

From Risk to Resilience

Working Paper 1

*The Cost-Benefit Analysis
Methodology*



Reinhard Mechler (IIASA) &
The Risk to Resilience Study Team



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SECTION 1

Cost-benefit Analysis and its Role in Disaster Risk Management

A limited number of studies have demonstrated that disaster prevention can pay high dividends and found that for every Euro invested in risk management, broadly 2 to 4 Euros are returned in terms of avoided or reduced disaster impacts on life, property, the economy and the environment (Mechler, 2005). Despite the benefits, disaster risk management (DRM) measures are rarely implemented and there is, for the most part, a reliance on reactive, after-the-fact approaches. For example, bilateral and multilateral donors still allocate 90% of their disaster management funds for relief and reconstruction and only the remaining 10% for disaster risk management (Tearfund, 2006). This low level of investment in prevention can be explained by a lack of understanding and concrete evidence regarding the types and extent of the cost and benefits of preventive disaster risk management measures.

Cost-benefit analysis (CBA) is an established tool for determining the economic efficiency of development interventions. CBA compares the costs of conducting such projects with their benefits and calculates the net benefits or efficiency (measured by the net present value, the rate of return or the benefit-cost ratio). While the benefits created by development interventions are the additional benefits due to, for example, improvements in physical or social infrastructure, in disaster risk management the benefits are mostly the avoided or reduced potential damages and losses, including the benefits of the primary development interventions.

OECD countries, such as the United Kingdom and the United States have used CBA frequently for evaluating DRM in the context of development assistance. CBA is also frequently utilized by development banks such as the World Bank, the Asian Development Bank and the Inter-American Development Bank. The World Bank is considered the "chief practitioner" of CBA. It is important to note, however, that actual usage of CBA in disaster management has been limited. This said, interest in economic aspects of DRM has been increasing with high profile disaster events such as the Indian Ocean Tsunami, the East Pakistan Earthquake and Typhoon Sidr in Bangladesh and CBA is increasingly seen as a key tool for economic evaluation. Additionally, with climate change impacts already being

observed and projected with higher confidence, adaptation to extreme events and climate variability and the fair and efficient allocation of adaptation funding is rising to the forefront of climate and DRM policy.

This working paper discusses key methodological aspects and findings from CBA of DRM strategies in a detailed case study in Uttar Pradesh, India (Risk to Resilience Working Paper No. 5). It also provides a backdrop for other case studies carried out under the Risk to Resilience project. It is a shorter version of a more detailed guide on conducting CBA to be published in the main Risk to Resilience Project Report.

We conclude that CBA can be a useful tool in DRM *if* a number of issues related to conducting a CBA assessment and using results are properly taken into consideration. These issues are discussed briefly in the sections below before discussing the essentials of CBA and its application in the specific context of DRM.

Clarify objectives of conducting a CBA on DRM

Before engaging in a CBA assessment, it is necessary to clarify the objectives, information needs and data situation among different potential stakeholders. Such stakeholders may include representatives from local, regional and national planning agencies, NGOs working in development and disaster risk management, disaster risk managers, officials concerned with public investment decisions, development cooperation staff and local communities. The type of envisaged product is closely linked to its potential users. A CBA may be conducted for merely informational purposes (such as in the Lai Basin case - Risk to Resilience Working Paper No. 7), as a pre-project appraisal (the India Uttar Pradesh flood study- Risk to Resilience Working Paper No. 4), as a full-blown project appraisal (the India Uttar Pradesh drought study- Risk to Resilience Working Paper No. 5) or as an ex-post evaluation (touched upon in the India Uttar Pradesh flood study as well). Purposes, resource and time commitments and the expertise required differ significantly for these products. At a very early stage of the analysis, 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 and climate change adds substantial additional complexity. Disaster events in essence are probabilistic events and, as a consequence, benefits to risk management are probabilistic and arise only in case of an event occurring. Accordingly, benefits should be assessed in terms of probability multiplied by the consequences, leading to an estimate of risk as the product of hazard, vulnerability and exposure. While enormous progress has been made in recent years in better understanding and modelling disaster risks, the uncertainties in projecting future climate conditions at local levels and thus the probability of hazard events

(droughts, extreme storms, floods, and so on) adds additional complexity. This is due to inherent limitations in modelling the climatic system and anthropogenic interventions.

Often, attempts to probabilistically estimate future disasters risks in ways that include the effects of climate change are defeated by the lack of reliable probabilistic information. Furthermore, even given a good understanding of the system as a whole, conducting a CBA of DRM measures is often difficult due to lack of data, expertise and the high demand on resources. Often, methodological shortcuts have to be used and assumptions made in order to arrive at a broader understanding of key risks and benefits of DRM. These specific challenges and characteristics of disaster risk management need to be properly communicated and understood in order to properly interpret results derived in a CBA.

Process-Oriented

Given the complexities involved in estimating the costs and benefits of DRM and the history and current usage of CBA as a decision support tool, we conclude that the role of CBA in DRM is strongly related to *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 with processes such as climate change affecting risk significantly, CBA should not be viewed as a purely outcome-oriented tool for evaluation of DRM. This is particularly true in data-restricted environments such as those frequently encountered in developing countries.* If this is properly understood, this caveat effectively may be used to the advantage of CBA in DRM, where process-orientation and inclusion of a host of stakeholders play critical roles. One tool to organize such a process is *shared learning dialogues (SLDs)*, which, by bringing together the perspectives of diverse community, expert and government groups, can be used to assess uncertainties. They can also be used to refine and bound assessments of recurrence periods, valuations, etc. As a result, SLDs provide perhaps the best avenue of assessing many of the variables where quantitative data are lacking or insufficient.

Based on the case studies conducted in India, Pakistan and Nepal in the Risk to Resilience project, we explore the above findings in more detail in the following sections. The next focuses on the essentials of CBA generally. Following that, we outline key components necessary for utilizing CBA to assess DRM interventions. We continue by providing more detail on these key aspects by discussing the assessment of risk in Section 4, the identification of risk management measures and associated costs in Section 5, the analysis of the benefits of risk management in Section 6 and finally provide an outline of methods for calculating the economic efficiency of DRM. In the final sections, 8 and 9, we summarize key aspects of the case studies conducted and conclude.

SECTION 2

Essentials of 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 (Kopp et al., 1997). CBA is similar to (and often confused with) rate-of return assessment or financial appraisal methods undertaken in business operations to assess whether investments are profitable or not. Yet, CBA takes a broader perspective and aims at estimating the overall "profit" for society rather than mere financial gains accruing to an individual business.

