HI-AWARE Working Paper 3

HI-AWARE
Himalayan Adaptation, Water and Resilience Research

CARIAA
Collaborative Adaptation Research Initiative in Africa and Asia

Assessing Costs and Benefits of Climate Change Adaptation

Consortium members

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About HI-AWARE Working Papers

This series is based on the work of the Himalayan Adaptation, Water and Resilience (HI-AWARE) consortium under the Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA) with financial support from the UK Government's Department for International Development and the International Development Research Centre, Ottawa, Canada. CARIAA aims to build the resilience of vulnerable populations and their livelihoods in three climate change hot spots in Africa and Asia. The programme supports collaborative research to inform adaptation policy and practice.

HI-AWARE aims to enhance the adaptive capacities and climate resilience of the poor and vulnerable women, men, and children living in the mountains and flood plains of the Indus, Ganges, and Brahmaputra river basins. It seeks to do this through the development of robust evidence to inform people-centred and gender-inclusive climate change adaptation policies and practices for improving livelihoods.

The HI-AWARE consortium is led by the International Centre for Integrated Mountain Development (ICIMOD). The other consortium members are the Bangladesh Centre for Advanced Studies (BCAS), The Energy and Resources Institute (TERI), the Climate Change, Alternative Energy, and Water Resources Institute of the Pakistan Agricultural Research Council (CAEWRI-PARC) and Alterra-Wageningen University and Research Centre (Alterra-WUR). For more details see www.hi-aware.org.

Titles in this series are intended to share initial findings and lessons from research studies commissioned by HI-AWARE. Papers are intended to foster exchange and dialogue within science and policy circles concerned with climate change adaptation in vulnerability hotspots. As an interim output of the HI-AWARE consortium, they have only undergone an internal review process.

Feedback is welcomed as a means to strengthen these works: some may later be revised for peer-reviewed publication.

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Abbreviations

BCR	Benefit Cost Ratio
CA	Conservation Agriculture
CBA	Cost Benefit Analysis
CCM3	Community Climate Model
CEA	Cost Effective Analysis
CGCM3	Third Generation Coupled Global Climate Model
CMIP3	Phase 3 of the Coupled Model Intercomparison Project
EAG	Empowered Action Group
FGD	Focus Group Discussion
GBM basin	Ganga, Brahmaputra and Meghna basin
GCMs	General Circulation Models
GVA	Gross Value Added
HADCM3	Hadley Centre Coupled Model, version 3
HadRAM2	Hadley Centre Regional Climate Model 2
HKH	Hindu Kush Himalayas
MCA	Multi-criteria Analysis
MDG	Millenium Development Goals
NPV	Net Present Value
P-CBA	Pacific Cost Benefit Analysis
PCM	Parallel Climate Model
PDD	Positive Degree Day
PRECIS	Providing Regional Climates for Impacts Studies
RCMs	Regional Climate Models
RCP	Representative Concentration Pathway
SBM	Swachh Bharat Mission
SRES	Special Report on Emissions Scenarios
SRM	Surface Runoff Model
SWAT	Soil and Water Analysis Tool
UGB	Upper Ganga Basin
WRF	Weather Research and Forecasting
WTA	Willingness to Accept
WTP	Willingness to Pay

Introduction

Existing documentation establishes evidence that the Hindu Kush Himalayan region is vulnerable to climatic and weather variability, and to extreme events whose adverse impacts are already being observed. The climatic and weather related events create stresses that add to the multiple non-climate stressors that the region experiences. The latter include chronic and transient poverty, high levels of migration, inadequate provision of basic amenities and health care, high density of population and the region's dependence on natural resource based livelihoods such as agriculture, forestry and allied activities. Under these circumstances, it is important to put in place appropriate adaptation responses that build resilience and can reduce risks associated with a changing climate. Adaptation responses can follow multiple pathways to address the large gaps in achieving threshold levels of the quality of life, and the new risks posed by climate change.

In view of the resource constraints in the region, decision makers make choices to prioritise the most appropriate measures for resource allocations. Cost benefit analysis has for long been a tool for facilitating such decision making. The approach to cost-benefit analysis (and cost-effectiveness analysis) has evolved over time to address the many social and inter-generational challenges that have a bearing on social wellbeing, such as distributional issues and the impacts of climate change. In this context the current study of the HI-AWARE programme was conducted with a focus on the economic assessment of adaptation to climate change in the HI-AWARE study area. The primary objective is to develop a methodology for assessing the costs and benefits of adaptation strategies for planning an appropriate adaptation response in the Hindu Kush Himalayan region.

The study is organized in three parts. Part I provides an assessment of climate change risks for the HKH region. Risks associated with the impacts is assessed by determining the risk levels under alternative climate change scenarios. These scenarios vary according to the timeframe within which impacts occur, and the extent of socioeconomic changes that are expected to take place. The scenarios are therefore categorized by the timeframe (near term and long term) and by expected futures (low to high levels of development and options for climate responses). The major climatic risks to the region are subsequently identified through a critical review of the literature, and a risk scale is developed to categorize the risks as minor and major risks. Part II presents an assessment of the existing literature on adaptation interventions in the region and the methodology for economic assessment of adaptation interventions. A methodology for assessing the economic costs and losses averted due to adaptation measures, which includes all the direct and indirect or market and non-market costs, is developed. The point to note is that indirect costs and benefits, such as institutional costs or convenience benefits associated with an intervention, need special attention in the context of a low income economy. The overall purpose is to develop a methodology that allows comparison across proposed options on adaptation; on the extent of costs incurred (due to non-intervention or alternative intervention) or benefits derived (from the intervention) on various heads in attaining a desired objective. Assessment of the relevant risks from climate change to the region (Part I) and the development of a methodology that can be used to evaluate an adaptation measure to manage a risk (Part II) form the building blocks for Part III of the study. A major risk identified is floods. In Part III, the approaches for economic evaluation are applied to adaptation measures in sanitation for flood affected areas. The cost effectiveness of the alternative options for adaptation through sanitation is measured in terms of the reduction in risk levels that it brings about or in terms of the losses averted due to the adoption of the measure.

It is globally acknowledged that improvements in sanitation are essential for improving the quality of life and reducing future risks for soil and water contamination, and water stress. For instance, lack of access to toilets during floods creates additional risks and causes additional stress to human welfare. Climate change, which is likely to increase the occurrence of floods in the region, adds to the existing risks that arise due to lack of access to proper sanitation. A cost effective measure for sanitation is an adaptation response as it builds current resilience and reduces both current and future risks. For assessing cost-effectiveness, data from a field survey was used along with standardized norms to compute the costs and benefits of alternative sanitation interventions in flood affected areas.

Study findings reveal that the region faces major risks in terms of impacts on streamflow, temperature, precipitation and flood events although impacts differ by time scales, seasons and the extent to which these are mediated by developmental processes. Of particular significance among these are the changes likely to occur in flood events, both in the near term and long term, and the potential increase in frequency and associated flow levels. The analysis of field data reveals the high levels of vulnerability to floods and the extreme inconveniences faced in the field area due to inadequate sanitation. Cost-benefit analysis and the construction of adaptation cost curves reveal that substantial health costs and convenience losses can be averted by ensuring access to toilets in the field area. Ecological sanitation options provide the most cost-effective adaptation option in this specific context.

Assessment of Climate Change Risks in the Hindu Kush Himalayan Region

Introduction

Glaciers, snow and permafrost cover an area of more than 112,000 sq.km in the Hindu Kush Himalayan (HKH) region. This is second only to the poles (Eriksson et al. 2009). Ten large rivers originate from the mountains of the HKH region. These rivers cater to the need of 1.3 billion people in the downstream basin areas and significantly influence biodiversity, agriculture and hydropower in the region (Eriksson et al. 2009; Vaidya et al. 2014). However, the region is vulnerable to the impacts of climate change. An alarming possible impact is the reduction in glaciers, which may directly affect downstream water resources (Eriksson et al. 2009; Xu et al. 2009; Shrestha et al. 2012; Li et al. 2016). Predicted changes in the strength and timing of the Asian monsoon and winter westerlies may adversely affect water availability and people's livelihoods in the region (Eriksson et al. 2009; Xu et al. 2009). Further, increased rainfall during monsoon may raise the intensity and frequency of river floods in the basin (Vaidya et al. 2014).

There is growing evidence that the region is facing increasing water stress due to climate change. There are several recent studies on future projections of the impact of climate change on stream flows, the melting of glaciers, temperature, precipitation and ground water recharge. Most existing studies have used hydrological models to predict water availability at various sites in the Hindu Kush Himalayan (HKH) river basin for different emission scenarios. For instance, in a recent study, Li et al. (2016) use an integrated approach that couples a hydrological model and a glacier retreat model to assess the impacts of warming in future on water resources for two Himalayan basins: the Chamkhar Chhu basin in Bhutan (Eastern Himalayas) and the Beas basin in India (Western Himalayas). Two Regional Climate Models (RCMs) for South Asia under three Representative Concentration Pathways (Rcp2.6, Rcp4.5 and Rcp8.5) are used to simulate future climate. Findings project that the available water resources per capita of both basins are likely to decrease in the period 2010–2050. Knowledge of the present and future hydrology of the region is crucial for managing water resources in the future (Vaidya et al. 2014).

This paper provides a review of existing studies of the region and an assessment of climate-related risks for different climate change scenarios. This is an essential step towards understanding what adaptation measures are required in the region, and how effective these are likely to be, including their cost effectiveness.

Risk has been defined in various ways in the literature. Risks for disaster contexts typically refer to the likelihood of severe alterations in normal functioning traceable to a hazardous event, when physical hazards combine with socioeconomic vulnerabilities and lead to widespread adverse outcomes. The SREX report (IPCC 2012) provides a probabilistic definition of risk where risk can be quantified as the product of the probability that an event will occur and the adverse consequences of the event. Most definitions of risk are a function of the sensitivity of the natural or physical systems in responding to climate change (or occurrence of a hazard), degree of exposure and the possibility of an adverse consequence (vulnerability or loss) (Shao, Tao & Shan 2012; Miola and Simonet 2014). Some researchers make a distinction between a risk and a hazard (Helm 1996; Smith 1996; Downing et al. 2001). A risk takes note of the probability of the occurrence and consequences of a hazard, while a hazard is a potential threat to human welfare. Adger (2004) suggests proxy indicators to measure climate risks based on mortality, morbidity and displacement that occur due to climatic events.

The major observed impacts of climate change in the HKH region include a progressive rise in temperature at higher altitudes (Shresthaet al.1999), fluctuations in precipitation trend (Xu et al. 2009), and a rapid receding of the glaciers, ice and snow cover in the region. Some scholars suggest that the rate of recession is faster than the global average (Dyurgerov & Meier 2005).The melting of glaciers influences the stream flow and has a direct impact on freshwater supply, irrigation and hydroelectric power potential (Khadka et al. 2014). Meltwater, along with the monsoon precipitation, makes the wet season wetter, while water availability remains a serious problem in the dry season. Most of the region receives more than 80% of the annual precipitation during the monsoon. Lack of storage facilities exacerbates the situation. Reduction in availability of water in dry season and evapo-transpiration adversely impact ground water recharge. River basins in the western HKH region depend heavily on river and ground water for irrigation. The incidence of water related hazards such as flash floods is also likely to increase (Xu & Rana 2005; Vaidya et al. 2014).

Given the potential significance of the impacts, a critical review of studies relating to the region has been done in order to assess comprehensively the future risks posed by changing climate. Section 2 discusses the methodology while Section 3 presents the findings of the literature review on four major risks. Section 4 presents the results of risk assessment and assigns them a position on the risk scale for the four identified impacts namely, stream flow, temperature, precipitation and flood events. Section 5 provides the conclusion, drawing attention to the possible impact of these risks on the agricultural sector in the region.

Methodology

Sixteen major studies relevant to the HKH region were selected for the review; these focus on biophysical risks and the probability of adverse climatic outcomes. These studies look at alternative scenarios based primarily on the Special Report on Emissions Scenarios (SRES).1 Each of the SRES scenarios is based on alternative assumptions about economic development. The storylines of these scenarios are oriented along two axes: whether priority is given to economic or environmental objectives, and whether development is global or regional. The scenarios seek to capture alternative possibilities for the rate of economic growth, population growth and environmental sustainability. Combinations across these scenarios produce alternative possible futures. The SRES scenarios have been used extensively in climate risk models and impact analysis, including in studies related to the HKH region. The review considered four most commonly studied scenarios because the researchers wanted to study the overall risks rather than arbitrarily selecting one as most appropriate to the region. This is also intuitively more appealing since the region represents substantial diversity in terms of economic development and bio-geophysical features. At present there is no comparable body of work available to build a consistent comparative storyline across alternative development pathways. The representative concentration pathways (RCPs) are far more recent, and there is no sizeable body of literature on the region that could be used for a comprehensive assessment of risks in the region.

The studies cover the period from 2008 till date and examine the predicted impact on streamflow, incidence of floods, temperature, and precipitation. Studies on potential impacts of agricultural yield arising from these predictions were also reviewed .As the observed impacts exhibit profound seasonality, the annual and seasonal projections were analysed separately for various climate change scenarios. The projected impacts were also differentiated in terms of near-term (2001-2050) and long-term (2050-2100) impacts. Risk levels were differentiated across alternative SRES scenarios A2, B2, A1B and B1 (see Box I).

The risk analysis highlights the major risks flagged in the literature. For each identified risk, only sources that analyse that particular risk were considered. The risk ratio was then computed based on the proportion of sources that agree that the given risk is a relevant one, and whether it is a minor or a major risk for the region, under a particular SRES scenario. This risk ratio which captures the extent of agreement on the given risk, was then compared across risks. Thus the attempt was to capture both the nature of the risk and the extent to which scholars agree on the type of risk faced by the region. The total number of papers that dealt with a particular risk and the number of papers that agreed (or disagreed) on the relevance of this risk to the region, thus varied across different types of risks. A risk scale was defined, ranging from very low to very high. The risk level was ascertained based on the percentage of studies that confirmed the identified risk under each scenario. Risks were divided into

[1] While globally, more recent climate scenarios have been developed, such as those using the Representative Concentration Pathways (RCPs), there is relatively less published material available which draws upon these to construct risk scenarios and probabilities specific to the HKH region. One recent study by Li et al. (2016) reinforces the findings on the decline in glaciers under the RCPs. Thus a comparative review across different types of risks, short term and long term, is conducted using the SRES scenarios for which substantial literature is available, ensuring that the review is robust.

