From Risk to Resilience

Working Paper 4

Evaluating Costs and Benefits of Flood Reduction under Changing Climatic Conditions : Case of the Rohini River Basin, India

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Cover: Flood waters on both sides of the Rohini embankment, north of Gorakhpur, Uttar Pradesh, India during 2007 monsoon. Photo by Anil Pokhrel.

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Contents

Key Messages

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

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

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

Although the above conclusions appear robust, limitations on data availability and quality constrained the analysis. Such limitations are an inherent in most risk management contexts, particularly in the developing world. As a consequence, however, the outcomes from cost-benefit analyses depend heavily on key assumptions and data. Testing the accuracy of available data and any assumptions that must be made through extensive stakeholder involvement in the analytical process is, as a result, essential. Benefit/cost ratios and other quantitative outputs are most meaningful as order of magnitude estimates rather than absolute values, especially when the inherent uncertainties in climate change projections are considered. As a clearly structured participatory process for strategy evaluation, however, cost-benefit analysis has benefits that go beyond the quantitative economic results generated.

If undertaken in an inclusive stakeholder-based manner, the process of undertaking a cost-benefit analysis forces participants to systematically evaluate the details of risk management strategies and the assumptions underpinning them. This analytical process can ensure that the strategies ultimately selected are socially and technically viable, broadly owned and likely to generate solid economic returns. It can also ensure that the distributional consequences of strategies - who benefits and who pays - are addressed; a factor not incorporated in conventional cost-benefit analysis. Without inclusiveness, debate and iterative learning among stakeholders, cost-benefit analysis can easily be manipulated and thus misused.

Introduction

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

Beginning with a risk analysis, past flood impacts were adapted to current conditions and then projected for future changes in risk due to climate and population changes. Flood risk reduction strategies were selected based on both real and potential interventions. Field experience and estimations were used to quantify and monetize costs, benefits and disbenefits (potential negative consequences of interventions), which were subsequently compared under a probabilistic cost-benefit framework. Finally the methodology, experiences and results of the analysis process were reviewed for robustness and utility within the policy context.

Downscaled climate change projections to the year 2050 indicate monsoon rainfall will increase. Translated into potential changes in flooding, the frequency of smaller, less-intense events will increase greatly, for example with a current 10-year flood becoming a 5-year flood, while rarer but more intense floods will remain relatively constant. This will result in a twofold increase in future average annual economic loss due to floods.

The economic performance of embankments, reflecting a historically dominant centralized flood risk reduction approach, was analyzed in comparison to a more egalitarian "people-centered" basket of interventions. People-centered interventions were assumed to be implemented at the individual, community and societal levels with the goal of reducing vulnerability within the relatively poor population in the basin by increasing general socio-economic resilience to floods. Embankments, on the other hand, are threshold-driven, meaning that they are designed for a certain flood magnitude, beyond which they fail to provide protection.

The analysis showed that when actual costs, performance and "disbenefits" (externalities) are considered, since their inception the embankments in the Rohini Basin cannot be concluded to have been economically efficient. Future proper maintenance of existing embankments, even under climate change projections, would however be economically efficient. This efficiency declines with the increased flooding that is projected to occur as a consequence of climate change. The people-centered approach also performs efficiently. Furthermore, because benefits do not depend on advance knowledge regarding specific flood magnitudes, the approach continues to perform well under projected climate change. In addition the presence of annual non-flood related benefits further strengthens the robustness of the strategy.

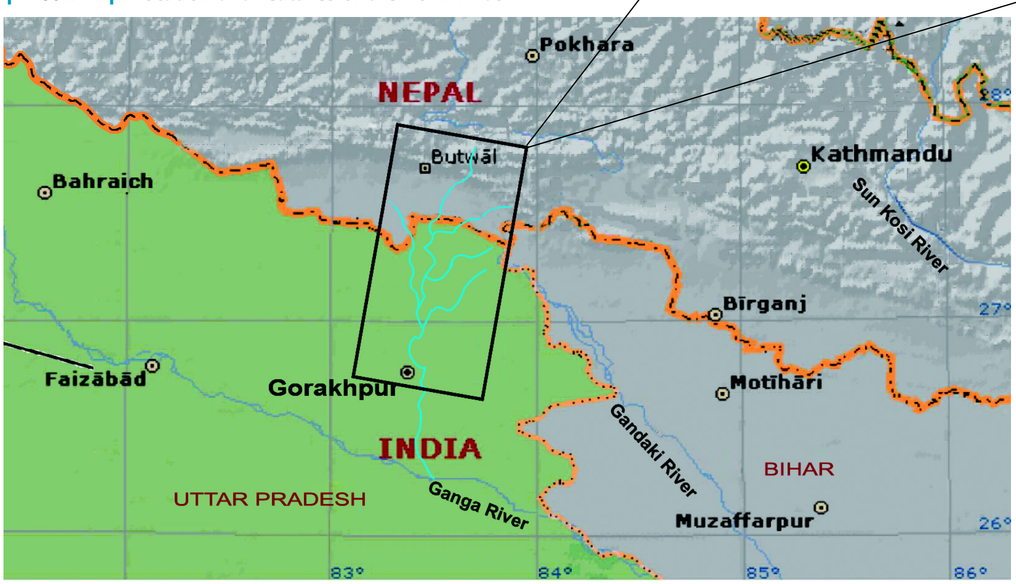
The limitations inherent in applying cost-benefit analysis to complex situations such as disaster risk reduction should be recognized in reviewing the results of this, and any other, similar evaluation. Cost-benefit analysis is a useful support tool for decision-making, but does not capture distributional (who benefits?) and non-monetizable aspects of disaster risk reduction. It should thus not be used as a standalone decision-making metric, but rather in conjunction with vulnerability-based stakeholder-driven processes. Final benefit/cost ratios generated through cost-benefit analysis are order of magnitude estimates. Rather than such numbers, the real benefit from cost-benefit analysis lies in the framework and process used. The approach provides a logical and transparent framework for organizing and reviewing assumptions. It also provides a clear basis key stakeholders can utilize to evaluate tradeoffs and the implications of their own assumptions. As a result, it can help operationalize and promote dialogue and integration of policies and programmes across ministries, departments and other organizations.