The need for economic evaluation is related to the basic economic functions of governments. These include the allocation of public goods (education, safety, clean environment) and assets (infrastructure), and achieving a more equal distribution of income (e.g. Gramlich, 1981). The overarching objective is to increase per capita income and consumption. In order to judge if a project or other investment is a worthwhile undertaking, benefits have to be compared to costs by a common yardstick. Costs are the opportunity costs of not being able to invest scarce government resources (essentially tax revenue) into other objectives. Broadly speaking, if benefits exceed costs then a project should be undertaken. The task of CBA is to systematically assess the costs and benefits and check whether social welfare is indeed maximized. The following box outlines the typical stages of a project cycle. The stages where CBA may play a key role are marked in bold (Box 1).

General development programming defines guidelines, principles and priorities for development cooperation. The actual project planning starts with project identification and specification. This leads to the next, the appraisal stage where project feasibility from different perspectives is checked. Alternative versions of a project will be assessed under criteria of social, environmental and economic viability. In a fourth stage, the financing dimension of the projects will be determined which is followed by the actual

BOX 1

Stages of project cycle with stages where CBA can be used shown in bold face

1. Programming
2. **Project identification and specification**
3. **Appraisal: technical, environmental and economic viability**
4. Financing
5. Implementation
6. **Evaluation**

Source: Based on Benson/Twigg, 2004.

implementation. Finally, projects should be evaluated after completion in order to determine actual project benefits and whether the implemented projects did meet the expectations (Benson and Twigg, 2004; Brent, 1998).

While CBA's main function is to inform the actual project appraisal stage, it is important in the other phases of a project cycle as well. Broad-based analyses may inform the programming stage regarding priority sectors. CBA may also be used to generate very specific information in the project identification and specification stage (pre-project appraisal stage) where it can be used to help select potential projects and reject others. In the evaluation phase, CBA is regularly used for assessing if a project really has added value to society.

Pros and Cons of CBA

There are numerous limitations to CBA that must be considered. One important issue is that CBA does not address the distribution of benefits and costs.¹ Societal welfare is maximized by simply aggregating individual welfare over all people affected and changes therein due to projects and policies. A focus on maximizing welfare, rather than optimizing its distribution is a consequence (Dasgupta and Pearce, 1978). Changes in outcomes of "winners" are lumped together with those of "losers", and compensation between those two groups is not required. Moreover, perceptions regarding who is losing or winning can be subjective. CBA also cannot resolve the 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 why the Risk to Resilience project has focused on distributional factors by incorporating them in the qualitative analyses and shared learning dialogues discussed in the project summary (Risk to Resilience Working Paper No. 9) and the case studies. Generally, it is advisable to use CBA in conjunction with other decision support methods, such as cost-efficiency or multi-criteria analysis.

A difficulty with CBA is the challenge of assessing of non-market impacts, such as on health and the environment. Although methods exist for quantifying such values, this often involves difficult ethical judgments, particularly regarding the value of human life, for which CBA should be used with caution. Another important issue is the issue of discounting. In economic efficiency calculations, future benefits are discounted in relation to current benefits to reflect an (empirically confirmed) preference for living and consuming today versus doing so in the future. Applying high discount rates, as often suggested particularly for development cooperation, expresses a strong preference for the present while potentially shifting large burdens to future generations assuming future generations will be better off and able to deal with those burdens. Yet, this underlying key assumption is not valid

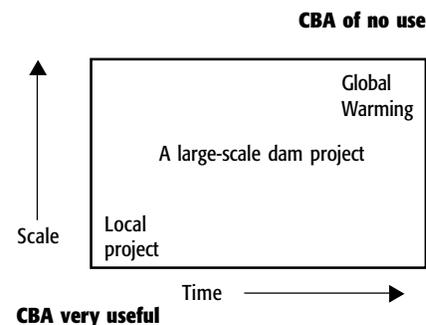
¹ A key tenet of CBA is that those benefiting from a specific project or policy should potentially be able to compensate those that are disadvantaged by it (Dasgupta and Pearce, 1978). Whether compensation is actually done, however, is often not of importance. Also, methods to account for the distribution of costs and benefits exist, but are hardly used in practice due to the additional methodological complexity involved (Little and Mirrlees, 1990).

when impacts are large-scale and irreversible, and consequently the application of a discount rate demands careful scrutiny. For example, for the analysis of embankments in the Uttar Pradesh flood case, when following strictly an analysis that focuses on engineering benefits only, high benefit/cost ratios in terms of flood losses avoided are calculated. Yet, given the many disbenefits such large-scale infrastructure brings about (waterlogging, health disamenities, etc.) and associated uncertainties with such estimates, it cannot reasonably be concluded that embankments have historically performed economically satisfactorily.

Time and scale of projects are important considerations when doing a CBA. While originally strictly focused on a project level, CBA has frequently been used to inform larger-scale investment decisions such as dam construction and other large scale infrastructural development such as the siting of airports and nuclear reactors, It has even been used to inform global climate change policy related to the UNFCCC negotiations. Generally, as the scale and time horizon of projects and thus uncertainties increases, as illustrated in the accompanying chart, it is important to question the usefulness and robustness of CBA.

Yet, keeping these limitations in mind, CBA can be a useful tool and its main strength is its explicit and rigorous accounting of those gains and losses that can be effectively monetized, and in so doing, making decisions more transparent. CBA is a framework that supports coherent and systematic decision-making and provides a common yardstick with a money metric against which to measure projects (Kopp et al., 1997). However, CBA has to be seen as a guide to decision-making and leading to an approximation of preferences of society rather than an expression of the exact economic value of a given investment. CBA and economic efficiency considerations should not be sole criterion for evaluating policies. They should rather be part of a larger decision-making framework incorporating social, economic and cultural considerations. However to many (government) decision-makers, economic efficiency is the most important aspect. In the USA, for example, cost-benefit considerations have "at times dominated the policy debate on natural hazards" (Burby, 1991).

FIGURE 1 | Usefulness of CBA in time and space



Source: Gowdy, 2007

SECTION 3

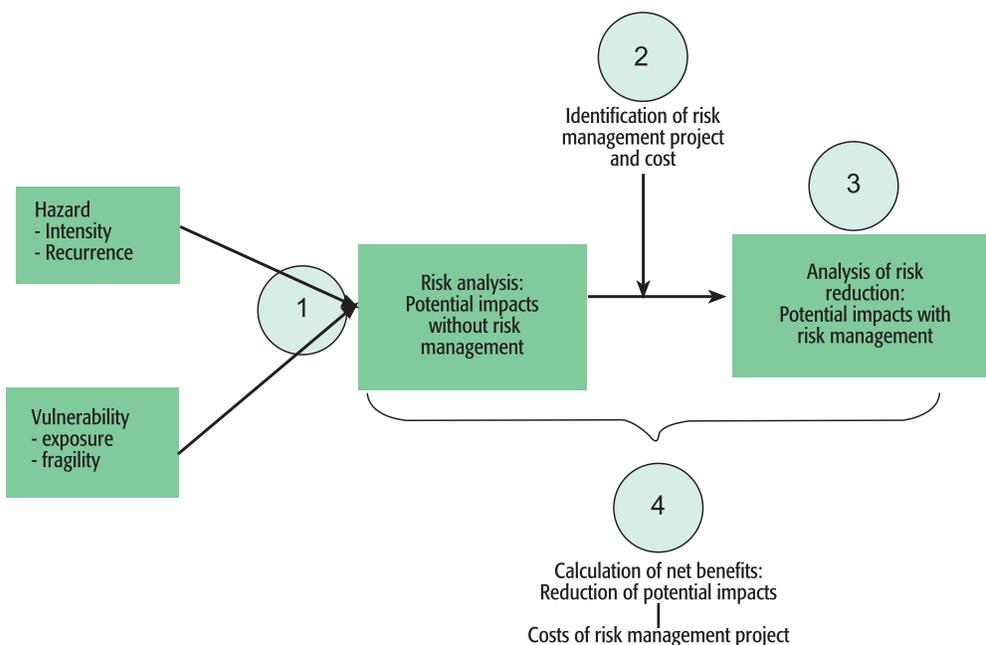
Application of CBA to Disaster Risk Management

