choosen capture the majority of physical processes governing rainfall in the Rohini Basin, by seeing how well the model could hindcast rainfalls for 1976-2006. Several comparison techniques to test the model's performance were employed.

[1] For a detailed description of the A2 and B1 climate change scenarios, refer to the IPCC (2000) *Special Report on Emission Scenarios.*

STEP 4: Generating future rainfall conditioned on climate change scenarios A2 and B1

The generation of future rainfall for the Rohini Basin is based on comparing the projected large-scale climate variables from CGCM3 with the historically observered large-scale climate variables from NCEP. For example, the large-scale climate indices of May 2020 calculated from CGCM3 are compared with the large-scale climate variables of all Mays 1976-2006 calculated from NCEP. The rainfall amounts of the K-NN from the historical period are resampled to produce the mean rainfall projections for May 2020. The differences between the main rainfall projections and the model fit (residuals) are also resampled and added (bootstrapped) onto the main projections to generate rainfall ensembles. Bootstrapping of the residuals quantifies the range of variability (uncertainty) of the future rainfall projections.

STEP 5: Verifying the model over the testing period 1976-2006

Each ensemble forecast is equally probable for the period 2007-2050, such that only time will tell which was the most accurate. Therefore only indication of model validity is revealed during hindcasting, as described in Step 3. The best indicator of the validity of future projections, therefore, is the degree to which it can replicate conditions over the 1976-2006 testing period.

STEP 6: Disaggregating the monthly model rainfalls to daily rainfalls for the flood and drought models

The flood and drought models require daily precipitation values, while the downscaling model was run on a monthly timestep. The monthly rainfalls were disaggregated to daily timesteps by multiplying the daily rainfall percentage distributions from the K-NN. For example, say May 2020 had six K-NN (e.g. 1978, 1992, 1995, 2001, 1987 and 2003). In May 1978, rain fell on six days throughout the month, with each day receiving a percentage of the total monthly rainfall. The percentage rainfall patterns were then multiplied by May 2020's monthly rainfall projection to produce hypothetical daily rainfall distributions.

Results and Discussion

The model was better able to hindcast rainfall for some months than others for the period 1976-2006, in particular the months of February-May, August, November and December. The model showed limited, but still useful, confidence in rainfall hindcasts for June and July. The rainfall hindcasts for January, September and October exhibited little success.

The ability to hindcast rainfall in certain months over others is largely due to atmospheric conditions and the ability of the selected large-scale variables to capture the atmospheric conditions. January is dry in most years. When rainfall does occur in this month, it is usually due to remenants of depressions that formed over the Mediterranean that transport moisture into Nepal. The timescale of these depressions is on the order of a few days and are therefore not captured in the monthly timestep of the model. During September and October, the atmospheric conditions that create and sustain the monsoon decompose and the atmosphere does not stabilize until November. The model cannot capture these rapid atmospheric processes. *This implies that higher confidence in the climate change* *projections for February, March, April, May, August, November and December, limited confidence in June and July and no confidence in projections for January, September and October.*

There is a great deal of uncertainty in the future projections of climate change impacts on rainfall in the Rohini Basin. Mean rainfall predictions are shown in Table 4.

TABLE 4 | **Projected seasonal per cent changes in median precipitation for the years 2007-2050**

Season	A2	B1
Pre-monsoon (Jan-May)	- 46%	- 45%
Monsoon (June-Sept)	1%	2%
Post-monsoon (Oct-Dec)	- 40%	- 71%

While the median rainfall projections show a significant decrease in rainfall during non-monsoon months and a slight increase in precipitation during the monsoon. However, there is a high degree of variability in projections for all months of the year, indicating that the rainfall can be much higher or lower than the median projections in each month. The rainfall projections during non-monsoon months, while low, are consistent with the downward rainfall trends over all of India during non-monsoon months projected by other scientists (Kumar et al., 2006; Gosain et al., 2006). Likewise, other studies are projecting increases in monsoon rainfall, although the projections vary. *The most important consistent finding between this study and others is that variability in rainfall is projected to increase greatly in all months.*

Use of Results from Downscaling

Results from the quantitative climate downscaling exercise are of critical importance for both qualitative and quantitative evaluation of the costs and benefits likely to be generated by different disaster risk management strategies.