Case Study Location, Issues and Responses

Location

The Rohini River is part of the Gangetic Basin, located in Gorakhpur and Maharaganj Districts in the northeast Tarai region of Uttar Pradesh, India, in what is also known as the trans-Sarayu plains. Starting in Nepal, the river flows approximately north to south, with a catchment area in India of about 872 km². The Rohini ends at its junction with the Rapti River near Gorakhpur City. The basin location and its features are shown in Figure 1.

With a very small slope, even the smallest disruption in the natural flow of water can cause large-scale and long-term flooding. The area had a



| FIGURE 1 | Location and features of the Rohini Basin

large number of permanent water bodies which developed over time, due both to changing river courses and abandoned channels becoming blocked by silt (locally called *charans*). Historically, these water bodies/areas played an important role in flood management and provided livelihoods to a large population. In the last two decades, however, the water bodies have been heavily encroached upon.

The climate of the area is monsoonal. The temperature ranges between 5º and 46ºC, and average rainfall is approximately 2000-2200 mm/annum, over 80% of which falls during the monsoon. July and August are the wettest months, receiving about 60% of the monsoon season rainfall.

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

Flood Hazard

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

In the upper part of the basin, *piyas*, or small hill streams and drainage channels, are prone to erosion and sudden course changes. In the lower part the very low gradient causes the Rohini to meander sluggishly through the plains. Water logging occurs because of drainage congestion caused mainly by embankments and other linear developments (roads, railways, canals, urbanization, etc.). In certain areas the water logged area increased by 65-95% during 1971-1991. In many cases waterways developed across road and railway embankments drain insufficiently. Excessive rainfall can cause overflowing of low and poorly formed riverbanks, and drainage congestion is a serious problem. Flood hazard is pronounced where drainage channels merge into the Rohini and especially lower in the basin above the confluence of the Rohini and Rapti Rivers. The overall nature of flooding has therefore changed; inundation depths have become higher and more unpredictable (embankment failures), with constant water logging in certain areas. While earlier floods were considered to have done more good than harm, they now cause immense damage to life and property and have become an obstacle to the development of the region.

People at Risk

Villages located close to the river or the embankments are vulnerable to erosion, sand deposition, river flooding and water logging. Thirteen villages are trapped between the river and the embankment, suffering increased flooding and sand deposition. People in these villages tend to shift their houses over the embankments, living in temporary shelters. These villages lack the most basic infrastructure and due to water logging and/or regular deep flooding most of their lands have become unfit for cultivation.

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

High population density (about 1000 persons per km^2) puts many people at risk. Over the past 10 years about 45% of households have had at least one death in the family due to floods, and in 65% of these households the victims were the earning member. While a significant percentage (23%) of casualties was caused by drowning, flood related deaths are also caused by other factors such as snakebites, malaria, diarrhea and viral infection.

The study districts of the basin lag in all the aspects of human development indicators, compared to both national and state averages (Uttar Pradesh itself being lower than most of India). Official figures report about 30% of the local population live below the poverty line, as compared to 25.5% for Uttar Pradesh and 21.8% in India. In rural areas poverty is strongly associated with land ownership, which is the main productive asset. In the study area, about 50% of households own less than 0.4 hectare of land.

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

Most of the population does not have access to potable water, with the majority of households (71%) fetching drinking water from open dug wells. Privately owned handpumps provide poor water quality, especially during and after floods because of their shallow nature and tendency to become submerged. Government handpumps generally deliver potable water during non-flood periods, but they are rare. Private sanitation facilities are often poor and very few households actually use these public toilets due to cultural/religious habits.

Flood Risk Reduction

The primary flood management strategy that has been implemented by national and state government actors in the Rohini Basin has focused on flood control through structural measures, in specific the construction of embankments and spurs. Although the major focus on structural measures for flood control started in the 1950s, most of these have been constructed since the 1970s. Despite large investments in such measures, they frequently breach causing perhaps more damage than if they had not been built. Embankments fail for a variety of reasons. In some cases failure occurs due to lack of maintenance. In other cases, however, hydraulic design capacities are exceeded during extreme flood events. This is an inherent challenge facing the design of structures in regions where long-term data are unavailable and extreme event frequencies are changing as climatic conditions evolve. In addition, embankments slow river flows causing sediment deposition in the channel and resulting in riverbeds rising above the surrounding lands. In parts of the Ganga basin, riverbeds in areas where embankments have been constructed rise at over 10cm/yr - or a metre per decade. Four decades following initial construction of the embankments, river beds can be as much as four metres above the surrounding lands. This decreases the river's carrying capacity between the embankments and is a major factor contributing to frequent breaches.

Although the history of flood control has focused on structural measures, local populations have developed their own strategies for mitigating the impact of floods. These more people-centered strategies could, if expanded and supported, provide a foundation for planned interventions to reduce risk at a basin-scale. Local populations, for example, often raise the plinth level of houses, construct high protected points for grain storage, keep boats in reserve for transport during flood periods, have traditional systems for early warning and diversify livelihoods through migration to access external labour and product markets. Such strategies substantially reduce the impact of floods on local livelihoods and are much less dependent on knowledge regarding flood frequencies and characteristics than structural measures. As a result, the protection they provide may be more resilient in the face of changing climatic conditions.

Institutionally, at present community level risk management activities are generally undertaken through the initiative of individuals or limited to actions by self help groups (SHGs). In most cases SHGs are meant only as savings and lending groups, which are able to access loans from public sector banks, providing women from poor households with lower-interest credit. There appears to be little attempt to use these institutions as vehicles for flood risk management. They could, in theory, represent a starting point for this. That said, it is important to recognize that many SHGs function irregularly or even disintegrate because of mistrust and conflicts. Beyond SHGs, not much is being done to promote flood risk management. In the study area, a farmers' school run by a local NGO is attempting to promote flood-adapted agriculture. The government focuses on distributing post-flood relief, but does invest in improving health care or other resilience building basic services in this basin.