In the context of DRM, two important issues deserve special attention when conducting a CBA.

1. Assessment of risk: The analysis should be done in a stochastic manner in order to account for the specific nature of natural hazards and associated disaster impacts. This is to say that analyses should take account of the probability of future disaster events occurring.
2. Assessment of avoided risks: As disaster risk is a downside risk, benefits are the risks avoided. The core benefit generated by investments in disaster risk management is the reduction in future impacts and losses.

For the DRM context, we operationalize the CBA process in four steps as shown in Figure 2.

FIGURE 2 | Framework for estimating risk as a function of hazard and vulnerability



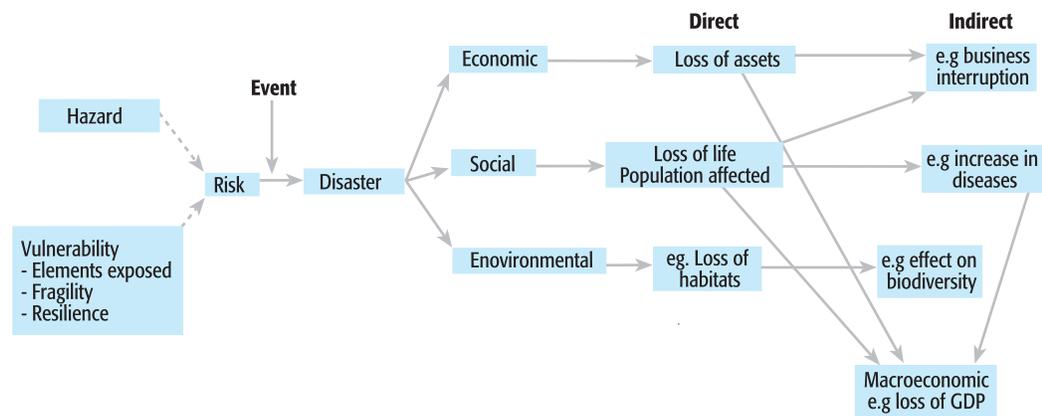
1. **Risk analysis:** risk in terms of potential impacts without risk management has to be estimated. This entails estimating and combining hazard(s), exposure and vulnerability.
2. **Identification of risk management measures and associated costs:** based on the assessment of risk, potential risk management 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:** finally, economic efficiency is assessed by comparing benefits and costs.

In the following sections, we will go through each of these steps in detail.

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 (Figure 3).

FIGURE 3 | Natural disaster risk and categories of potential disaster impacts



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

Hazard

Hazard analysis involves determining the type of hazards affecting a certain area with a specific intensity and recurrency period in order to derive a stochastic representation of the hazard. In order to systematically represent weather, a climate downscaling model is a useful tool for generating scenarios future rainfall or temperature values conditioned on observed weather and climate change projections. As climate change is already happening and is projected to effect low magnitude variability and extreme

weather-related events in terms of frequency and/or severity in many places, as most prominently elaborated in the 4th assessment report of the IPCC (Solomon et al., 2007), its effect on hazards needs to be factored into the analysis. In order to derive a representation of regional or local future weather, information of global climate models has to be downscaled to the local conditions. This involves considerable expertise and resources and requires substantial data. It is important to recognize that the validity of probabilistic cost-benefit analyses depends heavily on the accuracy and robustness of results from downscaling. If high levels of uncertainty exist regarding the accuracy of future projections, then there is little basis for making probabilistic estimates of costs and benefits.

Exposure

The *exposure* of people, assets and the environment to a certain hazard needs to be identified next. This involves assessing current and future socioeconomic, landuse and other trends. Accounting for changes in exposure is important, as reductions in future damages and losses often may be compensated by the sheer increase in people and assets in harm's way.

Vulnerability

People's vulnerability to hazards of a specific intensity and recurrence period have to be assessed as part of cost-benefit analysis. *Vulnerability* is a multidimensional concept encompassing a large number of factors that can be grouped into physical, economical, social and environmental factors (see GTZ, 2004). In order to operationalize and estimate vulnerability for CBA purposes, it can be defined (and we do so for the Risk to Resilience project) more narrowly as the degree of impact observed on people and exposed elements as a function of the intensity of a hazard.

In addition to exposure and vulnerability, *resilience* -- the ability to "bounce" back to pre-disaster conditions -- is an important dimension of vulnerability. Resilience decreases vulnerability. The size and duration of indirect impacts strongly depends, for example, on resilience. In contrast to exposure and vulnerability (concepts that focus more on the immediate impacts of disasters), resilience has a longer time frame and relates more to the secondary impacts of disasters. Appropriate organizational structures for prevention, mitigation and response have a decisive influence on resilience. Risk is the combination of hazard and vulnerability. Estimates of it can be used to identify the potential effects to be expected. Risk management projects aim at reducing these effects. It is difficult to capture the numerous factors that contribute to resilience (such as availability of organizational structure and know-how to prevent and deal with disasters) in quantitative terms. As a result, resilience is often not addressed effectively. This is, again, a major reason for coupling quantitative techniques with more qualitative assessment measures and processes. Discussions in shared learning dialogues, for example, often highlight factors that contribute to resilience but are absent in official data sets or difficult to quantify.

Data Sources and Availability

Table 1 gives an overview of key data sources useful for estimating risk. Collecting data on the elements of risk can be time-intensive and difficult. Particularly, information on the degree of damage due to a certain hazard is usually not readily available. As a consequence, in some instances, estimates need to be based on past impacts.

