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Cost-benefit analysis of springs revival in the Indian Himalayan Region

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Published by
International Centre for Integrated Mountain Development (ICIMOD)
GPO Box 3226, Kathmandu, Nepal

ISBN 978-92-9115-783-9 (electronic)
https://doi.org/10.53055/ICIMOD.1096

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Citation
Adhikary, A., Aryal. S., Nepal, M., and Pattanayak, S. K. (2025). *Cost–benefit analysis of springs revival in the Indian Himalayan Region*. ICIMOD Research Report 2025. ICIMOD, Kathmandu.

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Executive summary

Mountain springs in the Indian Himalayan Region (IHR) are the primary water source for both rural and urban communities, and play an indispensable role in supporting over 15 per cent of India's population by providing water for drinking, irrigation, and livestock-rearing purposes. Furthermore, springs and watersheds are essential for securing water availability, maintaining biodiversity, and supporting ecosystem services such as carbon sequestration and nutrient cycling. The IHR is facing significant threats from climate change and anthropogenic activities. It is experiencing rapid and alarming changes in precipitation patterns, increased frequency of extreme weather events, and watershed degradation due to human activities – these have collectively led to reduced spring discharge or even the complete drying up of some springs. In response to these critical challenges, the International Centre for Integrated Mountain Development (ICIMOD) has launched a science-based springshed management initiative across four states – Himachal Pradesh, Manipur, Sikkim, and Uttarakhand – in the IHR. This initiative aims to move away from traditional watershed-focused conservation programmes to more inclusive groundwater management strategies in order to ensure the sustainability of water resources for future generations. To support and improve this springshed initiative, an expert economics team from the South Asian Network for Development and Environmental Economics (SANDEE) conducted a cost–benefit analysis (CBA) of spring revival and springshed management in the Himalayan states of Himachal Pradesh, Sikkim, and Uttarakhand.

Specifically, we opted for a CBA framework that combined an extensive review of scientific literature (including grey literature) with secondary and primary field data; the latter was collected through rapid community appraisals. The cost categories included material, labour, operations, and transport; while the benefit categories included improved health, time saved, and enriched non-timber forest products like grass for fodder. The field appraisals also suggested some broader ecosystem and cultural services, which were hard to quantify, let alone monetise, given the constraints of time and budget. Similarly, some local costs such as those involving organising community events/meetings, and the opportunity cost were not accounted for. Therefore, our estimated costs and benefit could be considered as the lower bound. We made two key assumptions for our CBA: a discount rate of 5 per cent and a standard appraisal period of 25 years. For sensitivity analysis, we also considered a discount rate of 10 per cent and an appraisal period of 10 years.

The CBA of 14 study sites suggests a per household per month (private) net benefit of approximately USD 12 in Uttarakhand, USD 12 in Himachal Pradesh, and USD 7 in Sikkim. Prima facie, this implies that the investments made in springs revival have been socially beneficial (the results show a similar trajectory even with the 10 per cent discount and the 10-year appraisal period). Beyond this basic conclusion, our report highlights a set of research gaps and a set of policy recommendations.

The main policy guidance coming out of this research is that the benefits of springs revival in the Hindu Kush Himalaya region exceed the costs; beyond this, the research has led us to make the following policy recommendations, especially from a sustainability perspective: first, it is imperative to **foster community participation** in making decisions, both about benefit distribution and springshed management; second, springs revival must be **augmented by biodiversity and cultural heritage goals**; third, springshed initiatives require **building of local capacity for their effective monitoring and evaluation**; and finally, sustainability and maintenance can be ensured by **a combination of donor contributions and community investments**, as well as **public–private partnerships**.

Abbreviations and acronyms

ACWADAM	Advanced Centre for Water Resources Development and Management, India
CBA	cost–benefit analysis
CORD	Chinmaya Organization for Rural Development
CRF	capital recovery factor
FGD	focus group discussion
GPU	Gram Panchayat Unit
HKH	Hindu Kush Himalaya
ICIMOD	International Centre for Integrated Mountain Development
IHR	Indian Himalayan Region
INR	Indian rupee
KII	key informant interview
LMICs	Low- and Middle-Income Countries
MEA	Millennium Ecosystem Assessment
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
NFCC	National Forest Certification Committee
NITI	National Institution for Transforming India
PRA	participatory rapid appraisal
PSI	People's Science Institute, India
RDD	Rural Development Department, Sikkim, India
RM&DD	Rural Management and Development Department
SANDEE	South Asian Network for Development and Environmental Economics
SCA-Himalayas	Strengthening Climate Change Adaptation in the Himalayas
SDC	Swiss Agency for Development and Cooperation
SDGs	Sustainable Development Goals
VWSC	Village Water Security Council
WUC	Water User Committee
WUG	Water User Group

Acknowledgements

This study was conducted by team of economists from SANDEE (South Asian Network for Development and Environmental Economics), a research capacity and academic leadership development network of ICIMOD which supports ICIMOD's programmatic work and strengthens its economic and policy analysis. We would like to extend our gratitude to the field partners, People's Science Institute (PSI), Advanced Centre for Water Resources Development and Management (ACWADAM) and Rural Development Department (RDD), Sikkim, for their active involvement in providing all the information relevant for our study. We would also like to acknowledge the contributions of ICIMOD's staff – Sanjeev Bhuchar (Senior Water Management Specialist), Madhav Dhakal (Watershed and Springshed Specialist), Usha Ghimire (Springshed Associate), and Srijan Thapa (Research Associate); and the rapid appraisal team – Shyam D. Yawale (Hydrogeologist, PSI), Arvind Patterwal (CORD), Anuradha Bhatt (CORD), and Sher B. Karki (Dhara Vikas Coordinator, RDD, Government of Sikkim) – for assisting with the data collection in the three states. The authors are grateful to Karishma Khadka (ICIMOD), Dikshya Upadhyay (Civil Engineer, PSI), Kunal Upsani (ACWADAM), and Sher B. Karki (RDD, Sikkim) for sharing the cost data with us; and to Erin Sills (Professor at the Department of Forestry and Environmental Resources, North Carolina State University) North Carolina, USA for providing practical suggestions. The financial support for the spring revival activities was provided by the Swiss Agency for Development and Cooperation (SDC), India; this helped in coordinating the science-based springshed management initiative of ICIMOD and the SCA-Himalayas project.

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SECTION I

Introduction

The Indian Himalayan Region (IHR), home to over 50 million people and spanning 10 hill states and two partial states (union territories) of India, is an integral part of the world's highest mountain range, the Himalaya, which serves as a critical water source for millions. The mountain springs in the IHR are the primary water source for both rural and urban communities, and play an indispensable role in providing water for drinking, irrigation, and livestock-rearing purposes for over 15 per cent of India's population (NITI Aayog, 2017). These springs, serving as a crucial source of high-quality and perennial freshwater for remote communities, are pivotal for sustaining the region's rich biodiversity and ecosystems (Verma & Jamwal, 2022). A study by Immerzeel et al. (2020) points out that the health of mountain springs and watersheds is critical for the communities that depend on them for their livelihoods, and also for the broader ecosystem. Specifically, springs and watersheds are essential for securing water availability, maintaining biodiversity, and supporting ecosystem services such as carbon sequestration and nutrient cycling (NITI Aayog, 2017; Bhaduri et al., 2014; Viviroli et al., 2007).

The IHR's ecosystem, known for its rich biodiversity and unique climatic conditions, provides ecosystem goods and services that extend well beyond its geographic limits. But that is currently under significant threat, owing to climate change and anthropogenic activities. The deterioration of mountain ecosystems, fuelled by climatic, demographic, and economic shifts, has been progressively endangering critical ecosystem services for the mountain people and also for those living in the plains (Grêt-Regamey & Weibel, 2020; Verma & Jamwal, 2022). In particular, the Himalaya is experiencing a warming trend which is faster than the global average, thereby affecting snowpack and glacier dynamics, and thus, the region's hydrology (Bolch et al., 2012; Immerzeel et al., 2010; Nie et al., 2021; Pepin et al., 2015). These environmental changes, coupled with deforestation, earthquakes, land-use changes, and increased soil erosion, have significantly contributed to the vulnerability of the IHR's water resources, particularly its springs and watersheds (Barfal et al., 2022; Negi & Joshi, 2002; Tambe et al., 2012; Verma & Jamwal, 2022).

Moreover, changes in precipitation patterns, increased frequency of extreme weather events, and watershed degradation through human activities have led to reduced spring discharge or even the complete drying up of some springs (Negi & Joshi, 2002; Sharma & Goyal, 2020; Tambe et al., 2012). This, while obviously being a clear threat to the water security of millions, also has had cascading effects on biodiversity, agriculture, and the overall ecological integrity of the region, thus potentially leading to the loss of unique habitats (Viviroli et al., 2007). In terms of policy and actions, the decline in spring water availability underscores the urgent need for integrated water resource management strategies.

In response to these critical challenges, the International Centre for Integrated Mountain Development (ICIMOD) has launched a science-based springshed management initiative across four states (Himachal Pradesh, Manipur, Sikkim, and Uttarakhand) in the IHR as part of the Strengthening Climate Change Adaptation in the Himalayas (SCA-Himalayas) project, funded by the Swiss Agency for Development and Cooperation (SDC), India. Recognising the vital importance of mountain springs and the ecosystems they support, this initiative, centred

around a six-step protocol for spring revival (Shrestha et al., 2018), has been focusing on comprehensive hydrogeological assessments, and has also been implementing various intervention measures to restore these crucial water sources. The SCA-Himalayas project aims to move away from traditional watershed-focused conservation programmes to more inclusive groundwater management strategies in order to ensure the sustainability of water resources for future generations (Khadka et al., 2019; Nowreen et al., 2023).

By integrating systematic mapping, database creation, capacity building, and ground-level interventions – such as the construction of recharge structures and the practice of community-based water management – the springshed management initiative addresses the immediate threats to water security in the IHR. It contributes to the broader objectives of sustainable development and ecological preservation. The initiative also underlines the necessity of adopting integrated approaches to water resource management wherein there is an emphasis on the interdependence of human well-being and environmental health. Through the SCA-Himalayas project's focus on springshed management and revival, it sets a unique precedent for addressing the global challenge of climate change by working towards ensuring the resilience of water resources and safeguarding the livelihoods of the millions who depend on the Himalaya's natural resources.

1.1 Study objectives

The primary objective of this study was to conduct a comprehensive cost–benefit analysis (CBA) of springs revival initiatives in the IHR, with a particular focus on selected springs located in three states:[2] Himachal Pradesh, Sikkim, and Uttarakhand. A total of 14 springs from these three states were part of the CBA, among which, seven of them come under the SCA-Himalayas project (for details, see Section 2.3). This analysis is critically important given the current weaknesses in India's mainstream water management policies, which have led to significant strategic response gaps (Chakraborty et al., 2019; Rout & Singh, 2024). Addressing these gaps is essential and can be achieved through focused research on spring hydrology. In this context, the CBA emerges as an indispensable tool by facilitating resource estimation and impact monitoring, and by aiding in the formulation of future intervention strategies. This CBA aims to contribute to the practical and sustainable management of spring revival projects, which is crucial, among others, for aligning with global Sustainable Development Goals (SDGs) and addressing national water security needs.

1.2 Research summary

In order to effectively evaluate the economic viability of spring revival interventions in the Hindu Kush Himalaya (HKH) region, we adopted a CBA framework of comprehensive assessment of costs and benefits through an extensive review of scientific and grey literature on the HKH springs, as well as through field appraisals. Our literature review also encompassed global studies and reports on ecosystem services from the Low- and Middle-Income Countries (LMICs), which were selected for their geographical, socio-economic, and cultural parallels to our study areas. In addition to secondary data, we employed rapid appraisal methods to gather primary data. This involved focus group discussions (FGDs) and key informant interviews (KIIs) across the three states under study. These participatory rapid appraisals (PRAs) were crucial for deriving quantitative as well as qualitative insights into the localised benefits of spring revival projects.

For our exercise, cost data were procured from ICIMOD partners, who provided detailed, cumulative financial estimates for the revival of springs in each state, following a structured six-step protocol. Leading into the final CBA, we also utilised the capital recovery factor (CRF) approach to compute the overall benefits. This method facilitated the conversion of future benefit streams into present value terms, thus allowing for a direct comparison with the incurred upfront costs, which provided a clear picture of the economic feasibility of the spring revival interventions.

1.3 Report organisation

This report is organised into sections that are designed to progress logically from the introduction to the final recommendations. Section 2 sets the context by discussing ecosystem services and detailing the protocol for reviving springs in the HKH; this is followed by a description of the study sites. Methodological details are provided in Section 3, including a broad overview of the CBA and its specific application in this study, alongside detailed methodologies for calculating both benefits and costs. Section 4 outlines the results, offering insights from rapid appraisals at the study sites and preliminary analyses of benefits and costs based on site-specific data. The concluding Section 5 includes a discussion that revisits the study's objectives, along with a recap of the study methods and primary findings; it also describes the limitations of the analysis. Recommendations on future research and policy considerations are then presented. Supporting references and an appendix containing relevant tables and figures complete the report.