Climate Change Impacts

The Rohini River has its origins in the Chure Hills of Nepal. Rivers here are highly dependent upon rainfall and respond rapidly to rainfall events. During months of low precipitation, base flow in Chure rivers is sustained through groundwater. In the headwater reaches of the Rohini, approximately 86% of the annual precipitation occurs during the monsoon months of June to September (NWCF, 2003; Dixit et al., 2007).

Climate change is projected to influence river flow patterns through changes in the amount and timing of rainfall in the basin. The IPCC (Christensen et al., 2007) projects an approximate 11% increase in precipitation during the monsoon months for the entire Gangetic Basin. The IPCC projections, however, are based on the geographic resolution of the general circulation models synthesized by the IPCC (on the order of 100-200 km), which is too large a geographic range to support targeted climate change adaptation interventions in the Rohini Basin. Therefore, a statistical downscaling model was developed to investigate potential climate change impacts on precipitation patterns in the Rohini Basin and to be used in flood models.

Statistical downscaling models work by finding a relationship between large-scale climate variables (e.g. wind, pressure or air temperature) and a local variable, such as the rainfall in the Rohini Basin. The particular downscaling method used is a robust, analogue method that looks for similarities in large-scale climate variables across a period for which historical observations are available (1976-2006) to replicate historical rainfalls. Projections of potential climate change impacts on precipitation are made by comparing future projections of large-scale climate variables (in this study obtained from the Canadian Third Generation Coupled Climate Model or CGCM3) with historical observations of large-scale climate variables and then resampling the rainfalls of the most similar historic years.

Climate change projections for the Rohini Basin are based upon two climate change scenarios: A2 and B1. The A2 scenario refers to a world with continued high reliance on fossil fuels and high population growth. The B1 scenario assumes that carbon dioxide levels in the atmosphere stabilize at around 550 ppm. The A2 and B1 scenarios were each comprised of five simulations, resulting ultimately in 10 different scenarios.

Rainfall projections were fairly similar for the runs within each scenario. Each of the model runs is equally probable under that given climate change scenario. In order to

| TABLE 1 | Median rainfall projections under select A2 and B1 scenarios, in mm of rainfall

	Historic	A2R1	A2R5	B1R3	B1R4
January	18	9	5	8	7
February	16	6	6	6	6
March	21	3	5	6	3
April	41	4	4	4	4
May	127	87	153	82	188
June	367	410	410	389	471
July	648	569	512	568	604
August	476	503	503	505	501
September	322	347	353	365	293
October	87	36	27	20	24
November	8	1	2	1	2
December	19	117	9	9	8

test the potential impacts of climate change on flooding, the rainfall projections were run through the flood model, which took several days of computing time per rainfall projection. It was therefore decided to use only the runs from each climate change scenario A2 and B1 representing the highest and lowest annual rainfall projections: A2Run1, A2Run5, B1Run3 and B1Run4. The results are shown in Table 1.

Each model run of scenario A2 or B1 indicates the potential for an increase in drought conditions the majority of the year, which might lead to overpumping of groundwater resources and greater crop failure. During the monsoon months, rainfall amounts are projected to increase, leading to increased flooding and water logging. There is also a shift in the timing of rainfall, with smaller amounts happening in July and greater rainfall in August and September.

Projected Flood Changes

Rainfall-runoff and hydraulic river modelling were used to estimate present and projected future flood risk. A geographic information system (GIS) allowed for the compilation and analysis of a digital elevation model (based on the NASA Shuttle Radar Topography Mission - SRTM), official topographic maps of varying scales, land cover and soil maps, and information on administrative boundaries, roads, settlements, etc.

Rainfall-runoff analysis was based on data from the period 1982-2005, however omitting 1986, 1987, 1995 and 2000 due to missing or clearly erroneous data. A model using a parametric description of the main hydrological processes at the catchment scale, such as infiltration and evapotranspiration, was calibrated with the existing data. The model then used projected rainfall from the climate change analysis and soil information to predict future flows.

River flow hydraulics and inundation mapping was performed with free and well-established software. The ultimate results used in the cost-benefit analysis were current and future probabilities of flooded areas within the Rohini Basin. To support analysis of embankments, modelling was performed both with the existing embankments as well as under the assumption of no embankments.

Cost-Benefit Analysis

Purpose

Cost-benefit analysis was performed to evaluate, under several potential climate change scenarios, two contrasting flood risk management approaches in the Rohini Basin, based on existing as well as potential interventions. In addition, the use of cost-benefit analysis under complex and dynamic conditions was investigated. By applying a highly data-and resource-intensive probabilistic cost-benefit approach, a detailed modelling approach was reviewed and evaluated for applicability, robustness (especially under uncertain conditions), and utility for the disaster risk reduction decision-making process.

The flood risk reduction strategies were evaluated through both quantitative and qualitative frameworks, the focus of this report being the quantitative cost-benefit analysis. The qualitative framework involved shared learning dialogues (SLDs) and focus group discussions with various community groups, as well as interviews of key informants. This complemented the quantitative cost-benefit analysis and captured many of the non-tangible and non-monetary aspects of costs and benefits of disaster reduction strategies.

Evaluated Strategies

The traditional highly centralized and hierarchical (in terms of decision-making and implementation processes) strategy to control rivers through embankments was analyzed for its past as well as projected future economic performance. A contrasting decentralized and more egalitarian ("people-centered") strategy, implemented at different levels, was also designed and analyzed for projected future economic performance. Interventions in this strategy at the household, community and wider societal level that were evaluated included:

At the individual level:

- raising of house plinths,
- raising of fodder storage units, and

- a water and sanitation package (rainwater harvesting, raising existing private handpumps and toilets).