TABLE 1 | Data sources for hazard, exposure, vulnerability and impacts information

Component	Data source	Comment on data availability
Hazard	Scientific publications and official statistics, post-disaster publications, geological meteorological and water authorities, local governments. Disaster management authorities. For climate change: global circulation models, regional downscaling.	Reliable weather and climate data often not available or incomplete. The need for climate downscaling and climate change information adds considerable complexity
Exposure	Statistical agencies, private firms. Disaster management authorities	Often some data available
Vulnerability	Specialized engineering reports. Disaster management authorities	Usually not available, often approximated by using information from other sources or from past events. Need to do survey or use expert assessment.
Impacts of past events	Official post- disaster publications. Standardized databases. Local, regional and national governments, industry and commercial groups. Disaster management authorities	Normally some data available, normally on direct economic impacts as well as direct social (loss of life)

In the Risk to Resilience project, most of the primary information required to evaluate hazards has been collected through the initial scoping activities and associated searches of available databases. Exposure and vulnerability data have been taken from secondary data sources. Information on future climatic conditions was required and necessitated a major investment in climate downscaling to estimate future rainfall patterns in the Uttar Pradesh case studies in India (see Risk to Resilience Working Paper No. 3). In addition, a survey was conducted for the flood and drought studies in Uttar Pradesh, leading to an extensive database on exposure and vulnerability of rural households. This information has been supplemented and cross-checked through the shared learning dialogue processes. Despite this extensive data collection and generation effort, data gaps remained and significant assumptions were required to estimate costs and benefits.

Overview of Risk and Potential Impacts

The combination of hazard, exposure and vulnerability leads to risk and the potential impacts a natural hazard may cause. Risk is commonly defined as the probability of a certain event multiplied by the impacts. In most cases there are a large number of potential impacts. In practice however, only a limited amount of these impacts can and usually are assessed. Table 2 presents the main indicators for which usually at least some data can be found.

TABLE 2 | 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				
<i>Private Sector</i>				
Household	Housing damaged or destroyed	Loss of wages, reduced purchasing power		Increase in poverty
<i>Public Sector</i>				
Education Health Water and sewage Electricity Transport Emergency spending	Assets destroyed or damaged: building, roads, machinery, etc.	Loss of infrastructure services		
<i>Economic Sectors</i>				
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				

The list of indicators is structured around three broad categories: social, economic and environmental; whether the effects are direct or indirect; and whether they are originally indicated in monetary or non-monetary terms (Table 3). Options for monetizing non-monetary data will be discussed further below.

TABLE 3 | 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

Social consequences may affect individuals, households or have a bearing at the societal level. Most relevant *direct* effects are the loss of life, people injured and affected, loss of important memorabilia (e.g. pictures or other sentimental, non-replaceable items), damage to cultural and heritage sites (in addition to the monetary loss). *Indirect social* effects include: increases in diseases (such as cholera and malaria), increases in stress symptoms or increased incidence of depression, disruption in school attendance, disruptions to the social fabric, disruption of living environments and the loss of social contacts and relationships post-event.

Economic impacts are usually grouped into three categories: direct, indirect, and macroeconomic (also called secondary) effects (ECLAC, 2003). These effects fall into stock and flow effects. *Direct* economic damages are mostly the immediate damages

or destruction to assets or "stocks", due to the event *per se*. A smaller portion of these losses results from the loss of already produced goods. The direct stock damages have indirect impacts on the "flow" of goods and services. *Indirect* economic losses occur as a consequence of physical destruction affecting households and firms. Most important indirect economic impacts include:

- Diminished production/service due to interruption of economic activity,
- Increased prices due to interruption of economic activity leading to reduction of household income,
- Increased costs as a consequence of destroyed roads, e.g. due to detours for distributing goods or going to work,
- Loss or reduction of wages due to business interruption.

Assessing the *macroeconomic* impacts involves estimating the aggregate impacts on economic variables like gross domestic product (GDP), consumption and inflation due to the effects of disasters, as well as, due to the reallocation of government resources to relief and reconstruction efforts. As the macroeconomic effects reflect indirect effects as well as the relief and restoration effort, these effects cannot simply be added to the direct and indirect effects without duplication. Such effects are already partially accounted for by the effects already incorporated in the analysis (ECLAC, 2003).² It should be kept in mind that the social and environmental consequences also have economic repercussions. The reverse is also true since loss of business and livelihoods can affect human health and well-being and local environmental sustainability.

Environmental impacts generally fall into two categories. The first category consists of impacts on the environment as a provider of assets that can be made use of (use values). Impacts on water for consumption or irrigation purposes or soil for agricultural production are examples of this. These impacts are or should be taken care of in the valuation of economic impacts. The second category relates to the environment as creating non-use or amenity values. Effects on biodiversity and natural habitats fall into this category where there is not a direct, measurable monetary benefit, but ethical or other reasons exist for protecting these assets and services.

Natural disasters often also may have positive effects such as an increase of pasture area for raising livestock, increased water availability or replenishment of aquifers. When planning preventive measures, these benefits can often be made use of and thus do not need to be subtracted. Furthermore, in the indirect effects on economic sectors such as agriculture (increase in livestock numbers), or in the construction sector (reconstruction boom post-event) these positive effects already appear. For this reason, and as the adverse impacts of disasters generally by far overshadow the positive effects, the positive effects are not listed separately in the following section.

² There is some discussion in the literature concerning potential double-counting involved in adding direct and indirect impacts; this is due to the relation between direct impacts on assets (quantity at a single point in time) and indirect effects on flows (services/cash flows due to using the stocks over time). However, this argument assumes that all direct and indirect impacts can be assessed and the cost concept used for valuing asset losses is that of the book value (purchase value less depreciation), which are not realistic assumptions for disaster impact assessment. In applied impact assessments and CBAs deriving order of magnitude estimates and often using reconstruction values generally direct and indirect impacts are added up (see ECLAC, 2003).

SECTION 4

Assessing Risks

Risks – and benefits when reduced, transferred or avoided – that can be measured are included in quantitative cost-benefit analyses. Often, an attempt is made to monetize costs or benefits that are not indicated in such a metric, such as loss of life, environmental impacts, etc. However, as is generally the case with CBA, some effects and benefits will always be left out of the analysis due to estimation problems.

Generally, in assessing risk, *revealed vs. expressed preference* approaches can be distinguished (Penning-Rowsell et al., 1992). In the revealed preference approach, available market prices for goods, such as those needed for reconstructing a damaged building, are used. In practice, this involves adding up potential avoided impacts in terms of *reconstruction costs*. Alternatively, in the expressed preference approach, the value of a non-marketed good, such as the value of flood protection, is directly elicited by asking the potentially affected individuals or businesses. The revealed preference approach is more common and followed in disaster risk management due to the general availability of some data, while for the expressed preference method, specific surveys would be required.

For the expressed preferences, there is a large collection of literature on the monetization of non-market impacts, particularly driven by the application of CBA in the field of environmental economics. Methods can be broken down into indirect and direct methods. Direct preference assessment is done by means of contingent valuation where subjects are surveyed and their preferences determined (e.g. willingness to accept a change in the environment, willingness to pay for avoiding premature death). One important application is the valuation of life (*Value of a Statistical Life* (VSL)) that is based on assessing the willingness to pay for avoiding premature death. A major problem is the resulting differential in values between developed and less-developed countries as the willingness to pay is proportional to income. The indirect method estimates the value attached to risk reduction based on actual market behaviour. The medical costs for treating a disease or the income lost due to disease or death is a good example of this.

