From Risk to Resilience

Working Paper 6

Costs and Benefits of Flood Mitigation in the Lower Bagmati Basin: Case of Nepal Tarai and North Bihar

Ajaya Dixit,
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Cover: Temporary bamboo bridge south of Gaur used during non-rainy season. The Bairgania embankment with a dysfunctional sluice is seen in background. Photo by Ram Adhar Yadav.

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Key Messages

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

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

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

Nepal Tarai by the Kosi River, which occurred as this paper was being written, was devastating.

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

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

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

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

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

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

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

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

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

TABLE 2 | Status of road system

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

Source: Road Statistics, 2004

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

Administrative Characteristics

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

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

TABLE 3 | Status of land ownership

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

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

accessed via the town of Bairgania in Bihar. After 1969, however, Gaur became accessible through Chandranigahapur, which lies on the highway about 40 kilometres north of the district centre. Once the region had been opened still more roads were built. Development in Sarlahi District followed a similar pattern. Still this region is less developed than other parts of the Nepal Tarai. More specifically, the length of roads in Rautahat and Sarlahi districts is much lower than the national average in 2004 of 11.7 kilometres per 100 km2. Most land in both districts is cultivated; the second most common land use is forest.

TABLE 4 | Household's average annual Income

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

Source: Survey 2003

Social and Economic Characteristics

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

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

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

Source: Field Study

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

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

Hydrologic and Geologic Characteristics

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

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

The study area is drained by numerous large and small rivers, including the Bagmati, Lal Bakaiya, Chandi, Manusmara and Jhanjh, all of which are tributaries of the Kosi River and, ultimately, of the Ganga. The Bagmati River originates in the Mahabharat hills (the middle range of the Himalaya below those areas fed by snow or glaciers). Its headwaters are in the Shivapuri range about 16 kilometres northeast of Kathmandu at an elevation of 2,800 metres. The river merges with the Kosi River at Badlaghat in

Bihar after travelling a distance of 195 kilometres in Nepal and 402 kilometres in India. Its total catchment area is about 13,400 km^2 of which about 7,000 km^2 are in Nepal.

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

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

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

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

TABLE 6 | Impacts of 2007 floods in Rautahat District

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

Source: Compiled from Nepal Red Cross Data, 2007

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

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

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

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

Note * Generated data
** Missing data

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

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

Climate Change Impacts

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

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

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

Evaluating Alternative Flood Management Strategies

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

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

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

The Qualitative CBA Methodology using Shared Learning Dialogues

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

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

BOX 1

Indicators of well-being

A society is doing well when its members enjoy

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

Adapted from Kuiper (1971)

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

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

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

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

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

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

Example of the Methodology Employed

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

a) capture the local nuances of the interventions carried out in various villages and their relation to the various characteristics of the flood hazard; and
b) zoom out for a wider and therefore more complete picture of the issues that is not possible if interventions carried out in just one village are the sole focus.

The shared learning dialogues conducted in villages along transects were combined with a systematic assessment of vulnerability. Other dialogues were carried out with local government agencies such as the VDCs, district development committees

(DDCs), local and International NGOs as well as with sector-specific high-level institutions such as the Department of Irrigation and the Department of Agriculture. Dialogues moved through a typical sequence, beginning with a discussion of the specific local characteristics of flooding to government, NGO and community responses to it. Then discussions shifted to the advantages and disadvantages of those responses and ended with the identification of those advantages and disadvantages as specific benefits or costs. The evolution of the nature of the discussion, which often occurred over several meetings, enabled researchers to develop a disaggregated list identifying the specific direct and indirect benefits and costs associated with each individual strategy.