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

At the societal level:
- promotion of flood adapted agriculture and
- strengthening of the overall healthcare system.

An important issue for such a people-centered strategy is "who pays?", as often costs are shared between different stakeholders. For the purposes of this analysis, it was assumed that all costs would be covered by a single external entity as opposed to being funded by individuals or the community.

Data Issues

An overview of data required for analyzing the multiple factors that contribute to hazard exposure, vulnerability and the effectiveness of risk reduction strategies was developed to guide data acquisition and analysis. Data were collected from secondary sources (government agencies, non-governmental organizations, etc.) and through a detailed survey of a sample of households in the basin. Confidence in data collected through the survey is higher than in data gathered from secondary sources, particularly for hydro-meteorological data.

Focusing on evaluating flood risk reduction strategies, survey villages were selected within zones at varying distances from the river and existing embankments. This involved identifying 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. Alltogether, 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. Drawn-up through extensive consultation with field teams during a pre-survey visit and testing, the survey questionnaire was designed to collect specific disaster-related loss, coping, exposure, vulnerability, preference and cost/benefit data.

Despite this intensive data acquisition effort, data availability and quality remained key issues in determining not only the specific analysis structure, but also the robustness of the results. Table 2 summarizes the key data elements required for a probabilistic cost-benefit analysis and issues that arose specifically in the Rohini Basin.

TABLE 2 | Data requirements and issues for the Rohini Basin flood risk analysis

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

Approach and Analysis

A combined backwards- and forwards-looking approach was applied to assess current and future flood risk. Review of past flood impacts provided estimates for current risk, while projected climate and exposure changes were used to estimate risk for the period 2007-2050.

Backwards-looking analysis

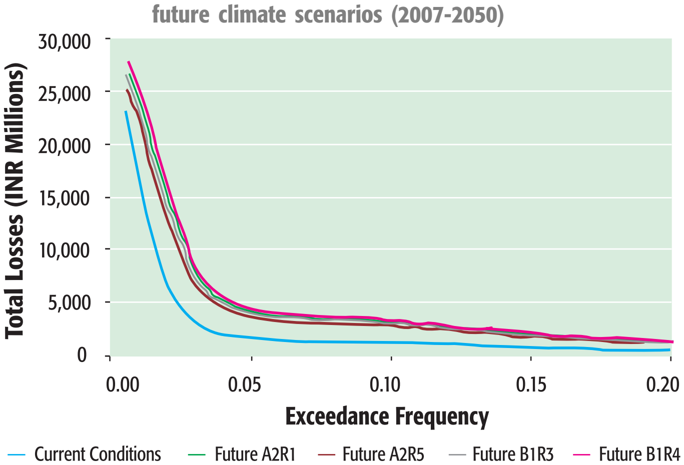
Basin-wide flood losses for the large 1998 and 2007 floods were primarily estimated using household averages from the survey, calibrated with secondary data. Considering that the survey focused in high flood risk areas, it was not representative of average basin conditions. Up-scaling of survey results to the full basin therefore took into account differences in the risk profiles of the survey sample versus the full basin.

Cost-benefit analysis of different risk reduction interventions required information on various categories of household financial losses due to floods. The survey yielded direct loss information for housing, assets, crops, livestock, wages and health/medical expenditures. Fodder losses were estimated indirectly based on crop damages and normal fodder purchases, while food and grain losses were developed from households' reported flood food aid needs. Increased debt-servicing loads due to floods were estimated by computing total interest paid for loans covering consumption losses and at high post-disaster interest rates. Due to the static nature of the analysis, multi-year reconstruction loans could not be considered. Secondary data was used to estimate public infrastructure losses (including public buildings). It must be noted that while data on relief was available, relief is a response to losses in the above categories and is therefore is not considered a loss category in its own right. Exclusion of relief data also prevents potential double counting.

As cost-benefit analysis must be performed under present conditions, losses from past floods were adapted to present conditions. Observed regional population dynamics were used to account for changes in exposure. Due primarily to a trend of switching from mud to brick construction, housing vulnerability has decreased by about 40% over the past 10 years. Enhanced rural communication (particularly the advent and rapid expansion of mobile telephones) has also led to better early warning, allowing for increased response time. After considering these exposure and vulnerability dynamics, as well as economic inflation, the estimated total flood losses in present value terms for the 1998 and 2007 events were INR 3.3 billion and INR 2.0 billion respectively.

Probabilistic cost-benefit analysis requires loss-frequency curves, providing loss estimates for a full range of return periods. Based on anecdotal evidence, overall monsoon descriptors and general loss trends, it was estimated that the 1998 flood was approximately a 50-year event, and 2007 a 25-year event. Using these two events, as well as an assumption that floods up to 2-year return periods do not cause losses, statistical distributions for each of the loss categories were developed.

| FIGURE 2 | Flood loss-frequency curves for current conditions and future climate scenarios (2007-2050)



Forwards-looking analysis

Modelled changes in flooded areas for the climate change scenarios were used to adapt the current condition loss-frequency curves developed during the backwards-looking analysis to projected future climate conditions. Figure 2 shows the results, representing best estimates of current and future monetary flood risk. It can be seen that climate change is projected to have a greater impact on frequent smaller events than rarer but larger events. In other words, while what is now a 10-year loss will in the future be about a 5-year event, a current 100-year loss will in the future be about a 60-year loss.

Expected Annual Losses

The primary outputs of the risk analysis for the cost-benefit analysis are the expected annual losses for the different loss categories and climate scenarios. These are determined by integrating under the estimated loss-frequency curves, the results of which are shown in Table 3. Major components of the basin-wide monetary flood impacts include crop losses (about 30% of the total), housing (20%), assets (15%), public infrastructure (10%) and wages (10%).