Box I: **SRES Scenarios**

The scenarios developed in the Special Report on Emission Scenarios (SRES) by the Intergovernmental Panel on Climate Change (IPCC 2012) have been important for analysing future climate change scenarios and for assessing the associated impacts, mitigation and adaptation. Four storylines were developed constituting different directions for future development. The four storylines, which are based on factors such as demographic change, economic development, and technological change, are as follows:

A1 Scenario: Describes a future world with rapid economic growth, peaking of the global population in mid-century followed by a decline thereafter, and rapid introduction of new and more efficient technologies. The major underlying themes are the convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The scenario is further divided into three groups:fossil intensive (A1FI), non-fossil energy sources (A1T), and (A1B), where there isbalance across all sources rather than an overdependence on one particular energy source. This scenario assumes thatsupply of all energy sources and end uses will improveat similar rates.

A2 Scenario: Describes a heterogeneous world where the main focus is on self-reliance and preservation of local identities. Population increases continuously as fertility patterns across regions converge very slowly. Economic development is primarily regionally oriented, and per capita economic growth and technological change is more fragmented and slower than in other storylines.

B1 Scenario: Describes a world with the same demographic characteristics as the A1 storyline. There is a rapid change in economic structure toward a service and information economywith reduction in material intensity and the introduction of clean and resource-efficient technologies. The main focus is on finding global solutions for economic, social and environmental sustainability, including improving equity, but without additional climate initiatives.

B2 Scenario: Describes a world in which the focus is on finding local solutions for economic, social and environmental sustainability. Global population increases continuously at a rate lower than in A2 scenario. Economic development is at the intermediate level. Technological changes are less rapid and more diverse than in the A1 and B1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

five categories: very low (less than 20% of studies confirming the risk); low (21%–40%); medium (41%–60%); high (61%–80%); and very high (80–100%). The length of the horizontal bar in each table indicates the extent of agreement on the specific risk. The tables allow comparison of a particular risk across scenarios. It is important to interpret the risk ratio in terms of the extent of agreement on the type of risk and not as an absolute measure of risk.

For instance, the risk ratio for temperature rise indicates that there is a relatively low level of agreement among scholars about the risk of temperatures rising above 2 degrees Celsius by 2050. This risk ratio is much higher for the period after 2050. By contrast, the risk ratio for increased flood events in the region, both in the near and long term, is much higher irrespective of the developmental scenario.

Findings from the Literature Review

Projected impact on stream flow

Increase in average temperature and in precipitation will have direct impact on the streamflow of rivers in the HKH region. Change in the streamflow is a key indicator of the impact of climate change on the hydrology of this region. Among the studies selected for this review, 9 studies predicted changes in streamflow under different emission scenarios, which mostly used downscaled GCMs and RCMs. Bharti et al. (2011) modelled the hydrology of the Upper Ganga Basin (UGB) to determine water availability using Hadley Centre Regional Climate Model 2 (HadRAM2) weather data as input for the Soil and Water Analysis Tool (SWAT) hydrological model under SRES scenarios A2 and B2. Projections were made for the period 2071-2100, with 1971-2005 as the baseline period. Under A2 scenario, streamflow was found to be lower than the current rate in the upstream and higher in the downstream, for both wet and dry seasons. The flow during dry and wet season under B2 was higher and lower respectively than those under A2. Using downscaled GCMs for the A2 and B2 scenarios over the period 2000-2100, Immerzeel (2008) studied the impact of climate change on hydrology and the subsequent effect on the streamflow of the Brahmaputra River. Average monthly discharge during the monsoon is projected to increase by 20% and 30% under B2 and A2 scenarios respectively. Rainfall is the main contributor to downstream flow. Increased discharge is likely to raise the frequency of extreme discharges. Only a small change is observed in winter, whereas an intermediate change is observed for autumn and spring.

Mean upstream water supply from the five major rivers originating from the HKH has been projected to decrease during the period 2046-2065 (Immerzeel et al. 2010). Water availability from the upstream rivers was assessed using the output from five GCMs for the SRES A1B scenario as inputs for the surface runoff model (SRM). The most pronounced change was observed in the upper Indus and Brahmaputra. Summer and late spring flow decreased considerably during the projection period prior to which the flow increased due to rapid glacier melt. Immerzeel et al. (2012) studied the future glacier movement and hydrology of the Langtang catchment in Nepal using the downscaled GCMs data for SRES A1B scenario over the period 1999-2100. Discharge is projected to increase by 32% by 2050, partly due to rapid melting of the glaciers (this is expected to reduce by 50% in 2055) and partly due to increased net annual precipitation. Stream flow will be highest in July, coinciding with a peak in melt water and monsoon precipitation. The changes will be most pronounced in summer.

Khadka et al. (2014) studied the impact of climate change on snow and glacier cover reflected in a change in streamflow in the Tamakoshi basin using downscaled GCMs - HADCM3 and CGCM3 for the A2, A1B and B1 scenarios over the period 2000-2059. A maximum increase of 18.92% in river discharge is observed in HADCM3–A2 scenario followed by 15.38% increase in CGCM3–A2 scenario. The discharge increases by 12.5% in HADCM3–B2 scenario. A minimum increase in discharge of 9.68% has been projected for A1B scenario. Hassan et al. (2014) have modelled the impact of climate change on the availability of water in the Ganga, Brahmaputra and Meghna (GBM) basin in the 2050s. For this, they have used 16 downscaled GCMs for A2, A1B and B1 scenarios. A 10–17% increase in monsoon flow in A2, 4–8% in A1B and 7–10% in B1 has been predicted in the GBM basin. Strong seasonality in the changes is also predicted. Flow in all three rivers increases during monsoon and post monsoon in all three scenarios. In the Ganges, a decrease in flow in the pre-monsoon period is most pronounced in all the three scenarios. The maximum increase in flow in the Brahmaputra occurs in the winters and in post-monsoon period in A1B and B1. In Meghna, the maximum increase in flow is in the pre-monsoon season in all three scenarios.

Using downscaled CMIP3 for A1B and A2 scenarios, Pervez and Henebry (2015) have predicted availability of freshwater in the Brahmaputra under climate change scenarios during the period 2060-2075. In both scenarios, a 6% decrease in stream flow is predicted during the pre-monsoon period (February–April). An almost similar rate of decrease – 19% for A1B scenario and 20% for A2 scenario – has been predicted during the early monsoon months (May–July). Increase in flow has been predicted during monsoon and post monsoon in both the scenarios. In August through October, the flow increases by 14% for scenario A1B and 18% for scenario A2, and in November through January, it increases by 21% and 28% for A1B and A2 scenarios respectively. The timing of peak streamflow shifts from July to August under both scenarios. Most importantly, streamflow from November to January is predicted to increase from the baseline by 21% and 28%. A noticeable change is observed in the case of 2°C and 4°C temperature rise as streamflow is predicted to increase by 4.7% and17.5% in February.

Some studies have predicted streamflow under scenarios other than SRES scenarios. Sharma et al. (2013) predicted future streamflow of the Jhelum River for the period 2030-2050 using SRM. Under two realistic scenarios based on air temperature trends recorded over the last century. In Scenario I, air temperature reported for the entire north-west Himalayas for the past century increased at the rate of +0.11°C/decade. In Scenario II, regional warming was indicated by an increase in observed temperature in the last two decades of the century, by 0.7°C every decade. Under both scenario conditions, peak discharge increases during the 2030s. In scenario I, discharge volume increases by more than 5% in March-June and later decreases in July-September. In scenario II, discharge increases considerably by more than 15% to 23% from March to May in 2030 and then decreases drastically by 15% to 29% in later months. In 2050, from March to May, discharge increases by 30% to 37%, while it is projected to decline by 36% to 49% from June to September. In another similar study, Kayastha et al. (2014) assessed discharge from the glacierized Langtang River and Kafni River using revised positive degree day (PDD) model for the period 2010-2050. Regional climate model WRF for RCP4.5 scenario was used for the Langtang River, and PRECIS for A1B scenario was used for the Kafni River. Increasing trend in discharge for the entire period was observed in the Langtang River. In the Kafni River, a drastic decreasing trend in river discharge was observed after 2040, consistent with a decrease in precipitation. An increasing trend in river discharge during the wet season and a decreasing trend during the dry season was observed for both the rivers.

The main findings of the studies are summarised in Table 1. Streamflow prediction for different scenarios, both near term (2001-2050) and long term (2050-2100), are presented.

Projected impact on flood events

Only three of the selected studies projected future flood events in the near term (2001-2050) and the long term (2050-2100) under different scenarios. Rajbhandari et al. (2015) predicted changes in flood incidents in the Indus basin using PRECIS data for A1B scenario over the period ranging from the 2020s to 2050s and 2080s. Simulations conducted for the study revealed an increase in the number of rainy days, leading to flash floods in the 2020s, 2050s and 2080s. Khanal et al. (2014) simulated the incidence of flash flood using the ECHAM5 climate model under A2, A1B and B1 scenarios in the Poiqu/Bhotekoshi/Sunkoshi watershed over the period 2046-2065. The study revealed that the frequency of less intense floods is likely to increase during 2046-2065. Hassan et al. (2014) projected an increase in the frequency of flood events of higher magnitude in the period up to 2050. Under A2 and B1 scenarios in the Ganges basin, 50-year flood events are likely to become 20-year events, while in A1B scenario, they may become 10-year events. In the Brahmaputra and Meghna basins, 50-year events are projected to be reduced to 35-year and 20-year events respectively.

Projected impacts on precipitation

Eleven studies have projected future changes in precipitation under different climate scenarios. Projections have been made for different areas in the HKH region for the nearterm, i.e., 2001-2050 (Hassan et al. 2014; Khadka et al. 2014; Rajbhandari et al. 2015; Sijapati et al.2014) and the long term, i.e., 2050-2100 (Immerzeel 2008; Immerzeel et al. 2010; Immerzeel et al. 2012; Mathison et al. 2013; Khanal et al. 2014; Sijapati et al.2014; Mahmood et al. 2015; Pervez and Henebry 2015; Rajbhandari et al. 2015). Under A2, B2, A1B and B1 scenarios, findings for the near term suggested an increase in average precipitation with marked seasonality. Average annual precipitation is similarly expected to increase in the long term under all the scenarios, while precipitation will likely decrease in summer or in the monsoon. A marked decrease in precipitation is also projected in the pre-monsoon months (May to July), along with a shift in the timing of peak precipitation from July to August. Rainfall from August to October is likely to increase, with excessive rain in October, suggesting an expansion of the monsoon. Winter and spring rain will also increase. Incidence of precipitation extremes is likely to increase during summer and autumn.

Projected impacts on temperature

Future changes in temperature under different scenarios have been projected by 7 out of the 16 studies selected. Near-term (2001-2050) projections under different SRES scenarios for different areas in the HKH region have been carried out by Khadka et al. (2014) and Rajbhandari et al. (2015), while long-term (2050-2100) projections have been carried out by Immerzeel (2008), Immerzeel et al. (2012); Mathison et al. (2013), Khanal et al. (2014), Rajbhandari et al. (2015) and Mahmood et al. (2015). Mean annual temperature during 2010-2050 increases

Table 1: **Projected streamflow changes in HKH rivers in near term (2001-2050) and long term (2050-2100)**

	Scenario	2001-2050	2050-2100
Annual	A2	Downstream flow to increase by 10–19%	Decrease in upstream flow, Increase in downstream flow
	B2	Increase in average discharge between 2010-2050s: 12.5%	
	A1B	Increase in discharge expected to range between 4–32%. Decrease in discharge after 2040	Decrease in water supply from the upper Indus (–8.4%), the Ganges (–17.6%), Brahmaputra (–19.6%), and Yangtze rivers (–5.2%)
Seasonal	A2	**Ganges:** Decrease in flow in pre-monsoon and increase in monsoon through post monsoon with almost no change in winters (dry season). **Brahmaputra:** Increase in all seasons with maximum (10%) in dry season. **Meghna:** Maximum increase in pre-monsoon (22%) followed by increase in monsoon and post-monsoon, and decrease in winters (dry season).	**Pre-monsoon (February-April):** Streamflow likely to decrease by 18–20% **Early-monsoon (May-July):** Decrease by 19% **Monsoon (August-October):** Increase in streamflow **Winter:** Very little change Spring and Autumn: Intermediate change Increase in summer may lead to extreme discharge
	B2		**Monsoon:** 30% increase in average monthly discharge **Winter:** Small change in discharge **Autumn and spring:** Intermediate increase in discharge Higher in dry season and lower in wet season as compared to A2 Increase in summer will increase the number of extreme discharges.
	A1B	Overall increase in discharge in summer and spring with a slightly decreasing trend in dry season Ganga: Decrease in flow in pre-monsoon and increase in monsoon through post-monsoon and winter (dry season) Brahmaputra: Almost no increase in pre-monsoon, little increase in monsoon and maximum increase in post-monsoon through winter (November-March). Meghna: Maximum increase in pre-monsoon (17%) followed by monsoon and then decrease in post-monsoon and very little increase in winter (dry season)	Summer and late spring –Consistent and considerable decrease in discharge after 2046-2065. Flow to decrease compared to pre-2050. Flow will peak in July coinciding with melt and monsoon season. Steady flow is maintained in winter.
	B1	Overall 7–10 % increase in monsoon Ganga: Decrease in flow in pre-monsoon and increase in monsoon through post-monsoon and winter (dry season) Brahmaputra: Almost no increase in pre-monsoon, little increase in monsoon and post-monsoon, maximum increase in winter (November-March). Meghna: Maximum increase in pre-monsoon (16%) followed by increase in monsoon and then decrease in post-monsoon and no change in winter (dry season)	
	RCP 4.5	Increasing trend in wet season with a slightly decreasing trend in dry season	
	+0.11°C/ decade.	> 5% increase in discharge volume from March–June Decrease from July–September	
	+0.7°C/ decade	15–25% increase from March-May and 15–30% decline during the rest of the months in 2030 30–37% increase from March-May and 35–50% decline during the rest of the months in 2050	

Source: Based on the findings from Bharti et al. (2011); Immerzeel (2008); Immerzeel et al. (2010); Immerzeel et al. (2012); Khadka et al. (2014); Pervez and Henebry (2015); Sharma et al. (2013); Kayastha et al. (2014); Hassan et al. (2014).

by 2.34°C–3.56°C in A2 and A1B scenarios over the period 2010-2050 as per these findings. In the long term (2050-2100), mean annual temperature is projected to increase in A2, B2, A1B and B1 scenarios, while minimum temperature is projected to increase more than maximum temperature. During the same period, temperature is projected to increase markedly in all seasons, particularly in winters in the A2 and A1B scenarios.

Results on Risk Assessment

Based on the findings of the review, the most important risks were identified and risk scales were assigned. The risks were categorized in terms of (a) annual and seasonal risks and (b) near-term (2001-2050) and long-term (2050-2100) risks. The results for the four major impacts are presented below.

