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SUBMISSION

Scientific research information

Submission by the International Centre for Integrated Mountain Development (ICIMOD)

April 2026

The International Centre for Integrated Mountain Development (ICIMOD) is pleased to provide this submission under the Subsidiary Body for Scientific and Technological Advice (SBSTA) agenda item 4 on Research and Systematic Observation (RSO) of the United Nations Framework Convention on Climate Change (UNFCCC), in response to the mandate agreed (conclusion 13) at SBSTA 62 (June 2025). ICIMOD is an intergovernmental knowledge and learning centre serving the Regional Member Countries (RMCs) of the Hindu Kush Himalaya (HKH): Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan.

At SBSTA 62, Parties underlined the importance of discussions on scientific advances and on research gaps and needs relevant to supporting work under the Convention and the Paris Agreement (Articles 4, 7, 8 and 14), as well as the need to ensure sustained systematic observation of the climate system as a fundamental basis for scientific research and for informing climate action (FCCC/SBSTA/2025/4, Add.19-34). SBSTA 62 requested its Chair to prepare, with the assistance of the secretariat (FCCC/SBSTA/2025/L.5), an information note that maps how research gaps identified since SBSTA 22 (June 2005, FCCC/SBSTA/2005/4/Add.1, Page 31) under this agenda item are being addressed by the scientific community, for consideration at the eighteenth meeting of the research dialogue to be held in conjunction with the June 2026 session of the Subsidiary Bodies.

ICIMOD, an intergovernmental organisation with observer status at the UNFCCC, uses this submission to present an overview of its contributions to addressing the identified research needs and gaps under the RSO agenda item. The submission also highlights the need for dedicated attention to mountain regions and mountain people, who are experiencing warming rates higher than the global average and whose environments remain relatively data-sparse in global observation systems and assessments.

Institutional mandate and relevance to RSO priorities

ICIMOD's Strategy 2030, *Moving Mountains*[1], sets out a vision of a greener, more inclusive and climate-resilient HKH and a mission to build and share knowledge that drives regional policy and action and attracts investment for sustainable mountain development. The HKH provides essential ecosystem services as the source of ten major Asian river systems and as a global "water tower" that supports the wellbeing of almost two billion people downstream.

At the same time, the HKH is experiencing accelerated cryospheric change, increasing climate extremes and cascading transboundary risks, and has been recognised in successive assessment reports of the Intergovernmental Panel on Climate Change (IPCC) as a region where long-term, high-quality observations and integrated research remain comparatively limited. ICIMOD's work therefore responds directly to the priorities under Article 5 of the UNFCCC on research and systematic observation and to SBSTA's calls to broaden representation of developing-country science in the research dialogue and related processes (FCCC/SBSTA/2025/4, Add.19-34).

[1] ICIMOD. (2023). ICIMOD Strategy 2030: Moving Mountains. International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.1027

ICIMOD and RSO research needs categories

The UNFCCC secretariat, in its synthesis of research needs and gaps identified (FCCC/SBSTA/2025/L.5) since SBSTA 22 (June 2005), has structured these needs under five broad categories (A–E), as outlined in the information note prepared by the RSO co-chairs (March 2025). Specifically, Parties at SBSTA 62 requested mapping of progress against the following research dialogue foci:

- **Category A**: Understanding climate change, related climate data, and scenarios
- **Category B**: Adaptation, loss and damage, and extreme events
- **Category C**: Ecosystems and nature-based solutions
- **Category D**: Mitigation, related technologies, and GHG emissions and reporting
- **Category E**: Cross-cutting issues

The UNFCCC secretariat has compiled a synthesis of research needs and gaps identified under the RSO agenda item since SBSTA 22 (FCCC/SBSTA/2005/4/Add.1), structured under five broad categories (A–E). In line with this structure, ICIMOD's submission:

- Describes how selected ICIMOD research, systematic observation and capacity-building initiatives undertaken since 2005 respond to specific elements of these categories, using concrete examples from across the HKH.
- Highlights, as far as possible, the regional and multi-country nature of the work and its relevance for Parties' implementation of the Convention and the Paris Agreement, including in relation to adaptation, mitigation, loss and damage and means of implementation.
- Identifies cooperative and capacity-building dimensions, particularly those that strengthen the ability of institutions in developing-country Parties in the HKH to generate, access and effectively use climate-related data and knowledge.
- A set of one-page descriptions of selected ICIMOD projects and studies is provided in the annexes, using the standardised template described in the secretariat's guidance. These one-page entries indicate the specific RSO research needs addressed (A–E), the timeline, geographic scope, methods and observation systems used, and links to outputs and data.

ICIMOD contributes to all five categories through research, systematic observation and capacity-building initiatives implemented since 2005, directly responding to SBSTA's mandate to identify how the scientific community has addressed these gaps. Table 1 (next page) summarizes selected ICIMOD initiatives mapped against these categories, with brief descriptions in the table and detailed one-page notes, as requested by the RSO, provided in the annexes.

Table 1: Overview of selected ICIMOD initiatives responding to RSO research needs (A–E)

No.	Project / study title	Brief Note	RSO categories (A–E)	Geographic scope	Timeline
1	Hindu Kush Himalaya Assessment and related flagship publications (including WISE Outlook)	Comprehensive HKH assessment synthesising climate, cryosphere, water and ecosystem data for IPCC and national planning	A, B, C, E	HKH region	Ongoing
2	SANDEE – The South Asian Network for Development and Environmental Economics	Regional network building capacity in environmental economics through 250+ grants and 1,500+ trainees	A, E	South Asia and HKH	1999–ongoing
3	Action research on residential space heating as a gender-inclusive and socially responsible solution	Rocket stove pilot showing 51% fuelwood/emission reduction and health benefits in Bhutan high-altitude households	B, D, E	Bhutan and Nepal, with major focus on high-altitude settlements in Bhutan.	2024–2025
4	Clean Bricks	Zig-zag kiln conversion avoiding 106k tonnes CO_2 across 7,000 South Asian kilns with regional stakeholder platform	B, D, E	Nepal, Pakistan, India, Bangladesh (major focus on Nepal and Pakistan)	2014–2021
5	Kailash Sacred Landscape Conservation and Development Initiative	Transboundary ecosystem approach benefiting communities across China-India-Nepal with first Himalayan GLORIA site	B, C, E	Transboundary Kailash Sacred Landscape (China, India, Nepal)	2012–2022
6	Springshed Management for Sustainable Water Resources	Six-step protocol documenting springs drying in 74% of Nepal LGUs and scaling NbS for water security	B, C, E	HKH region	2015–ongoing
7	Sustainable Management of High-Altitude Rangelands as Nature-based Solutions	Community-led rangeland restoration increasing soil carbon and fodder by 20% across HKH pastoralist systems	C, E	Afghanistan, Bhutan, China, India, Nepal, and Pakistan	1999–ongoing (with phased programmes)
8	Disability and disaster in the HKH region – cross-country analysis of disability patterns and disaster linkages	Harmonised analysis showing disaster exposure drives disability prevalence in remote HKH hazard zones	B, E	Bangladesh, India, Nepal, Pakistan	2023–2025
9	Thame Valley Glacial Lake Outburst Flood 2024 – Causes, impacts and future risks	Post-GLOF analysis of cascading lake breaches destroying 25 homes, school, health post; risk assessment of 5 lakes	A,B,C,E	Thame Valley, Dudh Koshi basin, Everest region, Nepal (HKH)	2024-2025