Average annual expected flood losses are projected to approximately double during the next 50 years due to climate change. This massive impact is again due to projections that losses from smaller but more frequent events will greatly increase. As this occurs, the annual average loss burden increases, such that these "small" floods become more important in terms of long-term economic impacts. With this increasing importance, the lack of real loss data for such events becomes more prominent. Estimates of small event losses based on statistical distributions could over- or under-estimate reality, greatly impacting the final results.

| TABLE 3 | Total average annual expected flood losses for Rohini Basin (INR)

Climate Scenario	Expected Annual Loss
Current conditions	564 million
Future A2R1	1169 million
Future A2R5	1052 million
Future B1R3	1141 million
Future B1R4	1226 million

Key Assumptions

Review of the risk analysis has identified a number of key assumptions driving the cost-benefit analysis design and results, summarized in Table 4. Further key assumptions in terms of costs, benefits and disbenefits are also listed in Table 4, and discussed in the following section.

TABLE 4 | Key assumptions driving the cost-benefit analysis

Assumption	Basis	Issues
District level secondary data representative of basin	Can pro-rate based on per cent of area in basin	District outside basin includes other rivers, regional major city.
Survey data representative of entire basin	Secondary data incomplete, no other choice	Although upscaling considered risk profiles, could still misrepresent basin.
Return periods of past events	Anectodal, overall monsoon descriptors and general loss trends	Inconsistent with hydrologic analysis, has major impact on estimated loss frequencies.
Pareto distribution best represents loss frequencies	Commonly used extreme value distribution, based on two loss events and no loss below 2-year event	Statistical fit based on 3 points is weak, has major impact on estimated loss frequencies. Estimates of high frequency flood losses a driving factor.
Rainfall and large-scale climate data are valid and accurate	Standard practice – no other choice.	Significant gaps and uncertainty in the geographically limited historic rainfall data adds uncertainty.
Relationships between rainfall and large-scale climate will remain valid in future	Standard practice – no other choice.	Monsoon rainfall has historically been linked to ENSO (El Niño) and other large-scale climate features. These relationships are changing and breaking down.
GCM (General Circulation Models) climate change projections are sufficiently dependable	Standard practice – no other choice.	Climate change appears to be happening much faster than the GCMs predict, e.g. the melting of Arctic and Greenland icesheets is faster than predicted. Actual climate change could be much different than model projections.
Basic hydrologic and hydraulic analysis sufficiently dependable.	Data limitations and desire to keep analysis simple.	In relatively flat basins with large anthropogenic alterations like the Rohini (embankments, land use changes, etc.), hydrology and hydraulics become dynamic and multi-dimensional.
Flood losses linearly related to flooded area	Simplification of modelling	Over-simplifies a complex issue, particularly for small events and economic flow (versus stock) losses.
Future exposure represented by projected populations	Nothing else available	Does not consider all autonomous adaptation.
Shifting of larger loss frequencies to reflect embankment failures	1998 and 2007 floods	Not calibrated with observations of flooded areas.
Intervention costs	Field experience	May not be appropriate for basin/programme specifics.
Intervention benefits	Modelling, field experience, expert judgement	Monetized values generally unproven, based on multiple small assumptions.
Intervention disbenefits	Modelling, field experience, expert judgment	Monetized values often unproven.
Discount rate	Standard "best practice"	Has major impact on results.

Embankment Costs

Costs from an embankment project completed in 2003 in Gorakhpur District were used as a basis, but compensation for land lost due to embankment construction was found to be inadequate. Using real land area compensated at market values, the original project capital costs of embankment construction doubled. While in the project annual operations and maintenance costs are given as 4% of capital costs, historical data shows actual spending in the basin was only about one quarter of this.

Embankment Benefits

The benefit of embankments is the difference between expected annual losses with and without embankments. The backwards-looking risk analysis provided estimates of these for the with-embankment or "real life" situation. The hydrologic/ hydraulic analysis produced flooded areas with and without embankments for the historical time period as well as future scenarios. Assuming losses to be linearly dependent on flooded areas, theoretical without-embankment expected annual losses were determined by pro-rating the with-embankment losses by the ratio of without- and with-embankment modelled flooded areas. While standard practice, the assumption that flood losses are linearly dependent on flooded areas is an over-simplification, but often due to data and time restrictions necessary.

To capture the realities of imperfect embankment maintenance and therefore performance, it was assumed that for the with-embankment condition a 50-year flood actually experienced 100-year losses. Such a shift in the loss-frequency curve could be justified based on observations during the 1998 and 2007 floods.

Cost-benefit analysis compares situations with and without a given project or intervention. The forward-looking cost-benefit analysis of existing embankments in the Rohini Basin must therefore consider the current reality that the embankments have already been built. As the immediate removal of all embankments is not realistic, the comparison is therefore not with versus without-embankments, but rather with versus without proper maintenance (thus impacting performance). Under the without-maintenance scenario, the embankments will lose effectiveness over time. Utilizing a typical engineering project lifespan of 30 years, the analysis assumes an annual decrease in performance leading to complete failure after 30 years. Benefits over time are further expected to increase due to increased exposure based on demographic trends.

Embankment Disbenefits

While costs reflect specifically the financial investments necessary for implementation of an intervention, the concept of "disbenefits" refers to the possible negative consequences of an intervention. Low intensity flood events, while causing damage, are also beneficial because they provide nutrients and water to the floodplains. With the construction of embankments, however, this natural nutrient and soil water recharge cannot occur. It is also well known that embankments cause water logging on land immediately behind the embankments, due to the inability of local rainfall and tributary flows to adequately drain into the main river. This water logging causes both losses in crop production and increases in waterborne vector-based diseases. These disbenefits were monetized and included in the analysis.

People-Centered Strategy Costs

Costs for the individual interventions were based primarily on field experiences. For given interventions, costs are probabilistic depending on flood intensity and frequency. In these cases an averaged annual value was computed. Annually recurring costs are relatively high, about two-thirds of capital costs (as opposed to 4% for embankments). This reflects the more systemic resilience-driven approach of the strategy, which requires constant and consistent resources rather than massive up-front investments.