Stream Flow

i) Major risks 2001-2050:

Annual: Annual average increase in streamflow ranging from 4% to 32%

Seasonal: Increased streamflow in wet season or summer and spring (April to October) with a slightly deceasing trend in dry season (November to March)

ii) Major risks 2050-2100:

Annual: Annual average decrease in upstream flow of major rivers

Seasonal:

- Decrease in streamflow in pre and early monsoon (February to June), increase in monsoon (August to October), steady flow in winter
- Consistent and considerable decrease in summer and late spring after 2046
- Increase in summer flow will increase the number of extreme discharges

The risk levels identified for the near term (2001-2050) have been provided in Table 2. The risk of 4%–32% increase in annual average streamflow is high in A2, medium in B2 and very high in A1B scenario. Seasonal risk of increased streamflow in wet season or summer and spring (April to October) with a slightly decreasing trend in dry season (November to March) is very high in B2 and low in A2 and A1B scenarios.

Table 3 provides the risk levels associated with the identified risks for the long term (2001-2050). The risk of decrease in annual average upstream flow of major rivers is low in A2 and A1B. Seasonal risk of decrease in streamflow in pre and early monsoon (February to June) and increase in monsoon (August to October) with a steady flow in winter is very high in B2, medium in A2 and low in A1B scenario. Risk of consistent and considerable decrease in flow in summer and late spring is high in both A1 and A1B scenarios. The risk of increase in the number of extreme discharge due to increased flow in summer and late spring is very high in B2 and low in A2.

In the near term (2001-2050), the risk of an increase in annual average streamflow (ranging from 4–32%) in the A1B scenario is found to be 'very high.' as per the risk ratio indicator. In the long term (2050-2100), the risk of a consistent and considerable decrease in flow in summer and late spring is also important.

Flood Events

i) Major risks (2001-2050):

Annual: More frequent floods of higher magnitude

Table 2: **Risk levels associated with streamflow in HKH region in near term (2001-2050)**

	Scenarios	Very low (<20%)*	Low (21–40%)	Medium (41–60%)	High (61–80%)	Very High (80–100%)
	Risk: Annual average increase in streamflow (ranges from 4% to 32%)					
Annual	A2					
	B2					
	A1B					
	B1					
	Risk: Increased streamflow in wet season or summer and spring (April to October) with a slightly decreasing trend in dry season (November to March).					
Seasonal	A2					
	B2					
	A1B					
	B1					

Note: *Figures in parentheses represent the percentage of the studies that confirm the risk under the given scenarios. The length of the bar indicates the strength of the corresponding risk level.

Table 3: **Risk levels associated with streamflow in HKH region in long term (2050-2100)**

	Scenario	Very low (<20%)*	Low (21–40%)	Medium (41–60%)	High (61–80%)	Very High (80–100%)
	Risk: Annual average decrease in upstream flow of major rivers					
Annual	A2					
	B2					
	A1B					
	B1					
Seasonal	**Risk:** Decrease in streamflow in pre and early monsoon (February to June), increase in monsoon (August to October), steady flow in winter					
	A2					
	B2					
	A1B					
	B1					
	Risk: Consistent and considerable decrease in summer and late spring flows after 2046					
	A2					
	B2					
	A1B					
	B1					
	Risk: Increase in summer flows leading to increase in the number of extreme discharges					
	A2					
	B2					
	A1B					
	B1					

Note: *Figures in parentheses represent the percentage of the studies that confirm the risk under the given scenarios. The length of the bar indicates the strength of the corresponding risk level.

ii) Major risks (2050-2100):

Annual: Number of less intense floods likely to increase

Table 4 provides the risk levels identified for the near term (2001-2050) and long term (2050-2100). The risk of more frequent floods of higher magnitude was found across scenarios; the risk level ranged from medium to high in B1 scenario in the near term (2001-2050). The risk of increased number of less intense floods in the long term (2050-2100) was medium in both A2 and A1B scenarios.

Precipitation

Major risks (2001-2050):

Annual: Increase in average annual precipitation with marked seasonality

Table 4: **Risk levels associated with flood in HKH region for near term (2001-2050) and long term (2050-2100)**

	Scenario	Very low (<20%)*	Low (21–40%)	Medium (41–60%)	High (61–80%)	Very High (80–100%)
	Risk: More frequent floods of higher magnitude					
Near-term (2001-2050)	A2	■	■	■		
	A1B	■	■	■		
	B1	■	■	■	■	■
Long-term (2050-2100)	**Risk:** Number of less intense floods likely to increase					
	A2	■	■	■		
	A1B	■	■	■		
	B1					

Note: *Figures in parentheses represent the percentage of the studies that confirm the risk under the given scenarios. No seasonal changes in flood incidence have been projected. The length of the bar indicates the strength of the corresponding risk level.

Major risks (2050-2100):

Annual: Annual average precipitation to increase

Seasonal:

- Less precipitation in monsoon and decrease in pre-monsoon period (May-July)
- Precipitation in October, suggesting extended monsoon
- Extreme precipitation increased in summer

Table 5 shows the risk levels under different scenarios for the near and long term. The risk of increase in average annual precipitation in the near term (2001-2050)is very high in B1, medium in B2 and low in A2 and A1B. In the long term (2050 – 2100), there is convergence across scenarios with a medium level of risk for an increase in average annual precipitation in A2, B2 and A1B scenarios. High and medium risk is associated with decrease in precipitation in future monsoon and pre-monsoon rainfall in B2 and A1B scenarios respectively. There is high to medium risk of increase in extreme precipitation in summer. The projections on seasonal risks vary substantially across scenarios for the long term.

Temperature

Major risks (2001-2050):

Annual: Mean temperature to increase by more than 2°C.

Major risks (2050 -2100):

Annual: Annual average temperature to increase

Table 6 shows the risk levels associated with identified impacts under different scenarios both for near and long term. In the near term (2001-2050), the risk of increase in average annual temperature is low. In the long term (2050-2100), the risk of increase in mean annual temperature is very high in B1, high in A1B and A2, and medium only in B2 scenario.

Conclusion

The studies reviewed above suggest that future projections of impacts of climate change on streamflow, flood incidence, precipitation and temperature in the HKH region are likely to be substantial. The high levels of risks associated with these impacts suggest that there will be wide ranging implications for the economic and social well-being of the region. Identifying risks and assessing the risk level is crucial for developing context-specific adaptation measures and for measuring their effectiveness in coping with the risks.

Table 5: **Risk levels associated with precipitation in the HKH region in near term (2001-2050) and long term (2050-2100)**

	Scenario	Very low (<20%)*	Low (21–40%)	Medium (41–60%)	High (61–80%)	Very High (80–100%)
Near-term (2001-2050)						
	Risk: Increase in average annual precipitation with marked seasonality					
Annual	A2					
	B2					
	A1B					
	B1					
Long-term (2050-2100)						
Annual	**Risk:** Annual average precipitation to increase					
	A2					
	B2					
	A1B					
Seasonal	**Risk:** Less precipitation in future monsoon and decrease in pre-monsoon period (May-July)					
	A2					
	B2					
	A1B					
	Risk: Increased precipitation in October, suggesting extended monsoon					
	A2					
	B2					
	A1B					
	Risk: Extreme precipitation increased in summer					
	A2					
	B2					
	A1B					

Note:*Figures in parentheses represent the percentage of the studies that confirm the risk under the given scenarios. The length of the bar indicates the strength of the corresponding risk level.

Table 6: **Risk levels associated with temperature in HKH region in near term (2001-2050) and long term (2050-2100)**

	Scenario	Very low (<20%)	Low (21–40%)	Medium (41–60%)	High (61–80%)	Very High (80–100%)
Near term (2001-2050)						
	Risk: Increase in annual average temperature by more than 2°C					
Annual	A2					
	B2					
	A1B					
	B1					
Long-term (2050-2100)						
Annual	**Risk:** Increase in annual average temperature					
	A2					
	B2					
	A1B					
	B1					

Note: * Figures in parenthesis represent the percentage of the studies that confirm the risk under the given scenarios. No seasonal changes in the flood incidence have been projected. The length of the bar indicates the strength of the corresponding risk level.

Climate change risks identified above can have important social and economic ramifications for the agricultural sector. This concluding section sheds light on some of the biophysical impacts on agriculture in the region. They include:

Socio-Economic Implications: Projected impacts on crop yield

A significant portion of the geographic area under cultivation in the HKH region depends on irrigation for crop production. The projected water imbalance in the region is thus expected to have severe impact on crop yield in the region. Using CCM3 climate model for doubling of CO_2 scenario, Ortiz et al. (2008) projected the impact on wheat production in the Indo-Gangetic plains. Findings reveal that that as much as 51% of the Indo-Gangetic plains might be reclassified as heat-stressed, irrigated, short-season production mega-environment by 2050. At present the Indo-Gangetic plains is classified as favourable, high potential, irrigated, low rainfall mega-environment and the region accounts for 15% of global wheat production.

Findings of the study carried out by Hassan et al. (2014) shows that yield of monsoon rice is projected to increase by about 3% in 2050 under A2, A1B and B1 emission scenarios in the GBM basin. Yield of dry season rice will decrease. The negative impact of changes in temperature and precipitation is offset by carbon fertilization during monsoon but not during the dry season. Another similar study by Immerzeel et al. (2010), which covered the five major river basins in the HKH region, found that under A1B scenario during the period 2046-2065, food supply will decrease due to a decrease in crop yield, lowering the number of people that can be fed. The number of people that can be fed will decrease by 34.5 + 6.5 million people in Brahmaputra basin, 26.3 +3.0 million in the Indus basin, 7.1 +1.3 million in the Yangtze basin, and 2.4+0.2 million in the Ganges basin. The study estimated that reduced water availability will threaten the food security of 4.5% of the total population of the region.

Besides studies that focus on the HKH region, studies carried out in India and the rest of South Asia also provide strong evidence of the impact of climate change on crop yield. Sorghum grain yield is projected to decline between 2-14% by 2020, with worsening yields by 2050, while in the Indo-Gangetic plains, up to 51% reduction in wheat yield in the most favourable area is projected. In rice plant cultivation, it is claimed that current temperatures are already approaching critical levels during stages of growth, e.g., in northern India (October), southern India (April, August) and eastern India (March-June). Variations exist in long-term and near-term projections. Srivastav et al. (2010) studied the impact of climate change on the yield of sorghum in the central zone (CZ), south-central zone (SCZ) and south-west zone (SWZ) of India using the HadCM3 global climate model outputs on temperature (minimum and maximum) and rainfall for 2020, 2050 and 2080 for A2 scenario. Results showed there will be up to 7% reduction by 2020, up to 11% by 2050 and up to 32% by 2080, mainly in the south-west zone. Based on systematic review and meta-analysis of data from 52 research papers, Knox et al. 2012 assessed projected impacts of climate change on the yield of major crops in Africa and South Asia. The review found robust evidence of impact on the yield of wheat, maize, sorghum and millet in South Asia. No impact or inconclusive impacts on the yield of rice, cassava and sugarcane was observed. By the 2050s, a decline in the mean yield across all crops by 8% is projected. One recent study projects an overall decline in food-grain production by 18% by 2050 (Dasgupta et al. 2013).

Changes in crop yield and resultant production in the region have wide ranging implications. The economic and social distress caused by reduced yield will directly affect the lives of farmers and agriculture dependent households. An overall reduction in food production raises issues of food security and price shocks in food markets, which can impact the national economy as well as international markets. It is therefore important to understand the extent of the impact on this sector, as agriculture plays a very important role in national output, employment and the livelihoods of people in the entire HKH region. The need for adaptation measures to reduce the alarming impact on water availability and water balance in the region cannot be overemphasized.

Assessing Adaptation Costs and Cost Effectiveness of Adaptation Measures

Introduction

This part of the report (Part II) assesses the existing literature on adaptation costs, with a focus on the methods used to evaluate adaptation interventions. This assessment is then used to develop a methodology that can be applied for pilot testing for evaluating costs in the context of one adaptation intervention from the HI-AWARE study region.

The rationale for the study is that the methodology for assessing costs should be context specific. The report is divided into three parts. Part I reviews the literature to identify the various climatic risks posed to the region from a biophysical perspective. In view of the major risks identified in Part I, Part II enumerates possible adaptation measures and options for the HKH region; reviews the methodology for costing adaptation interventions; and proposes the appropriate adaptation costing methodology relevant to the study area. Part III of the report subsequently conducts adaptation costing assessment of one adaptation measure in the sanitation sector to illustrate the methodology.

In recent decades, several efforts have been made to determine the cost of adaptation at the global, regional, national and sub-national levels. Based on their methodologies, these studies have been broadly classified as first generation and second generation estimates (Frankhauser 2010). First generation estimates essentially use a top-down methodology, as exemplified by the World Bank (2006).This includes estimating the cost of adaptation using current financial flows such as foreign direct investment, gross domestic investment and official development aid that are climate sensitive and adding to it the mark ups for climate proofing. The approach has been followed for the infrastructure sector by The Stern Review (2007), Oxfam (2007), UNDP (2007), Project Catalyst (2009), and UNFCCC (2007) (Springermann 2014).

Among first generation estimates, Oxfam (2007) extended the World Bank methodology by adding three additional costs to the financial flows and mark ups for climate proofing. The additional costs included the cost of scaling up community based projects run by NGOs, the most urgent adaptation needs, and hidden costs that are otherwise not taken into account. These hidden costs include the costs associated with ecosystem protection, preventing gender inequality, organizational capacity building and unexpected impacts. Once these costs were included, the overall adaptation cost became much higher than existing estimates.

First generation studies, however, lacked adequate empirical information on the size of mark ups for climate proofing, leading to estimates that were not considered sufficiently robust. Second-generation estimates follow a bottom–up approach and take into account sector-wise adaptation costs. These include studies by the UNFCCC (2007) and the World Bank (2010), which estimated the additional amount of investment needed to address climate change by comparing the investment costs required under the current climate scenario with the costs for one or more projected future climate scenarios. Recent studies have also emphasized the need for integrated frameworks that bridge the gap between top-down and bottom-up approaches while selecting the most appropriate adaptation measures for the water sector (Girard et al. 2015).

A more detailed framework for estimating the adaptation cost was provided by McKinsey, in collaboration with Swiss Re and the Global Environment Facility (2009). The study considered adaptation costs and adaptation priorities for eight case studies in developed and developing countries. This approach to climate adaptation involves two steps: (i) quantification of 'total climate risk' of the study area by assessing expected annual loss under existing climate patterns and under a range of alternative climate change scenarios; (ii) evaluation of a feasible portfolio of adaptation measures for managing expected risks including infrastructural, technological, behavioural and financial interventions using a cost-benefit analysis.