[2] These sites were chosen because ICIMOD and its partners implemented the project in these states. While some springs in Manipur were initially chosen for inclusion in this study, due to the prevailing security situation in the state at the time of the CBA, it was not feasible to collect primary data. Consequently, it was excluded from the list of study sites.

SECTION II

Background

2.1 Ecosystem services and human well-being

Ecosystem services, fundamentally crucial to human existence, encompass the vast array of benefits that humans obtain from nature (Costanza et al., 1997; Das et al., 2020; Kosanic & Petzold, 2020; MEA, 2005; Summers et al., 2012). These services are typically categorised into four main types: provisioning, regulating, supporting, (MEA, 2005). Provisioning services include food, water, timber, and fibre; regulating services involve climate regulation, flood control, disease management, and water purification; supporting services are essential for nutrient cycling and soil formation; and cultural services offer recreational, aesthetic, and spiritual benefits (Díaz et al., 2019; Watson et al., 2019). The 2005 Millennium Ecosystem Assessment (MEA) has highlighted the importance of these services in supporting human well-being as they provide the essential materials for a good life, including security, health, and harmonious social relations.

Anthropogenic activities, including but not limited to land-use change, deforestation, and pollution, coupled with the effects of climate change, have significantly degraded these invaluable ecosystem services. Studies such as those by Bellard et al. (2014), Hooper et al. (2012), and Pacifici et al. (2015) have documented the alarming rate at which biodiversity is being lost and ecosystems are being altered, with grave implications for the services they provide. The loss of ecosystem services directly impacts human well-being, as it affects health, livelihoods, and community resilience (Costanza et al., 1997; Immerzeel et al., 2020).

The interconnection between human well-being and ecosystem services is complex and deeply rooted in ecosystem health (Balvanera et al., 2020; de Groot et al., 2013; Díaz et al., 2019; MEA, 2005; Ouyang et al., 2020). As ecosystems degrade, so does the capacity of human societies to thrive. This relationship is evident in matters related to clean water, food security, climate stability, and cultural identity – all underpinned by healthy, functioning ecosystems (Bommarco et al., 2013; Carlson et al., 2021; Dasgupta, 2021; de Groot et al., 2013; Kosanic & Petzold, 2020). The challenge, therefore, lies in managing human activities in a way that preserves these critical services for present and future generations (Díaz et al., 2019).

The MEA (2005) and subsequent studies call for an integrated approach to managing human impacts on ecosystems. This approach requires an understanding of the multifaceted interactions between ecosystems and human societies, as well as the economic, social, and environmental dimensions of ecosystem management (Carlson et al., 2021; de Groot et al., 2022; Ouyang et al., 2020). Effective management strategies, such as for the revival and sustainable management of springs and watersheds, offer pathways to restore and enhance ecosystem services (McFarlane et al., 2019). These strategies aim to recover the provisioning services of water supply and maintain the regulating services such as flood control and water purification, thereby supporting broader ecosystem health and resilience.

Sustainable ecosystem management practices recognise the value of ecosystems beyond the immediate economic benefits they offer. By incorporating ecological, cultural, and social values into decision-making processes, these practices

aim to balance human needs and environmental sustainability (Huynh et al., 2022). This balanced approach is crucial for ensuring the long-term well-being of human populations and the preservation of biodiversity since humanity is embedded in nature (Dasgupta, 2021).

As the degradation of ecosystem services poses significant risks to human well-being, urgent and concerted efforts are required to mitigate anthropogenic environmental impacts. As part of broader ecosystem management strategies, the revival and management of springs and watersheds exemplify the practical steps that can be taken to preserve the vital services that ecosystems provide. By fostering an understanding of the intrinsic link between ecosystem health and human prosperity, society can move towards a more sustainable and equitable future where both nature and humanity can flourish.

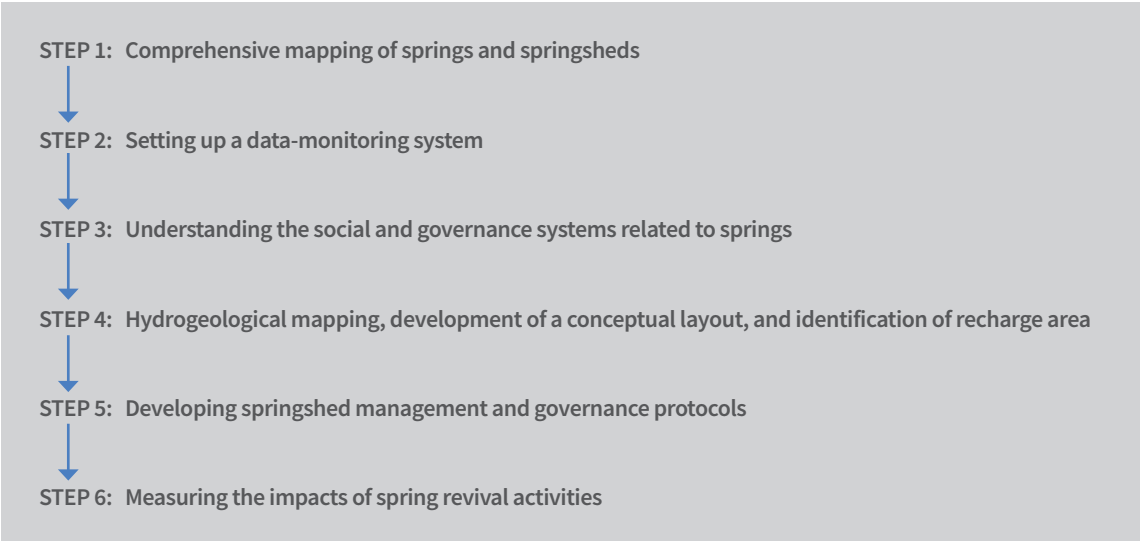
2.2 Six-step protocol for reviving springs in the Hindu Kush Himalaya

ICIMOD, in collaboration with the Rural Management and Development Department (RM&DD), Government of Sikkim, and the Advanced Centre for Water Resources Development and Management (ACWADAM), has developed a structured six-step protocol for the revitalisation of springs in the HKH by incorporating a holistic approach that melds hydrogeology, social sciences, and community action (Shrestha et al., 2018). The protocol is designed to create a foundation for generating essential knowledge for scaling up the intervention and serves as a blueprint for executing detailed local-level implementation plans for spring revival. Figure 1 summarises the six-step protocol.

Here is a brief description of each step:

1. **Comprehensive mapping of springs and springsheds**: This initial step involves a detailed mapping of springs and their catchment areas, which is essential for understanding their spatial distribution and characteristics.
2. **Setting up a data-monitoring system**: This involves establishing a system for continuous monitoring of spring discharge, water quality, and other relevant data to track the health and performance of springs over time.
3. **Understanding the social and governance systems** related to springs: This involves assessing the social dynamics, governance structures, and community interactions surrounding spring use and management, which is crucial for designing effective management strategies.
4. **Hydrogeological mapping, development of a conceptual layout, and identification of recharge area**: This step entails detailed geological and hydrological studies to identify the recharge areas of springs, which are critical for targeted conservation and recharge efforts. It includes creating a conceptual hydrogeological layout of the springshed and classifying spring types based on aquifer characteristics.

FIGURE 1 SIX-STEP PROTOCOL FOR REVIVING SPRINGS IN THE HKH (ADAPTED FROM SHRESTHA ET AL., 2018)



5. **Developing springshed management and governance protocols**: This entails formulating strategies and protocols for the sustainable management and governance of springsheds by incorporating community inputs and scientific findings.
6. **Measuring the impacts of spring revival activities**: Lastly, the outcomes of spring revival interventions are assessed to understand their effectiveness and to inform future actions.

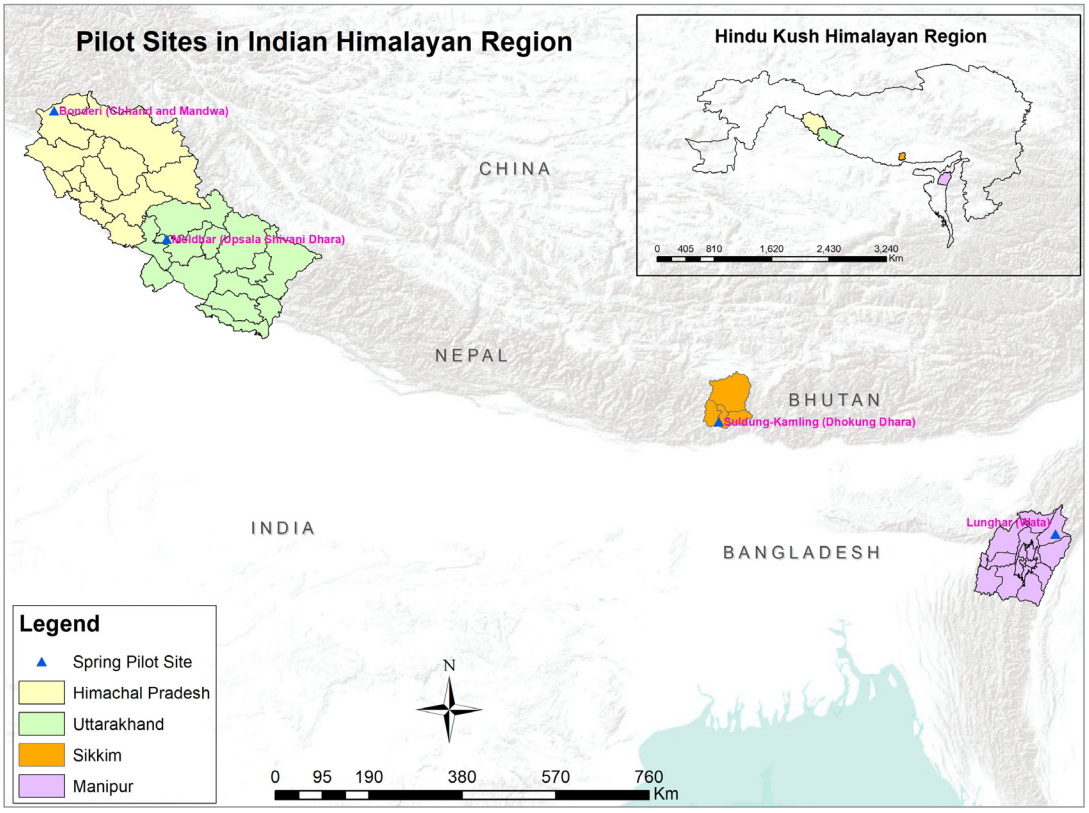
The implementation of this protocol requires an interdisciplinary team of geologists, hydrogeologists, botanists, economists, social scientists, and watershed management experts. The protocol's comprehensive approach is designed so that spring revival efforts are scientifically grounded and socially inclusive; it also clears the way for sustainable management of vital water resources. Moreover, ICIMOD's partners have used this six-step protocol to assess the associated costs involved in spring revival and management at the study sites.

2.3 Study sites

The spring revival and springshed management initiative carries out fieldwork across four pilot sites in the IHR: Himachal Pradesh and Uttarakhand in the western part of the IHR; and Manipur and Sikkim in the east (see Figure 2). Before the commencement of the fieldwork, ICIMOD, in conjunction with its partners, local communities, government departments, and other state agencies, as well as relevant stakeholders, selected the village pilot sites based on a set of comprehensive criteria. Each of these sites has a cluster of springs on which the village households depend for their water needs. These sites are Bonderi in Himachal Pradesh, Lunghar in Manipur, Moldhar in Uttarakhand, and Suldung-Kamling in Sikkim each chosen for its unique water security situation, hydrogeological features, agro-climate, and socio-economic dynamics.[3]

The selection was based on criteria involving geographical details, demographics, and existing challenges related to water scarcity, as well as the community infrastructure to facilitate the action-research project. Emphasising on community cooperation, accessibility, and the potential for sustainable impact, the selection process laid the groundwork for addressing critical water management issues in the pilot site villages. Typically, the experiences from these sites could be used to inform similar interventions in places with comparable geographical features, particularly those located in Afghanistan, Bangladesh, Bhutan, Nepal, Pakistan, and other Himalayan states of India.

FIGURE 2 MAP OF PILOT SITES IN THE IHR (UTTARAKHAND, HIMACHAL PRADESH, MANIPUR, AND SIKKIM)



[3] Refer to Table A 1 in Appendix for the geographic coordinates of the sites chosen for this study.

SECTION III

Methodology

In this section, we outline the methodology employed in conducting the CBA for this spring revival initiative. We begin by providing an overview of the CBA and its application. Then, we specify the feasible interventions and their alternatives, and categorise the benefits and costs. Later, we carry out an elaborate evaluation of the spring services by employing qualitative and quantitative approaches involving KIIs and FGDs for field data collection. Collectively, these constitute the PRA approach for conducting the CBA. Ultimately, our approach identifies the benefits and costs of the intervention; this entails quantification and monetisation, and the application of a discount rate to evaluate the costs and benefits in present terms. Based on this analysis, we provide recommendations for policymakers and researchers working on similar issues.