People-Centered Strategy Benefits

Benefits for each intervention were considered individually for each loss category defined in the risk analysis. Table 5 provides an overview of the assumed loss categories reduced by each intervention. In many cases an intervention provides benefits only for one or two loss categories while, at the other extreme, the maintenance of key drainage points was considered to reduce losses for all categories, as it would reduce the actual flooding hazard.

Ultimately the various interventions combine to reduce losses. As a simple modelling approach, loss reductions from different interventions are added, but not allowed to exceed full loss prevention. In some cases the total sum would far exceed total flood losses, indicating that there are either benefits beyond flood reduction, or inefficiencies in the strategy design. Benefits beyond flood reduction, such as increased agricultural productivity, are considered separately in the cost-benefit analysis, but the issue of strategy design efficiency (avoiding duplication of efforts) must be considered during planning.

TABLE 5 | **Financial loss categories reduced by the various people-centered interventions**

Interventions	Housing	Assets	Crops	Seeds	Livestock	Fodder	Debt servicing	Wages	Health/medical	Food & Grain	Infrastructure
Individual Level											
Raise house plinth	X	X			X	X				X	
Raise fodder storage unit					X	X					
WatSan package							X		X		
Community Level											
Early warning		X									
Elev. handpumps & toilets					X				X		
Flood shelters		X			X				X	X	
Community grain bank							X				
Community seed bank							X				
Maintain key drainage points	X	X	X	X	X	X	X	X	X	X	X
Self help groups							X				
Purchase community boat								X			
Societal Level											
Flood adapted agriculture			X								
Strengthen overall healthcare							X	X	X		

People-Centered Strategy Disbenefits

As opposed to the embankments, possible disbenefits identified for the people-centered strategy are, for example, loan defaults by self help groups and groundwater contamination due to poor oversight of private toilets. Such disbenefits were not considered in the cost-benefit analysis, however, as they were considered unlikely to occur.

Discount Rate

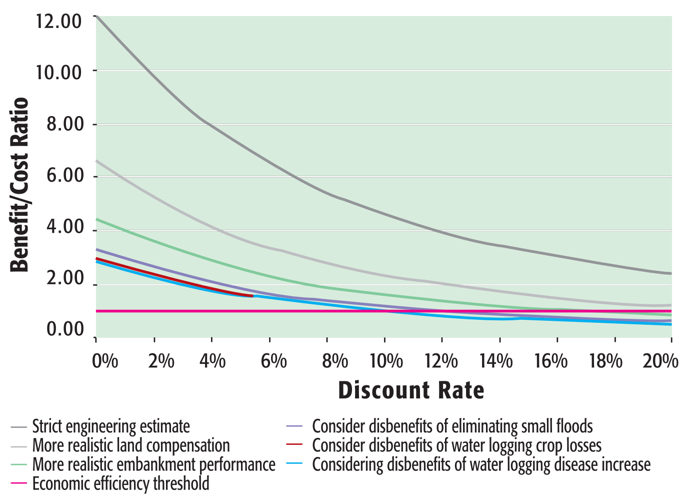
In economic calculations, future benefits are discounted in relation to current benefits to reflect the cost of capital. This is justified on the assumption that the current value of future benefits from investments should be compared to existing secure alternative investment alternatives for the same funds. Applying high discount rates expresses a strong preference for the present while potentially shifting large burdens to future generations. Standard practice in developing countries assumes a discount rate of 10-12%, while sensitivity analysis covering the full range of 0-20% is useful to understand the implications of the chosen rate.

Main Results

Historical Embankment Performance

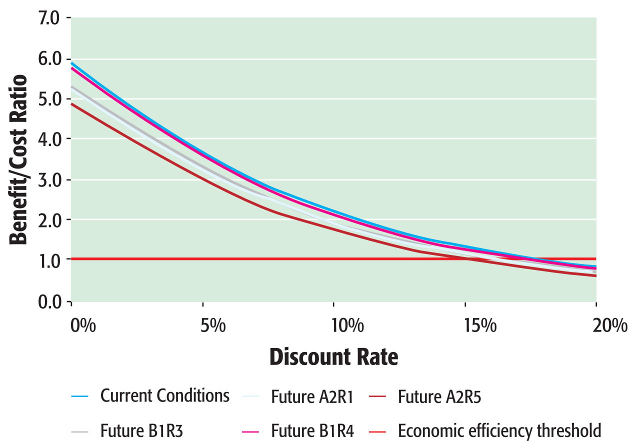
Figure 3 shows the computed benefit/cost ratios, under multiple modelling assumptions and a range of discount rates, for past embankment performance since 1973. A benefit/cost ratio over 1.0 generally reflects that the intervention is economically efficient.

| FIGURE 3 | Results of CBA for historical performance of embankments



Traditional engineering analysis of infrastructure projects tends to ignore disbenefits and often does not capture all societal costs. Such an approach based on official embankment costs and hydrologic engineering analysis yielded at a discount rate of 10% a benefit/cost ratio of about 4.6, indicating high economic efficiency. It could therefore be concluded that the embankments have been "worth it." When refining the analysis, however, the economic efficiency reduces greatly. By considering real land compensation costs, the benefit/cost ratio is about halved. Further adding to the analysis a better reflection of real embankment performance, that is insufficient maintenance (as also reflected in the costs) leading to failures, the benefit/cost ratio further reduces to about 1.6 (again at discount rate 10%). When these disbenefits are explicitly taken into account, the embankments become economically inconclusive (benefit/cost ratio of 1.0 at discount rate of 10%). Considering that all disbenefit assumptions and computations were conservative, and reflecting on the many uncertainties within this probabilistic analysis, it cannot be concluded with any confidence that the embankments of the Rohini Basin have been economically effective since 1973.

| FIGURE 4 | Results of CBA for future embankment maintenance



Future Performance

Figure 4 shows the results of the cost-benefit analysis of proper embankment maintenance under different climate projections.