The methodology entails identifying a comprehensive set of potential adaptation measures based on a review of literature including NGO documents and interviews with local experts and government officials. Subsequently a final set of measures is selected based on their applicability and feasibility, which is determined by the preferences of stakeholders. Measures which can be identified, sized, funded and implemented in the short-term are given priority. Societal costs and benefits of the selected measures are determined and the measures are ranked accordingly. Each adaptation measure is plotted on the cost curve in terms of its cost effectiveness.

The current study considers cost assessment for adaptation as involving two sequential stages, after identification of risks posed by climate change. The study thereby adopts the second generation approach for the costing exercise being based on identified potential adaptation measures (for details of the exercise, refer to Part III), Key risks posed to the region are identified (as discussed in Part I), existing methods are critically reviewed, and adaptation measures for the region are analysed (as discussed in part II) to build a rationale for adaptation costing studies. The risk assessment exercise reveals that risks for the HKH region arise primarily from water related stresses. Therefore, the first step in the cost assessment exercise was to identify existing and potential adaptation measures related to the water sector for the region. The second step was to conduct a costing exercise and evaluate the cost effectiveness of these measures in terms of their potential to reduce losses due to the impacts of climate change or to reduce the risks posed by climate change. The succeeding paragraphs begin with the first step, then provide a critical review of literature on costing, and also present the proposed methodology for costing adaptation.

Identification of Adaptation Measures for Water Stress in the HKH Region

Based on available studies on the HKH and other river basins in South Asia, this study (Part II) has identified a comprehensive list of adaptation measures for managing water stress, including both autonomous and planned measures. Some of these are already being practised while others are suggested by scholars and experts working in the area. These measures have been classified using two criteria: (1) whether the measure is currently practised or is proposed for the near and future term, and (2) whether the measure is an autonomous adaptation measure or a planned adaptation measure. These criteria have economic implications in terms of the costs and investment required for implementing the measure.

The adaptation measures are presented in Table 7, along with information on the original sources from which these are drawn, the geographical area studied and the type of climate risks or impacts involved. Some of the studies that have contributed to the understanding of these adaptive measures are discussed below.

Pradhan et al. (2015) have examined adaptation measures that can enhance farmers' ability to cope with the impacts of climate change on the community-managed irrigation system in the Indrawati river basin in Nepal. In the Punjab province of Pakistan, Abid et al. (2015) identified adaptation measures practised by farmers. Lu et al. (2015) have identified crop diversification using tree crop as an important measure for increasing the resilience of communities in selected study areas of China, Nepal and Pakistan. Findings from these studies indicate that autonomous adaptation at the farm level is already being practised, and includes a range of farm management practices such as changes in crop type and cropping calendar, crop diversification, soil moisture conservation and rain water harvesting. The studies clearly imply that lack of planned adaptation is a major drawback in increasing the resilience of communities in the region. Suggestions for planned adaptation measures include installation of a weather information system; institutional support for restoring and maintaining sufficient irrigation water supply; provisioning of resources like climate smart crop seeds, mechanized tools, and water and soil testing laboratories; and increased price of agricultural products and crop insurance.

The ever increasing demand for food, water and energy, lack of synergy among the three sectors and current policy incentives have promoted overexploitation of water resources and discouraged investment in measures to conserve

Table 7: **Identification and Classification of Adaptation Measures**

Sectoral risks	Study area	Authors	Adaptation measures being practised	Adaptation measures suggested
Water stress - Agriculture	Rainfed and farmer-managed irrigated agriculture in the Indrawati Basin, Nepal	Pradhan et al. (2015)	**Autonomous adaptation** • Introduction of new crops like spring rice, maize, onion, garlic, cucumber, and cardamom • Abandoning of crops like pulses, traditional cereal crops, tuber, and sweet potato • Mulching, minimum tillage and similar practices for in situ moisture conservation using locally available materials like rice straw and crop residues • Harvesting rainwater by collecting it in farm ponds for supplementary use in irrigation • Adjusting sowing and harvesting times to better cope with perceived changes in rainfall pattern	**Autonomous adaptation** • Cultivating more than one crop at a time (multi-cropping) very useful for small-scale farmers **Planned adaptation** • Support farmers to restore traditional rainwater harvesting practices by constructing farm ponds, sand/ subsurface dams, earth dams, tanks, and others) • Need to establish a weather information system to enable the farmers to make rapid decisions about sowing, irrigation and other farm practices using community radio programme or mobile phones
	Punjab province of Pakistan	Abid et al. 2015	**Autonomous adaptation** • Changing crop varieties • Changing planting dates • Planting shade trees • Changing fertilizers followed by changing crop types • Increasing irrigation • Soil conservation • Crop diversification • Migration to urban areas • Renting out land	**Planned adaptation** • Providing information and support (subsidies and microcredit facilities) • Accessibility of resources: *Physical resources:* farm inputs (improved seed, fertilizers), farm implements (tools for soil conservation, cultivators, harvesters etc.); *Institutional resources:* water and soil testing laboratories • Sufficient irrigation water supply • Introducing climate smart varieties, promoting soil conservation and new adaptation measures based on different agro-ecological zones
	China, Nepal, and Pakistan.	Lu et al. (2012)	**Autonomous adaptation** • Crop diversification by introducing tree crops along with previously grown crops, as tree crops are more resilient.	**Planned adaptation** Adaptation measures suggested by respondents (in decreasing order of importance): • Improved village-level irrigation facilities • Extension services, such as drought-resistant technologies • More access to government disaster relief subsidies • Improved county or district irrigation facilities and management and coordination • Off-farm work opportunities • Forecasting and dissemination of disaster information • Improved individual irrigation • Increased price for agricultural products • Disaster insurance • Upgrading of rural power grids

Water Stress – Domestic and Agriculture	HKH region	Vaidya 2015		**Planned adaptation** Possibilities for developing seasonal water storage capacity for agricultural and domestic uses by: • Augmenting natural systems of water storage such as glacial melt and snow melt, mountain springs, soil moisture and high-altitude wetlands • Wetlands conservation and watershed management in the hills and mountains • Groundwater aquifer recharge through infiltration ponds and others in the foothills • Construction of artificial systems such as small ponds and tanks for rainwater harvesting, which can be built on farms, and small reservoirs that can be constructed on mountain streams and along natural drainage channels in the hills • Scientific information and technical support to communities to be provided by local offices of government agencies and NGOs • Capacity building of local community institutions for making decisions related to the allocation of water to farmers and households • Taking upstream-downstream linkage into consideration while designing watershed management
	Chitral district in Pakistan	Nadeem et al. 2012	**Autonomous adaptation** • Upgrading traditional ponds to concrete structures • Siphon irrigation systems • The rights of individuals are defined and water is distributed based on these rights. • The cluster organization takes responsibility for distributing water among villages. **Planned adaptation** • Development and lining of irrigation channels • Water supply schemes	
Flood -Domestic and Agriculture	Brahmaputra and Koshi river basin	Das et al. (2012)	**Autonomous adaptation** • Traditional adaptation: Houses on stilts, planting more flood-tolerant crops, devising food storage systems suited to riverine environments, and developing social support systems **Measures after building of embankments –** • Construction of earthen highland in villages within the embankment to take shelter from the floodwaters • Living in stilted houses • Settlements near parts of the embankments that are strong or that have been recently renovated • Round the clock monitoring of any breaches in the embankments and providing information through a mobile phone to the district administration for timely intervention (rescue and relief)	**Planned adaptation** Non-structural measures in addition to structural measures for adaptation to flood, such as: • Increasing people's capacity to adapt to floods and related disasters • Establishing and strengthening coordination among relevant government agencies, civil society, and vulnerable communities • Government-initiated programmes for flood-resistant housing, flood tolerant agricultural practices, soil reclamation and restoration, innovative agriculture on sandy soil • Diversification of livelihoods based on community skills and resources • Set standards and guidelines for the construction and maintenance of flood mitigation infrastructure such as embankments

Drought -Domestic and Agriculture.	Upper Bhima catchment, Krishna Rrver basin, Maharashtra	Udmale et al. (2014)	**Autonomous adaptation** • Changes in the crop calendar • Using crops that consume less water • No sowing (in anticipation of drought) • Using improved irrigation practices (sprinkler, drip irrigation) • Water harvesting (farm pond, in-situwaterconservation practices, etc.) • Reducing wastage of water during drought **Planned adaptation** • Employment through NREGA, • Drinking water supply e.g. through tankers • Fodder camps for cattle • Compensation for the losses • Provision of loan, subsidy scheme, interest waiver and extension of loan repayment period as relief measures for the farmers	**Autonomous adaptation** • Community participation for Implementing water harvesting practices at the community level and in situ water harvesting practices such as conservative agriculture. • Traditional flood irrigation practices should be changed to water saving irrigation practices such as sprinkler or drip irrigation. • Community based effective planning, implementation and management to ensure success of the relief measures. **Planned adaptation** • Television, radioand newspapers should be used as a tool to disseminate weather information about the current and predicted state of the drought and also drought adaptation practices

resources in the region. The major problem is that current policies and existing measures in these three sectors are not interconnected (Golam 2015). Nadeem et al. (2012) look at adaptation measures practised in response to water stress in Chitral district of Pakistan. Measures identified include upgrading the irrigation system and water schemes, and allocation of water rights. Das et al. (2012) discuss adaptation measures adopted by communities in the Brahmaputra and Koshi basins before and after the implementation of structural measures for floods such as the building of embankments. In addition to traditional measures such as building houses on stilts and planting flood tolerant crops, other prominent measures included living on higher land within an embankment or in an area closer to the stronger portion of the embankment. Udmale et al. (2014) investigated adaptation measures adopted by communities in the upper Bhima catchment of the Krishna river basin in the drought prone state of Maharashtra, India. The measures included crop management, water harvesting and reducing wastage of water. Government schemes for employment, providing water through tankers, and providing financial assistance are some of the major planned adaptation measures.

A summary of the major adaptation measures, based on a critical review of studies on how to increase resilience in the HKH region, is presented in Table 8.

The ideal way to judge the effectiveness of an adapation measure for coping with or reducing losses would be to measure the additionality that is wholly attributable to climate change. However, this can pose both conceptual and practical challenges for several reasons. As climate variability in the HKH region is an ongoing phenomena, the magnitude of the impacts and scale of responses to these impacts get mediated by the current development processes. Many developmental activities also enhance adaptive capacity such as those that impact public health, education and the capacity to take up adaptation measures. Thus, due to ongoing exposure to both climatic variability and extreme climatic events, autonomous adaptations take place continuously among communities. Planned adaptation may also take place at the behest of different actors including policy makers and community leaders although it may not always be labelled as such, for instance, in planning for disaster response activities. However, experience suggests that there are significant gaps in tackling climate impacts through adaptation in most sectors, with large residual effects remaining which are beyond the scope of autonomous adaptation. These need to be addressed in a planned way. Planned or anticipated adaptation not only mitigates residual impacts, but also helps communities prepare themselves against intensification of existing and potential risks. For example, adaptation that involves changing farm practices may be autonomous and reactive, while buying insurance or installing an early warning system requires more planning and should be anticipatory in nature. In the case of flooding, a study on the Mekong Delta found that residents have different levels of capacity for coping with seasonal flooding, such as raising the ground floor of their homes, but their capacity to prepare for extreme floods is limited in spite of their awareness of the changing dynamics of natural disasters in their locality (Ling et al. 2015).

Table 8: **Major Adaptation Measures for HKH Region**

Autonomous Adaptation	Planned Adaptation
Agriculture	
• Crop diversification • Change in crop varieties • Water harvesting • Improved irrigation facilities • Soil conservation	• Improved irrigation facilities (RI) • Soil conservation • Weather information system (RI) • Providing subsidies (RI), microcredit and insurance
Water stress	
• Upgrading or augmenting traditional water storage practice • Effective distribution of water - water rights (RI)	• Integrated/large scale water supply scheme (RI)
Flood	
• House on stilts and on a raised area of land • Adjustments to embankments(RI) • Diversification of livelihood	• Monitoring of the embankments and early warning in case of an imminent breach in embankment • Flood resistant housing and related structures such as sanitation facility (RI) • Flood tolerant agricultural practices

Note: RI indicates measures that are likely to be resource intensive.

This study treats the two, autonomous and planned adaptation, as complementary while focusing on measures that actually contribute to adaptation to climatic events. For instance, while considering the benefits of various kinds of sanitation, the extent of the additional benefit attributable to flood events is meant to be explicitly accounted for and adaptation interventions compared thereafter. The challenge lies in teasing out the additionality in specific contexts when conducting an empirical valuation exercise.

Table 8 also identifies measures that are likely to be more resource intensive (RI), requiring more planning, and human, institutional and financial resources. Identifying such measures in time is important because delaying them can prove costly for a number of reasons. First, the negative impacts may have already started. Second, concerned stakeholders might invest in actions that turn out to be maladaptive in the longer run, such as building wrong infrastructure. All this can be avoided through timely action. Further, wherever adaptive action can delay or avoid turning points these need to be anticipated and planned for in a timely manner. This requires prioritization of adaptation action, adequacy of plans and commitment of resources for adaptation action. Resource intensive measures are identified because if an adverse impact can be anticipated, then it is important to be able to make a decision on whether it needs planned adaptive responses. If resources are subsequently made available, then timely response will hopefully be achievable.

Literature Review: Costing for Adaptation Assessments

Costing exercises for adaptation have for the most part been conducted on a large scale, using either global or regional assessment models, often at the national level. However there could be significant regional differences due to difference in vulnerability of different countries within a region (Frankhauser and Tol 1996). It should be noted at the outset that, most studies on the Hindu Kush region stop at identifying or proposing adaptation options. There is a huge gap in conducting holistic adaptation costing studies for the region. The third part of this study, in particular, is an attempt to illustrate how such gaps can be filled by innovatively applying the tools of cost-benefit analysis. The few available studies often apply only engineering or construction cost based norms to capture differences across options, and these can thereby under-estimate the benefits of adaptation.

Several studies have modelled adaptation in agriculture, focusing on household decision-making models to study the determinants of adaptation choices by individual farmer households (Di Falco et al. 2011, Nwachukwu et al. 2015). Some also examine farmer decision-making at the micro level for specific adaptation measures. For instance, crop diversification as an adaptation measure is known to have many benefits such as enhancement of income and reduction in variance in income (Komarek 2010). Typically, data gathered from primary surveys is used to estimate econometric models in these approaches, based on economic analytical frameworks that maximise household utility, Cobb-Douglas or Leontief production functions. The input costs may or may not be a focus of the analysis, but in most cases the costs of the adaptation measure is not derived separately. Most studies on adaptation measures in agriculture assess or evaluate the effectiveness of the adaptation measure on the basis of direct impacts on outcome parameters such as income or yield or food security, while very few estimate the cost of adaptation measures as an input into evaluating effectiveness or conducting cost effectiveness studies. Both sets of studies are considered below.