10	Changing dynamics of glaciers in the Hindu Kush Himalayan region from 1990 to 2020	HKH-wide dataset documenting 12% glacier area loss and 9% ice reserve decline with accelerating post-2010 retreat	A, B, C, E	HKH region	1990–2020 (analysis); report 2026
11	HKH Glacier Outlook 2026 – Insights from 50 years of Himalayan glacier monitoring	Synthesis of 302 mass-balance observations from 38 glaciers identifying monitoring gaps and benchmark sites	A, B, C, E	HKH region	1974–2026
12	HIGRID – Building capabilities for green, climate-resilient and inclusive development in the Lower Koshi River Basin	GEDSI-responsive DRR planning across 28 Nepal municipalities scaling flood EWS and inclusive value chains	A, B, E	Lower Koshi River Basin, eastern Nepal (Terai, mid-hills, high hills)	2022–ongoing (as of 2025)
13	2025 drought in Nepal's Madhesh Province – A rapid situational analysis	Analysis of cascading meteorological-hydrological-agricultural drought projecting 400-450k tonne rice shortfall	A, B, E	Madhesh Province, south-eastern Terai, Nepal	2025 (event and analysis)
14	Himalayan Climate Change Adaptation Programme (HICAP)	Basin-scale climate and water scenarios, vulnerability and gendered adaptation research, and pilots such as CB-FEWS and Resilient Mountain Villages	A, B, C, E	China, India, Nepal, Pakistan	2011-2018
15	Himalayan Adaptation, Water and Resilience (HI-AWARE) – Research on glacier and snowpack dependent river basins	Comparative, transdisciplinary research in Indus, Ganges, Gandaki and Teesta basins on climate projections, vulnerability, adaptation pathways and pilots	A, B, C, E	Bangladesh, India, Nepal, Pakistan	2014-2018

These initiatives were selected to illustrate the breadth of ICIMOD's contributions across the five categories and to demonstrate how research, systematic observation and capacity-building interventions address the research needs identified under the RSO agenda item. The following subsections link these initiatives explicitly to each of the RSO categories.

Category A: Understanding climate change, related climate data, and scenarios

ICIMOD contributes to Category A: Understanding climate change, related climate data, and scenarios by generating higher-resolution regional climate information and by advancing understanding of warming pathways and associated uncertainties in the HKH. The *Hindu Kush Himalaya Assessment*[2] and the *Water, Ice, Societies and Ecosystems in the HKH: An Outlook*[3] (HI-WISE) synthesise long-term observation records, regional climate and hydrological modelling, and scenario analysis to characterise elevation-dependent warming, changing monsoon dynamics and projected cryosphere loss under different warming levels.

Key strands of work include generation and analysis of downscaled climate projections and high-resolution regional climate information for the HKH, including basin-scale hydrological and cryospheric modelling in the Indus and Koshi basins, which provide information relevant to near-term climate risks and to seasonal to decadal changes in hydrology and extremes. Scenario analyses presented in these assessments indicate that, even if global warming is limited to 1.5 degrees, the HKH is projected to lose a substantial share of its glacier volume by the end of the century, with cascading implications for water, energy and food security.

Collaborative work with regional and global modelling centres on multi-model ensembles and event attribution contributes to advances in attribution science and understanding of changing monsoon patterns at regional scale. SANDEE complements this physical-science work by building regional capacity in environmental and development economics, enabling researchers to analyse the socio-economic impacts of climate change and to apply climate and hydrological data to policy-relevant questions on growth, poverty and environmental sustainability.

Recent cryosphere studies deepen the evidence base for Category A by providing long-term, HKH-wide glacier change information based on consistent methods. The *Changing dynamics of glaciers in the Hindu Kush Himalayan region from 1990 to 2020* [4]develops the first comprehensive, multi-decadal glacier change dataset for the entire HKH, showing a 12 per cent loss of glacier area and a 9 per cent loss of ice reserves between 1990 and 2020, with accelerated retreat after 2010 and marked basin- and range-specific differences. The *HKH Glacier Outlook 2026*[5] synthesises 50 years of field-based mass-balance observations from 38 glaciers (302 annual measurements, of which 270 are negative), identifies benchmark glaciers and major monitoring gaps, and sets priorities for strengthening cryosphere observation networks during the International Year of Glaciers' Preservation 2025 and the Decade of Action for Cryosphere Science (2025-2034).

The Himalayan Climate Change Adaptation Programme (HICAP) and the Himalayan Adaptation, Water and Resilience (HI-AWARE) programme both provide basin-scale climate and water information that directly responds to Category A needs. HICAP developed downscaled climate and water-availability scenarios for sub-basins of the Indus, Ganges, Brahmaputra and Salween–Mekong, synthesised in the *Himalayan Climate and Water Atlas*[6] launched at COP21 and widely accessed by policy and research communities. HI-AWARE generated robust, region-specific climate projections for the Indus, Ganges and Brahmaputra river basins,

[2] Wester, P., Mishra, A., Mukherji, A., & Shrestha, A. B. (2019). The Hindu Kush Himalaya assessment: Mountains, climate change, sustainability and people. Springer International Publishing. https://doi.org/10.1007/978-3-319-92288-1

[3] ICIMOD. (2023). *Water, ice, society, and ecosystems in the Hindu Kush Himalaya: An outlook*. (P. Wester, S. Chaudhary, N. Chettri, M. Jackson, A. Maharjan, S. Nepal, & J. F. Steiner [Eds.]). ICIMOD. https://doi.org/10.53055/ICIMOD.1028

[4] Maharjan, S. B., & Sherpa, T. C. (2026). Changing dynamics of glaciers in the Hindu Kush Himalayan region from 1990 to 2020. International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.1122

[5] Azam, M. F. (2026). HKH Glacier Outlook 2026: Understanding Change Through 50 Years of Field Observation (p. 14 p.). International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.1123

[6] HICAP. (2015). The Himalayan Climate and Water Atlas; Impact of Climate Change on Water Resources in Five of Asia's Major River Basins. International Centre for Integrated Mountain Development (ICIMOD).

using advanced model-selection and downscaling approaches to improve representation of high-altitude precipitation and extremes, and to support national adaptation planning processes.