Not surprisingly, the benefit/cost ratios for practicing proper embankment maintenance are above 1.0. Even with their disbenefits, it is economically efficient to maintain existing embankments. The benefit/cost ratios for all scenarios are however not greatly above 1.0. Considering that already incurred capital costs are not included in this analysis, a much higher benefit/cost ratio for simply maintaining the embankments may be expected. These not-too-high benefit/cost ratios point to the importance of proper embankment maintenance, which implies higher costs but also more effective performance.

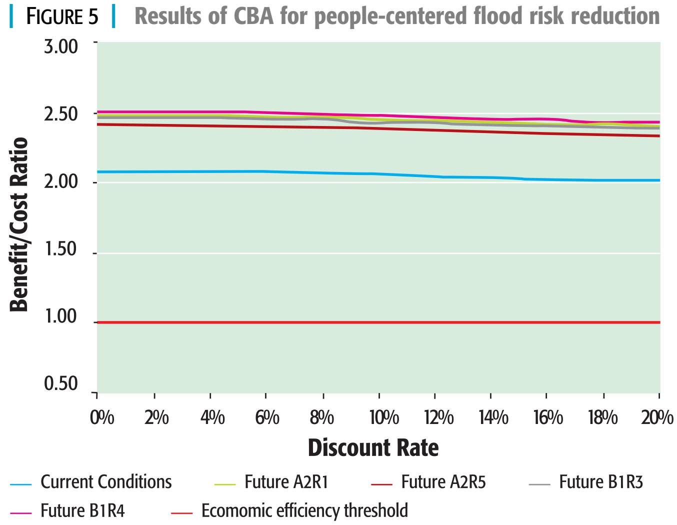
Projected climate change impacts lead to reduced embankment performance. While the embankment designs and implementation remain the same, with an increasing intensity of floods they become less effective.

People-Centered Strategy

The results of the cost-benefit analysis of the people-centered strategy for 2007-2050 considering different climate change projections are shown in Figure 5.

Benefit/cost ratios for the people-centered strategy are above the economic efficiency threshold of 1.0. The discount rate has a limited impact on the results, with benefit/cost ratios barely changing over the spectrum of tested discount rates. This is because although annual costs may be high, annual benefits are still always greater, such that the weight given to current versus future years is less important. Considering that the only non-flood related benefits explicitly considered were those resulting from adapted agricultural practices, it must be assumed that the true economic efficiency of the strategy, when considering other direct and indirect benefits, may well be higher than what is shown in Figure 5.

| FIGURE 5 | Results of CBA for people-centered flood risk reduction



As opposed to the embankments, the economic efficiency of the people-centered strategy increases when climate change is considered. Due to the resilience-driven approach of the strategy, increases in flooding result in increases in benefits (while the flooding may be greater, their impacts are still reduced, leading to greater benefits). The actual flood risk reduction of the people-centered strategy in light of climate change is admittedly difficult to quantify. However, even if the current assumptions of future risk reduction are overly optimistic, sensitivity analysis shows that with a 50% reduction in the assumed benefits, the benefit/cost ratios under climate change projections are still around 1.2. While due to uncertainties and the probabilistic nature of the analysis a benefit/cost ratio of just over 1.0 does not guarantee economic efficiency, considering that this represents a worst-case scenario, a certain robustness of the results can be inferred.

Comparison of Strategies

While cost-benefit analysis of classical engineering solutions like embankments is considerably easier than for more community/household-based approaches, the results appear to be less robust. People-centered resilience-based flood risk reduction approaches tend to provide benefits (many not even captured in this study) that occur every year, regardless of if a flood occurs or not. As costs are also primarily annual (as opposed to one-time initial), it is safe to say that if annually benefits are greater than costs, than the project is "worth it." This holds true also for embankments, but such threshold-driven benefits are probabilistic (they may or may not be realized in any given year), while resilience-based approaches tend to yield at least some benefits every year.

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

Estimating the costs and benefits of the embankment strategy proved more straightforward than the people-centered strategy. Embankments are engineering constructions with specific dimensions and thus costs, as well as threshold-driven designs that make it relatively easy to estimate benefits. These are, however, challenged by the primary assumptions that embankments will always be perfectly maintained and subsequently perform as planned, and that all flood losses including those involving financial flows and regional supplies are reduced proportionally to the reduced area of flooding.

People-centered benefits are more difficult to assess. Assumptions must be made on intervention impacts at the household level, also varying by flood intensity. Further, the combining of benefits of multiple interventions, while performed linearly in this study, is in reality likely not a simple sum of benefits. As different interventions provide benefits, behaviours and risk choices may change, leading to dynamic starting points for other benefits. Non-flood related benefits, while clearly of importance to people-centered strategies, may also be difficult to quantify.

In theory, the resource management of a people-centered strategy, defined by relatively high annual costs, should be left to the served communities and include self-propagating resource mobilization (return on investments). It also, however, begs the question of securing guaranteed long-term outside support as opposed to one-off "donations."

Cost-Benefit Analysis Issues

Evaluation

Intense data collection efforts in the Rohini Basin provided very useful insights into household flood impacts and coping strategies, particularly through the survey. At the same time, however, the collected data still provided only an incomplete picture of flood losses for two large and recent events. Broad assumptions were needed to estimate various categories of losses, both at the household and basin levels. In light of the multitude of uncertainties introduced during other stages of the CBA, the data collection effort, while indeed increasing confidence in assumptions, cannot be considered to have been worthwhile in terms of improving the CBA results.

Given the vast uncertainties in the collected data, risk analysis and cost, benefit and disbenefit estimations, the results of cost-benefit analyses are racked with compounded uncertainty. Final numbers must therefore be treated in terms of order of magnitude to draw reasonable conclusions, and a benefit/cost ratio of over 1.0 cannot without hesitation be accepted as an indicator that an intervention is "worth it."