Illustrations of Approaches for Adaptation Assessments

Methods of assessing vulnerability and adaptation tend to be mostly demand driven, and are tailored to respond to the needs of stakeholders. Here, the scale on which the adaptation measure is planned is important. One important advantage of models is that they can facilitate integration across scales and stakeholders or users. While conventionally economic models have sought to do this through monetary assessments, the role of non-monetary values is increasingly being recognized. Special tools and techniques have been developed to integrate the monetary and non-monetary aspects. Non-monetary metrics are now used alongside monetary ones. The uncertainty surrounding the impact of climate change complicates matters. It is hard to determine the extent and intensity of likely exposure. As impacts vary across communities and countries, it is a challenge to calculate costs and benefits of a measure based on simple aggregation. Context is very important while assessing an adaptation measure. What works in one place may not be the right option for another community or nation.

Some approaches for cost assessment at the global, national and local level are presented below.

Ward et al. (2010) suggest a methodology for estimating the adaptation cost for the supply of industrial and municipal water at the global and regional level. Supply of water for industrial and municipal purposes is highly vulnerable to the impacts of climate change. The technical costs of providing raw water to meet projected demand in 2050 is considered as the adaptation cost. Increasing surface reservoir storage capacity to meet the demand has been considered an adaptation measure.

Hughes et al. (2010) estimated the costs of climate change adaptation with respect to water infrastructure under different climate scenarios using a top-down approach in OECD countries. The study estimates the cost in two parts: additional costs of building infrastructure (change in design) for maintaining the original level or baseline performance and the capital and O&M costs of expanding infrastructure for ensuring adequate adaptation. Demand for water infrastructure, raw water supply for domestic and industrial uses and sewer networks and the impact of climate change on infrastructure (up to year 2050) has been determined using econometric models. Based on the projected demand for infrastructure under the baseline scenario with no climate change, the study estimates new investment as well as investment required to replace those that have reached the end of economic life. This is followed by cost estimates for infrastructure under alternative climate scenarios. The unit cost of the changes is then estimated using the dose-response relationship. The results show that the cost of adapting to climate change is just 2% of the total cost of providing infrastructure for OECD countries.

Sutton et al. (2013) have studied the cost and benefits of adaptation measures for the crop and livestock sector of the eastern European and Central Asian countries. They assessed impacts such as changes in crop yield and water demand for irrigation using process based crop models in different agro-ecological zones (AEZ) under alternative climate projections. Adaptation measures were subsequently identified; these included improvement of agriculture related infrastructure, strengthening of existing agriculture programmes, farm-level measures or autonomous adaptation, and indirect adaptation measures such as market development, education and water management. Costs were estimated at the representative farm level for implementing the adaptation options and the benefits were determined based on revenue implications, i.e., potential increase in crop yield. Other non-market costs were not directly included although an attempt was made to incorporate them in making policy recommendations. In general, valuing non-market goods and services remains a critical challenge for cost-benefit analysis of adaptation measures. Some of the valuation methods suggested by the Pacific Cost-Benefit Analysis initiative (P-CBA) includes contingent valuation for environmental quality, production function approach for water availability and avoided cost approach, to estimate the value of health benefits (USAID 2016).

DeBruin et al. (2009) use an approach that includes qualitative and quantitative assessments of adaptation measures for managing climate change impacts in the Netherlands. The qualitative assessments include preparation of an inventory of adaptation measures in consultation with the sector experts and a multilevel multi-criteria analysis (MCA) to identify, categorize and rank feasible options. Ranking of adaptation options was carried out using one of the scenarios of the Royal Netherlands Meteorological Institute. The ranking is based on criteria weighting. The scores and weights are based on expert judgment to enable comparison across various sectors.. The quantitative assessment involved a social cost-benefit analysis for selected adaptation measures for which data was available. The method includes consideration of social and environmental costs and benefits.

Various models have been used to estimate the value of water scarcity in different contexts. These include Input-Output models (Freire Gonzàles 2011) or Willingness to Pay (WTP) approaches and combinations of these (e.g. Pulido-Velazquez et al. 2009). Guiu et al. (2015) used an approach that aimed towards a comprehensive cost estimation of adaptation measures, including capital and O&M costs, costs of market effects and cost of non-market effects. The study modelled future impacts on water availability, followed by an economic valuation exercise to identify the most cost-effective adaptation strategy. Here, a water deficit leads to a decrease in economic activities and impacts the welfare of the population. Adaptation benefits are measured by comparing the losses suffered before the introduction of adaptation measures and those suffered after. A regional input-output model is used to calculate the total market effect. The model provides an estimate of the decrease in gross value added (GVA) of the sectors where output is affected by water deficit. The non-market effects are measured through the WTP of households for an assured water supply service, or the willingness to accept (WTA) compensations for water shortages. The welfare loss under restricted water supply services is equivalent to the value they are willing to pay yearly in order to avoid this situation.

Economic Models for Adaptation Cost Assessments for Agriculture

Studies at the farm level have been carried out using either an agro-economic approach or the Ricardian approach (Di Falco 2011). Agro-economic models determine the impact of climate change on yield using crop models (Fuhrer 2003). The output of the model is then used as an input for behavioural models to assess the impact of different agronomic practices that represent adaptation measures, such as crop switching on farm income or welfare (Adams et al. 1990; Di Falco 2011).

The Ricardian approach gained importance after the pioneering work of Mendelsohn et al. (1994). It has been used extensively to determine the impact of climate change on farm income and the value of the farmland. The effects of climate are determined using econometric analysis of farm level cross sectional data. The approach is based on observed behaviour of farmers, and 'natural experiments' (including adaptation measures) by the farmer are implicitly captured, including all the adaptation possibilities (Mendelsohn et al. 1994; Mendelsohn & Dinar, 2003). The approach, however, fails to identity the specific adaptive measure and therefore, deriving its cost explicitly becomes difficult.

Other concerns relating to the approach include the lack of controls across the farms (treated as experiments) and assumptions such as those of zero adjustment cost (Mendelsohn & Dinar 1999; Quiggin & Horwitx 1999; Deschen and Greenstone 2007; Kurukulasuriya & Mendelsohn 2008; Di Falco 2011).

Kurukulasuriya & Mendelsohn (2008) use what is called the 'structural Ricardian model' to overcome the major drawback of the Ricardian approach by modelling adaptation measures explicitly. A sample of 5,000 farmers in 11 countries in Africa was used for the model estimation. The *choice of crop by farmers* is the adaptation measure. The model assumes that farmers maximize expected profit through crop decisions. A discrete-continuous model is estimated in two stages: a particular crop or a combination of crops is selected using multinomial logit and subsequently, an ordinary least squares estimation is used to estimate the conditional net revenue model for each choice. The probability of choice of a crop from the first stage is multiplied by the conditional revenue from stage two to get the expected income associated with current climate. Choice of crop and conditional income is then estimated under two future climate scenarios –a Parallel Climate Model (PCM) and the Canadian Climate Centre model. The welfare effect of the crop choice decision is estimated by subtracting the expected income under current climate from the expected income under future climate scenarios. The welfare effect under each scenario is estimated with the assumption that there was no crop switching and the results compared with those obtained with crop switching. Farmers suffered huge losses when there was no crop switching. The resultant loss can be taken as the cost of the adaptation measure. Using a hydro-economic model, Siderius et al. (2016) also found that being flexible in seasonal land and water use has positive effects. The value of flexibility, i.e. the foregone costs of choosing not to crop in years when water is scarce, was determined for rice and wheat in the Ganges basin

The farm management practice of conservation agriculture (CA) is another important coping measure adopted by farmers. It involves zero tillage or at least minimum soil disturbance, retention of crop residues for soil cover (mulching), and rotation (or sometimes intercrop-ping) of cereals with legumes. Through an extensive review, Pannell et al. (2014) tried to understand the economics of CA in smallholder agriculture, mainly in Africa and South Asia. The study provides a general model for approaching farm-level economics of conservation agriculture. The model is used to illustrate the economic benefits of conservation agriculture. The conceptual framework emphasizes the need for cost and benefit analysis of CA, which recognizes that for resource poor farm households, domestic consumption of their agricultural product is a high priority. A complete accounting of costs and benefits is required to capture the full opportunity cost of resources used in CA. Such an accounting would take note of non-monetised aspects along with direct financial cost of inputs. An example of opportunity cost would be the cost of crop residue that has non-cash value for feeding livestock but enhances pest control on burning.

A number of other studies have highlighted the importance of accounting for all opportunity costs while evaluating the benefits of CA. One such study is by Lai et al. (2012), conducted in the tribal villages of Kendujhar district, Odisha. Using household survey data from 145 households, they compared profitability from yield with CA and without CA practices. The study used the survey data to construct the baseline farm budget, followed by estimation of yield and production cost, which specifically included the changes in labour cost for the selected CA practices. Findings revealed that CA practices had a positive impact on yield. However, the profit decreased in the case of farm households where females and the elderly are engaged in farm activities. In contrast, it increased in the case of farm households with young males who could pursue avenues for off-farm employment, mainly in mining. CA reduced their working hours on the farm, allowing them to make an extra income from off-farm jobs.

The general message of these studies is that a cost assessment exercise needs to include and evaluate opportunity costs, especially in developing and least developed economies where a large proportion of transactions may be non-monetised. For instance, a significant proportion of produce might be for self-consumption, while ecosystem services that provide inputs may be overexploited and degenerate. In either case these may be non-marketed or only partially valued even where markets exist. A range of techniques have emerged in the literature to address valuation issues, including multi-criteria analysis and non-probabilistic approaches for addressing adaptation in rural areas (Dasgupta, Morton, et al. 2014).

The challenge lies in estimating the benefits and costs of soft adaptation (World Bank 2010).Such measures can include early warning systems, capacity building, R&D for drought resistant crops, and institutional changes where benefits need to be inferred from behavioural changes in multiple actors in the private sector. Benefits of hard adaptation (such as construction of an irrigation system or a rural road) are relatively easier to estimate because of the direct relationship between investment and output, though issues of time lag and uncertainty are common to both types of adaptation.

It is very important to be comprehensive in the conceptual framing and development of methodology for including all costs and benefits, though practical issues such as the availability of data and even tools to conduct monetary evaluation of all the costs and benefits (for instance, of regulatory ecosystem services or biodiversity) may pose challenges in estimating the actual values. Being comprehensive is particularly important in the context of climate change as climate change affects different communities differently and at different points in time. This means that apart from dealing with concerns about aggregating values, CBA exercises must ensure that costs and benefits (or values) accruing to any particular community are not left out, because the decisions subsequently made might place the community at a disadvantage, especially the poor, whose values may not otherwise be adequately accounted for in monetised estimates (Chambawera et al. 2014, Dasgupta 2016).

Proposed Methodology for Adaptation Assessment in HKH Region

Some general principles can be associated with the two main approaches to cost assessment, namely cost-benefit analysis and cost-effectiveness analysis for adaptation interventions/measures. Table 9 provides a comparison between the definitions, suitability, data requirements, methods for determining the relevant range of values, steps for computation, examples and limitations of each approach.