Representing Risk and Uncertainty

Disaster risk so far has been defined as the probability of potential impacts affecting people, assets or the environment, but at this point an important distinction should be made between risk and uncertainty.

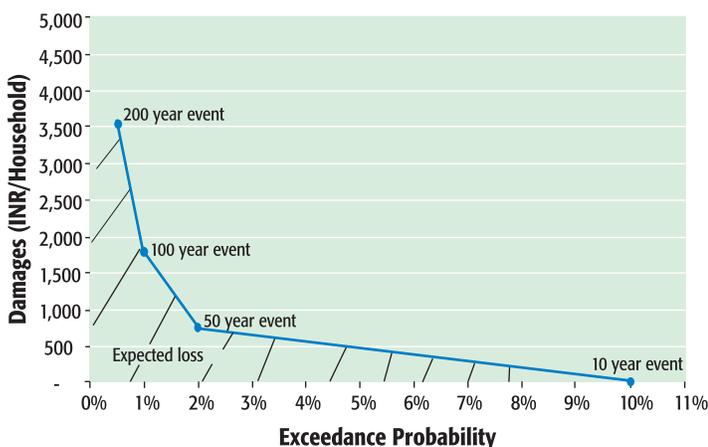
If the probability of events and impacts can be determined, one talks of *risk* ("measured uncertainty"); if probabilities cannot be attached to such events, this is a case of *uncertainty*. A standard statistical concept for the representation of natural disaster risk is the loss-frequency curve, which indicates the *exceedance probability* of an event not exceeding a certain level of damages. Another important concept, is the inverse of the exceedance probability, the *recurrence period*. The recurrence period can be thought of as an event with a recurrence 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 its consequences in a probabilistic manner. A 100 year event could also occur twice or more 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. As one example, Table 4 and Figure 4 list values calculated for the case of drought risk in Uttar Pradesh.

TABLE 4 | Risk as represented by the loss-frequency function for drought risk in Uttar Pradesh

Recurrence (years)	Annual probability	Damages (INR/household)	Risk= Probability x Damages (INR/household)
10	10.0%	0	0.0
50	2.0%	675	13.5
100	1.0%	1,672	16.7
200	0.5%	3,344	16.7
Annual expected loss			46.95

In this case, damages due to the 10, 50, 100 and 200-year drought events were estimated. For example, the 100-year event, which is an event with an annual probability of 1%, was estimated to lead to losses of about 1670 INR per household. The last column shows the product of probability times the damages; the sum of all these products is the expected annual loss.

FIGURE 4 | Example of loss-frequency distribution



Another 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 in translating infrequent events and damage values into an annual number

that can be used for planning purposes. Theoretically, values for a substantial number of points on the curve are required for accuracy. However, only a small number of values were available in this example. This is often the case since infrequent large magnitude events are the most common cause of disaster. As a result, in disaster risk management events up to 200, sometimes 500-year return periods are considered. Thus, potential disaster impacts have to be understood as an approximation and uncertainty of these calculations has to be acknowledged.

Means vs. Variability

In an expected value analysis, risk (represented by the probability distribution) is summarized by the expected, average outcome. This means, however, losing a considerable amount of information. As indicated above, natural disasters are not at all average or annual events, but characterized by their low-frequency, high-consequence nature. In contrast to a normal distribution, the mean/expected value does not well represent the relationship. For disaster events, it is also desirable to account for the variability of potential outcomes. In theory, limiting the analysis to average values is only permissible if there is risk neutrality, i.e. risk in terms of the variability of outcomes (extremes) is not important and can be handled. This risk-neutrality assumption generally holds true for developed countries, but is less applicable to lower-income, hazard-prone countries. Government decisions should be based on the opportunity costs to society of the resources invested in the project and on the loss of economic assets, functions and products. In view of the responsibility vested in the public sector for the administration of scarce resources, and considering issues such as fiscal debt, trade balances, income distribution, and a wide range of other economic, social, and political concerns, governments should not act risk-neutrally (OAS, 1991; Mechler, 2005).

An approach that is useful if variability matters and risk aversion is prevalent, is the mean-variance (EV) method. As the term suggests, this method takes account of the mean and variance (to account for variability) of a probability distribution. The EV method is often used in portfolio analysis in finance theory and applications. The EV method in essence relies on the mean and variance whereby the variance is used to measure volatility around the mean.³

³ The EV method is based on the Expected Utility (EU) framework, which is a standard method of dealing with risk in economics. The EV method basically relies on the mean and variance of the outcome variables and weights the variance by a risk aversion parameter as follows:

$$Y^* = E(Y) - RP = E(Y) - \frac{R}{2} * \frac{V(Y)}{\bar{Y}}$$

Where Y^* the CE, $E(Y)$ expected/mean income, RP : risk premium, R risk aversion parameter, $V(Y)$ variance of income, \bar{Y} average income.

Thus, the method accounts for the average impacts of catastrophes as well as for the extremes and volatility. It also considers the ability to cope with disasters by including the risk aversion parameter. If there is (perceived) risk neutrality, the analysis can be reduced to calculating averages.

Uncertainty

Estimating extreme event risk and the benefits of risk reduction is fraught with a substantial amount of uncertainty. As demonstrated by the Uttar Pradesh drought case (Risk to Resilience Working Paper No. 5), as disasters by definition are low-frequency, high consequence events. Uncertainties are inherent in

- **Hazard recurrence:** estimates are often only based on a limited number of data points. As noted above, this is a particular challenge in the context of climate change where the frequency and intensity of major weather events is likely to change in fundamental ways.
- **Incomplete damage assessments:** data will not be available for all relevant direct and indirect effects, particularly so for the non-monetary effects.
- **Vulnerability:** Information to construct vulnerability curves often does not exist.
- **Exposure:** the dynamics of population increase and urban expansion, increase of welfare need to be accounted for.
- **Benefits of risk management estimates:** often difficult to accurately measure the effects and benefits of risk management measures.
- **Discounting:** the discount rate used reduces benefits over the lifetime of a project and thus has a very important impact on the result.
- **Valuation issues:** exchange rates, deflators and different cost concepts (replacement, market values) used.
- Additionally for climate change, uncertainties are due to estimating the changes in frequency and intensity of natural hazards, especially when historic records are incomplete

When fitting probability distributions to a limited number of data points, losses may be overestimated or underestimated relative to the "true" loss probability relationship. Of course, in practice the "true" relationship is never known. With an increasing amount of data, the approximation to the underlying relationship may improve. However, as discussed above, often the number of data points that can be derived is limited due to lack of underlying primary data or time and money constraints. *Thus, where possible uncertainties should be assessed, caution is essential when using estimates of risk to evaluate the benefits of risk reduction.*

This is again another point that emphasizes the importance of linking quantitative CB analyses with more qualitative assessments and stakeholder inputs through shared learning dialogues. Shared learning dialogues, by bringing together the perspectives of diverse community, expert and government groups, can be used to assess uncertainties. They can also be used to refine and bound assessments of recurrence periods, valuations, etc. As a result, they provide perhaps the best avenue of assessing many of the variables where quantitative data are lacking or insufficient.