First, where qualitative evaluations are concerned, the range of potential rainfall patterns generated through even a relatively limited modelling exercise such as this can be used to give stakeholders a sense of the inherent uncertainty that is hidden in more general synthesis results from gobal scientific activities. Published projections of climate change for India as a whole, for example, suggest an overall median increase in precipitation of perhaps 20%. Results from our modelling exercise, however, show prominent decreases during some months for the Rohini Basin. Such differences drive home the point that broad climate projections may differ greatly from the realities likely to be experienced in specific basins or locations. This "realization" is of fundamental importance for any discussion of specific response strategies.

Second, appropriate techniques for modelling climate change generate ensembles of results. In our case, the limited modelling exercise produced an ensemble of 150 potential rainfall futures, each having an equal probability of acurately reflecting future conditions. Using statistical techniques to select scenarios that "bracket" conditions in all other scenarios (i.e. that reflect the extremes), we selected only a few of the ensemble members to use in the flood and drought modelling for cost-benefit analysis of risk management interventions. This was necessary due to limitations on computing capacity; the hydrologic model to estimate flooding for each scenario took two days of computer time. Ideally, however, the entire hydrologic and cost-benefit analysis would be run for each of the scenarios in the ensemble. This would have generated a distribution of cost-benefit results for each intervention that could have been used to determine the robustness of returns under the full selection of future scenarios. If CBA results are positive under all future scenarios, then confidence is much higher than if they are positive under only a portion of the scenarios.

Third, as the climate experts emphasize, the uncertainty inherent in projections of future climate conditions is very high. As emphasized in the following section on CBA and Risk to Resilience Working Paper No. 1, there is a fundamental difference between risk and uncertainty. When event probabilities can be calculated with some confidence, then risk can be estimated. If, however, it proves difficult to assign probabilities to events and quantify the forecasts' skill, lack of confidence is high. The fact that confidence levels for climate projections have not been fully established represents a fundamental constraint for probabalistic approaches to cost-benefit analysis of disaster risk management. Where lack of confidence in the likelihood of future climate scenarios is high, probabalistic approaches to cost-benefit analysis can be used to generate scenarios but not forecast probable returns. In such cases, sensitivity analysis is particularly important to test the robustness of scenarios and their potential predictive capacity. Furthermore, the fact that future projections of probabalistic returns depend on underlying climate scenarios whose skill and accuracy are not fully quantified because they are based on guesses of societal behaviour (what kind of energy cultures we will have), needs to be recognized. As a result, while still reflecting estimates of potential economic returns from DRR investments, the inherent uncertainty and scenario characteristics of such CBAs must be transparently reported.

The above points are important to keep in mind in any case where quantitative approaches to cost-benefit analysis are being used to assess the economic viability of climate related disaster risk management.

CBA: Quantitative Decision Support for Assessing the Costs and Benefits of Disaster Risk Management

Why CBA?

Cost-benefit Analysis (CBA) 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 CBA is to systematically assess the costs and benefits and check whether social welfare is indeed maximized.

In the context of disaster risk reduction (DRR), two important issues deserve additional attention when undertaking a CBA:

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

2. **Avoided risks:** As disaster risk is a downside risk, benefits are the risk avoided. The core benefit generated by investments in disaster risk management is the reduction in future losses.

Data Collection

By definition, quantitative CBA requires data to sufficiently reflect current and future risk, as well as the costs and benefits of the strategy being analyzed. Data are usually primarily acquired from secondary sources, for example 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.

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 CBA these aspects are ultimately needed in financial values, with social and environmental factors often being difficult to monetize. Even 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 to be considered. For example, in the Uttar Pradesh flood analysis (Risk to Resilience Working Paper No. 4), data shortfalls greatly impacted the final CBA. 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 will need to be made to account for insufficient data. If at all possible these should be based on some real information, whether direct or proxy data, and in any case be transparently described within the analysis.

BOX 1

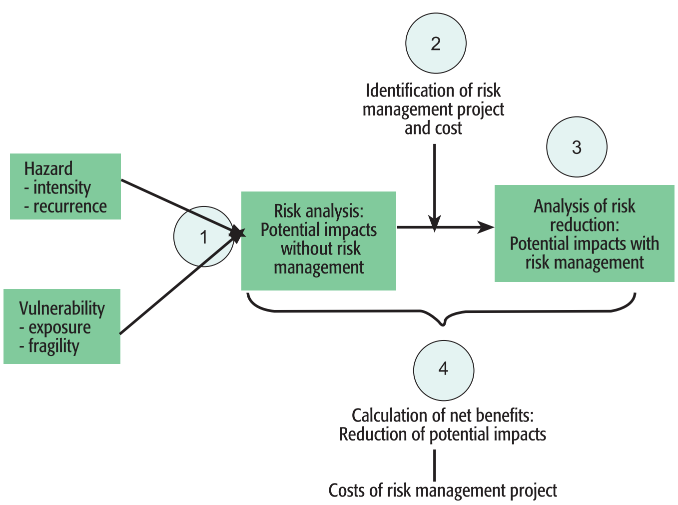
Surveying floods and risk reduction in Uttar Pradesh, India