3.1 Cost–benefit analysis: An overview and application

The CBA is a systematic method of evaluating any investment project to summarise the expected costs that would be incurred, as well as the expected benefits that could be generated during the lifespan of the project. This method is particularly valuable in assessing the viability of a project, policy, or programme. If the net benefits outweigh the costs, then the project could be implemented or scaled up, depending on the availability of resources. This approach considers both direct as well as indirect benefits and costs, including the opportunity costs of resources. Mainly, a CBA helps translate the effects of interventions into monetary terms, thereby enabling decision-makers to assess the net economic impact (Arrow et al., 1996; Boardman et al., 2017). Given its rigorous and comprehensive nature, CBAs have been extensively employed in the area of environmental and resource management to appraise projects from a financial and social perspective (Hanley & Barbier, 2009).

In the complex and interconnected socio-economic and environmental landscape of the HKH, CBAs facilitate informed decision-making that accounts for both financial implications and broader societal impacts. As detailed by Freeman III et al. (2014) and Hanley et al. (2009), such analyses ensure a comprehensive evaluation of potential projects, including their extensive and varied effects.

While there are standard formal steps (see Appendix), in this instance, we carried out a participatory CBA that integrated secondary and primary data sources in order to measure the potential impacts of spring revival; for this, the following steps were used:

1. **Development of a CBA framework**: We adopted a structured CBA framework that incorporated relevant equations and models for assessing the identified costs and benefits. This framework served as the backbone of our analytical process.
2. **Literature review**: Next, we extensively reviewed the existing relevant literature to identify and categorise the potential benefits and costs associated with spring revival. This review helped frame our analysis and ensured alignment with established studies.
3. **Participatory rapid appraisal**: We supplemented our literature review by conducting KIIs and FGDs in field settings. Collectively, these constituted the rapid appraisal for our CBA.

4. **Data analysis**: Finally, we conducted a detailed analysis using the data gathered from secondary sources and the primary data collected through FGDs and KIIs. This analysis quantified the benefits, specifically those accruing directly to the households relying on the revived springs.

We believe that this participatory approach has enhanced the reliability of our CBA, wherein we have ensured inclusivity and relevance by incorporating direct inputs from local communities and stakeholders in the IHR. Such a method, we believe, is essential for ensuring that policy recommendations are robust and contextually appropriate, thereby maximising the potential for sustainable impacts. (Sections 3.2 and 3.3 elaborate on the literature review and the benefits and costs methodologies, respectively.)

3.2 Literature review

Following the broad literature review, we categorised the benefits into four main types of ecosystem services: provisioning, regulating, supporting, and cultural services (MEA, 2005). For this, we tapped into the relevant literature that provides information on the multifaceted dimension of springsheds, ranging from direct services like water supply and livelihood support to indirect benefits such as disease prevention and biodiversity enhancement.[4]

We conducted a thorough literature search at several stages in order to retrieve parameters and ensure thoroughness and relevance across various regions.[5] For this, we followed a seven-step process to systematically review and identify the benefits associated with springsheds:

1. **Broad literature search and review**: We began our study with a thorough literature search using keywords like 'spring', 'Himalaya', 'India', 'cost', 'benefit', and 'valuation', which yielded 21 papers. This was critical for laying the groundwork for a deeper comprehension of the subject.
2. **Benefits transfer**: Using the benefits transfer method, along with other criteria, we identified 22 additional papers referencing a special issue on 'Benefit Transfer in Ecological Economics' from 2006. This helped us to determine whether the benefits identified in one context could be transferred to another.
3. **Forward citations**: We then conducted a forward citation exercise using 'Ferraro et al. (2012)' as a reference, which resulted in 765 papers. This helped in zeroing in on relevant recent research that builds on foundational studies.
4. **Refined literature search**: Combining the criteria from the above steps, we then narrowed our focus to studies relevant to the LMICs, which resulted in a more curated selection of 19 papers.
5. **Filtering**: We then filtered the large set of 827 papers, using keywords like 'spring', 'eco'*, 'valua'*, 'hydro'*, 'water'*, and 'Himalaya', and then screened further for titles and abstracts, which narrowed down the selection to 71 papers.
6. **Classification**: We categorised those 71 papers into three sets: 14 as most relevant papers; 19 as background/conceptual papers; and 38 as methodology-focused papers.
7. **Identification of the benefits of spring revival**: We then carried out a thorough analysis of the 71 papers to specifically identify the benefits of spring revival.

The list of springshed services identified during the literature search aligned with the range of benefits noted by ICIMOD and those that had been listed by the fieldwork team.[6] The main reason for relying on fieldwork was that certain pieces of information – such as the local wage rate for skilled/unskilled labour, the number of households directly/indirectly benefitting from the revived springs, medical expenses for water-related illnesses, and the amount of time saved – could not be obtained from the literature review. It is also pertinent to note that, while such information is likely to reflect the existing scenario in the LMICs and the HKH region, it cannot be stretched to reflect the global reality (Carson et al., 2001). We also found that there are relatively fewer papers that provide convincing estimates of the values of springshed services related to human well-being, particularly in the context of the IHR. Therefore, to supplement the information, we relied on the site-specific details that were obtained from the fieldwork.

[4] Refer to Figure A 1 in Appendix.
[5] Refer to Figure A 2 in Appendix.
[6] Refer to Figure A 3 in Appendix.

3.3 Rapid field appraisals

Our fieldwork consisted of two types of participatory appraisals with the households: FGDs with specific questions, and KIIs with people living near springs. We organised the field studies and conducted rapid appraisals at nine villages and 14 spring sites in Himachal Pradesh and Uttarakhand (from 1–15 February 2024) and Sikkim (from 10–16 March 2024)[7]. In the case of the SCA-Himalayas project sites, the appraisals were conducted at four villages and seven springs. Uttarakhand and Himachal Pradesh are located in the western Himalayan foothills, while Sikkim is part of the eastern Himalaya. Before the field studies at the IHR, we had carried out pilot appraisals at two sites in Kavrepalanchok district, Nepal, on 8 December 2023. There, we studied two springs, Patalko Dhara and Rakash Dhara, located in Panchkhal municipality, which were undergoing interventions. These two sites were chosen because of the specific hydrological/topographical feature; also, our field partners were familiar with them and ICIMOD has been working on spring revival in Kavrepalanchok.

For the sites in the IHR, most of the FGDs had around 10 participants on an average, who were mostly women. Overall, our analysis reflects the responses of over 90 participants who were representing 398 direct user households located at the study sites. Each discussion lasted for about two hours, with questions on site circumstance, demographic composition, socio-economic status, and perceptions regarding benefits from the revival of springs.

We began with some qualitative discussions with the participants on what the spring discharge was like before the intervention and what it is like after. We also asked them about what they perceived as benefits from their spring being revived. Once we learnt about the benefits, we asked a series of questions so as to quantify the benefits; for example, whether they were spending less time in fetching water after the revival. We also asked if there were any changes in crop yield and livestock production after the intervention. Further, we asked them about waterborne and watershed illnesses – how frequently did they fall sick before the intervention and whether there has been any reduction in such cases due to improved water quantity or quality.

We then enquired about the shadow value of the outcomes. For example, if they were able to save time, we asked them what they did with the saved time, whether they continued to work on their own farm or were they working on others' farms. This allowed us to get some important information about the shadow wages (of unskilled labour) or shadow prices of their opportunity cost of time. In cases where they did not have crops to sell, we asked them how much they had to pay for rice, vegetables, fruits, etc. On the matter of health, we asked them about their expenditure on illness, and how much time they had to spend on looking after ill family members (usually children with waterborne diseases). We also collected considerable information on the socio-economic status of the site households, such as about the number of households using springs (both direct and indirect users), the main farm activities that were reliant on springs, annual income of households, and the local wage rate for skilled/unskilled men and women.

An ideal situation would have been to conduct similar analyses in the neighbouring villages ('reference villages') with comparable socio-economic, geographical, and hydrological characteristics but without spring revival activities, so that any difference in the key outcomes could be attributed to the spring revival activities. In our case, collecting information from the reference villages appeared to be impractical due to two main reasons: most of the spring sites in the reference villages had completely dried up and were not in use; and it was quite challenging to identify a focal person or any key informant in the reference villages who could help organise FGDs as our resource persons from partner organisations had limited familiarity with these reference villages. Nevertheless, we managed to visit a few such sites but did not conduct rapid appraisals or FGDs.

3.4 Monetisation of benefits

The literature suggests a mix of market and non-market valuation techniques for benefit estimation in different policy settings, which borrow methods from hedonic regression, choice experiments, contingent valuation, travel cost procedures, and benefits transfer (Pattanayak & Pfaff, 2009). Specifically, we followed a paper by Jeuland and Pattanayak (2012) on the CBA of improved cookstoves. We also identified benefits through literature review and fieldwork, and examined the extent to which each household benefitted per month. Our plan was to examine the changes in outcomes – in terms of time saved, health, and agriculture production, etc. – as a result of the change in water quality or quantity due to the spring revival activities.

[7] Refer to Table A 2 in Appendix.

We began by identifying and defining the range of the parameters necessary for estimating benefits by standardising units across different dimensions, both physical and temporal units. Next, we ascertained the equations for benefits based on literature review and our professional judgement. Through these equations, we aimed to multiply the change in physical quantities by the shadow value, which allowed us to translate them into monetary[8] units. The unit for our overall analysis was expressed in USD, per household per month. Based on the information that we collected from the field visits, we analysed the economic benefits of springshed revival initiatives in three main components: saving of time, health benefits, and increased availability of fodder for livestock. For this, we deployed a simple specification in which the benefits accrued to a household were the function of about 10 parameters (Table 1). Below, we explain these calculations and examine the benefits across households per month at each spring site with a range of conditions.

Mainly, we applied this CBA to these illustrative cases as they were the main purported benefits while considering the situation before and after the intervention.

3.4.1 Time saved

We defined 'time saved' after the intervention based on the following types of cases:

- Time saved due to reduction of waiting time in queues even though the spring source from which the villagers fetched water has not changed (in the case of Uttarakhand).
- Time saved due to increased waterflow or due to complete or partial revival of previously dry sources, as villagers no longer had to walk long distances to fetch water from other springs as they did before the intervention (in the case of Himachal Pradesh).
- Time saved from not having to directly reach the source to fetch water as the supply has been facilitated by motors, pipes, or the establishment of tanks or reservoirs at community or individual household level (in the case of Sikkim).

We estimated the time saved by taking into account the round trip plus water collection time before and after the intervention; we calculated this by multiplying the time saved (in minutes) by the number of trips per day per household (Whittington et al., 2009).

$$B_{time} = t_{sav} \times trip \times w/(8 \times 60) \times 30 \quad (1)$$

TABLE 1 **BENEFIT PARAMETER DEFINITIONS AND UNITS**

Parameter	Description	Unit
Df	Change in discharge flow during lean season (*observe if df > 0*)	litres/minute
W	Daily wage rate	USD/day
bucksize	Typical capacity of a bucket ('gagri'/('banta', in local terms)	Litres
$colt_b$	Time taken for fetching water before the intervention	minutes/trip
$colt_a$	Time taken for fetching water after the intervention	minutes/trip
trip	Number of round trips	trips/day
t_{sav}	Time saved in fetching water ($t_{sav} = \Delta t_w = colt_b - colt_a$)	minutes/trip
$cases_b$	Incidence of watershed illnesses before the intervention	cases/household/year
$cases_a$	Incidence of watershed illnesses after the intervention	cases/household/year
red_{cases}	Reduction in cases of water-related illnesses ($red_{cases} = \Delta cases = cases_b - cases_a$)	cases/household/year
c_{med}	Cost of medical illnesses	USD/household/year
$price_{gr}$	Price per bundle of grass	USD/bundle
$cost_{gr}$	Cost saving from grass	USD/household/year

Note: We gathered information on these parameters from field observations at our study sites.

1 = INR 82.64, March 2024, ICIMOD).

[8] All monetary values were expressed in constant 2024 USD (conversion from INR to USD; exchange rate: USD

We did this for 30 days to get a monthly figure. We then monetised the saved time using the daily wage rate (w) of unskilled labour, which was a proxy for the opportunity cost of water collection time (Whittington et al., 1990). For this calculation, we considered eight hours of work per day.

3.4.2 Health improvement

We estimated the health benefits from the increased waterflow after the intervention by making two probable cases:

- Health benefits resulting from a reduction in cases of a variety of water-related illnesses, including diarrhoea, dysentery, typhoid, and cholera.
- The benefits accrued either by directly consuming water of improved quantity and quality or through hygienic practices such as household cleaning, hand-washing, dishwashing, bathing, or washing/scrubbing fruits and vegetables.

We then analysed the health benefits by considering the reduction in cases of water-related illnesses. Finally, we multiplied the reduced cases per household by the medical cost of such illnesses (USD/case/household/year) to arrive at the overall health costs saved per household (USD/household/year), which we then divided by 12 to get the monthly figure (Pattanayak & Wendland, 2007).

$$B_{health} = (red_{cases} \times c_{med})/12 \quad (2)$$

In our study sites, we found no recorded cases of mortality or fatality from water-related diseases, and therefore we did not compute mortality benefits.