Table 9: **Comparison of Approaches for Cost Assessment**

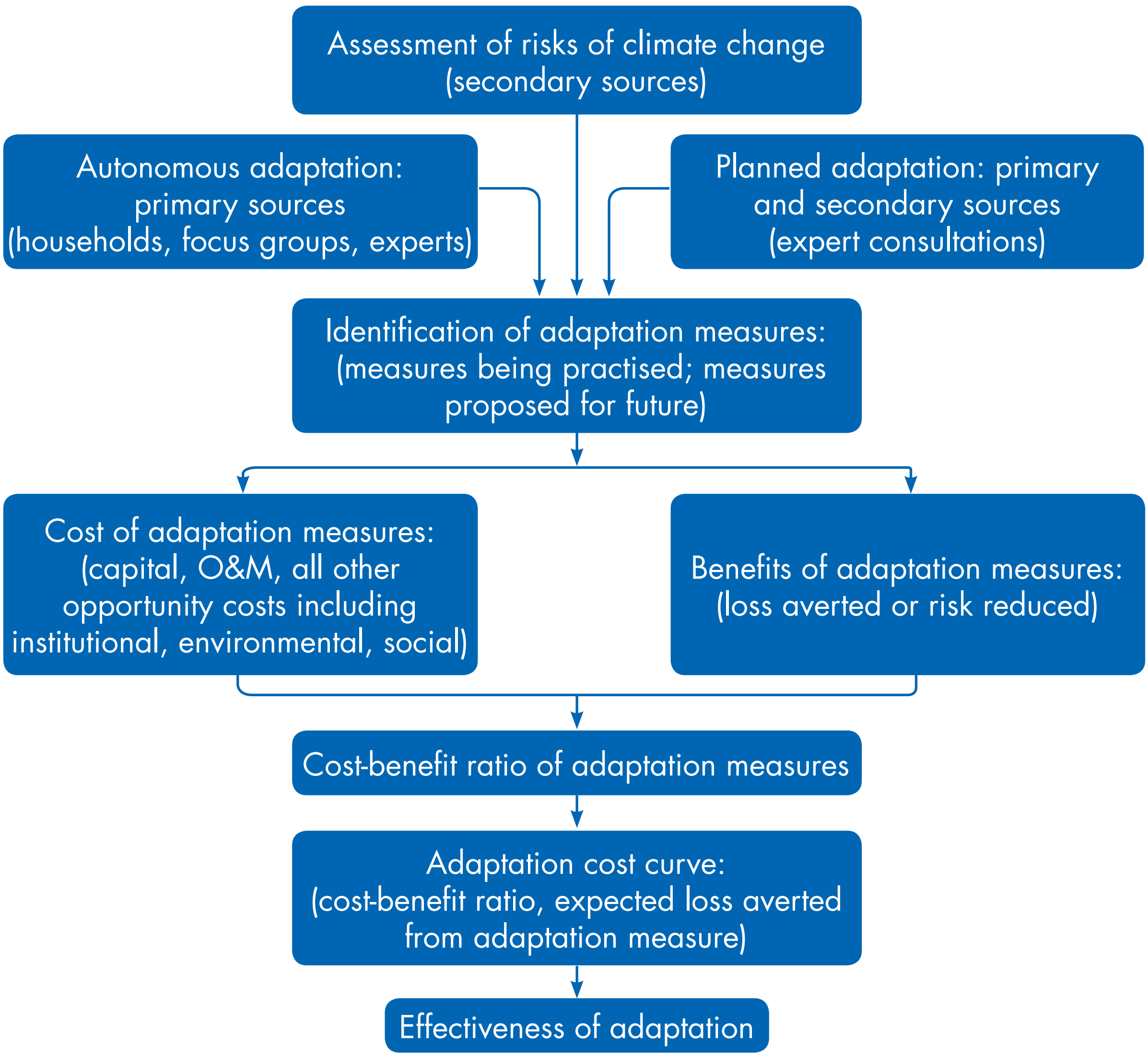
	Cost Benefit Analysis	Cost-Effectiveness Analysis
Definition	• Cost-benefit analysis involves the valuation of all benefits and costs associated with a programme, project or intervention in monetary terms, including non-marketed and marketed values (environmental, social and economic), in order to arrive at its net aggregate value.	• Cost-effectiveness analysis is conducted to identify the most cost-effective or least-cost option for achieving an objective. The cost is expressed in terms of units of the desired output or indicator.
Suitability	• Suitable for determining the financial or economic viability of investing in a particular intervention, project or programme • Criteria can be used to rank interventions in terms of their net social worth, in terms of their internal rate of return, benefit-cost ratio and NPV. • The total worth of a desired project is simultaneously determined and choices can be made among projects that have a high NPV or benefit-cost ratio which is greater than one.	• Suitable for intervention projects or policy whose goal or objective is already determined. • Used to determine the least-cost option for achieving the desired result. • It is particularly useful where valuation data is difficult to collect, or is likely to pose problems in interpretation, or where benefits are difficult to monetise.
Data required	• Capital and O&M costs, costs and benefits of marketed and non-marketed values	• Capital and O&M costs, costs of all market aspects and non-marketed impacts
Steps involved	• Identify relevant intervention (adaptation) measures. • Determine the costs and benefits ofall the alternatives in monetary terms. • To determine the economic and social cost and benefits, use Special Valuation methods for non-market values(approaches for determining the willingness to pay). These include: Stated preference approaches (e.g., contingent valuation, choice experiments, etc.); Revealed preference approaches(e.g., production function;travel cost; hedonic pricing;averted cost and cost of illness for health). • Discount the benefits and costs. • Conduct a sensitivity analysis. • Projects with the highest Net Present Value (NPV) or Benefit-Cost (B/C) ratio> 1 are the preferred options.	• Identify relevant intervention (adaptation) measures. • Determine all costs of each alternative in monetary terms. • To determine the economic and social costs, use Special Valuation methods for non-market values(approaches for determining the willingness to pay). These include: Stated preference approaches(e.g., contingent valuation, choice experiments, etc.); Revealed preference approaches(e.g., production function; travel cost; hedonic pricing; averted cost and cost of illness for health). • Discount the costs (and the physical output indicator). • Conduct a sensitivity analysis. • Determine the cost-effectiveness ratios; • Least-cost option is the most preferred one.
Examples	• Water sector(Guiu et al. 2015);Flood disaster (USAID 2016); Droughts, floods, hurricanes, sea-level rise and health (McKinsey 2009); Agriculture(World Bank 2010; Sutton et al. 2013; Pannell et al.2014)	• Water sector (Guiu et al. 2015); Droughts, floods, hurricanes, sea-level rise and health (McKinsey 2009)
Limitation	• Difficulties in valuation of costs and benefits of non-market values; mis-representation of these values, particularly where free markets do not exist; and the problems in collecting/interpreting benefit values. • Selection of accurate discount rate to capture intergenerational and inter-temporal aspects involves value judgements, particularly when it comes to interventions with environmental implications.	• Does not require estimation of the magnitude of the net worth of the intervention; benefits are not estimated. It does not assess the viability of the project or policy in terms of whether the social benefits exceed the costs. • Challenges arise in estimating costs where there is no free market system or costs that are only partially reflected in market prices. As a result, these costsmay be misrepresented. • Challenges in selecting discount rates (as in the CBA)

Source: Authors'assessment based on personal expertise and secondary literature relevant to a developing economy context

If all the likely costs and benefits of an adaptation intervention or project can be listed out to start with, followed by a reasonably accurate valuation of as many of these as possible, it can serve as a valuable input into decision making. Listing costs and benefits through interactions with stakeholders can also help flag interventions that are most likely to succeed in the long run. This will minimize the chances of maladaptation (USAID 2016). An adaptation intervention would draw support from stakeholders if it also takes note of distributional concerns, ensuring that those who bear the costs are not disproportionately burdened compared to those who gain, in case these are distributed differentially. In many developing economies, adaptation interventions in the sanitation sector (which is analysed as a case study in the Part III of the report) are subsidised and targeted at the poor and disadvantaged. In such situations, a cost-effectiveness analysis or a cost curve analysis that can compare across alternative measures to deliver the desired outcome provides valuable insights for policy. Both CBA and CEA have been used widely in decision-making contexts; the choice of method is based on the context and the objective of the given project, programme or intervention to be evaluated (UNDP 2013, Kunreuther et al. 2014).

Figure 1 presents the proposed methodological approach. The first step is to identify adaptation measures, both that are being practised and those that need to be considered to increase resilience under future climate change scenarios. An extensive literature review of available secondary material is an initial step in such an exercise, apart from interviews with key informants and expert consultations. Data on existing adaptation measures (both planned and autonomous) and the associated costs and benefits is to be collected through primary survey: household based questionnaires, focus group discussions and interviews with key informants. Information on planned adaptation

Figure 1: **Methodology for Adaptation Cost Assessment.**



measures such as irrigation systems, building of embankments, improving connectivity (e.g., rural roads) is to be obtained from consultations with experts including sector experts, government officials and stakeholders who have knowledge of local conditions. The cost of each adaptation measure is calculated by taking into account capital cost, O&M cost, and any other opportunity costs that are site-specific. Future costs are extrapolated from present costs based on assumptions regarding cost inflation, technological developments, and the scale and spread of the measure. The benefits of adaptation are measured in terms of the loss or damage averted, or if data permits, in terms of reduction in the risks. The benefit-cost ratio is then determined following the standard approach. An estimate of the difference in cost (or losses) with and without adaptation measures is obtained. The effectiveness of each adaptation measure can then be determined using the adaptation cost curve.

Adaptation Cost Curve

The adaptation cost curve is obtained by jointly plotting the cost-benefit ratio for each of the adaptation measures and the cumulative expected loss thereby averted. The cost-benefit ratio is plotted on the vertical axis and the cumulative (expected) loss that has been averted on the horizontal axis. Each bar of the adaptation curve represents the adaptation measure and the width of each bar represents the potential of that measure to avert the expected loss due to climate change. The vertical height of each bar represents the cost-benefit ratio for that measure. Adaptation measure progresses from the least cost-efficient to most cost-efficient as we move from left to right along the horizontal axis of the cost curve. The height of the vertical bars provides the magnitude of the cost-benefit ratio for the measures, presenting the decision maker with a comparative analysis of the portfolio of the adaptation measures.

Economic Costing of Adaptation Options for Sanitation: A Case Illustration from West Champaran District, Bihar

Introduction

Many countries are taking cognizance of climate-related risks and prioritizing amongst response options for dealing with such risks. The economic assessment of the costs and benefits of managing climate risks is thus becoming increasingly important. The Hindu Kush Himalayan region faces multiple risks from the biophysical impacts that occur due to variability in climate and weather conditions. Many of the risks associated with climate change in the region are related to water stress .A review of existing literature and risk analysis conducted in this study) reveals that future climate change impacts on streamflow, flood incidence, precipitation and temperature in the HKH river basins is likely to be substantial. While almost all climatic events would have adverse consequences for the well-being of ecosystems and the livelihoods of people in the region, a major concern relates to the occurrence of flood events (for details, refer to Part I).

Floods have been occurring in the Indo-Gangetic rivers for centuries. However, the pattern of flooding has changed, both in terms of the number of flood events, the timing of floods and the intensity of the flooding. There are several reasons for this, including variations in precipitation patterns, changes in land use and built-up area, human interventions to prevent floods in particular areas, infrastructure development including hydel power projects, and changes in the course of rivers and water flows due to natural phenomena. What makes the region additionally vulnerable is the changes in precipitation events and stream flows resulting from changes in glacial activity due to climate change. It is claimed that some of these changes have already occurred, e.g., changes in the pattern and intensity of precipitation events and temperature. Projections indicate major risks of an increase in the frequency of floods of higher magnitude in the near and medium term (now up to 2050) and an increase in the number of less intense floods in the longer term (2050-2100).

Climate change can adversely impact agricultural productivity and consequently nutrition and food security. Projected impacts on food production systems and food security due to rising air temperatures include a reduction in wheat yields in the Indo-Gangetic plains by up to 51% in areas currently designated as most favourable. In rice plant cultivation, it is claimed that current temperatures are already approaching critical levels during stages of growth, e.g. in northern India (in October) and eastern India (in March-June) (Hijioka et al. 2014, Dasgupta, et al. 2014, Porter et al. 2014). Floods and changes in precipitation events lead to far-reaching consequences. They threaten the health and livelihoods of the affected people, destroy assets and property, lead to adverse health consequences, and damage standing crops and agricultural stocks, which might potentially contribute towards reduced food availability and inflation in the economy.

Planned adaptation responses to flooding have not received enough attention in the region. While the threat of flood events is well recognized and measures have been taken over the past few decades to mitigate the consequences, not all of these interventions have worked well for the affected communities.[1] In most countries in the region, management of floods has been entrusted to the government's irrigation and water resources departments. A short-run focus on developmental goals has led to many issues relating to land tenure and changes in land use. This has posed challenges in planning large scale or programmatic adaptation responses for the region.

[1] There is a vast body of literature that has looked at these issues and analysed them in depth. It is beyond the scope of this paper to review these here.

There are large developmental deficits in the countries of the HKH region. Lack of access to basic amenities, clean energy and health care facilities, unemployment, poverty and inequity create multi-stressor situations, in which climate change impacts add to already existing vulnerabilities. An improved understanding of the science of climate change helps to shift the focus from economic development to sustainability of the development process itself (Dasgupta 2015). The need of the hour is developmental interventions that include the capacity to deal with climate risks and to ensure that the gains from development are not eroded by climatic impacts. Many autonomous and micro level responses can hence be considered important adaptive responses along with planned response strategies.

The study evaluates two interventions that seek to improve access to sanitation in a district in the state of Bihar, India. Bihar has been classified as an Empowered Action Group (EAG) state in recognition of its special developmental needs. West Champaran is a flood prone district in the state. Both regular and flash floods affect several of the blocks in the district. Many of the affected households are poor. The researchers have conducted a cost-benefit analysis of the interventions in an attempt to evaluate the cost effectiveness of the interventions.

Methodology for Economic Assessment of Adaptation Benefits and Costs

Cost-benefit analysis (CBA) is a standard method for economic decision making, particularly for evaluating the economic worth of an investment. It is generally used for evaluating individual projects and programmes. The inclusion of natural capital as a component of the wealth of a nation, and the recognition of the contribution of ecosystem services in the productive processes in the economy, led to the extension of cost benefit analysis to projects and programmes that included ecosystems and their services. Given that most ecosystem services do not have markets, or at best there exist partial markets for some, special methods of valuing such services have been developed. Typically, economic valuation methods yield a monetary measure of the benefits and costs associated with the intervention or programme; costs and benefits are aggregated separately, to enable a comparison of the two. Conventionally, three measures are used for this comparison: the net present value, the benefit-cost ratio, and the internal rate of return[2].

Climate change impact analysis throws up new challenges to the application of standard CBA techniques and the interpretation of the findings thereof. As a consequence, the literature has evolved, urging a shift towards approaches that explicitly take note of these dimensions. These approaches address uncertainty related issues through a plurality of methods, ranging from advances on conventional ones such as cost-benefit approaches that include a time dimension, to newer and heterodox ones, including multi-metric approaches and non-probabilistic methodologies. Unfortunately, the application of these methods is still in its infancy, and few studies have actually used these extensively to arrive at empirical estimates. The role of non-market values, prevailing inequities, behavioural biases, and ancillary costs and benefits of response options become extremely relevant to the climate context, but remain true of most analysis relating to the environment as a general principle.

In the present study, data was gathered on a pilot basis for the two interventions through a primary survey. The requirement for monetized values as inputs to economic decision-making implies that ecosystem values that are either not captured or at best partially captured get left out of the decision-making context. In such situations, economic decision-making has to be embedded within a much wider context of risk analysis and management for reducing the risks and managing the threats through adaptation responses. Therefore, available data on costs and benefits has been gathered from the study area as far as possible, with added assumptions about certain aspects of the intervention being drawn from secondary literature and data sources. This is done in order to avoid leaving out key aspects of benefits or costs for which data is not directly available in the study area.

The interventions have been adopted for varying lengths of time in the study area, though none of these have completed full life cycles yet. Hence data on the duration of the asset created under circumstances specific to the local context is not available. However, standardized assumptions based on experiences elsewhere are used in the analysis for calculating the net benefits. Similarly, literature on developing countries provides inputs on the

[2] A large body of literature exists on methods of economic valuation for environmental services. The interested reader may refer to these (e.g., Freeman 2003, Freeman et al. 2014, Dasgupta 2009) for more details.

extent of benefits accruing from sanitation interventions in terms of reduced morbidity and mortality associated with waterborne diseases. Households were also unable to provide accurate data on the amount of individual nutrients in the compost generated from Eco-san toilets, though they were able to report the quantities of compost generated and the extent to which it was being used in their fields. Wherever such instances arose and reliable data was not readily available in the study area, standardized norms and benefit measures were taken from other Indian or developing economy contexts to fill the gaps. These were then adjusted appropriately using the baseline data from the survey in order to make the estimates as robust as possible and relevant to the study area. A CBA has been conducted for each of the three intervention measures. Subsequently, the feasibility of the intervention measures is discussed based on the benefit-cost ratio and the net present value.

Study Area: Kairi village, West Champaran District, State of Bihar, India

Kairi village falls under Domat Panchayat in Gaunaha block of West Champaran district. The village is highly prone to flash floods caused by the Pandai River. It was selected for the study because two major interventions were started in this village to improve access to sanitation. These are Eco-san toilets and double-pit pour flush toilets. The present study focuses on these interventions and the economic costing of alternative technologies embodied in these for promoting sanitation.

Most countries focused on sanitation as a key area of development intervention during the 1980s. This trend gained further momentum after sanitation was also incorporated in the MDGs. In India, the government has launched various programmes since the 1980s to improve sanitation, such as the Central Rural Sanitation programme (1986), Total Sanitation Campaign (1999), and the ongoing Swachh Bharat Mission (SBM)[3] (TSC Guidelines 2010). Financial incentives to build toilets were developed from the time of the TSC. While the majority of the toilets being built are pour flush or pit latrines, Eco-san toilets have been recognized as a feasible technology option since the TSC was adopted. The SDGs also lay emphasis on sanitation.