To gain a deeper insight into the household impacts of floods and risk reduction strategies in the Rohini Basin in Uttar Pradesh, India, a household survey was carried out. Survey villages were selected at varying distances from the river and existing embankments. This involved six zones, including one actually between the river and the embankments. One village from each of these six zones was selected in the upper, middle and lower reaches of the basin. In total, 18 villages were selected, 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, wealth, caste, women-headed households and engagement in different risk reduction activities. The questionnaire was designed with closed-ended questions targeting cost-benefit data needs, drawn up through extensive consultation with field teams during a pre-survey visit and testing. The questionnaire development and survey implementation process required over six months to complete.

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	Considering the relatively flat topography, topographical maps and the available digital elevation model (DEM) of only one cross-section were available for the entire river.
Hydrometeorologic time-series	Rainfall data was available only for the Nepal 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.
On-going 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 global climate model results and transformation into changes in flood regime have high uncertainty due to poor quality and insufficient length of historic rainfall data.

FIGURE 3 | Framework for operationalizing risk-based CBA



Analysis

In this project, the CBA process has been operationalized in four steps (see Figure 3):

1. **Risk analysis:** risk in terms of potential impacts without risk management has to be estimated. This entails 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 can be identified.
3. **Analysis of risk reduction:** benefits of reducing risk are estimated.
4. **Calculation of economic efficiency:** economic efficiency is assessed by comparing benefits and costs.

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 which 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 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, for instance 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 CBA purposes, 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 factors that contribute to it in quantitative terms (such as availability of organizational structure and know-how to prevent and deal with disasters). As a result, in quantitatively oriented assessments, resilience is often 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. Potentially, there are a large number of impacts. In practice, however, only a limited number of those can and are usually assessed. Table 6 presents the main indicators for which usually at least some data 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				

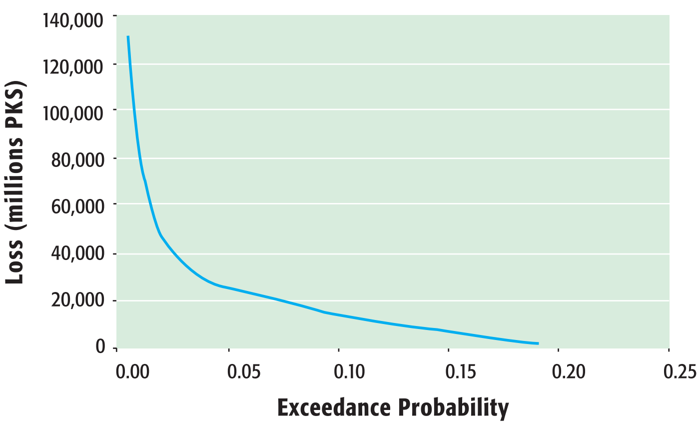
TABLE 7 | Categories and characteristics of disaster impacts

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.*

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



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. It has to be kept in mind that 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 CBA, benefits reflect the potential reduction of expected annual value of damages every year.

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

CBA are the specific costs of conducting a project focusing on the financial costs: the monetary amount that has to be spent for the project. There are also the so-called opportunity costs, which are the benefits foregone from not being able to use these funds for other important objectives. These opportunity costs, which are generally considered to be 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.