While the absolute results may not always be robust, the process of developing the analysis itself was quite useful. Beyond the fundamental challenge of risk analysis, assumptions about disaster reduction strategies were developed in a transparent and logical manner. Particularly for people-centered approaches, the compounding of benefits had to be considered, possibly also contributing to the optimization of limited resources. Without transparent and detailed discussions between the involved stakeholders, however, cost-benefit analysis can be easily manipulated and thus misused.

For the people-centered flood risk reduction strategy cost-benefit analysis was used to provide an aggregated economic analysis of the full strategy. It could just as easily be applied individually to each intervention to provide component evaluations. This would, however, lead to incomplete results as some more coordination-driven actions, while contributing to the overall strategy impacts, may on their own provide little monetizable risk reduction benefits (for example, the development of self-help groups).

A known drawback of cost-benefit analysis is that it does not consider distributional aspects, that is “who pays?” and “who benefits?”. This continues to be a challenge when analyzing centralized disaster reduction strategies like embankments, but is somewhat better handled through the inherent designs of people-centered risk reduction strategies.

Possibilities for Improvement

Provided the necessary data were available, the hydrometeorlogic hazard analysis could well be refined by utilizing more complex analysis methods. Given the intense data acquisition required for this, as well as current limitations on climate modelling, such an effort is likely not worth the effort in terms of improving overall results. This conclusion is further supported by the identified analysis limitations: results should be considered in terms of orders of magnitude with the process being more important than the exact values.

As discussed, the cost-benefit analysis did not explicitly consider who loses and who benefits from disaster reduction interventions ("distributional aspects"). Such information is particularly critical for specifically targeting assistance to the poor and vulnerable. It is thus important to simultaneously consider more qualitative vulnerability, preference and risk reduction analyses. These should help guide not only strategy design, but also support assumptions used within the cost-benefit analysis. Less tangible and therefore difficult to monetize costs, benefits and disbenefits would be given due consideration, unlike in the current approach.

The analysis as performed has captured only benefits with regards to reductions in immediate asset losses. Flow effects, such as dynamic impacts on household income, savings and consumption over many years, are better indicators for individual and societal welfare and changes therein due to shocks such as disasters. In our case, asset effects were used as a proxy for the flow effects, which may be sufficient given the scope of the analysis. A more comprehensive yet more complex analysis such as conducted in the Risk to Resilience Working Paper No. 5 would better reflect long-term welfare issues.

The Policy and Programme Context

Cost-benefit analysis can be used to contribute to effective decision-making and bridging coordination gaps across ministries and departments dealing with flood management. Assumptions driving the analysis have been transparently presented and could be refined through targeted consultations among ministries, departments, community organizations and other stakeholders.

Disaster risk reduction interventions are implemented by various ministries and departments. The Government of India has recently developed a framework for better coordination to address horizontal and vertical integration across ministries and departments. Cost-benefit analysis could help to operationalize such coordination through a clear and transparent process.

In India, embankment construction has been the dominant strategy considered for flood management in spite of the attempts of civil society groups to force a reconsideration of the strategy. Many of the reasons behind this are reflected in the cost-benefit experience:

- challenges of understanding the (disaggregated) impacts of embankments and (aggregated) impacts of decentralized risk reduction strategies,
- inability of civil society to engage effectively with relevant government departments,
- unwavering support or criticism of different risk reduction approaches without a sound scientific baseline and
- promotion of a single approach rather than a diversified basket of options.

Attempts to undertake a quantitative cost-benefit analysis for different risk management strategies have highlighted major gaps in data availability. This has important policy relevance: if basic data are not available, then it is impossible to generate the knowledge and information base required to inform policy-making. Identifying such gaps can assist relevant government departments refining their data acquisition. The results of this study also suggest that, if maintained, existing embankments have the potential to reduce some of the flood risk even under climate change projections. Adequate and consistent maintenance is, however, required and resources within organizations such as the irrigation department should be committed for this. Overall, approaches need to emphasize the development of strategies, such as the more "people-centered" approaches that local populations already practice, that are resilient under changing climatic conditions while deemphasizing reliance on structural control measures.

Traditionally, cost-benefit analysis is driven primarily by monetized figures of costs and benefits. Often undertaken through non-transparent processes utilizing biased assumptions, as well as ignoring important negative and positive externalities (disbenefits), cost-benefit analysis can be used to steer decision-making towards the interests of dominant stakeholders. This risk, especially within a strongly hierarchical discourse, continues to exist.

Conclusions

Historical analysis of embankments following a strict engineering cost-benefit analysis shows a high benefit/cost ratio, indicating economically efficient performance. However, when conservative estimates of disbenefits, more realistic costs and actual structural performance are incorporated, the ratio reduces substantially. Given the many uncertainities involved, it cannot be concluded that the Rohini River embankments have performed in an economically satisfactory manner. Future analysis indicates that proper embankment maintenance, even under climate change projections, is economically efficient. Projected climate change will, however, reduce embankment economic performance.

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

Simplified estimation of the costs and benefits of embankments is relatively straightforward, but challenged by issues of proper embankment maintenance and vast loss assumptions. People-centered cost and benefits are even more difficult to assess, with assumptions required not only at the household level, but also with regards to compound impacts of multiple interventions. Add to this vast uncertainty in the risk data, assumptions and analysis, as well as intervention disbenefits, and the results of the cost-benefit analysis are themselves highly uncertain. This is even more pronounced when climate change is taken into consideration.

Cost-benefit analysis is a useful support tool for decision-making, but it does not capture distributional (who benefits?) and non-monetizable aspects of disaster risk reduction well. It should, thus, not be used alone, but rather concurrently with more vulnerability and stakeholder-driven processes. While the ultimate results of cost-benefit analysis should be considered only in terms of orders of magnitude, the approach provides a logical and transparent framework for organizing and reviewing assumptions. It can thus help operationalize and promote dialogue and integration of policies and programmes across ministries, departments and other organizations.

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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

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

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