3.4.3 Fodder availability for livestock

Spring revival interventions at most of the SCA sites have also contributed to an increase in the amount of grass which is mainly used as fodder for livestock. Previously, for a household owning a certain number of cattle, fodder used to be bought from nearby markets or other villages. However, with the revival of the springs, the increased soil moisture around the trenches and the spring area during the dry season helped increase fodder production, which benefitted the households in terms of cost savings on fodder.

$$B_{fodder} = cost_{gr}/12 \quad (3)$$

3.4.4 Biodiversity and ecosystem services

In addition to water availability, the other major benefits from spring revival could be improved biodiversity and ecosystem services. In rural areas, springs may also have cultural significance. Given the budget and time constraints, it was not possible to conduct a comprehensive non-market valuation study to estimate the benefits of biodiversity and ecosystem services or the cultural benefits.

3.5 Computation of costs

In our assessment of the spring revival interventions, we adopted a structured approach in categorising costs and formulating assumptions to ensure the integrity and reliability of our analysis. This study drew from an array of data sources and methodological frameworks which are discussed below.

STEP 1: IDENTIFYING THE COST CATEGORIES

Identifying cost categories is a critical step in constructing an economic evaluation framework for spring revival projects. Our literature review (summarised above), coupled with insights from field studies, guided our understanding of distinct project expenditures and relevant costs. Given the scarcity of directly relevant studies on spring valuation or a CBA in similar settings, we adopted a selective approach. We engaged with the available literature that offered indirect insights pertinent to our context. Notable examples include studies by Rai et al. (2015, 2018) and Rai & Nepal (2022), which provided valuable perspectives for our analysis. This targeted review helped us develop a robust cost methodology, detailed in Section 3.4, which drew on key findings and methodologies from seminal works in the field (Boardman et al., 2017; Freeman II, 2014; Pattanayak & Kramer, 2001; Pattanayak & Wendland, 2007; Pattanayak et al., 2017). Additionally, to refine our approach, we considered recent advancements in and critiques of ecosystem service valuation (Ciasca et al., 2023; Ferraro et al., 2015; Giacomo, 2023; Krishnapriya et al., 2021; Lele, 2009; Litzow et al., 2019). Consequently, we established six core cost categories:

1. **Material (Cmat)**: This encompasses expenditures on the essential items procured or rented for the project, such as survey equipment, construction materials, and machinery; these are typically characterised as one-time or fixed costs.

2. **Skilled labour (CSL)**: This involves payments to professionals like scientists, consultants, and field staff who have been integral to the project, from its inception till its completion, with some roles potentially recurring, such as those of experts assessing ongoing performance.
3. **Unskilled labour (CUL)**: This covers payments to the local labourers engaged in manual tasks like trench digging and material transport; these costs vary between fixed and recurring depending on the project phase.
4. **Operational (COP)**: This is crucial for the smooth execution and maintenance of the project, and involves expenses related to software, repairs, and personnel salaries, which can be both fixed and recurring.
5. **Cartage/Transportation (CT)**: This accounts for the movement of materials, generally in the category of fixed cost, but potentially recurring if replacement of components like tin roofs is necessary due to damage.
6. **Miscellaneous (CM)**: This captures expenditures that do not neatly fit into the other defined categories, and ensures that all financial aspects of the project are addressed.

These categories are inclusive of all financial aspects from the procurement stage through to the operational phase, thereby ensuring a comprehensive accounting of the project expenses. Putting together the details from this and the previous section, the costs and benefits of the spring revival initiative are summarised in Table 2.

TABLE 2 **BENEFITS AND COSTS OF THE SPRINGS REVIVAL INITIATIVE**

Costs	Definition and examples	Benefits	Definition and examples
Material (C_{mat})	Costs associated with purchase of materials for a spring revival project in a given location. This includes items that were either bought or rented, such survey equipment, servers, maps, stationery items, machinery, and construction materials (cement, sand, boulder, wire mesh). The costs are normally one time or fixed in nature.	Saving of time (B_{time})	Benefits from the time saved due to the revival of a dry spring, and water supply being facilitated through motors, distributors, reservoirs, and tanks. Benefits also in the form of reduced waiting time in queues for water collection.
Skilled labour (C_{SL})	Expenses related to payment for skilled individuals who contributed to the project from the start till the end. These could be in the form of payment made to scientists, experts, field staff, consultants, including the IT experts hired (if any), to get the project off the ground. Normally, these costs are one time or fixed, but some can be recurring (e.g. experts hired to analyse project performance in subsequent years of project implementation).	Health improvement (B_{health})	Benefits due to reduction in cases of water-related illnesses (diarrhoea, typhoid, cholera, dysentery, etc.).
Unskilled labour (C_{UL})	Expenses related to payments made to locally available labour inside the region(s) where the project was launched/ implemented. For instance, payments made to locals who helped in digging trenches and carrying pipes, bricks, bags of cement/sand/boulder, etc. These can either be fixed or recurring.	Fodder availability for livestock (B_{fodder})	Benefits from the increased amount of non-timber forest products such as fodder, and so households being able to get fodder for free, thus allowing them to save the money that would have otherwise gone into buying fodder.
Operational (C_{OP})	Costs associated with the successful functioning/operation of the project, e.g. software, maintenance/repair, water sample collection and its lab testing, surveys, and salaries of project personnel – including IT personnel for entering and analysing data related to the project.		
Cartage/ Transportation (C_T)	Costs associated with transportation of materials from one location to another. Normally fixed or one time but can be recurring if materials are to be transported for repair. For example, if a spring's tin roof collapses due to wear and tear or other reasons and needs to be replaced in the second year, the transportation cost would be recurring.		
Miscellaneous (C_M)	Costs that do not clearly fall into any of the aforementioned cost types.		

STEP 2: ADAPTING COST CATEGORIES TO STUDY SITES

In Uttarakhand, the field partner and implementing agency, the People's Science Institute (PSI), provided a detailed cost breakdown for five springs, from which we calculated the average cost per spring for this state. In addition, the PSI provided us with details about the costs associated with planting activities at the springshed. We classified costs associated with planting activities under the 'miscellaneous' category because they did not align with the other five major cost categories – 'material', 'skilled labour', 'unskilled labour', 'operational', and 'cartage/transportation' – described in Table 2. We then methodically put each individual cost item into the relevant category, drawing from the direct user data gathered during our field visit.

Similarly, for Himachal Pradesh, the PSI provided cost figures pertaining to the revival of five springs. From this, we first calculated the unit cost per spring by dividing it by five. After that, we multiplied it by 10 to reflect the costs for the 10 springs in Himachal Pradesh which came under our study. The expenditure was then categorised accordingly, with no miscellaneous costs reported. As in the case of Uttarakhand, we repeated the process of categorising the costs so as to ensure consistency across the board, and this was supported by the user data collected from the field for each spring.

In Sikkim, our approach had to be adjusted as our partner, ACWADAM, provided us with only miscellaneous costs, with no detailed breakdown aligned with the six-step protocol. So, to maintain comparability in our CBA, we averaged the unit costs from Himachal Pradesh and Uttarakhand for the five principal cost categories and multiplied them by three to calculate the total costs associated with Sikkim's three springs. This extrapolation was necessary to present a comparable analysis, though we acknowledge that this assumption may not fully represent the specific costs related to Sikkim's springs.

STEP 3: COMPUTING COSTS USING EQUATIONS

Our calculations were underpinned by the key assumptions that framed our CBA. Three of these key assumptions were: an annual discount rate of 5 per cent; a standard appraisal period of 25 years; and an estimate of 398 direct users (total number of households in the three states' sites) of the springs. We applied the discount rate and the appraisal period based on similar CBAs and our discussions with the ICIMOD team and its partners (Jeuland & Pattanayak, 2012; Litzow et al., 2019). We computed the number of direct users based on our visits to the study sites. Table 3 summarises the equations used for the cost analysis.

A key computation in our analysis was the use of CRF to represent lump sum costs as recurring monthly costs, using the formula:

$$CRF = \frac{\delta.(1+\delta)^{ti}}{(1+\delta)^{ti}-1}, \text{ where } \delta = \text{discount rate; } t_i = \text{lifespan of the project} \quad (4)$$

The CRF for our analysis was 0.07. , which is commonly used in financial calculations to determine the annual repayment amount needed to recover an investment over a period of time with interest. Here, we followed Jeuland and Pattanayak (2012) who had conducted a CBA for various cooking technologies and fuels.

FIXED AND RECURRING COSTS

The aforementioned six cost categories had fixed (or one-time capital cost) and/or recurring costs. This sub-categorisation was done based on the nature and description of the costs provided by the field partners and the implementing agencies (PSI and ACWADAM). Within recurring costs, there were two types: recurring annual cost, and five-yearly recurring annual cost. It is important to note here that not all cost categories have recurring costs. As the term suggests, an 'annual recurring cost' is a cost that incurs every year for the duration of a project's appraisal period.

For the purpose of this CBA, we calculated the annualised costs for both fixed and annual recurring costs. An annualised cost is calculated by amortising both the cost of an item over its lifetime in years and the discount rate, using the CRF (Jeuland & Pattanayak, 2012).

We computed the annualised fixed cost (*AFcc*) using the CRF as follows (Jeuland & Pattanayak, 2012):

$$AF_{cc} = CRF.\ C_{cc}; \text{ where, } C_{cc} = \text{fixed cost per cost category} \quad (5)$$

For the annualised recurring annual cost (AR_{cc}) for specific cost categories, we calculated their annualised costs (AR_{cc}) per month as follows (Jeuland & Pattanayak, 2012):

$$AR_{cc} = C_{_rc} \quad (6)$$

where, C_{rc} = *annual recurring cost per cost category*

For the appraisal of the five-yearly recurring costs for each cost category (AFRcc), we calculated the net present value as follows (Boardman et al., 2017):

$$AFR_{cc} = \sum_{ti} \frac{C5_{rc}}{(1+\delta)^{ti}} \quad (7)$$

where, $C5_{rc}$ = recurring cost that occurs every five years per cost category; δ = discount rate; ti = specific years when the cost occurs (5, 10, 15, 20, 25); and Σ_{ti} = sum of the present values of the costs per category over the specified years

The formulas for AR_{cc} and AFR_{cc} calculated the annualised recurring costs and five-yearly recurring costs, respectively, using the compounded effect of the discount rate over a specified time period, reflecting the true cost impact of recurring regular intervals.

EQUATIONS FOR ALL COST CATEGORIES

In Table 3, we present the equations used to calculate both the annualised fixed cost and the annualised recurring annual cost (Jeuland & Pattanayak, 2012); and/or five-yearly recurring costs for each cost category (Boardman et al., 2017).

Through these methodological steps and the integration of key assumptions, we strove to construct a reliable economic profile for the project. Our detailed, yet concise, financial narrative provides a thorough economic assessment tailored to the distinct nuances of each project location.

STEP 4: CALCULATING ANNUALISED COSTS PER SPRING AND MONTHLY COSTS PER HOUSEHOLD

After we calculated the annualised costs for each cost category using the equations in Table 3, they were then summed up to calculate the total annualised cost per year per state (TAC_i).

$$TAC_i = AF_{Cmat,\,i} + AF_{CSL,\,i} + AR_{CSL,\,i} + AFR_{CSL,\,i} + AF_{CUL,\,i} + AR_{CUL,\,i} + AF_{COP,\,i} + AR_{COP,\,i} + AF_{CT,\,i} + AF_{CM,\,i} \quad (8)$$

where, i = state (i.e., study site)

These TAC_i were then converted into total cost per month per household per state as follows:

$$TC_i = TAC_i / (12 \,.\, HH_i) \quad (9)$$

where, HH_i = direct number of households utilising spring(s) in state i

Finally, the TC_i was converted into USD by dividing it by 82.64, which is the exchange rate that we used earlier to calculate benefits.

3.6 Net benefits

At the conclusion of all the cost–benefit calculations, the net benefits of the spring revival initiative were then calculated as follows:

$$Net\ benefits = Benefits - Costs = Btime + Bhealth + Bfodder - TCi \quad (10)$$

TABLE 3 **COST EQUATIONS**

Equations	Fixed (AF_{cc}) (5)	Recurring annual costs (AR_{cc}) (6)	Five-yearly recurring annual costs (AFR_{cc}) (7)	Description
C_{mat}	(5.1) $AF_{Cmat} = C_m$. CRF	Not applicable	Not applicable	C_m is the total fixed material cost.
C_{SL}	(5.2) $AF_{CSL} = C_{skl}$. CRF	(6.1) AR_{CSL} =	(7.1)	C_{skl} is the total fixed skilled labour cost; $C_{RSL_{yi}}$ is the recurring annual cost in year 'y' in the project's timeline; C_{5S_L} is the five-yearly recurring skilled labour cost.
C_{UL}	(5.3) $AF_{CUL} = C_{uskl}$. CRF	(6.2) AR_{CUL} =	Not applicable	C_{uskl} is the total fixed unskilled labour cost; $C_{RUL_{yi}}$ is the recurring annual cost in year 'y' in the project's timeline.
C_{OP}	(5.4) $AF_{COP} = C_{oper}$. CRF	(6.3) AR_{COP} =	Not applicable	C_{oper} is the total fixed operational cost; $C_{ROP_{yi}}$ is the recurring annual cost in year 'y' in the project's timeline.
C_T	(5.5) $AF_{CT} = C_{tr}$. CRF	Not applicable	Not applicable	C_{tr} is the total fixed transportation cost.
C_M	(5.6) $AF_{CM} = C_{Mis}$ x CRF	Not applicable	Not applicable	C_{Mis} is the total fixed miscellaneous cost.