Category B: Adaptation, loss and damage, and extreme events

ICIMOD's observations and research on cryosphere change, hydrometeorology and climate impacts underpin risk assessments and early-warning systems for extreme events such as floods, droughts, landslides and glacial lake outburst floods in the HKH. Across the initiatives listed in Table 1, Category B: Adaptation, loss and damage, and extreme events is addressed through long-term monitoring and analysis of snow, glaciers, glacial lakes and river flows, evaluations of community-based adaptation and livelihood diversification, integrated assessments of climate risks, and research on differentiated impacts for vulnerable groups.

The Kailash Sacred Landscape Conservation and Development Initiative (KSLCDI) has established long-term socio-ecological monitoring sites, including the first permanent GLORIA high-altitude vegetation monitoring site in the Himalayan region, alongside harmonised vegetation and cultural heritage maps and improved information on glaciers, land use and rangelands. Evidence from KSLCDI shows that ecosystem-based and nature-based approaches can enhance the resilience of mountain communities to climate-related hazards and stresses, benefitting more than 91,000 people, including over 37,000 women, while informing planning for water security, biodiversity conservation and livelihoods.

Recent event-focused studies in Nepal also contribute directly to Category B by analysing the evolution and cascading impacts of extreme events, and by informing early-warning systems and risk reduction. The *Thame Valley Glacial Lake Outburst Flood 2024*[7] investigation combines high-resolution satellite imagery, field surveys, UAV mapping and lake-risk classification to reconstruct how a rock avalanche into Upper Ngole Cho triggered a displacement wave, breached two moraine-dammed lakes in sequence and generated a hyper-concentrated flood that destroyed 25 houses and guesthouses, a school, a health post, a bridge and the intake of the Khumbu hydropower plant, displacing 135 people. The study classifies remaining lakes by risk and recommends targeted structural and non-structural measures, including geophysical surveys, channel stabilisation, and installation of hydrometeorological monitoring and early-warning systems, illustrating how post-disaster analysis can strengthen adaptation and loss-and-damage responses.

The rapid situational analysis[8] of the 2025 drought in Nepal's Madhesh Province addresses slow-onset extremes by combining rainfall and forecast analysis, satellite-based vegetation indices and ground data on groundwater and agriculture. It documents the progression from meteorological to hydrological and agricultural drought, with groundwater depletion, a rice transplantation rate of only 52 per cent compared with 92 per cent in 2024, an estimated 35–40 per cent of rice area under extreme drought stress (rising to 60–78 per cent in some districts) and a potential national rice production shortfall of 400,000–450,000 tonnes. The study highlights the disproportionate burden on women and smallholders and sets out immediate relief and longer-term adaptation options, including climate-resilient agronomic practices, groundwater recharge and strategic water-infrastructure investments.

The HIGRID project in the Lower Koshi River Basin complements these analyses by focusing on how local governments and communities respond to "too much and too little water" (floods and droughts) in an inclusive manner. Through support to 28 municipalities, HIGRID integrates gender equality, disability and social inclusion (GEDSI) into disaster risk-reduction planning and budgeting, scales community-based flood early-warning systems and nature-based solutions, and develops climate-resilient, inclusive value chains,

[7] Maharjan, S. B., Sherpa, T. C., & Shrestha, A. B. (2025). Thame Valley Glacial Lake Outburst Flood 2024: Causes, impacts and future risks. International Centre for Integrated Mountain Development (ICIMOD); National Disaster Risk Reduction & Management Authority (NDRRMA). https://doi.org/10.53055/ICIMOD.1101

[8] Shrestha, S., Shrestha, S., Dulal, B., & Khadgi, V. R. (2025). 2025 Drought in Nepal's Madhesh Province: A rapid situational analysis. International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.1097

thereby providing practical examples of how adaptation progress can be designed, implemented and tracked at basin scale.

The Springshed Management for Sustainable Water Resources initiative treats springs as critical socio-ecological systems and documents how high-discharge perennial springs in Nepal and other HKH countries are under stress from in-migration, rising demand, rainfall decline and land-use change. Empirical studies reveal that springs have dried up in around three quarters of surveyed local government units in Nepal, with medium to severe problems in nearly half, and that drying trends are linked to roads and infrastructure, earthquakes, climate change, and other environmental drivers.

In Bhutan, action research on residential space heating compares traditional *bukhari* stoves with Himalayan rocket stoves in ten high-altitude households using low-cost air quality sensors and fuelwood measurements. The study finds that, despite confounding forest fire events, households using Himalayan rocket stoves exhibit lower indoor $PM_{2.5}$ and CO concentrations and achieve substantial reductions in fuelwood consumption (up to 66 per cent in Uesu and 46 per cent in Katsho), indicating mitigation and health co-benefits alongside reduced exposure to cold stress.

The cross-country analysis[9] of disability and disaster in the HKH region brings an explicit focus on non-economic losses and damages and on intersectional vulnerability to climate-related disasters. Using harmonised national surveys and disaster data for Bangladesh, India, Nepal and Pakistan, the research shows that disability is concentrated among older populations, people with low literacy and residents of remote, hazard-prone mountain areas, and that living in high-hazard districts is independently associated with higher disability prevalence after controlling for socio-economic factors. The study concludes that disaster risk is a structural driver of inequality, and that disability must be considered as a climate justice and adaptation challenge in policy and practice.

HICAP and HI-AWARE also contribute substantially to Category B by analysing climate risks and adaptation options across glacier- and snowmelt-dependent river basins and piloting concrete responses. HICAP's action-research and piloting pillars include Resilient Mountain Villages and community-based flood early-warning systems (CB-FEWS), which provided communities with tools, technologies and capacities to detect and respond to floods and other water-induced hazards. CB-FEWS was recognised through the UNFCCC Momentum for Change - Lighthouse Activity Award in 2016, and HICAP's work on gender-sensitive vulnerability assessments and livelihood diversification highlighted the importance of flexibility, empowerment and social protection in reducing risks for poor and marginalised groups. HI-AWARE's comparative, cross-scalar research across 12 sites in the Indus, Ganges, Gandaki and Teesta basins documents how increasing temperatures, heat waves and more intense precipitation events interact with socio-economic drivers to shape vulnerability. Its findings show that projected temperature increases of 3.5–6 degrees by 2100 in these basins far exceed the 1.5–2 degree global targets and that downstream water consumption, driven by socio-economic development, will be a dominant driver of future water gaps, with important implications for agriculture and food security. HI-AWARE's pilot interventions and adaptation pathways work – including climate-smart water-management practices, gender-sensitive livelihood measures and migration as an adaptive strategy – provide evidence on the effectiveness, limits and scalability of community-based adaptation across mountain and downstream contexts.