SECTION 5

Identification of Risk Management Measures and Associated Costs

Based on the assessment of risk, potential risk management projects and alternatives can be identified. Methods for doing this are discussed extensively in Risk to Resilience Working Paper No. 8.

The costs in a CBA are the specific costs of implementing a project and consist of investment and maintenance costs. There are the financial costs, which are the monetary amounts that have to be spent for the project. However, of more interest are the so-called opportunity costs, which are the benefits foregone from not being able to use these funds for other important objectives. There is a wide spectrum of potential mitigation, preparedness and risk financing measures that can be taken in order to reduce or finance risk. Table 5 lists a selection of these measures, and in bold concrete interventions studied in the Risk to Resilience project (see Working Paper Nos. 3, 4 & 7).

TABLE 5 | Overview of risk management measures

Type	Prevention	Preparedness	Risk financing
Effect	Reduces risk	Reduces risk	Transfers risk (reduces variability)
Key options	Physical and structural mitigation works (e.g. irrigation, embankments)	Early warning systems, communication systems	Risk transfer (by means of (re-) insurance) for public infra-structure and private assets, microinsurance
	Land-use planning and building codes	Contingency planning, networks for emergency response	Alternative risk transfer
	Economic incentives for proactive risk management	Shelter facilities, evacuation plans	National and local reserve funds

Source: Modified based on IDB, 2000.

These measures reduce risk (prevention and preparedness) or transfer and spread it on a larger basis (risk financing). While prevention and preparedness *reduce* the losses, insurance and other risk financing instruments lessen the *variability* of losses, but not directly reducing them, by spreading and pooling risks.⁴ By providing indemnification in exchange for a premium payment, insured victims benefit from the contributions of the many others that are not affected, and thus in the case of a disaster, they receive a contribution greater than their premium payment. However, over the long run, insured persons or governments can expect to pay significantly more than their losses. This is due to the costs of insurance transactions and the capital reserved by insurance companies for potential losses (or reinsurance), as well as the financial return required for absorbing the risks (see also Section 6).

Key information on risk management measures required for quantitative cost-benefit analysis include: (i) the exact type of the option under consideration, (ii) its planned lifetime, (iii) the costs, such as investment costs and maintenance costs, (iv) planned funding sources, (v) possibly additional benefits and impacts. We derived such information from interaction with stakeholders during the SLDs. Concerning the costs of an option, usually there are major initial outlays for the investment effort, such as building an irrigation system, followed by smaller maintenance expenses occur over time, e.g. for maintaining the system. On the other hand, risk transfer measures usually demand a constant annual payment, e.g. an 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.

⁴ Insurance and other risk financing mechanisms are based on the *Law of large numbers*, which states that with an increasing number of observations the probability distribution can be estimated more precisely and the variance around the mean decreases.

SECTION 6

Analysis of the Benefits of Risk Management

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 DRM case, however, benefits are the risks that are reduced, avoided or transferred.⁵

Conceptually it would be ideal to assess the income and livelihood consequences (indirect risks) in relation to the proportionate loss of assets and structure (direct risks) of disasters for different groups. For example, a loss of 10,000 INR has a different significance for a poor labourer than to a large-scale farmer. In the case of the labourer, this loss would cause severe follow-on consequences such as malnutrition and deprivation, whereas the farmer would be able to absorb this financial loss with few such indirect impacts. Normally, the indirect risks cannot be easily assessed, as this involves conducting surveys, interviews and statistical and economic analyses. As a result, most analysts (including in this study) resort to the direct effects, which often in a development context actually understate the "real" impacts.

In order to estimate benefits, the effect of implementing DRM activities on risks need to be assessed in relation to the loss-frequency function developed earlier. As illustrated in Figures 5a and 5b, risk reduction activities generate benefits by

⁵ In CBA terminology, they are defined as the willingness-to-pay (WTP) to avoid/reduce risks. The WTP generally reflects the preferences of economic agents (households, business, public sector).

FIGURE 5a | Mechanics of irrigation intervention the Uttar Pradesh case

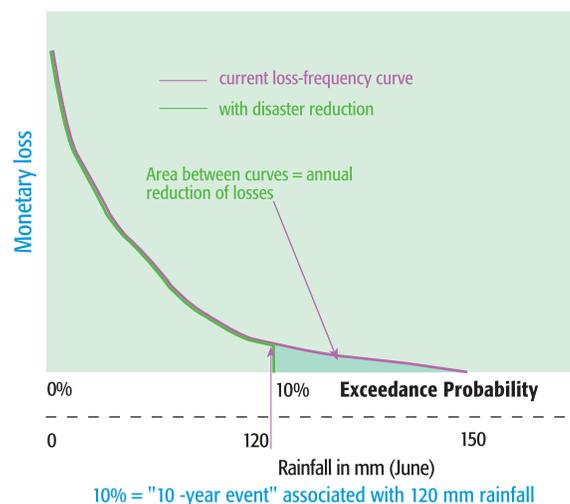
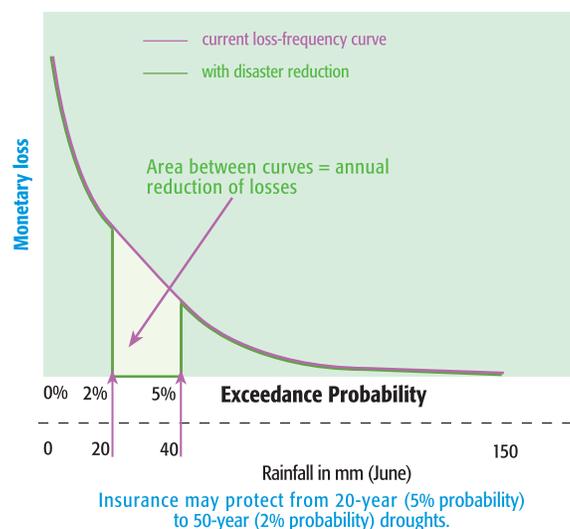


FIGURE 5b | Mechanics of insurance intervention in the Uttar Pradesh case



shifting the loss frequency curve downward in the areas where the intervention reduces disaster impacts. Risks may be completely avoided, reduced, or transferred. As an illustrative example, we consider the Uttar Pradesh case of drought risks to farmer livelihoods with irrigation and insurance interventions to reduce risk (see Risk to Resilience Working Paper No. 5 for a complete discussion of the case study). The mechanics of these interventions differ importantly.