SECTION IV

Results

4.1 Reflections from the rapid appraisals of three IHR sites

In the sections below, we focus on summarising the observations and reflections from the field studies in the three states.[9] In particular, we discuss the site conditions, climatic and anthropogenic risks, and perceptions about the purported benefits as identified by the household members.

4.1.1 Uttarakhand

In Uttarakhand, we organised our fieldwork in Moldhar village (Jaunpur block, Tehri Garhwal district). We located two main springs around the locality: Upsala Shivani Dhara and Kanthi Bagi Dhara. Since Kanthi Bagi lies a bit farther away, Upsala Shivani is the primary water source for the community around Moldhar gram panchayat. We conducted an FGD and KIIs with 24 Upsala Shivani Water User Group (WUG) members (four men and 20 women) who were representing over 80 households directly benefitting from the spring. The formation of the WUG and its men–women composition was based on the guidelines set by the PSI. Previously composed of 11 members, the group has now expanded to 29 members. It is mostly women who take the lead in the upkeep of the spring; they are involved in digging trenches and repairs. Notably, since the spring revival intervention in 2021/22, to date they have constructed about 700 trenches.

The village of Moldhar had faced numerous pressing problems in both water and food security over the past decades. What used to be farmlands 10–12 years ago had become barren due to the effects of climate change, erratic rainfall patterns, and acute water shortages. The villagers used to grow a variety of seasonal crops like wheat, paddy, 'mandua' (finger millet), 'chawla' (green pea), and 'jhangora' (millet). According to the villagers, these crops were completely rain fed since there was no irrigation available from any other water source. Perennial springs like Upsala Shivani and Kanthi Bagi were also on the verge of drying up due to lack of maintenance, and since the farmlands were barren, there was insufficient recharge in order to sustain them.

The villagers say that following the spring revival intervention, there has been a twofold increase in the discharge rate, even during the lean period of May–June. They rely on Upsala Shivani mainly for drinking and domestic purposes. The villagers were upbeat while talking about the economic benefits they have gained from the revival of the spring – they said that they have been able to save time which otherwise would have gone into fetching water and that there is more fodder now for their cattle. When asked specifically about non-economic benefits, the most common response had to do with the cultural value of the spring – it is regarded as a sacred site, one that is considered auspicious for wedding ceremonies. Moldhar village is also rich in biodiversity, with its range of deodar forests and abundant butterfly population ('chyana khad' butterflies); indeed, it is also

[9] Refer to tables A 2 and A 3 in Appendix for more information about the springs and the fieldwork. Photos from field visits to these sites are in Appendix (figures A 4 and A 5).

known as a 'butterfly zone', with hundreds of species of butterflies flying around the spring source. Notably, Moldhar is in the process of being recognised as the first biodiversity heritage spot in Uttarakhand.

4.1.2 Himachal Pradesh

In Himachal Pradesh, we conducted our analysis in 10 spring sites; we visited eight of those sites and conducted rural appraisals. As for the two springs in Bonderi village, we could not visit them due to bad weather conditions, but we obtained information from village leads through a virtual meeting.

Firstly, we inspected four springs in Thanakasoga panchayat (Nahan block, Sirmaur district). Among the five villages in the panchayat, we conducted FGDs and KIIs in two of them, Thanakasoga and Luhali. We conducted PRAs (one FGD and three KIIs) at three baudis (spring wells) at Thanakasoga, namely Thanakasoga Baudi Mandir 1, Thanakasoga Baudi 2, and Thanakasoga Baudi 3, and one at Luhali Baudi. Following the recharge interventions, which mainly took place in 2021/22, the villagers are now entirely dependent on these springs for their domestic water uses. They reported that the alternative source of water was the governmental Irrigation and Public Health Department's water supply system; however, this was irregular and supplied only for a few days a month. They said that after the intervention, water quantity has increased and they spend less time in getting water. Health, too, they said, has improved overall. Some of the FGD participants attributed the increased agricultural production to the spring water, but since the farmlands are located far from the springs and the majority of the crops are rain fed, we could not clearly ascertain the linkage between spring discharge and irrigation and agriculture outcomes.

Next, we studied Johad Baudi in Matiyal village (Barol block, Kangra district). There, the recharge intervention had taken place in 2022 in coordination with the PSI and Chinmaya Organization for Rural Development (CORD). Fifteen families depend on this spring for their daily water needs. From an FGD with 17 participants (two men and 15 women), it emerged that the villagers were benefitting from the considerable increase in water flow in the spring which was helping them in meeting domestic water needs and in saving time which would otherwise have been spent in water collection.

For the two springs in Bonderi – Chhand and Manduwa – we conducted virtual interviews with two village authorities. They said that previously, the springs had been in a partially dry state but now they have been fully revived. Asked about the major benefits from the improved waterflow in the springs, the two authorities cited saving of time in water fetching and increased fodder availability.

Finally, we studied sites in Khidku and Salag villages in Kangra district. At the Khidku spring site, we conducted an FGD with eight people (three men and five women) in coordination with CORD. It was apparent at the meeting that the major benefits were about the spring fulfilling drinking water and other domestic needs. However, since road construction activities were taking place in the upper catchment area, there was a worry that it could negatively impact water percolation and discharge from the spring. The substitute to the spring water was the water supplied by the government, but this was not dependable because of irregular delivery, the villagers reported. At the Salag springs sites – Jalosa Ram Baudi and Jori Mata Baudi – we conducted PRAs (one FGD and one KII) with eight people (two men and six women). They said that since the revival intervention in 2022, the springs have been providing drinking water to about 20 households in Salag and that the major benefits from the springs lay in improved health and increased fodder availability.

4.1.3 Sikkim

In Sikkim, we conducted several PRAs at three major spring sites – Dhokung Dhara in Kolbung village, Kalimatey Dhara in Suldung village, and Lampatey in Kamling village, all located in Soreng district.

The revival of the springs in Suldung-Kamling gram panchayat, which took place under the Dhara Vikas initiative of the Sikkim government's Rural Development Department in coordination with ICIMOD and ACWADAM in 2021–22, was based on the landscape method, similar to the one carried out in Gerethang gram panchayat's reserve forest. For the revival of the Suldung-Kamling springs, the valley-to-valley approach (rather than the springshed approach, which is ridge to valley) was adopted in the Rangeet river belt. The locals dug up to 5,000 trenches and built 150 ponds on a wage rate of USD 2.85 per two pits (under the Mahatma Gandhi National Rural Employment Guarantee Act – MGNREGA) and USD 6.05 per day (under the National Forest Certification Committee – NFCC) to capture surface run-off during the rainy season.

In Kolbung, the FGD with the Dhokung Dhara-II Ranum Kolbung Water User Committee (WUC) and KIIs with 14 locals (nine men and five women) at the Dhokung Dhara site provided information on the

impact of the spring revival intervention in the village. The villagers reported that there has indeed been an increase in the discharge rate of the spring after the intervention, but they couldn't exactly quantify it. Earlier, during the lean seasons, households had to rely on the multiple springs nearby, such as Lepcha Kuwa, Kana Dhara, and Dhokung. Then, the villagers also had to travel long distances to fetch water from other villages such as Parrengaon, Sribadam, and Sumbuk. Notably, post intervention, Dhokung Dhara alone has been sufficient to fulfil the water needs of the village, even for five to 10 more households. In response to the increased discharge of Dhokung Dhara, the local community financed the installation of motors (as part of the community's 20 per cent funding contribution towards the intervention). The motors have been mainly beneficial for the upsteam users, as water gets pumped and distributed to the tanks or reservoirs set up under MGNREGA and by the Village Water Security Council (VWSC).

The water demand in Kolbung village is generally 80 litres per household per day, and the intervention has helped mainly in terms of reliable water for drinking and other domestic purposes, and by the time saved in not having to fetch water. However, a major challenge lies in maintenance, since trench pits tend to become quickly filled with leaves and mud, which necessitates periodic clean-up. Another issue is of households being reluctant to share their land for intervention activities; this is especially because they have not been provided with any incentive to do so and neither do they get incentives for carrying out maintenance activities.

At the Kalimatey spring site, we had a KII with the village authority representing the Suldung Water User Group. The spring has 35 households as direct users. Despite being a water source for 10 additional households, the spring has not depleted. However, during the PRA, the villagers expressed concern over groundwater exhaustion due to a tunnel built by the government in 2006. This, they say, has caused fissures and cracks in the rocks, which has led to water being directed to the nearby canal. However, we found no evidence to support this claim. For Kamling village's Lampatey spring, we conducted an FGD and a KII with six locals (three men and three women) from the Jal Jeevan Mission, and they reported increased discharge from the spring after the revival intervention. Out of the 120 households in Kamling village, 11 of them are direct users of the spring. After motors were installed, the spring water started getting stored in reservoirs and tanks. Earlier, the narrative was of 'barha mahina, barha jhari' (12 months, 12 monsoons), but that changed and erratic rainfall – both in terms of timing and pattern – came into play, with quick run-off within just 30 minutes of a rainfall event. Besides, some minor springs around Lampatey dried up, leaving only Lampatey as the sole functional spring and water source for the whole village. During the interactions with the villagers, there was a mention of piped water being available in the nearby Sri Badam village, but Kamling is yet to receive water through this facility.

4.2 Results of the benefits analysis

As discussed in Section 3.4, the three major economic benefits from the spring revival interventions have been in the form of saving of time, improvement in health, and increased availability of fodder. Below are brief notes on each of these components.

4.2.1 Saving of time

In terms of saving of time, we came to know that before the revival intervention, the villagers usually used to fetch water from nearby springs or reservoirs/tanks, usually by carrying a bucket or banta/gagri, which can hold 15–20 litres of water. For example, at the Uttarakhand study sites, villagers, on average, used to spend 10–15 minutes to fill their vessel, apart from the travel time from home to the water source and back. After the spring revival initiative, the time taken to fill water has been reduced to 5 minutes, but the travel time remains the same. So, going by the average of 1.5 trips per day, we infer that an average of 12 minutes per day has been saved for each household in Uttarakhand. This adds up to each household saving 6 hours per month. Assuming that a household member earns an unskilled market wage rate of USD 4.8 per day (USD 0.6 per working hour and assuming 8 working hours per day), this amounts to each household saving time worth USD 3.4 per month after the intervention.

In Himachal Pradesh, the scenarios were somewhat different for different sites. In sites like Thanakasoga and Bonderi, we observed the partial revival of springs (Thanakasoga Mandir Baudi 3 and Manduwa) which would earlier dry up during the lean seasons. Before the revival intervention, the villagers used to go to spring sites like Thanakasoga Baudi 1 and Thanakasoga Baudi 2, which are in different villages, and had to walk long distances. The villagers told us that it used to take them up to 1 to 1.5 hours to reach those sites. However, soon after the revival of the nearby spring site, Thanakasoga Baudi 3, they no longer have to walk long distances. They now have to walk for just 15–20 minutes, which has saved them 45–60 minutes of travel time. Similar is the case after the partial revival of Bonderi village's Manduwa spring – on average, it has

saved the villagers 30 minutes per water collection trip. In the case of Matiyal, the time that has been saved in fetching water has mainly to do with the installation of a tap in the village; this has helped the villagers to save 30–45 minutes of their time per trip. On average, each household makes two to three trips per day; the unskilled wage rates are within the range of USD 3.6–4.8 for Thanakasoga and Bonderi, and USD 7.3 per day for Matiyal. Therefore, the average monetary value of time saved in fetching water from the Himachal Pradesh spring study sites comes to around USD 13.5 per household per month.

In the case of Dhokung Dhara in West Sikkim, before the revival intervention, the villagers used to carry water directly from it, which took them around 1.5 hours per round trip. Over the last two to three years following the intervention and the installation of motors, as well as distributor tanks and reservoirs (via MGNREGA, VWSC, and NFCC), the villagers have been able to save time – now it only takes 30–60 minutes for the round trip, which means a saving of about 30–60 minutes per trip per household. In two daily round trips (morning and evening) to fetch water, households are now able to save at least 90 minutes per day. If this time saved is translated into monetary units based on the average daily wage rates of MGNREGA (USD 2.8) and NFCC (USD 6.05), it amounts to a total value of USD 25 per household per month. If we take the total average, it amounts to USD 9.46 per household per month across the study sites in Sikkim (Table 4).

4.2.2 Health improvement

The second important component of the benefits analysis was the health benefits that the households obtained from better quality and quantity of water. Specifically, this was prominent in some sites in Himachal Pradesh where we noted some changes. Here, we assumed that the improved water supply and better water quality reduced various waterborne or watershed illnesses such as diarrhoea, typhoid, cholera, and dysentery. During the fieldwork in Himachal, the FGD participants reported a reduction in such cases (redcases) to three to six per household per year in Thanakasoga Mandir Baudi 1 and five to six in Kangra's Jori Mata Baudi.