Category C: Ecosystems and nature-based solutions

Category C: Ecosystems and nature-based solutions is addressed through ICIMOD's portfolio of landscape, biodiversity and ecosystem-based adaptation work, which contributes to understanding climate impacts on ecosystems and to testing and scaling nature-based solutions (NbS) in mountain and downstream environments. The Kailash, Springs and Rangelands initiatives, in particular, respond to Category C

[9] ICIMOD. (2026). HKH Disability and Disaster Report 2025-2026. HimalDoc.

sub-items on opportunities and challenges of implementing NbS, climate change impacts and risks for cryosphere-related ecosystems, and vulnerability and resilience of coupled human–natural systems.

KSLCDI operationalises a transboundary ecosystem approach to conserve biodiversity, sustain ecosystem services and enhance livelihoods in the Kailash Sacred Landscape across China, India and Nepal. The initiative applies integrated ecosystem management, ecosystem-based adaptation, sacred landscape and value-chain approaches, and establishes long-term environmental and socio-ecological monitoring sites, including GLORIA vegetation plots, to track climate and land-use change impacts on high-altitude ecosystems.

The Springshed Management initiative applies a six-step protocol that includes spring inventory and mapping, hydrogeological assessment, analysis of social, gender and governance dimensions, recharge-area and springshed planning, and hydrological and socio-economic impact assessment. This approach demonstrates how springshed management functions as a nature-based solution that can improve water security while generating co-benefits for biodiversity, climate resilience and local livelihoods in mountain communities.

The Sustainable Management of High-Altitude Rangelands as Nature-based Solutions intervention addresses alpine and sub-alpine rangelands and wetlands as critical socio-ecological systems that support biodiversity, carbon storage, water regulation and the livelihoods and cultures of an estimated 20 million pastoralists and agro-pastoralists in the HKH. Through co-management pilots, rotational grazing, restoration activities and tools such as the Bhutan *tsamdro* and herder mobility dashboard, the programme shows that community-led interventions can increase fodder availability and soil organic carbon within a few years while reducing degradation and strengthening pastoralist resilience.

Both HICAP and HI-AWARE incorporate ecosystem-based and nature-based approaches into their adaptation portfolios, responding to Category C priorities. HICAP demonstrates how ecosystem-based adaptation and payment for ecosystem services can be tailored to different agro-ecological zones, for example through Resilient Mountain Villages that refine local practices such as *jholmol* bio-pesticide and fertiliser using scientific knowledge, alongside sustainable energy technologies such as solar power and biogas. HI-AWARE pilots and evaluates ecosystem-based measures such as wetland restoration and sustainable water management as part of climate-resilient water and livelihood strategies, underscoring the importance of integrating NbS into basin-level adaptation planning.

The Thame GLOF investigation, the HKH-wide glacier-change analysis and the HKH Glacier Outlook all speak to Category C(b) by documenting how rapid cryospheric change reshapes mountain ecosystems and hazard regimes. Together they link multi-decadal glacier mass-balance trends and regional patterns of retreat to increased risks of glacial lake outburst floods and downstream geomorphic change, thereby providing essential evidence for ecosystem-based and nature-based solutions that account for evolving cryosphere–water–ecosystem interactions.

Category D: Mitigation, related technologies, and GHG emissions and reporting

ICIMOD supports Category D: Mitigation, related technologies, and GHG emissions and reporting by improving understanding of emissions, removals and co-benefits of mitigation actions in mountain and regional contexts and by informing science-based reporting and policy decisions. This includes methodological support and data for REDD+ and land-use, land-use change and forestry (LULUCF), analyses of short-lived climate pollutants such as black carbon, and work on sustainable mountain economies, renewable energy and just transitions.

The Clean Bricks initiative exemplifies sector-specific mitigation and technology transition informed by systematic observation and measurement. The project generated evidence for policy reform by measuring stack emissions from traditional fixed-chimney bull's-trench kilns and improved zig-zag kilns in Nepal and Pakistan, conducting energy audits for kilns using coal and biomass pellets, and establishing demonstration

kilns that served as training and learning sites. The findings show that adoption of zig-zag technology can reduce emissions by up to 600 tonnes of carbon dioxide per kiln annually, and that conversion of approximately 7,000 kilns in South Asia has already avoided an estimated 106,326.6 tonnes of carbon dioxide, with significant potential for further reduction if cleaner technologies are scaled to the region's roughly 100,000 kilns.

The residential space-heating pilot in Bhutan, described under Category B, provides complementary evidence that cleaner, more efficient heating technologies can simultaneously reduce indoor air pollution, lower fuelwood demand and decrease emissions in cold, high-altitude settlements. Together, these initiatives contribute to improved understanding of mitigation options and co-benefits in sectors that are highly relevant for mountain communities and for national climate and air-quality goals.

Category E: Cross-cutting issues

ICIMOD's work is inherently cross-sectoral and engages with knowledge systems, equity and sustainable development, thereby contributing to Category E: Cross-cutting issues. Strategy 2030 and the HKH Call to Action[10] emphasise the need to harness synergies between mitigation, adaptation and the Sustainable Development Goals, and to manage trade-offs in ways that benefit mountain communities and ecosystems.

Many of the initiatives listed in Table 1 co-produce knowledge with local communities and Indigenous Peoples, integrating Indigenous and traditional knowledge with scientific methods in risk assessments, adaptation planning and landscape management. The disability and disaster study provides a clear example of intersectional analysis that recognises disability as a climate justice and adaptation issue at the interface of gender, poverty, geography and access to services, and translates these insights into recommendations for inclusive climate and disaster risk reduction policy frameworks.