Sample Characteristics

Kairi village has 167 households with a total population of 589. The majority of the village households, i.e., 144 out of 167, belong to the Tharu community, which falls under the Scheduled Tribe category. The next largest community is Oraon or Dhangad community, spread across 14 households. The village comprises of 3 tolas – Khekaria, Kairi and Amarahawa. The field study was conducted in two phases. In the first phase, a pilot survey was done in the second week of February 2016. Some of the key informants were identified and interviewed using a semi-structured questionnaire. An informal FGD was conducted with the help of a checklist to understand the various challenges and opportunities relating to sanitation interventions in the village. In the second phase, a detailed household survey using a structured interview schedule was conducted in the village from 6 to 10 March 2016.

At present the village has 4 households with Eco-san toilets and 16 households with double-pit pour flush toilets. In view of the objective of the study, all households that had adopted these intervention measures were included. In addition, as controls, households that did not have any of these interventions, but matched the intervention households in terms of various criteria were identified and selected. The criteria included (a) Economic status – determined by the size of landholding (b) Social status– ensuring representation of all the castes, tribes and religions in the village (c) Geographic location – representation from the three tolas was required as the level of vulnerability to flooding differs across the tolas. While two tolas, Khekaria and Amarahawa, are closer to the river and entirely affected during flash floods, the third one, Kairiis only partially affected. A total of 43 households were selected for the sample survey. Table 10 presents the data for the households surveyed.

[3] The SBM is a nation-wide sanitation programme that seeks to achieve universal sanitation. It was launched in 2014 by the Government of India, with a strong focus on building toilets. (Swachh Bharat Mission-Gramin, Ministry of Drinking Water and Sanitation, Government of India. http://sbm.gov.in/sbm/#)

Table 10: **Characteristics of Sample Households**

		Number of households	Percentage of the total 43 households
Community (caste/religion)	Tharu	35	81.4
	Oraon	4	9.3
	Nai	2	4.7
	Paswan	1	2.3
	Muslim (religious category as the rest are Hindu)	1	2.3
Size of landholding (ownership)	Landless	19	44.2
	Less than 1 acre	16	37.2
	More than 1 acre	8	18.6
Type of dwelling structure	Kuccha	18	41.9
	Semi-Kuccha	13	30.2
	Pucca	12	27.9
Source of drinking water	Dug well	11	25.6
	Handpump	22	51.2
	Handpump with filter	10	23.3

Sanitation and Toilet Usage: Descriptive findings from the sample households

Of the total 43 households surveyed, only 15 (34.88%) households had toilets. However, not all of these are in use or currently functional. Of the 15 toilets, 8 were in use while 7 were not; the latter were all double-pit pour flush type toilets. Some of these toilets had parts that were missing or left unfinished, such as doors, connecting pipes, and so on. In the 4 households which had Eco-san toilets, household members reported regular use of the toilet. Table 11 details the situation with regard to sanitation and usage of toilets.

Table 11: **Sanitation and Toilet Usage in Sample Households**

		Number of households	Percentage of the households
Sanitation	Open defecation	28	65.1
	Use toilet	15	34.9
Type of toilet	Double-pit pour flush	11	73.3*
	Eco-san	4	26.7*
Usage	Non-functional	7	42.9*
	Functional	8	57.1*

* Expressed as a percentage of the 15 households in the sample that had toilets

Despite the fact that the village is prone to flash floods, the double-pit pour flush toilets are constructed such that their height is less than one feet above ground. Another issue of major concern is that in 5 out of 11 households with double-pit pour flush toilets, the toilet was located at a distance of less than 15m from the source of drinking water. This considerably increases the risk of groundwater contamination and is in breach of the regulation on the distance to be maintained between the two.

Households that did not have any toilets cited various reasons for that (Table 12). Some of these households stated that in the official records prepared and maintained by the Panchayat (local government institution at the village level), these households are recorded as already having toilets. This meant these households would not be eligible for the

Table 12: **Reasons reported for not having a toilet**

Reason	Number of households	Percentage of the households*
High construction cost/initial investment	6	21.4
Never thought of it	6	21.4
Space constraints	7	25.0
The baseline list prepared by the Panchayat says toilet already exists in their households.	9	32.1

* Expressed as a percentage of the 28 households in the sample that did not have a toilet.

reimbursement of INR 12,000 for constructing new toilets under the SBM. Therefore, they were not interested in constructing toilets. Unfortunately, Panchayat members were not available to comment on this aspect. The most prominent reason that emerged was space constraints. Most villagers were of the opinion that a toilet should be constructed separately in a stand-alone space, outside the living area of the house. Finding such a space for constructing the toilet is a major limitation, particularly for poorer households that have limited access to land or are landless. Additionally, land is so precious that whatever is available is prioritised for agricultural purposes. For this reason, even those who have built pucca[4] houses in the last two years, indicating a measure of affordability and willingness to bear construction costs, did not make any effort to build toilets. For the poor, coming up with resources to meet the initial cost can also become a constraint under a reimbursement scheme.

Cost-Benefit Analysis: Eco-san toilets

Eco-san (Ecological Sanitation) toilets have been promoted in India and elsewhere in developing countries as an alternative to conventional toilets. It has been argued that these toilets have certain advantages which make them ecologically more friendly and sustainable than other toilets. Among the advantages often cited are less need for water as compared to flush toilets, on site disposal in an environment-friendly manner which avoids the costs of large infrastructure for treatment and disposal of waste matter, segregation of urine and faecal matter and its subsequent use as manure and liquid fertilizer, and reduced faecal contamination of freshwater/groundwater sources. A recent study (SCOPE 2013) suggests that Eco-san toilets offer the most sustainable form of sanitation among available options for toilets. These toilets are built on a raised platform that ensures accessibility in areas prone to floods and water-logging. The design of the toilets can vary across local contexts depending on factors such as climate, soil and rock typology, and drainage, as well as construction features such as the quality and type of material used, number of chambers, features such as doors and ventilation, and so on. As observed in the study area, the cost also depends on the extent to which locally available material is used for the upper part (superstructure) of the toilet (e.g., thatch, bamboo) as opposed to masonry which is required for the base.[5]

Table 13 presents the details of the cost related to construction of one unit of Eco-san toilet, the operation and maintenance (O&M) cost incurred every year and the benefits in the form of averted health costs due to reduction in diarrhoeal incidence and averted losses from using the toilet even during floods. As mentioned earlier, in addition to the health benefits related to sanitation and prevention of groundwater contamination, the manure from the human waste (urine and faeces) generated in the Eco-san toilet can replace chemical fertilizers.

The cost of land required has been calculated based on the total area required for constructing an Eco-san toilet and the current cost of land. At present, the cost of 250 sq. ft (1dhur) of land in the village is INR 12,000. Accordingly the cost of the total area required for the toilet including the staircase is INR 2,140. In Kairi, the base and staircase of the Eco-san toilets are a permanent structure made of bricks and cement, while the upper half of the structure consisting of walls is in most instances a semi-permanent structure made from locally available material such as hay, dried grasses, and so on. The cost of the permanent structure and the semi-permanent structure has been taken from the detailed construction cost provided in the technical report on Eco-san by Megh-Pyne Abhiyan, Bihar. The O&M cost associated with the Eco-san toilet is relatively low. This cost has two components: minor repairs of the semi-permanent structure and the effort cost of emptying the manure from the vault every six months, for an average household size of 5–7 members. Both sets of activities are usually done by the household members. According to self-reported data, these costs amount to INR 200 per year under normal circumstances.

In Eco-san toilets, the vaults for storing faeces are above ground and thereby the risk of contamination of groundwater is less compared to toilets with underground pits. Since the faecal matter is also kept dry with ash being added to it, it helps kill the pathogens. This considerably reduces the risk of occurrence of diarrhoea from transmission of pathogens through groundwater contamination. Literature from developing countries established that use of improved water supply and sanitation facilities leads to a decline in diarrhoeal incidence. The rate

[4] Structures made of brick, mortar or cement.
[5] For further details on design and operation, refer to Ecological sanitation: Practitioner's guidebook (UNICEF, GOI, IITD, 2011), UNICEF (2011). Tilley et al. 2008.

Table 13: **Estimation of costs and benefits for Eco-san toilets**

Cost	Parameters*	Description	Value (in INR)
Capital	Total land area required (including stairs) in sq. ft.	44.6	2,140
	Cost of constructing (including materials and labour cost)		19,923.25[6]
		Total	**22,063.25**
O&M Cost	Cost of minor repair of the structure and labour required for emptying manure from vault per year		**200**
Benefits			
(A)	**Health**		
	Average number of diarrhoeal episode/ person/ year	2.7	
	Average number of days of illness during each diarrhoeal episode/person/ year	4.0	
	Average number of days of illness per person per year	10.8	
	20% Reduction in number of days of illness	2.2	
	i) Averted wage loss		
	Daily wage rate (INR.):	200	
	Wage loss averted for a household of 6 person**		1,289.52
	ii) Averted Treatment cost		
	Average treatment cost per episode of diarrhoea (INR)***	500	
	20% Reduction in episodes	0.5	
	Benefit from averting treatment cost for a 6-member household (INR)**		810
	Health benefits for a 6-member household	**Total (i + ii)**	**2,099.52**
(B)	**Convenience benefits**		
	Benefit of using Eco-san during flash flood events (INR 60 per day for a 6-member family. Average 3 events occur per year.)		180
	Convenience benefit from using toilet on a regular basis (365 days)		2,190
		Total	**2,370**
(C)	**Manure from Eco-san**		
	Fertilizer from urine (Household with 6 members)		
	Nitrogen (@4.01 kg/person/year)	24	216
	Phosphorus (@0.40 kg/person/year)	2.4	67.20
	Potassium (@1kg/person/year)	6	120
	Fertilizer from faeces (Household with 6 members)		
	Compost generated per year (kg)	100	
	Market price of compost (INR)	2.5	
	Benefits from compost		250
		Total	**653.20**
	Total benefits from Eco-san (A + B + C)		**5,122.72**

* All estimations are for a 6-member household.
** Probability of 0.5 (50%) of falling ill with diarrhoea in a given year has been assumed. Self-reporting by the households suggests this is the probability of occurrence of acute diarrhoea that lasts for more than 2 days and requires treatment. The other episodes are self-limiting and generally do not cause major disruptions in activities; therefore, no treatment is sought. Hence, only 50% of the incidence is used for making the calculations.
*** The cost includes costs of transportation, doctor's fees, and expenses of home remedies.

of decline ranges from 20% (for a pit latrine) to 90% (for piped water supply) (GWI, Whittington 2008, GDN 2013). Projections indicate that the effects of climate change will lead to increased incidence of diarrhoeal illnesses (Moors et al. 2013, Hales et al. 2014, Smith et al. 2014, UNFCCC 2007). For the purpose of this study, the minimum expected level of reduction in diarrhoeal incidence due to improved sanitation facilities, i.e., 20%

[6] Note that the cost of construction depends on the type of materials used. For instance, in the present study, most of the toilets were constructed with bricks, whereas in another recent study (SCOPE 2013) if the toilets are made out of hollow blocks, the cost is lower at INR 16, 350.

reduction, is attributed to Eco-san toilets. In other words, a 20% reduction in the number of days of occurrence of diarrhoeal illness per person per year is assumed to be attributable to Eco-san toilets as compared to a situation without any toilet. In rural India, the average number of diarrhoeal episodes per child per year is 2.7 (Bern 2004; Laksminarayanan and Jayalakshmy 2015), while the average number of days of illness during each episode ranges from 4.3 days in case of mild diarrhoea to 8.4 days in case of extreme diarrhoea for a child below 5 years. In adults, each episode is of 2.8 days (Lamberti et al. 2012). Average duration of illness is 6.35 days for a child and is 2.8 days for adults. The sampled households typically report two children below 5, while the rest are treated as adults since self-reporting of illness episodes shows that there is no difference between adults and children above 5 years of age. Assuming 6 members on average per household, the weighted average for the duration of each illness episode is 3.98. The reduction in the number of days of illness in a year due to this intervention is accordingly calculated and subsequently monetized by using the daily wage rate. Further, based on self-reported occurrence of diarrhoeal illness in the surveyed area, it was found that on average there was a probability of 0.50, i.e., 50% of the household members falling ill with diarrhoea in any given year. The calculated values are shown in Table 13. All values are in current prices.

A major benefit households derive from Eco-san toilets is fertilizer from human waste, which they can use as a substitute for chemical fertilizers instead of having to buy the latter in the market. The amounts of nitrogen, phosphorous and potassium generated from urine are 4.01 kg/person/year, 0.40 kg/person/year and 1 kg/person/year respectively. On an average, a household with six members generates 100 kg of compost each year (Water Aid 2008; UNICEF, GOI, IITD 2011).[7] The amounts of nitrogen, phosphorous and potassium (from urine) and compost (from faeces) generated by a six-member household has been calculated according to standardized measures. The costs of nitrogen, phosphorous and potassium have been estimated based on their content in urea, DAP and potassium and their market prices. Urea has 82% nitrogen while DAP has 20.2% phosphorous. For compost, market price has been used.

Eco-san toilets are usually constructed above ground level, at a height above the average height to which flood waters rise in the area surrounding the house. As a result, the toilet is usable even during and immediately after flood events. The household can thus avoid great inconvenience during floods. Kairi experiences flash floods on a regular basis and flood waters generally rise to a height of upto 2 ft. Waters tend to recede within 2–3 hours. As it is not possible to exactly quantify this benefit, we try to assess its value by comparing the situation with one of open defecation.

A focus group discussion was conducted with women in Charkhi, another village of the same district. The village experiences floods regularly, and most households are poor and have no access to toilets of any kind. Most residents therefore practise open defecation. A few of the better-off households have built pit toilets, but these are not used on a regular basis. The villagers face severe inconvenience during floods as the surrounding land gets inundated, and there is an added risk of snakebites. Women face excruciating situations. Some of them said they suffered from weakness after flood events as they deliberately reduce their consumption of food to avoid the need for defecation. "*Kum khaye, kum jaye,* " they said, meaning, "If you eat less, you excrete less."

In a village that regularly experiences floods and where people usually practise open defecation, women hire a boat to get to a dry patch of higher land to defecate. Women from better-off households usually pay the larger share of the boat fare. For the poorest, the expenditure for a day (for one trip) during a flood event is approximately INR 10 per day (self-reported). This is a minimum valuation or charge payable, and may seem like an insignificant amount compared to other benefits that accrue. For a 6-member household, the total cost is INR 60 per day. For the households in Kairi that use Eco-san toilets, the benefit value accrued (in the form of avoided costs) during three flood events lasting a day each would be INR 180. Again it must be noted that this is a minimum valuation. Women from better-off households pay upto triple the amount that members of poorer households pay.