Based on the reported reduction in such illnesses by about 4.5 cases per household per year (from 7.5 cases to 3 cases, i.e., a 60 per cent reduction) at Thanakasoga Baudi 1 and 5.5 cases per household per year (from 9 cases to 3.5 cases, i.e., a 61 per cent reduction) at Jori Mata Baudi in Himachal Pradesh, we then assumed the economic benefits of not suffering from such illnesses, which otherwise would have cost USD 36.3 per year per

TABLE 4 **BENEFIT CALCULATIONS ON TIME SAVED**

Site (State)	Time taken to fetch water before ($colt_b$)	Time taken to fetch water now ($colt_a$)	Time saved (t_{sav})	Number of round trips (trip)	Local wage rate (w)	Benefits from the time saved (B_{time})
	min./trip	min./trip	min./trip	trips/day	USD/day	USD/household/month
Upsala Shivani Dhara (Uttarakhand)	10–15	5	5–10 (7.5)	1.5	4.8	3.4
Thanakasoga Baudi 3 (Himachal Pradesh)	60–90	15–30	45–60 (52.5)	3	4.2	41.7
Matiyal Spring (Himachal Pradesh)	60–90	30–45	30–45 (37.5)	2.5	7.3	42.5
Bonderi- Manduwa Spring (Himachal Pradesh)	60	30	30	2.5	4.2	19.9
Dhokung Dhara Spring (Sikkim)	60–90	30	30–60 (45)	2	4.5	25.0
Average across all study sites = $\Sigma^{n}_{i} = 1(Btime)_i/n$, where 'n' is the total 14 sites						**USD 9.47/ household/month**

Note: The figure in parenthesis is the range's mid-value. While calculating the average benefits across all sites, we did not observe such changes in parameter t_{sav} (even though we have information on the number of trips and daily wage rate) in all sites. Therefore, instead of inputting several zeros for these parameters to get zero benefit, we have considered only the final average benefit for all sites. The same applies to the calculations for other benefits below.

household in Thanakasoga and USD 30.3 in Jori Mata. Thus, the households saved about USD 164.87 per year which translates to USD 13.75 per month. In the absence of information that could be used to estimate such parameters for our study sites, these values were transferred from a similar study by Pattanayak and Wendland (2007). Thus, the average benefit from improved health across all the study sites in the three states was calculated to be USD 1.96 per household per month (Table 5).

4.2.3 Fodder availability for livestock

In addition to the above benefits, households received benefits in the form of increased amount of grass around the springs. In sites like Moldhar's Upsala Shivani Dhara, the villagers could perceive an increase in the height of the grass. The grass, when bundled as pieces ('nundu' in the local Garhwali language), has economic value as it can be sold for USD 0.12 per bundle. Before the intervention, there was not much grass available for fodder during the dry season, but now with surplus growth, around 20 per cent of the grass is being consumed by stray cattle. According to a villager whose household had four cattle, they had to buy grass worth USD 108.9 per year (USD 9.1 per month) before the revival intervention. Similarly, in sites like Bonderi, the villagers reported that there has been a twofold increase in the amount of grass. Before the intervention, a Bonderi household with three cattle had to purchase grass bundle ('kullu') worth USD 2.5 per month, while a typical household at Jalosa Ram Baudi in Kangra had to purchase 'pulta' (term for a grass bundle in the Himachal Pahari language) for around a similar price per month. However, now with sufficient availability of grass, they are able to save that amount.

Overall, the average benefit from increased fodder across all the study sites amounts to USD 1.01 per household per month.

TABLE 5 **BENEFIT CALCULATIONS ON TIME SAVED**

Site (State)	Case before ($cases_b$)	Case after ($cases_a$)	Reduction in waterborne illnesses (red_{cases})	Medical expenses for waterborne illnesses (c_{med})	Benefits from improved health (B_{health})
	cases/ household/year	cases/ household/year	cases/ household/year	USD/household/ year	USD/household/ month
Thanakasoga Mandir Baudi 1 (Himachal Pradesh)	5–10 (7.5)	2–4 (3)	3–6 (4.5)	36.3	13.6
Jori Mata Baudi Salag (Himachal Pradesh)	8–10 (9)	3–4 (3.5)	5–6 (5.5)	30.25	13.9
Average across all study sites = $\Sigma^n_i = 1(B_{health})i/n$, where 'n' = 14 sites					USD 1.96 household/month

Note: We used only the average (mid-value) of reduction in cases for calculation of health benefits.

TABLE 6 **BENEFIT CALCULATIONS ON FODDER AVAILABILITY**

Site (State)	Cost saving from grass ($cost_{gr}$)	Benefits from fodder availability (B_{fodder})
	USD/household/year	USD/household/month
Moldhar (Uttarakhand)	108.9	9.1
Bonderi (Himachal Pradesh)	30.25	2.5
Jalosa Ram Baudi (Himachal Pradesh)	30.25	2.5
Average across all study sites = $\Sigma^n_i = 1(B_{fodder})_i / n$, where 'n' = 14 sites		USD 1.01/household/month

4.3 Results of the cost analysis

The CBA for the spring revival initiative indicates varying cost implications for households in the three states under study. In Uttarakhand, the monthly cost per household comes to USD 0.48. This figure is primarily a function of the 25-year appraisal period and the 5 per cent discount rate that was applied, which effectively spread the cost over a substantial duration, thereby lowering the periodic financial burden on the households.

The cost per household in Himachal Pradesh stands at USD 1.81 per month. Similar to Uttarakhand, this amount was influenced by the chosen appraisal period and the discount rate, which distributed the investment over a lengthy term to moderate the monthly cost for the households.

For Sikkim, the estimated monthly cost per household is USD 1.40. This estimate was derived from averaging the unit costs per spring from Himachal Pradesh and Uttarakhand – including operational expenses and costs for materials, skilled and unskilled labour, and cartage/transportation – due to the unavailability of Sikkim's cost figures. Only miscellaneous costs were provided which were higher than the other two states' miscellaneous costs. It is important to note that this method of cost approximation may not fully capture the unique project implementation conditions in Sikkim, as indicated previously in this report.

These variations in cost per household per month across the states emphasise the impact of fundamental economic assumptions, such as those related to the appraisal period and discount rate, on the financial

TABLE 7 **SUMMARY OF COSTS PER STATE (IN USD)**

Cost category	Uttarakhand	Himachal Pradesh	Sikkim
Annualised fixed material cost (AFCmat)	27	11	41
Annualised skilled labour cost (AFCSL)	13	268	59
Annualised unskilled labour cost (AFCUL)	9	73	25
Annualised operational cost (AFCOP)	6	138	30
Annualised cartage/transportation cost (AFCT)	1	0	2
Annualised miscellaneous cost (AFCM)	79	0	219
Annualised recurring annual skilled labour cost (ARCSL)	57	666	185
Annualised five-yearly recurring skilled labour cost (AFRCSL)	213	3194	798
Annualised recurring unskilled labour cost (ARCUL)	6	61	18
Annualised recurring operational cost (ARCOP)	46	519	147
Total annualised cost (by year) (TACi)	458	4,930	1,526
Total annualised cost (by month)	38	411	127
Cost per household per month (in USD)	**0.48**	**1.81**	**1.40**

TABLE 8 **OVERALL CBA ACROSS SITES PER STATE[10]**

State	Benefits per household per month (USD)				Cost per household per month (USD)	Net benefit per household per month (USD)
	Btime	Bhealth	Bfodder	Btotal = Btime+Bhealth+Bfodder		
Uttarakhand	3.40	0	9.08	12.48	0.48	12.00
Himachal Pradesh	104.08	27.48	5.04	13.66	1.81	11.85
Sikkim	25.05	0	0	8.35	1.40	6.95

[10] For detailed CBA results, refer to Table A 4 in Appendix.

evaluation of long-term projects. It is critical to acknowledge that the accuracy of cost estimations is contingent upon the robustness of the underlying data and the relevance of the assumptions to the local context. Table 7 shows the summary of the costs incurred in the three states.

The overall net benefits across all the study sites are presented in Table 8.

It is important to note that we have also considered a 10 per cent discount rate for a period of 10 years. This approach was utilised to gauge the robustness of our results under varied conditions. The analysis reaffirms that the quantified costs remain lower than the quantified benefits (see Table A 4).

The estimates of net benefits for each spring for the SCA-Himalayas intervention using the same discount rate and appraisal period, such as those we presented above in Table 9, show both positive and negative values (in some cases). The highest net benefit was recorded at Johad Baudi, of USD 39.8. However, for a site like Lampatey, the net benefits must have to be sufficiently large to cancel out the net costs of the interventions and achieve positive values. These data still do not necessarily encompass the broader ecosystem measures and cultural services, and only reflect the calculation of economic benefits per household per month – time saved, health outcomes, and fodder availability.

Instead of focusing on individual springs, we found that aggregating measures per spring per state by averaging all the observed springs in a state (as shown in Table 8 and Table A 4) was a more comprehensive approach, and thus we used those estimates for

TABLE 9 **CBA FOR SCA-HIMALAYAS SPRINGS**

Spring site	Village	State	Number of direct users (households)	Benefit per household per month per spring (USD)	Cost per household per month per spring (USD)	Net benefit per household per month per spring (USD)
Upsala Shivani Dhara	Moldhar (Tehri Garhwal district)	Uttarakhand	80	12.48	0.48	12
Johad Baudi	Matiyal (Kangra district)	Himachal Pradesh	15	42.54	2.74	39.80
Manduwa and Chhand	Bonderi (Chamba district)	Himachal Pradesh	90	22.37	0.46	21.91
Dhokung Dhara	Kolbung (Soreng district)	Sikkim	45	25.05	0.94	24.11
Kalimatey	Suldung (Soreng district)	Sikkim	35	0	1.21	-1.21
Lampatey	Kamling (Soreng district)	Sikkim	11	0	3.85	-3.85

Note: In Lampatey, benefits may have been realised (e.g., improved water availability), but those benefits were not quantifiable under the three benefit categories used in the CBA due to limited availability of data. This actually reflects the ground reality and hence is included in our analysis. In Kalimatey, recharge interventions could not be carried out because the entire recharge area fell under private land.

SECTION V

Conclusion

This study conducted a CBA of spring revival initiatives across 14 sites in Himachal Pradesh, Sikkim, and Uttarakhand within the IHR to assess the economic viability and guide future policy decisions on springshed management within the HKH. The findings underscore the importance of mountain springs as a primary water source for several purposes, including drinking, irrigation, and rearing of livestock, thereby supporting over 15 per cent of the IHR's population.

The springs not only sustain direct water supply but also enhance biodiversity, ecosystem services, and water security, all of which are currently under threat from climate change and anthropogenic activities. Some significant challenges include shifting precipitation patterns, more frequent extreme weather events, and watershed degradation, all of which result in reduced spring discharge or complete drying up of springs in some areas. ICIMOD's science-based springshed management initiatives address these challenges by integrating sustainable groundwater management approaches.

The ICIMOD team and its partners adopted a mixed CBA framework, combining thorough desk reviews of the published literature on potential costs and benefits with rapid rural appraisals; they also incorporated benefit transfer methods, along with facts on the ground and project costs to estimate both the costs and potential benefits of spring revival activities. The analysis focused on 14 study sites in the three states. The rapid rural appraisals revealed that there were three likely major quantifiable benefits from the improved flow of springs: time saving, wherein the households get to save time which would have otherwise been spent in collecting water; health improvement, wherein the households experience fewer cases of waterborne diseases; and fodder production, wherein more moisture means higher production of grass for fodder. The costs include materials, labour (both skilled and unskilled), operational expenses, transportation, and miscellaneous expenditure. The study did not account for sociocultural and broader ecological benefits, which would be hard to quantify, let alone monetise, given the time and budget constraints. The results indicated net positive private benefits, with monthly net benefits of approximately USD 12 per household in Himachal Pradesh and Uttarakhand, and USD 7 in Sikkim, which should be considered as the lower bound given the absence of a full-fledged benefits estimate. The findings indicate that investments in spring revival projects are likely to be socially beneficial, with the results holding steady under a 10-year appraisal period and a 10 per cent discount rate.

Overall, it can be concluded that the revival of springs in the Indian Himalayan Region is a cost-effective strategy which can provide significant monthly net benefits to households, thus making it a promising investment in terms of sustainable water security at the household and village levels.

5.1 Limitations

One of the limitations of our study relates to the complexities associated with the calculation of benefits. Water user groups, who are directly associated with the springs as direct users (seasonal or perennial), are considered as the 'standing' of spring revival projects. Therefore, we primarily considered the benefits that would accrue to the

private households, although the positive spillovers of such benefits could be far-reaching, extending to next generations and non-human entities (Whittington & MacRae, 1986). In terms of social benefits, we did not consider their full range because of time and budgetary constraints. As for economic value (related to biodiversity), aesthetic value, and cultural value, these are expected to extend beyond the quantitative aspects that we could consider given our constraints. Furthermore, the benefits stream derived from improved water quantity has been assumed to be constant; however, such benefits may grow over time due to increased ecosystem services and rising incomes.