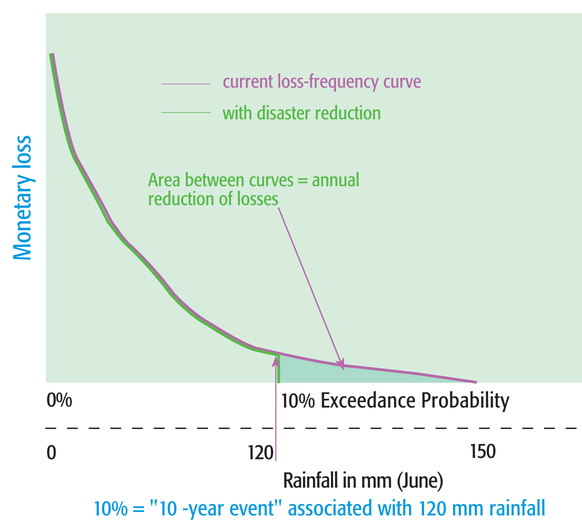
Usually there are major initial or capital outlays for the investment effort, such as building embankment, followed by smaller maintenance and operational expenses that occur over time, e.g. for maintaining embankment. On the other hand, risk transfer measures usually demand a constant annual payment, 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

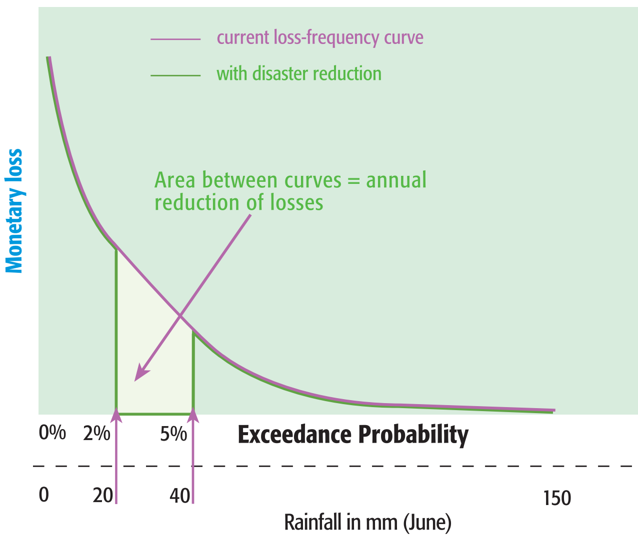
Next, the benefits of reducing risk are estimated. Whereas in a conventional CBA of investment projects, benefits are the additional outcomes generated by the project compared to the situation without the project, in the DRR case benefits are the risks that are reduced, avoided or transferred.

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 the original "without intervention" loss-frequency function. Risks may be completely avoided, reduced, or transferred. As an illustrative example, we consider the Uttar Pradesh case on drought risks to farmer livelihoods (Risk to Resilience Working Paper No. 5). 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 then computed as the area of

FIGURE 5a | Mechanics of irrigation in the UP case



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



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

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, defined here as "disbenefits." This is the case, for example, when flood control embankments cause water logging, resulting in losses of productive agricultural land and increases in waterborne health problems. These negative benefits need to be considered as well and factored in on the benefits side. While they can be computed on the costs side and considering 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 considered more appropriate to treat disbenefits within the CBA as negative benefits.

STEP 4: Calculation of economic efficiency

The final step in a CBA 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 CBA:

- **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 B/C ratio.

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

TABLE 8 | **CBA of river channel improvements in the Lai Basin, Rawalpindi, Pakistan (all values in millions of PKR)**

Year	Costs	Benefits	Net benefits	Discounted costs	Discounted benefits	Discounted net benefits	
2008	8,000	0	-8,000	8,000	0	-8,000	
2009	560	2,632	2,072	500	2,350	1,850	
2010	560	2,671	2,111	446	2,129	1,683	
2011	560	2,710	2,150	399	1,929	1,530	
2012	560	2,749	2,189	356	1,747	1,391	
2013	560	2,787	2,227	318	1,582	1,264	
2014	560	2,826	2,266	284	1,432	1,148	
2015	560	2,865	2,305	253	1,296	1,043	
2016	560	2,904	2,344	226	1,173	947	
2017	560	2,943	2,383	202	1,061	859	
2018	560	2,982	2,422	180	960	780	
2019	560	3,021	2,461	161	868	707	
2020	560	3,060	2,500	144	785	642	
2021	560	3,099	2,539	128	710	582	
2022	560	3,138	2,578	115	642	527	
2023	560	3,176	2,616	102	580	478	
2024	560	3,215	2,655	91	524	433	
2025	560	3,254	2,694	82	474	392	
2026	560	3,293	2,733	73	428	355	
2027	560	3,332	2,772	65	387	322	
2028	560	3,371	2,811	58	349	291	
2029	560	3,410	2,850	52	316	264	
2030	560	3,449	2,889	46	285	239	
2031	560	3,488	2,928	41	257	216	
2032	560	3,527	2,967	37	232	195	
2033	560	3,565	3,005	33	210	177	
2034	560	3,604	3,044	29	189	160	
2035	560	3,643	3,083	26	171	145	
2036	560	3,682	3,122	23	154	131	
2037	560	3,721	3,161	21	139	118	
2038	560	3,760	3,200	19	125	107	
Sum	**24,800**	**95,877**	**71,077**	**12,511**	**23,487**	**10,976**	**NPV**
						1.88	**B/C**
						27.6%	**IRR**