In the Uttar Pradesh drought case, irrigation (pumping groundwater and irrigating drought-affected wheat and rice fields) would help mitigate a rainfall deficit up to a 10 year drought event. This is equivalent to receiving 30 mm less in June than average (that is, 120 mm instead of 150 mm). Compared to the irrigation option, where basically a part of the loss-frequency curve is cut off (i.e. risks are reduced), insurance would guarantee a certain payout, if rainfall (or the lack thereof) falls into a certain range. Here this range would be 20-40 mm rainfall, which is a 130-110 mm rainfall deficit compared to the normal June rainfall of 150 mm, is associated in the illustration with a 50 to 20 year event. As the claim payment after the event is received in exchange for a premium payment before the drought, risk is not reduced but transferred.

Needless to say and as discussed above, certain DRM options may also create disbenefits. Embankments, for example, can cause waterlogging and associated increases in health problems. These negative benefits need to be considered as well and factored in on the benefits side.⁶

⁶ They should not be computed on the costs side, in order not to confuse these disbenefits with the fixed and variable costs of a government or donor sponsoring DRM interventions.

SECTION 7

Calculation of Economic Efficiency

Estimating the economic efficiency of an intervention, the final step, is assessed by comparing benefits and costs. 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. Furthermore, costs and benefits are compared under a common economic efficiency decision criterion to assess whether benefits exceed costs. Basically, 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, which represents the return on investments in the given project. A project is rated desirable if this IRR surpasses the average return of public capital determined beforehand (e.g. 12%).

In most circumstances, the three methods are equivalent. In the Risk to Resilience project, due to its intuitive appeal, we mostly focused on the B/C ratio.

The example below shows the CBA calculations for the case of micro crop insurance in Uttar Pradesh.⁷ In the first year of the project, the fixed technical assistance costs (for modelling the risks, training staff etc.) for setting up the scheme would dwarf

⁷ The assessment considered the case of setting up a novel microinsurance scheme for drought-affected farmer potentially involving an insurance company, NGO, local or state government or a donor, and the insured. The government or donor would sponsor the technical assistance (fixed costs) and partially subsidize the premium (variable costs). Benefits relate to the reduction in farmer income losses and reduced relief expenditure spending by the government. Key parameters were (per household): 5,000 INR cost of technical assistance, premium of 3.0% of the insured value, 50.0% premium subsidy.

the benefits. Over time, benefits would arise as income losses are partially offset by insurance payments (see Risk to Resilience Working Paper No. 5). Given the default discount rate of 12%, net benefits would amount to approximately 6,000 INR per individual within the scheme over the 15-year time period considered. Yet, when discounting with a rate of 12%, the (discounted) NPV would amount to only 440 INR. The B/C ratio is only marginally above 1, and the internal rate of return, as well, does not significantly surpass the default rate of 12%.

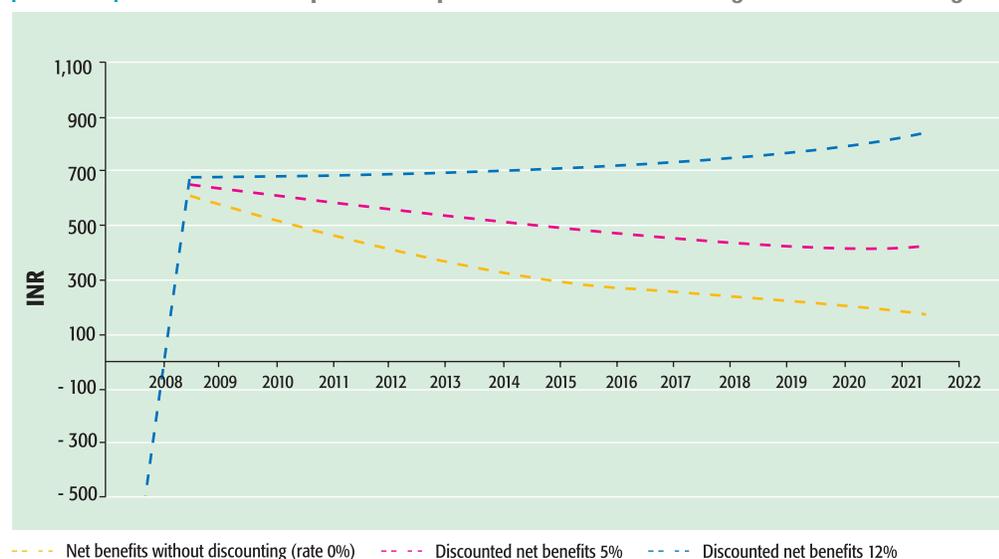
TABLE 6 | Calculation of costs and benefits in terms of NPV, B/C ratio and IRR (in INR)

Year	Costs: technical assistance and premium subsidy	Benefits: increased income households, reduced relief expenditure	Net benefits	Discounted costs	Discounted benefits	Discounted net benefits	
2008	5,194	880	-4,314	5,194	880	-4,314	
2009	194	880	686	173	785	612	
2010	194	879	686	154	701	547	
2011	194	882	688	138	628	490	
2012	194	886	692	123	563	440	
2013	194	887	693	110	503	393	
2014	195	900	706	99	456	357	
2015	195	911	715	88	412	324	
2016	196	923	727	79	373	294	
2017	197	936	740	71	338	267	
2018	198	953	755	64	307	243	
2019	199	971	773	57	279	222	
2020	200	993	793	51	255	204	
2021	201	1,017	816	46	233	187	
2022	203	1,045	842	42	214	172	
Sum	7,946	13,942	5,996	6,489	6,926	437	NPV
						1.07	B/C
						13.9%	IRR

Note: A 12% discount rate was used.

The discount rate has a key influence on the economic efficiency calculations. Figure 6 shows the net benefits for a 0%, 5%, and 12% discount rate. Not surprisingly, when a small or zero discount rate is used, the project seems more viable.

FIGURE 6 | Net benefits of crop insurance option in the Uttar Pradesh drought case and discounting



SECTION 8

Types of CBA Assessments and Requirements

The type of assessment to be conducted depends upon the objectives of the respective CBA, as well as data at hand on the hazard, vulnerability and exposure and finally, impacts. In order to operationalize the assessment of hazard, vulnerability, risk and risk reduction and considering data and resource limitations for conducting CBAs, two frameworks for quantitative analysis, forward-looking and backward-looking are available (Table 7).