As regards the benefits perceived (gathered through rapid appraisals) by the spring users, those may not be a true representation of the actual benefits, as the users may not have been fully aware that some changes, such as improved health, may not have to do entirely with better water services. In other words, the users might have lacked adequate understanding about the causal link between improved water services and related benefits, thereby leading to understatement about the actual effect. Such errors in perception are especially likely in the case of any indirect and/or future benefits stream, compared to direct benefits such as drinking water. Even in the case of direct household benefits, we focused only on the benefits accruing to adult men and women, while we did not estimate the benefits of saved time as far as children were concerned since they were not the primary wage earners. Yet, children could be the ones fetching water.

We were also not able to conduct a comprehensive statistical impact assessment, i.e., a counterfactual scenario of what outcomes the households would experience if the spring revival intervention had not taken place. For example, households would then have been forced to rely on the same spring source with less discharge or would have had to consider alternatives such as rainwater harvesting, surface water sources, government water schemes, and hand pumps. Although the 'before' and 'after' scenarios provided us with a comparative assessment yardstick to measure the impact of spring revival activities, a more robust evaluation would have required data from the 'control villages' without spring revival interventions. But this was beyond the scope of the study.

5.2 Recommendations

Given the constraints listed above, future research should aim at the following: first, **establish causal linkages** by implementing robust experimental or quasi-experimental designs to discern the causal impacts of spring revival activities, thereby isolating effects from confounding variables such as socio-economic status and hydrogeological features. Second, **expand the CBA framework** to incorporate the valuation of biodiversity and cultural services. Interdisciplinary studies that create quantifiable metrics for these amenities could provide a more holistic assessment of springshed interventions. Third, *assess long-term benefits* by considering the evolving benefits of spring revival projects, thus accounting for potential growth in ecosystem services and economic development over time. Fourth, **consider benefit distribution** by investigating how benefits versus costs are distributed among the different stakeholders, thereby identifying equity and sustainability.

For policymakers and practitioners, we have the following recommendations:

1. **Emphasise holistic objectives**: Encourage policies that not only target economic efficiency but also prioritise the broader objectives of community engagement, women's empowerment, and ecological conservation.
2. **Foster community participation**: Design initiatives that actively involve local communities in decision-making processes, thereby ensuring that they are the key stakeholders in both the benefits and responsibilities associated with water management projects.
3. **Augment biodiversity and cultural conservation**: Integrate measures to protect and enhance local biodiversity and cultural heritage within the framework of spring revival initiatives and accord due recognition to their intrinsic and contributory value to community well-being.
4. **Establish sustainable financing models**: Develop financial models that ensure the long-term viability and maintenance of water services by incorporating a mix of donor contributions, community investments, and public–private partnerships.
5. **Build capacity for effective monitoring and evaluation**: Strengthen the capabilities of local institutions to conduct regular monitoring, evaluation, and maintenance of springshed projects to ensure their continued success and adaptability to changing conditions.

By addressing these research and policy gaps, stakeholders can rely on spring revival projects to not only secure water resources but also to promote sustainable development and resilience in the IHR, and the HKH as a whole.

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Appendix

TABLE A1 **STUDY SITES**

Feature	Uttarakhand (Moldhar)	Himachal Pradesh (Bonderi)	Sikkim (Suldung-Kamling)
Latitude & longitude	30.54646° N, 78.20152° E	32.893079° N, 76.142069° E	27.20539° N, 88.31690° E
Average elevation	1750 m	1415–1900 m	847 m
Number of households	116	638	143
Population	956	3,217	754
Caste distribution	85% Open (without any caste-based reservation), 15% Scheduled Caste	Multiple caste groups	Not specified
Springs monitored	7	7	14
Critical springs selected for revival	8	7	3
Intervention	Digging of 700 toe trenches	Toe trenches and small trenches within fruit plantations – about 790 such trenches	Digging of 5,000 trenches and construction of 150 ponds under MGNREGA and NFCC
Key challenges	Water scarcity, unprotected catchment areas, terrace farming	Water scarcity, dependence on external supply	Declining spring discharge, limited access for hilltop communities
Feasibility factors	Year-round access, community cooperation, gender equity, active institutions	Accessible, community support, support from the forest department and active institutions under the Gram Panchayat	Accessible, strong support from the Gram Panchayat Unit (GPU), trained personnel under the Jal Jeevan Mission, active institutions
Existing institutions and stakeholders	Yuvak Mangal Dal, Self-Help Group, Nirmal Varg Jalagam Samiti, Krishi Vibhag, Swasthya Vibhag, Van Panchayat, Udyan Vibhag	Gram Panchayat, Mahila Mandal	Gram Panchayat, Women Water Monitoring Committee, Village Water and Sanitation Committee
Existing Water User Group	Jal Upabhokta Samuha, Jal Jeevan Mission	Village Water and Sanitation Committee, Jal Upabhokta Samuha	Suldung-Kamling Water User Group, Village Water and Sanitation Committee, Jal Jeevan Mission

TABLE A2 LOCATION AND COMPOSITION OF FGDS AND KIIS

Date (year 2024)	State	Village	Spring	No. of user households	FGD/KII participants				Partner(s)
					No. of PRAs	Men	Women	Total	
Feb. 3	Uttarakhand	Moldhar	Upsala Shivani Dhara	80	1 FGD	4	20	24	PSI
Feb. 8	Himachal Pradesh	Thana Kasoga	Thana Mandir Baudi and Luhali	95	1 FGD 3 KIIs	7	3	10	PSI
Feb. 10	Himachal Pradesh	Matiyal	Johad Baudi	15	1 FGD	2	15	17	PSI, CORD
Feb. 12	Himachal Pradesh	Bonderi	Chhand and Manduwa	90	1 KII	1	1	2	PSI, CORD
Feb. 13	Himachal Pradesh	Khidku	Khidku	7	1 FGD	3	5	8	CORD
Feb. 13	Himachal Pradesh	Salag	Jori Mata and Jalosa Ram Baudi	20	1 FGD 1 KII	2	6	8	CORD
Mar. 11	Sikkim	Kolbung	Dhokung Dhara[11]	45	1 FGD, 2 KIIs	9	5	14	RDD
Mar. 12	Sikkim	Suldung	Kalimatey	35	1 KII	2	0	2	RDD
Mar. 13	Sikkim	Kamling	Lampatey	11	1 FGD, 1 KII	3	3	6	RDD

TABLE A3 BRIEF INFORMATION ABOUT THE FIELDWORK SITES

Spring sites	Village	Intervention year	Water User Group	No. of direct user households	Water sources
Upsala Shivani Dhara	Moldhar, Tehri Garhwal district	2021/22	Upsala Shivani Jal Upabhokta Samuha	80	Spring, tap water
Thanakasoga Mandir Baudi 1	Thanakasoga, Sirmaur district	2012/13	Thana Mandir Jal Upabhokta Samuha	34	Spring, piped water (supplied by government)
Thanakasoga Baudi 2	Thanakasoga, Sirmaur district	2021/22	Thana Mandir Jal Upabhokta Samuha	23	Spring, piped water (supplied by government)
Thanakasoga Baudi 3	Thanakasoga, Sirmaur district	2022/23	Thana Mandir Jal Upabhokta Samuha	27	Spring, piped water (supplied by government)
Luhali Baudi	Luhali, Sirmaur district	2021/22	Luhali Water User Group, Mahila Mandal	11	Spring
Johad Baudi	Matiyal, Kangra district	2022/23	Johad Bawadi Jal Upabhokta Samuha	15	Spring, piped water (supplied by government)
Manduwa and Chhand	Bonderi, Chamba district	2022/23	Mahila Mandal Samuha	90	Spring, piped water (supplied by government)
Khidku	Khidku, Kangra district	2022/23	Mahila Mandal Samuha	7	Spring, piped water (supplied by government)
Jori Mata Baudi	Salag, Kangra district	2022/23	Jori Mata Jal Upabhokta Samuha	11	Spring
Jalosa Ram Baudi	Salag, Kangra district	2022/23	Jalosa Ram Jal Upabhokta Samuha	9	Spring
Dhokung Dhara	Kolbung, Soreng district	2021/22	Dhokung Dhara-II Ranum Kolbung Water User Committee	45	Spring water distributed through reservoirs, tanks
Kalimatey	Suldung, Soreng district	2021/22	Suldung Water User Group	35	Spring with reservoir, tanks
Lampatey	Kamling, Soreng district	2021/22	Jal Jeevan Mission	11	Spring with reservoir, tanks

[11] We also observed non-protected springs – Lepcha Kuwa and Devithan – near this site.

TABLE A4 **DETAILS OF THE CBA**

Spring(s)	State	Btime	Bhealth	Bfodder	Btotal/site	Btotal/site/ state	Costs/site/ state (at 5% discount & for 25 years)	Net benefits	Costs/site/ state (at 10% discount& for 10 years)	Net benefits
(Unit)		USD/ household/ month	USD/ household/ month	USD/ household/ month	USD/ household/ month/ site	USD/ household/ month/ site/ state	USD/ household/ month/site/ state	USD/ household/ month/site/ state	USD/ household/ month/site/ state	USD/ household/ month/site /state
Upsala Shivani Dhara	Uttarakhand	3.40	0	9.08	12.48	12.48	0.48	12	0.57	11.91
Thanakasoga Mandir Baudi 1	Himachal Pradesh	0	13.61	0	13.61	13.66	1.81	11.85	1.55	12.11
Thanakasoga Baudi 2		0	0	0	0					
Thanakasoga Baudi 3		41.69	0	0	41.69					
Luhali Baudi		0	0	0	0					
Matiyal (Johad Baudi)		42.54	0	0	42.54					
Manduwa and Chhand		19.85	0	2.52	22.37					
Khidku/Kangra		0	0	0	0					
Salag/Kangra (Jori Mata Baudi)		0	13.87	0	13.87					
Salag/Kangra (Jalosa Ram Baudi)		0	0	2.52	2.52					
Dhokung Dhara	Sikkim	25.05	0	0	25.05	8.35	1.40	6.95	1.54	6.81
Kalimatey		0	0	0	0					
Lampatey		0	0	0	0					

FIGURE A 1 MILLENNIUM ECOSYSTEM ASSESSMENT: LINKAGES BETWEEN ECOSYSTEM SERVICES AND HUMAN WELL-BEING (MEA, 2005)