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

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

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

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

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

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

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

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

| FIGURE 1 | **The three transects in lower Bagmati Basin**

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

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

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

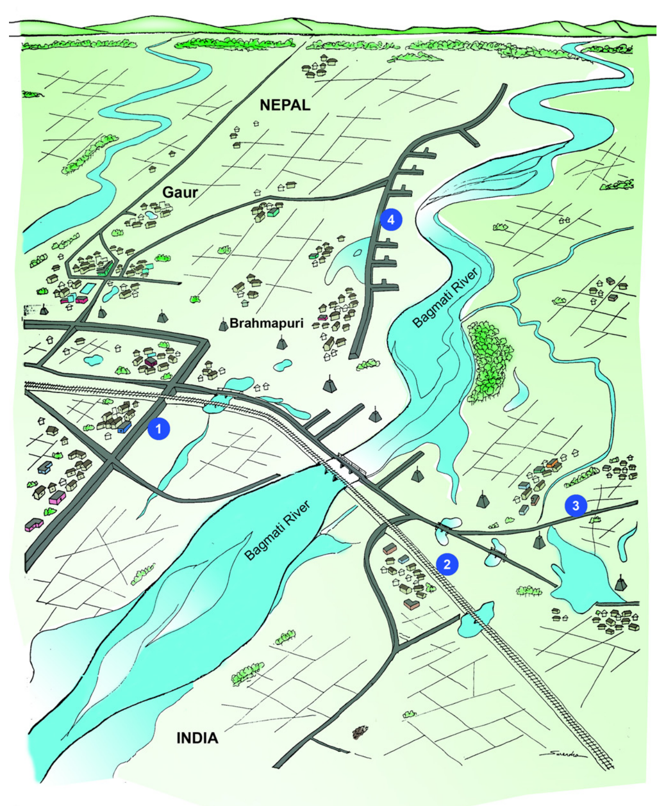
Results along the Transect

Transect I: Villages along the Bagmati River

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

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

FIGURE 2 | Transect I: Bagmati River



1. The Bairgania ring embankment was constructed in 1973/74 in order to safeguard the Bairgania block and the adjoining regions of north Bihar. The northern portion of this embankment runs east-west about 200 to 400 metres south, and parallel to, the Nepal-India border. It starts at Majorgunj, a market centre in Bara District, and ends north of Muzzafarpur. Except for a gap to the south of Bairgania, the embankment forms a complete ring. Although this 18 foot high embankment successfully protects the northern part of the area it encircles, it also obstructs most southward drainage. Drainage is further impeded because the sill level of the four sluices intended to allow non-monsoon waters to pass are at least two feet higher than the adjoining drain in Gaur, Nepal, and because these sluices are shut down during floods. Part of an adjoining railway embankment (described below) and the main road are also linked to and form part of this embankment system. These structures also greatly impede drainage in areas outside and upstream of the ring embankment, creating a backwater effect that causes extensive flooding in villages and in Gaur municipality, the headquarters of Nepal's Rautahat District, which lies north and outside the ring embankment.

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

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

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

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

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

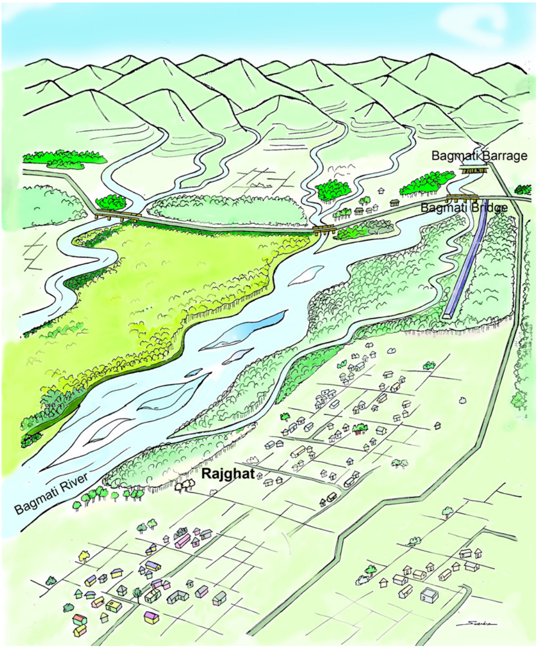
The outcomes of shared learning dialogues revealed that these four embankments have substantial negative impacts on the villages of Rautahat District of Nepal. These impacts include:

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

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

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

| FIGURE 3 | Transect II: Lal Bakaiya River



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

Transect II: Along the Lal Bakaiya River

This transect runs through villages along the Lal Bakaiya River, beginning at Bhasedwa VDC and ending at the Nepal-India border. Bank cutting is a major problem for these settlements: each year it destroys many acres of land. Occasional sand deposition also takes place. The Lal Bakaiya River is embanked along its southern reaches just before it enters northern Bihar. In

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

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

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

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

the upper reaches, spurs, small stretches of embankments and revetment walls have been constructed to protect villages against floods. The table below describes the types of spurs constructed and some of their impacts in and around Bhasedwa VDC. The railway bridge constructed over the Lal Bakaiya also constricts river flow. This area receives irrigation waters from the Bagmati irrigation project and the tail-end canals of the Narayani irrigation project. The costs and benefits and the relative magnitudes of various flood risk management strategies identified along this transect are listed in the table below.

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

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

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

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

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

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

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

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

After the Bairgania ring embankment was built, the area affected by water logging increased, particularly inside and adjacent to the southern section. Almost all of the musahar families living in the village of Marpa say that up to 150 acres of land is water logged throughout the year and that water levels can reach more than 15-feet deep. In 2007 October a local boy drowned while trying to cross the water logged section. It is not just water logging that has reduced the land available to the people of Marpa; 55 acres was acquire to build the embankment and another 17 acres purchased to build the raised platform. As a result of this acquisition most of the population of Marpa has become landless. The Bihar government compensated the landowners INR 6,000 per acre, a rate far below the market rate at that time.

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

TABLE 14 | Assessment of costs and benefits identified during SLDs along Gaur Municipality – Bairgania Ring Embankment–Pipradi Sultan

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

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

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

Analysis: Findings from the Transects

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

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

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

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

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

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

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

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

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

Issues Encountered in Conducting CBA

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

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

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

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

Conclusions

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

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

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

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

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

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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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