SANDEE plays a central cross-cutting role by building a critical mass of environmental and development economists in South Asia and the HKH, linking training, mentoring, research grants and policy engagement. Over two and a half decades, SANDEE has supported more than 250 research grants, trained over 1,500 professionals through summer and winter schools and other courses, and contributed more than 300 peer-reviewed journal articles and book chapters, thereby strengthening the analytical foundations for climate- and environment-related policymaking in the region. The HIGRID project and the Madhesh drought analysis further illustrate how cross-cutting approaches can integrate equity, gender and disability into climate and disaster risk governance. HIGRID works with municipalities, organisations of persons with disabilities, Indigenous and local communities, entrepreneurs and youth to embed GEDSI principles in disaster risk-reduction planning, gender-responsive budgeting and the design of nature-based and livelihood solutions in the Lower Koshi. The Madhesh drought study explicitly examines differentiated drought impacts on women and smallholder farmers and connects drought response to Sustainable Development Goals on poverty, food security, water, gender equality and climate action, thereby linking local evidence to global climate-justice discussions under the Convention and the Paris Agreement.

HICAP and HI-AWARE are also central to Category E through their emphasis on gender, equity, upstream–downstream linkages and translation of science into policy and practice. HICAP explicitly placed poor and vulnerable women and men at the centre of its research, using gender-disaggregated vulnerability assessments and targeted measures such as financial literacy training for remittance-receiving women, and generated evidence on how a combination of multiple drivers, beyond climate alone, shapes vulnerability across the region. HI-AWARE combined biophysical, socio-economic and governance analysis with stakeholder-driven adaptation pathways and has informed IPCC assessments and national adaptation processes through its contributions to the IPCC Special Reports and the Sixth Assessment Report, as well as

[10] ICIMOD. (2020). The HKH Call to Action to sustain mountain environments and improve livelihoods in the Hindu Kush Himalaya. International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.1

through datasets and working papers on climate projections, vulnerability, migration and adaptation costs and benefits.

Cooperation and capacity-building dimensions

Beyond specific research themes, ICIMOD's research and systematic observation activities are implemented through extensive cooperation with RMC governments, academic and research institutions, civil society and international partners. Regional networks such as the Himalayan University Consortium, the Upper Indus Basin Network and SANDEE foster joint research, data and knowledge sharing, and capacity building for early-career and established researchers in the HKH.

Targeted training, fellowships and technical support strengthen institutional capacities in RMCs for climate and hydrological modelling, cryosphere monitoring, GHG and short-lived climate pollutant inventories, and ecosystem-based adaptation and mitigation planning. The Springs and Rangelands initiatives, for example, have delivered practitioner manuals, field-based training, regional trainings for municipalities and sector institutions, gender-responsive capacity-building and the establishment of community resource-person networks to support sustained local observation and management[11].

Open-access data and knowledge platforms, and flagship assessments such as the *Hindu Kush Himalaya Assessment* and thematic outlooks on water, energy[12] and shocks such as COVID-19[13], improve access to regional information for Parties and for global assessments. Cooperation with the UNFCCC secretariat under the ICIMOD–UNFCCC partnership links regional research more directly to the needs of Parties for implementation of the Paris Agreement, including the Enhanced Transparency Framework (ETF) and processes under the Global Stocktake and the Global Goal on Adaptation. These cooperative and capacity-building elements respond directly to SBSTA's call to broaden participation from developing-country scientific communities in the research dialogue and to strengthen systematic observation in developing countries (FCCC/SBSTA/2025/4, Add.19-34).

Looking ahead

We appreciate the opportunity provided by the SBSTA research dialogue and the RSO work programme to share an overview of research and systematic observation in the Hindu Kush Himalaya (HKH). The mapping of research needs since SBSTA 22 and the request at SBSTA 62 to assess progress offer an important platform to better integrate mountain-focused evidence into the Convention and the Paris Agreement.

Despite this progress, the HKH region remains underrepresented in global observation networks, assessments, and climate finance and technology frameworks. Many data gaps identified since SBSTA 22 persist, and scientific contributions from HKH developing countries remain under reflected. The current RSO process provides a timely opportunity to enhance the visibility of HKH-specific risks and solutions, while strengthening regional capacities through sustained support for long-term observations, inclusive research partnerships, and better integration into global processes.

ICIMOD stands ready to continue working with the UNFCCC secretariat, Parties, and partners to advance RSO in the HKH region, including on cryosphere change, extremes, slow-onset events, and nature-based solutions, and to support key processes such as the Enhanced Transparency Framework, Global Stocktake, Global Goal on Adaptation, and work on loss and damage. Sustained investment in observation systems,

[11] Verma, R; Khadka, M (eds) (2016) Gender and pastoralism in the rangelands of the Hindu Kush Himalayas: Knowledge, culture, and livelihoods at the margins of the margins. Kathmandu: ICIMOD

[12] Hussain, A., Malla, A., Dhananjayan, P., Ahmad, B., Bajracharya, S., Maharjan, A., Nepal, M., Pandey, A., Qamer, F. M., Rasul, G., Sarangi, G. K., Shrestha, A. B., Silpakar, S., Siyal, A. W., Vaidya, R. A., & Wester, P. (2025). Together we have more power: Status, challenges, and the potential for regional renewable energy cooperation in the Hindu Kush Himalaya. International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.1090

[13] ICIMOD. (2020). COVID-19 impact and policy responses in the Hindu Kush Himalaya - Policy Paper. International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.2

interdisciplinary research, and institutional capacity will be critical to inform ambitious and equitable climate action in the decade ahead.

Annex 1: Flagship HKH assessments and outlooks relevant to SBSTA

Geographic scope: HKH regional

Timeline: Ongoing

RSO research needs (A–E)

- Category A: Understanding climate change, related climate data, and scenarios. Integrated assessment of climate trends, cryosphere change and scenarios.
- Category B: Adaptation, loss and damage, and extreme events. Analysis of climate impacts, risks and adaptation responses.
- Category C: Ecosystems and nature-based solutions. Evidence on ecosystem services, NbS and ecosystem vulnerability.
- Category E: Cross-cutting issues. Regional synthesis and support to global assessment processes.

Summary of research

The *Hindu Kush Himalaya Assessment* provides the first comprehensive assessment of the state of the HKH environment, societies and economies, synthesising data on climate trends, cryosphere change, water resources, biodiversity, livelihoods and governance. The WISE Outlook and related publications build on this foundation to provide updated analysis of water, ice, societies and ecosystems and to explore future scenarios under different warming pathways and policy choices.

These assessments combine observational data, remote-sensing products, modelling, scenario analysis and stakeholder engagement to inform both regional policy processes and global assessments, including IPCC reports. They highlight, among other findings, that even under 1.5-degree global warming, substantial glacier loss is expected in the HKH; that climate change is intensifying extremes and compounding risks across water, energy and food systems; and that mountain communities face intersecting vulnerabilities that require integrated, multi-sectoral responses. These publications have provided contributions to IPCC assessment cycles and other global science–policy processes and have enhanced the visibility of the HKH region and its research gaps and needs within global climate and development agendas.