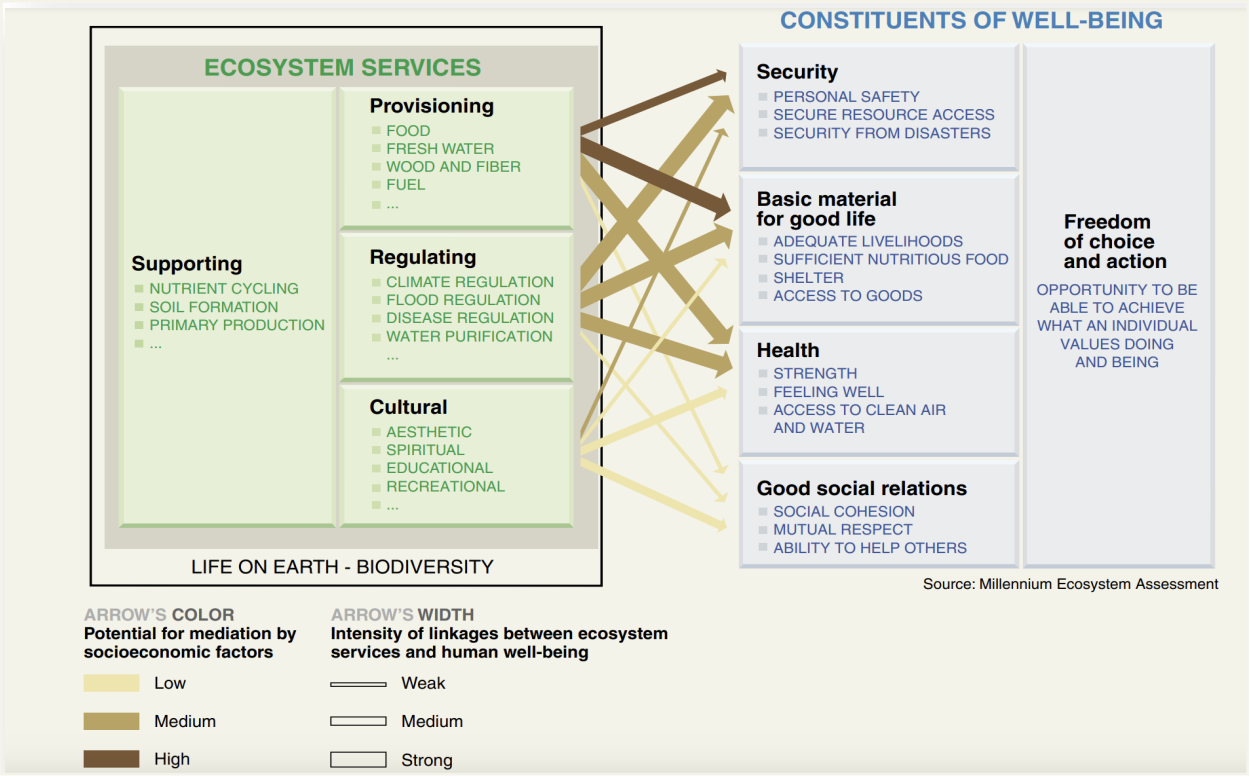

FIGURE A 2 LITERATURE REVIEW: A SCHEMATIC OVERVIEW

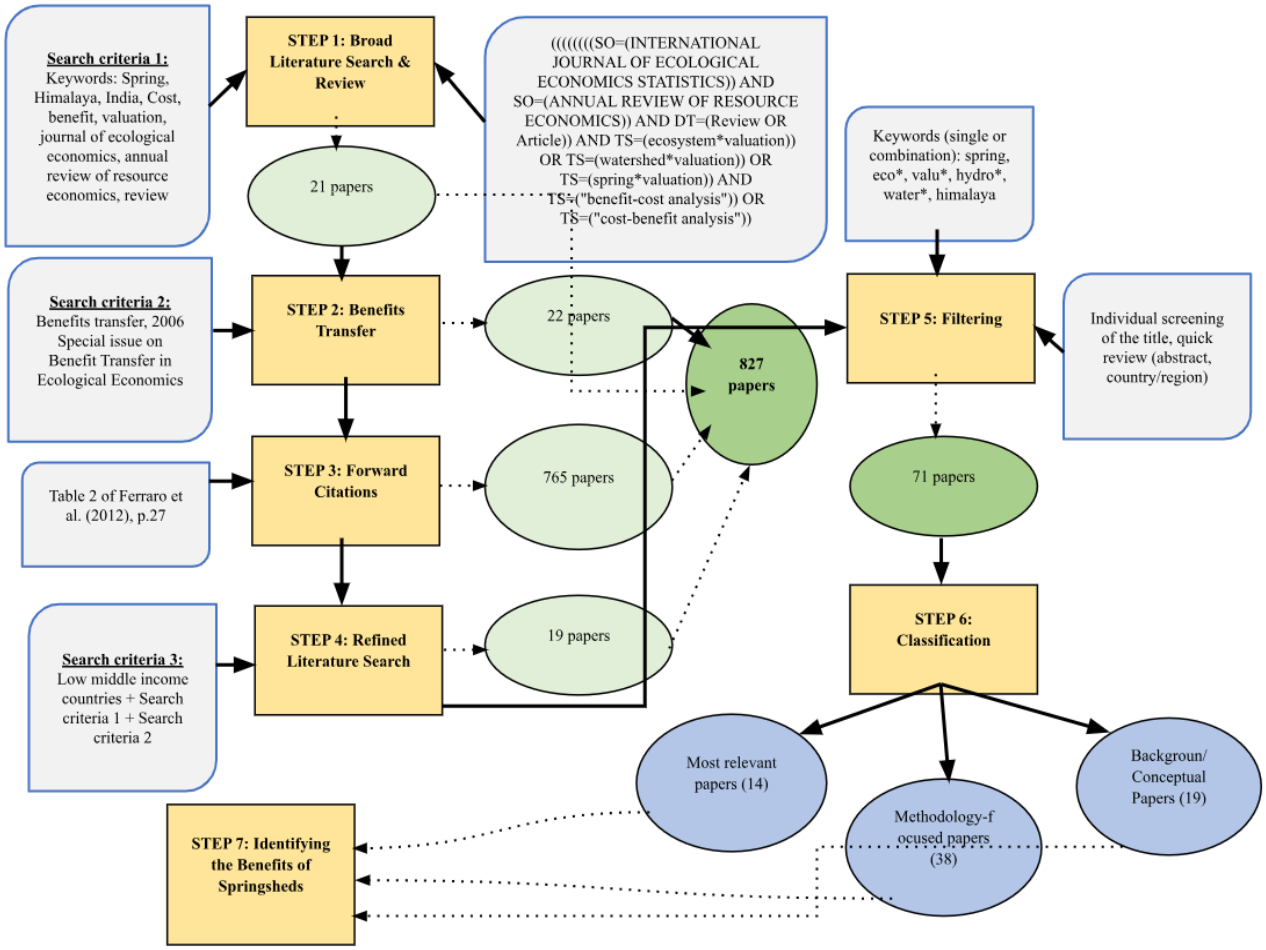

FIGURE A 3 **IDENTIFICATION OF KEY BENEFITS FORM LITERATURE REVIEW**

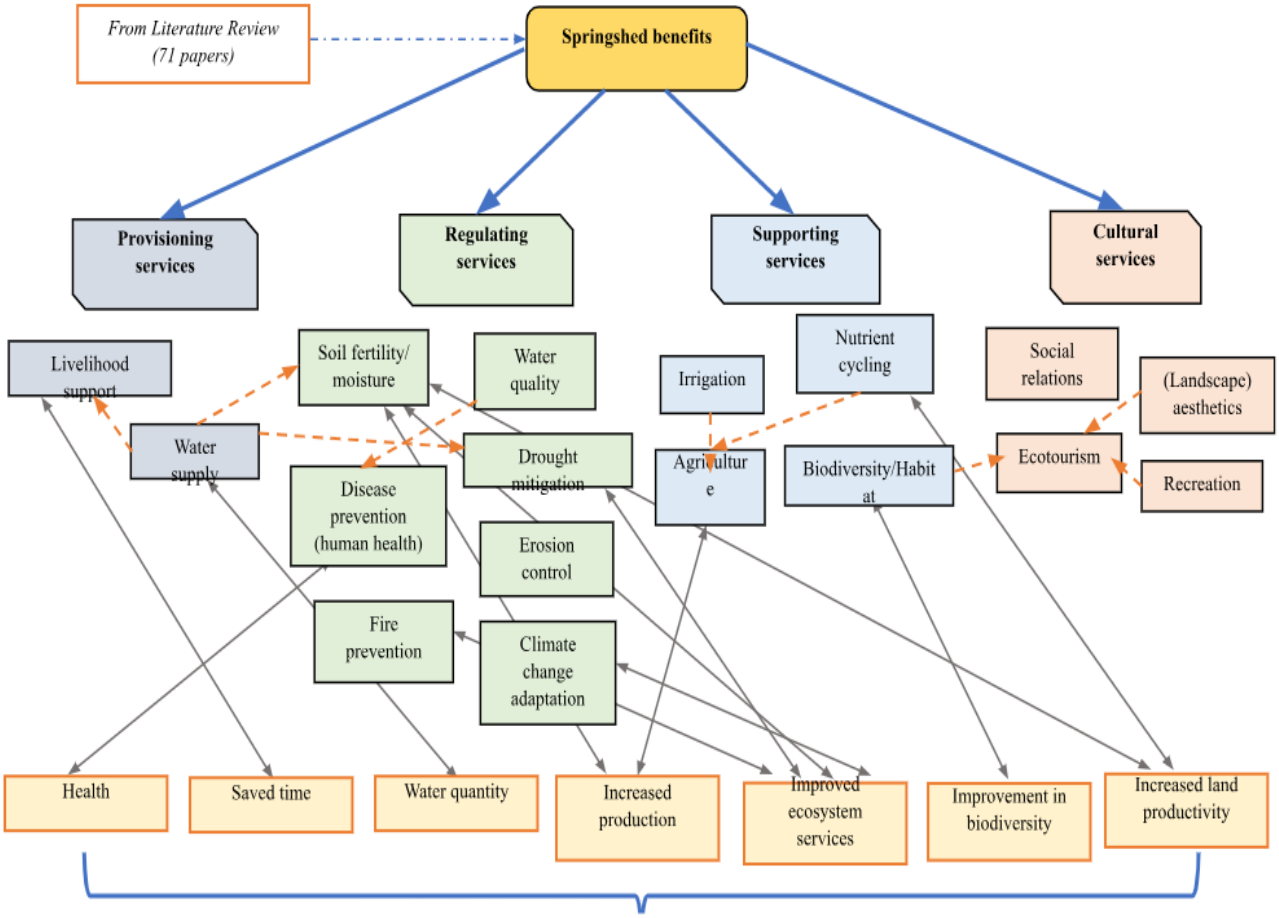

FIGURE A 4 FIELD VISITS TO UTTARAKHAND AND HIMACHAL PRADESH STUDY SITES

FIGURE A 5 **FIELD VISIT TO SIKKIM STUDY SITES**

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SURAJ

List of terms and definitions

Term	Definition
Anthropogenic activities	Human-induced activities that directly or indirectly impact the environment.
Appraisal period	Time frame over which the value of an investment, asset, or project is assessed.
Benefit transfer	A valuation technique of borrowing and transferring data from existing studies to adapt to a study site where field data may be unavailable or impractical to obtain.
Capital recovery factor	The ratio of the constant annuity to the present value of the future cash flow as annuity for a specified period of time (monthly in our case, obtained by dividing the annualised cost by 12).
Cost–benefit analysis	A systematic approach of evaluating any investment project that helps summarise the expected costs which could be incurred as well as the expected benefits accrued throughout the lifespan of the project in terms of net benefits.
Critical springs	Springs that are selected based on specific geographic and location characteristics and which are sensitive to climatic and anthropogenic risks.
Discount rate	The interest rate used to calculate the time value of money by converting the future cash flows of benefits and costs into present value.
Ecosystem services	The benefits that humans derive from the ecosystem for their well-being, including provisioning (food and water), regulating (climate regulation), supporting (nutrient cycling, soil nutrients), and cultural services (aesthetic, recreational, spiritual).
Ecosystem valuation	Assigning economic value to ecosystem services in monetary units.
Focus group discussion	A qualitative research method used to gather people of a similar background to discuss a specific issue or topic.
Functional springs	Active springs with consistent discharge flow and providing a reliable and continuous supply of water for domestic needs.
Hydrogeology	The branch of geology that deals with the study of distribution, movement, and overall characteristics of groundwater.
Impacts	Effects or consequences from a particular intervention, action, event, or environmental change that can occur due to natural processes or anthropogenic activities.
Interventions	Actions or implementations to bring about a desirable change (improvement) in a particular outcome.
Key informant interview	A qualitative research method used to gather individuals, authorities, or community stakeholders to discuss a specific issue or topic.
Net benefit	The difference between the total benefits and the total costs of a particular investment, project, or policy.
Net present value	The lifetime worth of the financial investment discounted to present value, accounting for the time value of money.
Rapid rural appraisal	A participatory approach to engage local communities in understanding current issues, identifying solutions, and prioritising resources/capacities for effective implementation of a project, action, or policy.
Springshed	The catchment area of springs with a groundwater recharge system and aquifers to sustain them.
Springshed management	An integrated approach to conserve the sustainability of springs through effective interventions on hydrogeology and sustainable practices by active mobilisation of the communities and local stakeholders.
Standing	Identification of beneficiaries or stakeholders whose costs and benefits need to be accounted for the analysis.
Watershed	An area of land with surface water such as rivers and streams that drain towards larger water outlets like oceans.

Formal steps of the CBA

The following were the standard formal steps that were taken while carrying out the CBA:

1. **Specifying a set of alternatives**: We started by detailing all the potential interventions and their feasible alternatives to tackle the identified issue.
2. **Deciding whose impacts count (standing)**: We determined which stakeholders' benefits and costs should be included in the analysis, typically encompassing a wide range of individuals affected by the intervention.
3. **Identifying impact categories and organising them; and selecting indicators (cost and benefit components)**: We categorised the various impacts and selected the appropriate indicators that effectively measured the costs and benefits associated with each category.
4. **Predicting impacts quantitatively over the life of the intervention**: We estimated the potential impacts over the project's expected duration by utilising historical data and predictive modelling.
5. **Monetising the impacts**: We assigned monetary values to the predicted impacts, thereby facilitating a straightforward comparison between benefits and costs.
6. **Applying a discount for future impacts (or benefits and costs)**: We applied a discount rate to future benefits and costs in order to value them in present terms, acknowledging the time value of money.
7. **Computing outcome metrics**: To assess the project's economic viability, we calculated the total benefits, total costs, and their difference – the total net benefits.
8. **Making recommendations**: We can offer clear, actionable advice to policymakers and stakeholders based on the analysis.

About ICIMOD

The Hindu Kush Himalaya (HKH) region stretches 3,500km across Asia, spanning eight countries – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. Encompassing high-altitude mountain ranges, mid-hills, and plains, the zone is vital for the food, water, and energy security of up to two billion people and is a habitat for countless irreplaceable species. It is also acutely fragile, and vulnerable to the impacts of the triple planetary crisis of climate change, pollution, and biodiversity loss.

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Supporting partners for CBA data collection:

ICIMOD and its Regional Member Countries gratefully acknowledge the generous support of Austria, Norway, Sweden and Switzerland for core and programme funding, and the Adaptation Fund, Aerospace Information Research Institute of the Chinese Academy of Sciences, Asian Development Bank, Australia, Canada's International Development Research Centre, Carleton University, Finland, Germany, Global Affairs Canada, Global Biodiversity Information Facility, Japan's Sasakawa Peace Foundation, Oxfam Novib, the United Kingdom, United Nations Environment Programme, and United Nations Development Programme and the World Bank Group for project funding.

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