[7] Assessment of urine-diverting Eco-san toilets in Nepal. Report by Water Aid, 2008.

However, regular access to a toilet facility even during non-flood events has substantially greater convenience value than open defecation. Although it is difficult to do a direct attribution of the value of this benefit, an imputation of the value can be done on the basis of a minimum of Re. 1 per day, which is the minimum charge for using a community latrine in an urban area. This implies a minimum net benefit of INR 365 (if used once a day) per household member. For a 6-member household this will amount to INR 2,190.

The CBA was carried out by comparing the aggregated capital and O&M costs with the aggregate benefits from the intervention (Eco-san toilet in this case) in terms of health, use of manure, usage during floods and convenience. As capital costs and benefits accrue over the life span of the toilet's usage, these have to be discounted to make a meaningful comparison. Three alternative discount rates have been used: 1%, 3% and 5%. A discount rate of 3% has been recommended by WHO-CHOICE (Choosing Interventions that are Cost Effective) (Classen and Haller 2008). In the absence of any nationally determined standardized discount rate, an alternative of a 5% discount rate has also been suggested for sanitation interventions (SuSanA 2009).[8] Apart from the benefits enumerated here, there may be other positive externalities such as long term improvements in soil and water conditions, improved social well-being and secondary benefits from improved health status due to reduced diarrhoeal illness that are associated with having access to toilets. These are expected to lead to substantial welfare gains both in the present and future although these may be difficult to monetise in the context of the present study. Consequently, an alternative discount rate of 1% has also been used to build one scenario to implicitly acknowledge that these positive values exist and would be realized in the long run.

Eco-san has a life span of 10–15 years. In keeping with the minimum value approach of the study for benchmarking feasibility, the life span is assumed to be 10 years. The benefit cost ratio is 2.24, 2.05 and 1.89 for discount rates of 1%, 3% and 5% respectively. As the BCR is greater than 1 and the Net Present Value (NPV) is high, the calculations reveal that the intervention is likely to be beneficial and economically feasible.

Cost-Benefit Analysis: Double-pit Pour Flush

The second sanitation intervention considered for the analysis is the double-pit pour flush latrine. CBA for the double-pit pour flush was also carried out. Table 14 presents the detail of the cost related to construction of one unit of double-pit pour flush toilet, the operation and maintenance (O&M) cost incurred every year, cost of non-usage during floods and the benefits in the form of averted health costs due to reduction in diarrhoeal incidence. Cost of land required has been calculated based on the total area required for construction and the current cost of land. Cost of material and labour is based on the information provided by the local people (exact split of the cost is not available). O&M cost includes the cost of emptying the pit once a year. This task cannot be undertaken by household members, unlike with Eco-san toilets, so people who are specifically trained for this kind of work and have access to appropriate equipment are hired and paid INR 600 (total) to empty it once a year. As the toilet is almost on ground level and the pits are underground, these toilets cannot be used for at least 10 days during floods. The cost of time spent on going for open defecation during this period also adds up to the annual cost. Thus the O&M cost is very high compared to that of Eco-san.

In double-pit pour flush toilets, soak pits are made under the ground. The soak pit should be at least 15m from any groundwater source (Ministry of Panchayati Raj, GOI, Handbook on Gram Panchayat and Sanitation 2014). In Kairi, the water table is high and soak pits are often located very close to the source of water, the latter being usually a handpump for pumping out groundwater, which is subsequently used for cooking and drinking purposes. The distance between the source of water for the households (*Chapakal* as a handpump is called locally) and a cluster of closely built soak pit latrines ranged from 12 to 40 feet. These conditions create a very real threat of contamination of groundwater due to its proximity to soak pits. Therefore, it is likely that double-pit pour flush toilets have a much lower potential of contributing to reduction in diarrhoea incidence as compared to Eco-san toilets. .Under the circumstances, it is unlikely that the 20% reduction in waterborne diseases usually associated with this intervention when carried out under more ideal conditions will take place. This study attributes a 10% decrease in

[8] SuSanA fact sheet: Costs and economics of sustainable sanitation, Version 1.3 (February 2009).

Table 14: **Estimation of costs and benefits for double-pit pour flush toilets**

Cost	Parameters*	Description	Value (in INR)
Capital	Total land area required (including stairs) in sq. ft.	34	1,132
	Cost of constructing the structure (including materials and labour cost)		7,257
		Total	**8,889**
O&M Cost			
(A)	**Cost of emptying pit once per year**		600
(B)	**Inconvenience cost**		
	Inconvenience cost due to non-usage during flash flood events (INR 60 per day for a 6-member household. Not in use for 10 days for 3 flood events)		600
		Total	**1,200**
Benefits			
(A)	**Health**		
	Average number of diarrhoeal episode/ person/ year	2.7	
	Average number of days of illness during each diarrhoeal episode/person/ year	4.0	
	Average number of days of illness per person per year	10.8	
	10% Reduction in the number of days of illness	1.1	
	i) Averted wage loss		
	Daily wage rate (INR):	200	
	Wage loss averted for a 6-member household**		644.76
	ii) Averted treatment cost		
	Average Treatment cost per episode of Diarrhoea (INR)***	500	
	10% Reduction in episodes	0.3	
	Benefit from averting treatment cost for a household of 6 person**(INR)		405
	Health benefits for a 6-member household	**Total (i + ii)**	**1,049.76**
(B)	**Convenience Benefits**		
	Convenience benefit from using toilet on a regular basis (355 days)		2,130
	Total benefits from Eco-san (A + B)		**3,179.76**

* All estimations are for a household with 6 members.
** Probability of 0.5 (50%) of falling ill with diarrhoea in a given year has been assumed. Self-reporting by the households suggests this is the probability of occurrence of acute diarrhoea that lasts for more than 2 days and requires treatment. The other episodes are self-limiting and generally do not cause major disruptions in activities; and no treatment is sought. Hence, only 50% of the incidence is used for making the calculations.
*** The cost includes costs of transportation, doctor's fees, and expenses of home remedies.

the number of days of occurrence of illness to this type of toilet. In fact, given the failure to comply with the standard regulation, it might be difficult even to attain 50% of the norm, i.e. a 10% reduction.

As noted earlier, in Kairi the water level during a flash flood can rise up to a height of 2 feet, and usually the water recedes in 2 to 3 hours. Although the water recedes reasonably fast, the flood poses inconveniences and the household has to stop using the pit latrine for sometime. The floodwaters inundate the double-pit pour flush toilets as the toilets are constructed less than one feet above ground level. The soak pits are also underground and fill up with flood waters, sometimes creating spillage and other associated inconveniences. The toilet is thus unusable during and after floods, till they are emptied and dried out. Based on the responses from the household members, it is safe to assume that on an average such toilets cannot be used for at least 10 days after a flood event. Thus, the inconvenience cost imposed on the households in this case is implicitly estimated to be INR 60 per household. Assuming there are three flood events in a year, with the total impact lasting for 10 days in a year, the total annual cost could come up to be INR 600.

It is assumed that the convenience value of the toilet is the same as that of the Eco-san toilet. However, as 10 days of floods have already been accounted for, the inconvenience cost here is taken only for 355 days.

The CBA exercise was carried out based on the capital cost, O&M costs and the health and convenience benefits that could accrue from the intervention. The values are provided in Table 14. Here, too, discount rates of 1%, 3%, and 5% have been used. A life span of 10 years is assumed. The benefit-cost ratio is 1.64, 1.58 and 1.53 for discount rates of 1%, 3% and 5% respectively. The BCR is greater than 1 for all the three discount rates, suggesting the overall feasibility of the intervention. However, the BCR is lower than that of Eco-san for all three discount rates. The Net Present Value (NPV) is also higher for the Eco-san toilet over its life span (Table 15). This indicates that the Eco-san option is more beneficial than the double pit toilet in economic terms.

Table 15: **Comparison of the BCR and NPV of the intervention measures**

	Eco-san toilet		Double-pit pour flush Toilet	
Discount rates	**BCR**	**NPV (in INR)**	**BCR**	**NPV (in INR)**
1%	2.2	30,169.17	1.6	13,342.84
3%	2.1	26,362.21	1.6	11,992.24
5%	1.9	23,046.24	1.5	10,805.61

Conclusion: Economic Costing of Sanitation as an Adaptation Option

The results indicate that the benefit-cost ratio of both interventions is more than one, indicating that the benefits exceed the costs. This is not surprising given that there are substantial externalities associated with the interventions, and these are probably well captured in the analysis. On the other hand, a comparison of the BCR and net present values indicate that Eco-san toilets are more cost effective as an intervention than double pit latrines.

Figure 2: **Comparison of the BCR of the two intervention measures**

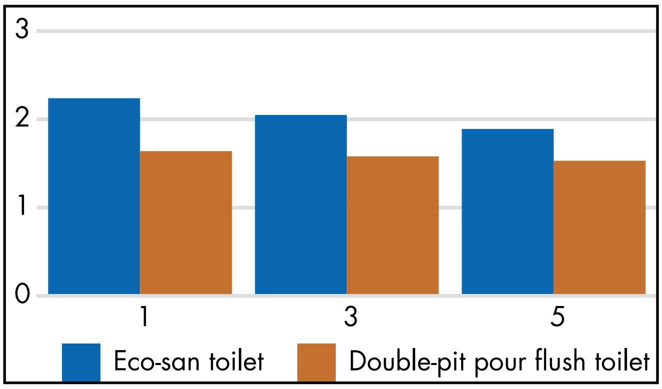


Figure 2 shows the comparison between the two sanitation options for differing discount rates. It is often argued that the discount rate for interventions that have environmental benefits should be kept low, in order to take note of long term consequences of the intervention. It is clear that the cumulative averted costs over the life span of the toilet, both in terms of health benefits (Figures 3a & 3b) and convenience (Figures 4a & 4b), are higher for Eco-san toilets. It is also important to remember that whereas the costs have been taken as actuals, only benefits that could be measured with confidence have been calculated, and their values have been monetized to represent the minimum values. Hence, the actual benefits, when aggregated at the community level, are most likely to exceed the benefits calculated here. The averted ill-health and inconvenience costs attributable to Eco-san toilets may also be higher than the estimates presented here for two reasons. First, pit latrines have been constructed in violation of the basic norms for maintaining a safe distance between the water source and the toilet. Second, there is an aversion among people to dispose soak pit material near their houses, or in some cases even in their fields. So costs associated with these two disadvantages of a soak pit can be substantial, although these are not directly captured here due to the subjective nature of the former and the lack of data to accurately measure the cost of the latter. In spite of the cautious approach, the findings suggest that the Eco-san intervention has substantially more benefits as compared to the double pit latrine.

Figure 3(a): **Cumulative value of averted health costs per household (10 years at 1% discount rate)**

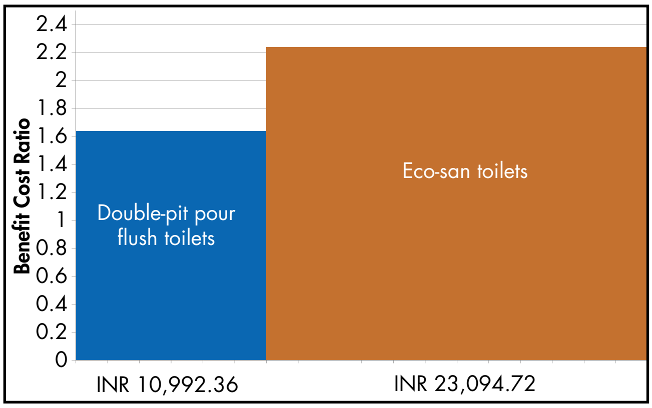


Figure 3(b): **Cumulative value of averted health costs per household (10 years at 3% discount rate)**

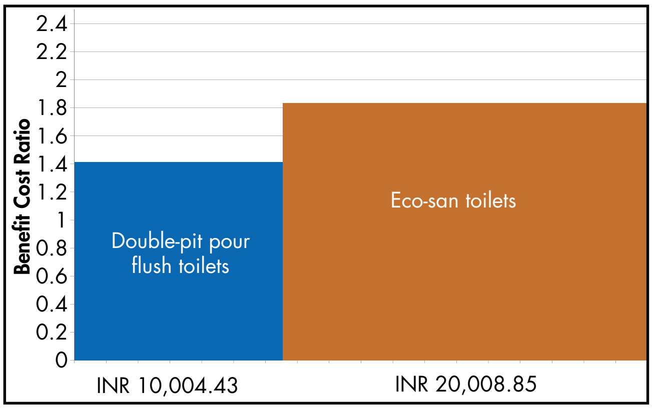


Figure 4(a): **Cumulative value of convenience benefit per household (10 years at 1% discount rate)**

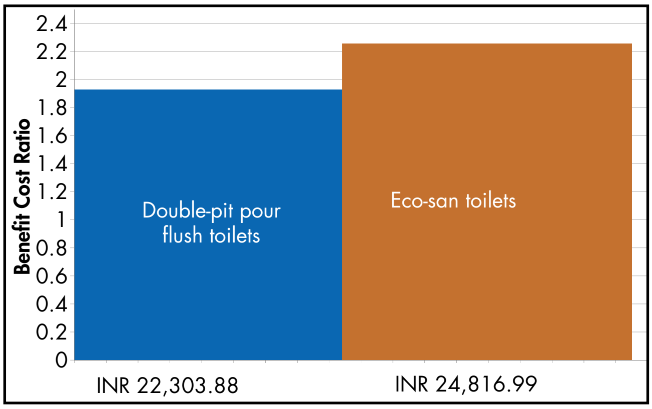
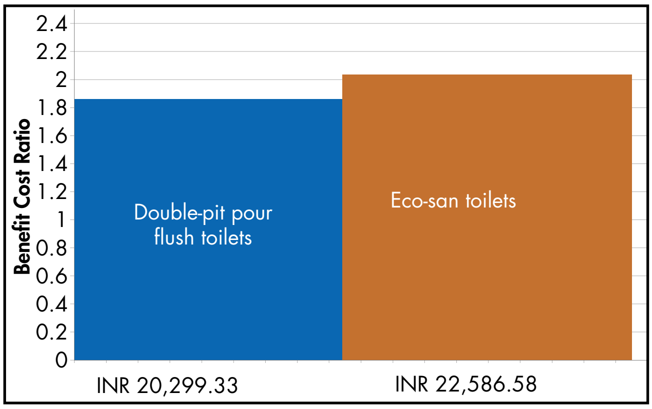


Figure 4(b): **Cumulative value of convenience benefit per household (10 years at 3% discount rate)**



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