Key outputs

1. **The Hindu Kush Himalaya assessment: Mountains, climate change, sustainability and people**. (Wester, P., Mishra, A., Mukherji, A., & Shrestha, A. B. (2019). The Hindu Kush Himalaya assessment: Mountains, climate change, sustainability and people. Springer International Publishing. https://doi.org/10.1007/978-3-319-92288-1).
2. **Water, ice, society, and ecosystems in the Hindu Kush Himalaya: An outlook.** (Wester, P., Chaudhary, S., Chettri, N., Jackson, M., Nepal, S., & Steiner, J. F. (2023). Water, ice, society, and ecosystems in the Hindu Kush Himalaya: An outlook. International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.1028).
3. **Together we have more power: Status, challenges, and the potential for regional renewable energy cooperation in the Hindu Kush Himalaya.** (Hussain, A., Malla, A., Dhananjayan, P., Ahmad, B., Bajracharya, S., Maharjan, A., Nepal, M., Pandey, A., Qamer, F. M., Rasul, G., Sarangi, G. K., Shrestha, A. B., Silpakar, S., Siyal, A. W., Vaidya, R. A., & Wester, P. (2025). Together we have more power: Status, challenges, and the potential for regional renewable energy cooperation in the Hindu Kush Himalaya. International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.1090).

4. **Review of climate action and environmental policies of the Hindu Kush Himalayan region - Summary for policymakers.** (Kandel, P. (2025). Review of climate action and environmental policies of the Hindu Kush Himalayan region - Summary for policymakers. International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.1092).
5. **COVID-19 impact and policy responses in the Hindu Kush Himalaya - Policy Paper.** (ICIMOD. (2020). COVID-19 impact and policy responses in the Hindu Kush Himalaya - Policy Paper. International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.2).
6. **Lessons from the COVID-19 pandemic for the Hindu Kush Himalaya countries to prepare for future shocks and disruptions.** (ICIMOD. (2025). Lessons from the COVID-19 pandemic for the Hindu Kush Himalaya countries to prepare for future shocks and disruptions. International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.1095).

Annex 2: SANDEE – The South Asian Network for Development and Environmental Economics

Geographic scope: South Asia and the HKH region

Timeline: 1999-ongoing

RSO research needs (A–E)

- Category A: Understanding climate change, related climate data, and scenarios. Economic research that interprets climate and environmental data for policy.
- Category E: Cross-cutting issues. Capacity-building in environmental and resource economics and support for policy-relevant research.

Summary of activities and relevance

SANDEE is a regional network that strengthens the capacity of researchers and institutions to conduct rigorous, policy-relevant research at the intersection of economic development, poverty and environmental change. It operates through competitive research grants, structured mentoring, training programmes and policy engagement, with an explicit focus on building a critical mass of environmental and development economists in South Asia and the HKH.

Over 25 years, SANDEE has supported more than 250 research grants, trained over 1,500 professionals through summer and winter schools and other courses, and produced around 300 peer-reviewed publications and 100 policy briefs, contributing to a pipeline of economists who use climate and environmental data to inform development and environmental policy. Alumni surveys in 2019, 2022 and 2025 show that SANDEE researchers are actively engaged in teaching, policy advising and applied research on climate- and environment-related topics.

For more information about SANDEE, please visit here: https://www.icimod.org/initiative/sandee/.

Key outputs

1. Research grants and publications on the economics of climate change, natural resource management and environmental policy. For a complete list of publications, please visit this link: https://www.icimod.org/initiative/sandee-publications/.
2. Training programmes in environmental and resource economics, research methods and policy communication.
3. A regional community of practice linking universities, research institutes, policymakers and practitioners.

Annex 3: Action research on residential space heating as a gender-inclusive and socially responsible solution

Main partner organisations: Foreign, Commonwealth & Development Office (FCDO), Government of the United Kingdom; local governments of Katsho and Uesu Gewogs in Haa; Dzongkhag Administration, Haa, Royal Government of Bhutan; Jigme Singye Wangchuck School of Law (JSW Law), Bhutan.

Timeline: 2024–2025 (ongoing pilot)

Geographic scope: Bhutan and Nepal, with major focus on high-altitude settlements in Bhutan.

RSO research needs (A–E)

- Category B (Adaptation, loss and damage, and extreme events): The project contributes to understanding how improved space-heating technologies can reduce health risks and vulnerability to cold stress and indoor air pollution in climate-vulnerable mountain communities.
- Category D (Mitigation, related technologies, and GHG emissions and reporting): The study generates evidence on emission reductions and fuelwood savings associated with cleaner residential heating technologies.
- Category E (Cross-cutting issues): The project adopts a gender-inclusive, socially responsible approach that considers differentiated impacts and benefits for women and marginalised groups.

Summary of research

Objective: By examining the household air pollution levels and fuelwood consumption rates between the two stove types, the study seeks to generate evidence-based recommendations to inform policies and programmes that promote cleaner, more efficient and sustainable heating technologies in rural communities. The main objectives of the pilot action research are:

1. To measure and compare $PM_{2.5}$ levels from the use of traditional Bukhari and Himalayan Rocket Stoves, using before and after design.
2. To assess and compare the amount of fuelwood consumed by each stove type under similar household conditions.

Methodology: Ten households were randomly selected across Katsho and Uesu Gewogs (village blocks) using a lottery system to avoid bias. These households, located between 2640–3100 meters elevation, used traditional Bukhari stoves and later adopted Himalayan Rocket Stoves. Air quality and fuelwood use were analysed during two selected periods. Non-intervention data with Bukhari stoves was collected from 28 February to 12 March 2025. Himalayan rocket Stoves were installed on March 13, followed by post-intervention data collection from 14 to 25 March 2025. The measured PM (particulate matter) 2.5 and CO (carbon monoxide) was used to assess indoor air quality and correspondingly measured ambient air quality in the two Gewogs (Katsho and Uesu). Atmos low-cost air quality monitoring sensors were used in ten households and AirBeam air quality monitoring sensors were used for measuring the ambient air quality in two Gewog offices. A structured questionnaire survey was conducted to assess fuelwood consumption, and each household was also provided with a pre-weighed quantity of fuelwood for meticulous estimation of fuelwood consumption. In addition, emissions of PM2.5, CO, and CO2 in the Haa district were estimated using emission factors sourced from published South Asian literature.