TABLE 7 | Types of assessments in context of CBA under risk and related case studies

Type of assessment	Methodology	Data requirements	Costs and applicability
Forward-looking assessment - risk-based	Estimate hazard, vulnerability, then combine with risk, combine with climate modelling, e.g. regional to local climate downscaling	Locale and asset-specific data on hazards and vulnerability. Minimum of three data points, Global or regional climate circulation modelling	More accurate, but time and data-intensive (up to several person years). More applicable for small scale risk management measures, e.g. retrofitting a school/building against seismic shocks Input to: Pre-project appraisal or full project appraisal
Backward-looking assessment - impact-based	Use past damages as manifestations of past risk, then update to current risk	Data on past events, information on changes in hazard and vulnerability. Minimum of three data points (past disaster events)	Leads to rougher estimates, but more realistic and typical for developing country context. More applicable for large scale risk management measures like flood protection for river basin with various and different exposed elements. Need experience with damages in the past. Time effort: in range of several person-months. Input to: Evaluation (ex-post) Informational study

In a more rigorous and resource-intensive *forward-looking, risk-based* approach, data on hazard and vulnerability are combined and lead to estimates of risk and risk reduction. Ideally in a forward-looking risk assessment, risk can be estimated by combining information on hazard and vulnerability. Often full-blown risk assessments are not feasible due to data, time and money constraints, particularly when the area at risk is large, is exposed to more than one hazard, or there are a large number of exposed assets with differential vulnerabilities.

In a more pragmatic *backward-looking, impacts-based* approach, past damages are often used as the basis for coming to an understanding of current vulnerability, hazard and potential damages. In such cases, in a backward-looking assessment of past damages is used to come to a rough understanding of risk and potential damages.

SECTION 9

Conclusions

We described the different steps, opportunities and key constraints for conducting a CBA of disaster risk management. This approach forms the backdrop for actually conducting CBA assessment in data-poor environments in India and Pakistan. More detail on how to actually do a CBA can be found in the Risk to Resilience Working Paper Nos. 4, 5, and 7. In addition, a more comprehensive methodology report will be available through the Risk to Resilience project by the end of 2008.

We conclude with a number of key messages derived from the case study process which may be useful when using CBA for informing decisions on DRM.

Clarify objectives of conducting CBAs in DRM

Before engaging in a CBA assessment, it is necessary to clarify the objective, information needs and data situations among the different potential stakeholders, which may comprise representatives from local, regional and national planning agencies, NGOs working in development and disaster risk management, disaster risk manager, officials concerned with public investments decisions, development cooperation staff and local communities. The type of envisaged product is closely linked to its potential uses and users. A CBA may be conducted for merely informational purposes, as a pre-project appraisal, as a full-blown project appraisal or as an ex-post evaluation. Purposes, resource and time commitments and expertise required differ significantly for these products. The specific information preferences will differ between cases involving a development bank or a municipality, between small-scale and large-scale investments, planning physical infrastructure or capacity building measures, and between mainstreaming risk in CBA vs. CBA for disaster risk management. At an very early stage, it is critical to achieve consensus among the interested and involved parties on the scope and breadth of the CBA to be undertaken. In the Risk to Resilience project, we pursued this for our case studies through a combination of scoping exercises, shared learning dialogues and qualitative assessment prior to any decision on undertaking a more comprehensive CBA. Purposes, resource and time commitments and expertise required differ significantly for these case and associated products as listed in Table 8.

TABLE 8 | Level of complexities and CBAs conducted in the project

Product	Purpose	Resource and time commitment	Case Study
Informational study	Provide a broad overview over costs and benefits	+	Lai Basin case (Pakistan), Nepal case
Preproject appraisal	Singling out most effective measures for matters of more detailed evaluation in project appraisal	++	Uttar Pradesh flood case (India)
Project appraisal	Detailed evaluation of accepting, modifying or rejecting project	+++	Uttar Pradesh drought case (India)
Evaluation (ex-post)	Evaluation of project after completion	++	Uttar Pradesh flood case (India), Nepal case

Often, CBAs and risk assessments are based on past impacts in a backward looking analysis. A forward-looking analysis in terms of risk is more complex and resource intensive, but leads to better results. Due to the higher level of complexity, it is rarely used. Depending on the objectives that the specific CBA undertaken should serve and resources and expertise available, both approaches can be used. The specific approach taken as well as assumptions employed should be clearly outlined.

Acknowledge complexities of estimating risk

Estimating risk and the costs and benefits of risk management is inherently complex. Disaster events are in essence, probabilistic events. As a consequence, benefits due to risk management are probabilistic and arise only in the case of events occurring. Benefits should be assessed in terms of probability times consequences leading to an estimate of risk. However, the treatment of risk in CBA (and DRM generally) is often done on an ad-hoc basis and assessments focus on events in the past rather than potential catastrophes in the future. This may result in an underestimation of damages and an underinvestment in preventive measures.

Furthermore, the need to account for climate change when assessing future hazard intensity and frequency adds considerable complexity and resource demands, as climate model downscaling is a key requirement. Often climate modelling does not produce data in probabilistic format representing natural variability, and as a key assumption average values, have to be used. In addition, at present substantial uncertainty exists regarding the accuracy of results from climate downscaling. As a result, cost-benefit analyses utilizing downscaled information on future climatic conditions need to be recognized as scenarios rather than accurate projections. These specific challenges and characteristics of disaster risk management need to be properly communicated and understood in order to properly interpret results derived in a CBA.

In addition to the above, numerous methodological challenges of CBA impact the analysis. Putting values on non-market impacts such as health impacts and environmental aspects is generally difficult and may involve ethical issues such as whether and how to monetize fatalities. A further challenge is to account for indirect effects and their reduction or increase (e.g. changes in the prevalence of diseases post-disaster, higher transport costs due to loss of infrastructure, increased costs

due to business interruption). Indirect damages can be substantial and sometimes even exceed direct impacts. Yet due to technical difficulties, other impacts such as social and indirect economic effects are rarely included and assessments focus mostly only on direct impacts, which leads to a partial picture of potential disaster impacts to be avoided.

Process-Orientation

Given the complexities involved in estimating the costs and benefits of DRM, climate change and the history and current usage of CBA as a decision support tool, it seems that the role of CBA in DRM is strongly related to process rather than outcome. CBA is a useful tool for organizing, assessing and finally presenting the cost and benefits, pros and cons of interventions. It demands a coherent methodological, transparent approach. Yet, given that data on extreme event risks are by definition scarce, and impacts often are very significant and subject to change over time, CBA is probably not as suited to be used as a purely outcome-oriented tool, at least in a data-restricted environment. To put this in another way, the evaluative process involved in conducting a CBA is generally more important and more reliable as a basis for decision making than the final benefit-cost ratios calculated. This is particularly true for DRM, where process-orientation and inclusion of a host of stakeholders plays a critical role.

One tool to organize such processes is shared learning dialogues, which, by bringing together the perspectives of diverse community, expert and government groups, can be used to assess uncertainties. They can also be used to refine and bound assessments of recurrence periods, valuations, etc. As a result, SLDs provide perhaps the best avenue of assessing many of the variables where quantitative data are lacking or insufficient. Focusing on outcome only may defeat the purpose of better mainstreaming DRM - essentially a crosscutting problem - into a host of development-related activities where stakeholders with diverse backgrounds and objectives interact, then decide and implement projects and policy.

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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 programme 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 Upadhyaya 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.