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 CBA, 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 robustness of the economic efficiency of the project, or, simply stated, the confidence in potential efficient economic performance, is not too high. Results of stochastic CBA should be viewed in terms of orders of magnitude rather than exact values.

Limitations of CBA

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

- CBA 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 CBA 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.
- Some of the benefits that DRR interventions have on the community are difficult to quantify. 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, let alone monetizable.
- CBA relies on the best available information, which in developing countries is often challenged with data being non-existent, unreliable or simply difficult to access. Data are particularly difficult to access if they fall in the realm of 'confidentiality' or, in other words, data which cannot be shared as they may affect national security.
- CBA also 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 CBA.[2] In a CBA, societal welfare is maximized by simply aggregating individual welfare over all people affected and changes therein due to projects and policies. A focus on

[2] A key tenet of CBA is that those benefiting from a specific project or policy should potentially be able to compensate those that are disadvantaged by it (Dasgupta and Pearce, 1978). Whether compensation is actually done, however, is often not of consideration. Also, methods to account for the distribution of costs and benefits exist, but are hardly used in practice due to the additional methodological complexity involved (Little and Mirrlees, 1990).

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 is losing or winning can be subjective, CBA cannot resolve strong differences in value judgments that are often present in controversial projects (for example, nuclear power, bio-technology, river management, etc.). This distributional issue has been a major reason for the Risk to Resilience project to ensure distributional factors are incorporated in the qualitative analyses and shared learning dialogues. Generally, it is often advisable to use CBA in conjunction with other decision support methods, such as cost-efficiency analysis or multi-criteria analysis.

Although challenged by the above issues, CBA can be a useful tool in DRR if a number of issues related to conducting a CBA and using results are properly taken into consideration.

Clarify objectives of conducting a CBA on DRM

Before engaging in a CBA, it is necessary to clarify the objective(s), foreseen process, information requirements and data situation among the different potential stakeholders, which may comprise representatives from local, regional and national planning agencies, NGOs working in development and DRR, disaster risk managers, officials concerned with public investment decisions, development cooperation staff and, of course, the communities themselves. The type of envisaged analysis and process should be closely linked to its potential users. A CBA may be conducted for informational purposes (such as in the Lai Basin case in Risk to Resilience Working Paper No. 7), for a pre-project appraisal (similar to the the India UP flood study in Risk to Resilience Working Paper No. 4), as a full-blown project appraisal (the India UP drought study in Risk to Resilience Working Paper No. 5) or as an ex-post evaluation (presented in the India UP 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 CBA 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, arise 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 CBA 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 CBA 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 disaster risk reduction need to be transparently communicated and clearly understood in order to properly interpret results derived in a CBA.

Process-orientation

Given the complexities involved in estimating the costs and benefits of DRR and the historical and current usage of CBA as a decision support tool, it seems appropriate to conclude that the role of CBA in DRR should be focused strongly on *process* rather than *outcome*. CBA is a useful tool for organizing, assessing and finally presenting the cost and benefits, and pros and cons of interventions; it demands a coherent methodological, transparent approach. Yet, given the difficulties of properly accounting for extreme event risk and climate change, CBA 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 CBA 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, they key role CBA can play in DRR becomes clear. In many ways, CBA 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. One tool, for organizing such a process is *shared learning dialogues*, which, by bringing together the perspectives of diverse community, expert and government groups, 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, utility of interventions, etc. 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 seen 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. In any cost-benefit analysis 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, CBA should be seen as part of a process involving extensive stakeholder involvement that moves from initial assessment, through 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 CBA 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 disaster risk reduction 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 regarding the nature of risk and the types of interventions that might be undertaken to reduce it. Supporting this type of dialogue process 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. Quantitative techniques for climate downscaling and CBA 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 ability 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, methodologies such as those outlined in this summary can be of critical use in developing effective and equitable responses to hazards including those emerging as a consequence of climate change.

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Annex I: Working Paper Series

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

Annex II: Acknowledgements

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