Main findings and conclusions: The concentrations of indoor air pollutants were compared during the usage/operations of old Bukhari stoves and Himalayan rocket stoves. Overall, households while using

Himalayan rocket stoves showed slightly lower PM2.5 and CO concentrations as compared to those at the time of using old Bukhari stoves. Results showed that only three out of ten households exhibited higher concentrations during the use of Himalayan rocket stoves. The increase in indoor and ambient air pollution during the Himalayan rocket stove installation and measurement period can be attributed to a massive forest fire (18 to 21 March 2025) near the settlement, which significantly impacted air quality. The findings indicate that the Himalayan rocket stove offers significant potential to reduce indoor air pollution compared to traditional old Bukhari stoves. The rocket stove not only consumes less fuelwood for heating but also demonstrates substantial reductions in household fuelwood usage up to 66% in Uesu and 46% in Katsho. These results suggest that the Himalayan rocket stoves have the potential to reduce indoor air pollutants compared to traditional old Bukhari stoves. It can also reduce emissions and fuelwood consumption by 51%. Further analysis is planned to address inconsistencies and to consolidate findings, but the pilot already demonstrates that cleaner heating technologies can play an important role in climate-resilient and low-emission development pathways in cold, high-altitude settings.

Key outputs

1. **Comparative Study of Traditional and Improved Heating Stoves: Impacts on Indoor Air Quality and Fuelwood Use in Rural Bhutan.** (ICIMOD. (2026). Comparative Study of Traditional and Improved Heating Stoves: Impacts on Indoor Air Quality and Fuelwood Use in Rural Bhutan. HimalDoc. Access at: https://lib.icimod.org/records/y84nt-42p52)
2. **Pilot datasets** on indoor and ambient air quality and household fuelwood use in high-altitude settlements in Bhutan.
3. **Practical learning** for scaling cleaner heating technologies in collaboration with local governments and communities.
4. Strengthened **collaboration** between ICIMOD, development partners and national agencies on integrated air-pollution, health, gender and climate objectives.

Annex 4: Clean Bricks

Main partner organisations: Foreign, Commonwealth & Development Office (FCDO), Government of the United Kingdom; Climate and Clean Air Coalition (CCAC); national partners in Nepal, Pakistan, India and Bangladesh

Timeline: 2014–2021

Geographic scope: Nepal, Pakistan, India and Bangladesh, with major focus on Nepal and Pakistan

RSO research needs (A–E)

- Category B (Adaptation, loss and damage, and extreme events): By reducing air pollution and improving working conditions, the project supports more resilient livelihoods in a sector that employs many vulnerable workers.
- Category D (Mitigation, related technologies, and GHG emissions and reporting): The project generates empirical evidence on the mitigation potential of improved brick-kiln technologies and alternative fuels.
- Category E (Cross-cutting issues): The initiative strengthens regional collaboration and knowledge exchange among brick sector stakeholders and supports policy reform.

Summary of research

Objective: The overarching objective is to support transformation of the South Asian brick sector into a cleaner and healthier industry with significantly reduced environmental impacts. The project seeks to demonstrate the technical and economic feasibility of improved kiln designs and cleaner fuels, and to inform policy reforms and sectoral strategies.

Methodology: The project generated evidence for policy reform by measuring stack emissions from both traditional and improved kilns. It combined capacity building with targeted policy recommendations to support the adoption of zig-zag technology. Showcase kilns were established across five provinces in Nepal, serving as demonstration sites where nearby kiln owners could observe, learn, and adopt the technology; these early adopters also acted as master trainers. In addition, two similar demonstration kilns were set up in Punjab, Pakistan. Energy audits were conducted in brick kilns using biomass pellets, coal, and mixed fuels (coal and biomass pellets) to assess the feasibility of replacing coal with densified biomass. Given the sector's heavy reliance on coal, both climate and economic considerations strongly support a transition to cleaner alternative fuels.

Main findings and conclusions: The project has delivered a trifecta of benefits, social, environmental, and economic. The brick sector in South Asia, often viewed as informal, neglected, and highly polluting, has seen a positive shift through ICIMOD's efforts. By building trust and confidence among brick entrepreneurs, the project has encouraged greater openness to change, learning, and continuous improvement. The adoption of zig-zag technology, along with associated mechanization options, has the potential to reduce up to 600 tons of CO_2 emissions per kiln annually. Around 7,000 kilns in South Asia had converted from fixed-chimney to zig-zag designs, leading to an estimated reduction of 106,326.6 tonnes of carbon dioxide and associated reductions in short-lived climate pollutants such as black carbon. Additionally, the promotion of renewable energy sources, such as biomass pellets, further contributes to emission reduction. The initiative has also strengthened regional collaboration among brick sector stakeholders from Nepal, Bangladesh, Pakistan, and India, culminating in the establishment of the Federation of South Asian Brick

Kiln Associations (FABKA). There are 100000 brick kilns in South Asia, adopting zig-zag or cleaner technologies will have potential in reducing CO2 and Black carbon. However, zig-zag remains an intermediate cleaner technology. More advanced options, such as tunnel kilns, are significantly more efficient and cleaner, but their high capital cost remains a major constraint.

For more information on the project, please visit: https://www.icimod.org/initiative/air-pollution-solutions/.

Key outputs

1. **A Comparative Study of Stack Emissions from Straight-Line and Zigzag Brick Kilns in Nepal.** (Nepal, S., Mahapatra, P. S., Adhikari, S., Shrestha, S., Sharma, P., Shrestha, K. L., Pradhan, B. B., & Puppala, S. P. (2019). A Comparative Study of Stack Emissions from Straight-Line and Zigzag Brick Kilns in Nepal. *Atmosphere*, *10*(3), 107. https://doi.org/10.3390/atmos10030107).
2. **Brick sector in Pakistan - Fact Sheet.** (ICIMOD. (2019). Brick sector in Pakistan - Fact Sheet. International Centre for Integrated Mountain Development (ICIMOD), access here: https://lib.icimod.org/records/hbn2k-xkm21).
3. **Brick sector in Nepal - Fact Sheet.** (ICIMOD. (2019). Brick sector in Nepal - Fact Sheet. International Centre for Integrated Mountain Development (ICIMOD), access here: https://lib.icimod.org/records/1t4jt-maf42).
4. **Brick sector in Bangladesh - Fact Sheet.** (ICIMOD. (2019). Brick sector in Bangladesh - Fact sheet. International Centre for Integrated Mountain Development (ICIMOD), access here: https://lib.icimod.org/records/yvvez-8yt13).
5. **Burnt clay brick sector in India - Fact Sheet.** (ICIMOD. (2019). Burnt clay brick sector in India - Fact sheet. International Centre for Integrated Mountain Development (ICIMOD), access here: https://lib.icimod.org/records/7g3bz-qnp57).
6. Demonstration kilns and training modules that support technology transfer and adoption of cleaner kiln designs.
7. Regional **collaboration** among brick sector stakeholders and the establishment of FABKA.

Annex 5: Kailash Sacred Landscape Conservation and Development Initiative (KSLCDI)

Main partner organisations

- **China:** Kunming Institute of Botany (KIB) and Chengdu Institute of Biology (CIB) of the Chinese Academy of Sciences (CAS)
- **India:** Ministry of Environment, Forest and Climate Change (MoEFCC); G.B. Pant National Institute of Himalayan Environment and Development (GBPIHED); Wildlife Institute of India (WII), Central Himalayan Environment Association (CHEA); Uttarakhand State Biodiversity Board
- **Nepal:** Ministry of Forests and Environment (MoFE); Department of Forest and Soil Conservation (DoFSC); Department of Hydrology and Meteorology (DHM); Department of National Parks and Wildlife Conservation (DNPWC); Department of Plant Resources (DPR), Tribhuvan University; Research Centre for Applied Sciences and Technology (RECAST); Ujyalo Nepal; HIMAWANTI Nepal, National Trust for Nature Conservation (NTNC); Dabur Nepal; Provincial and district forest authorities in Far-Western Province, Community forest user groups; Women's cooperatives, and local governments.
- **International:** ICIMOD (lead); UNEP, GIZ, DFID

Timeline: 2012–2022 (Phase I and II completed; activities now being institutionalised)

Geographic scope: Regional/Transboundary. The initiative was implemented across the Kailash Sacred Landscape spanning the Tibet Autonomous Region of **China**, Uttarakhand in **India**, and western **Nepal** (Humla, Baitadi, Bajhang, and Darchula), covering about 31,000 km² around Mount Kailash and linked headwater ecosystems and communities.

RSO research needs (A–E)

- Category C(a): Opportunities and challenges of implementing nature-based solutions in land systems in support of climate adaptation and mitigation. The project addressed it with the primary focus on the holistic NBS via participatory ecosystem management, livelihoods, and transboundary governance.
- Category C(b): Climate change impacts and risks for the cryosphere and related ecosystems. Activities like the glacier retreat/snowmelt variability monitoring, glacial lake outburst flood (GLOF) risk mapping, cryosphere-water-ecosystem linkages in high-altitude basins were also carried out in the project.
- Category C(d): Vulnerability of natural and human ecosystems and strengthening their resilience. Was addressed via land cover/fragmentation analysis, human-wildlife conflict (HWC) mitigation, and resilience-building pilots, including studies on high-altitude grazing lands.
- The initiative also has a secondary contribution to C(c): Emissions and removals from terrestrial ecosystems, and information on ecosystems with high-carbon reservoirs through agroforestry, ecosystem-service management, and landscape interventions with mitigation co-benefits.

Summary of research

Objective: KSLCDI aimed to operationalise a transboundary ecosystem approach to conserve biodiversity, sustain ecosystem services and enhance livelihoods in the Kailash Sacred Landscape amidst climate change and socioeconomic pressures. The initiative has a twenty year goal to ensure the transboundary Kailash Sacred Landscape is conserved and developed sustainably. Phase I laid this foundation through five major components: innovative livelihoods, ecosystem management, access and benefit sharing, long-term

conservation and monitoring, and regional cooperation/knowledge management. Phase II specifically focused on institutionalizing the Regional Cooperation Framework (RCF), scaling up climate-resilient livelihoods, and establishing long-term socio-ecological monitoring.

Methodology: The KSLCDI employed an integrated landscape approach based on the Regional Cooperation Framework, community based local ecosystem management plans, action research in pilot sites, harmonized research protocols, and long term environmental and socio ecological monitoring. Core methods include Integrated Ecosystem Management (IEM) and Ecosystem based Adaptation (EbA), supported by standardized GLORIA vegetation monitoring sites. The approach integrated ecosystem service valuation, land use and cultural heritage mapping, and vulnerability assessments measuring exposure, sensitivity, and adaptive capacity. It also applied a Value Chain approach to strengthen "sacred" mountain brands. Transboundary cooperation was facilitated through harmonized research protocols, "Landscape Journeys" for policy dialogue, and community-based monitoring systems. Scientific evidence was paired with local knowledge, capacity building, and participatory natural resource management to design conservation and livelihood interventions aligned with multi-scale realities across borders.

Main findings and conclusions: The initiative generated strong evidence that nature-based and ecosystem-based approaches can be operationalized in transboundary mountain systems through locally grounded yet regionally coordinated action. Key achievements included community-based ecosystem management plans, harmonized three-country vegetation and cultural heritage maps, long-term environmental and socio-ecological monitoring sites, the first permanent GLORIA site in the Himalayan region, and improved information on glaciers, forests, land use land cover, rangelands, and socioeconomic conditions. These outputs helped fill critical data gaps while also informing planning for water security, biodiversity conservation, livelihoods, and ecosystem resilience. Through Kailash project, 91,370 people benefited from project activities, including 37,844 women, people and produced 120 publications and related knowledge products and pilot value-chain interventions increased incomes by up to 10% or more in some communities. Recent research linked to the landscape strengthens this evidence base: a 2021 study on KSL China found that integrated landscape management reduced socio-ecological vulnerability and improved resilience, while a 2024 glacier study in the transboundary KSL reported 1,941 glaciers covering $1{,}169.04 \pm 27.71$ km^2 in 2020 and a 25.5% area retreat since 1990, underscoring mounting cryosphere risks for ecosystems and livelihoods.

KSLCDI serves as a global model for the CBD (Convention on Biological Diversity) Programme of Work on Mountain Biodiversity. It contributes to the Paris Agreement's emphasis on NBS for adaptation and mitigation (Articles 5 and 7) goals by monitoring cryosphere changes and promoting ecosystem-based adaptation (EbA) in one of the world's most climate-sensitive regions. It provides ground-level evidence for IPCC AR7 regarding high-altitude tipping points and supports the UN Decade on Ecosystem Restoration. The initiative also has strong linkages to other global science and policy with engagement to the CBD, IPBES, UNFCCC, CITES, and the Global Landscapes Forum, while Phase II deepened the science-policy interface through academic platforms such as Kailash CAFE and through locally grounded planning and scaling processes. KSLCDI provide a strong example of how mountain landscape research can translate into action on ecosystem resilience, community adaptation, and cross-border cooperation.

For more information on the project, please visit: https://www.icimod.org/initiative/ksl/.

Key outputs

1. KSLCDI has produced 120 publications and related knowledge products. Some major ones include:
    a. ICIMOD. (2020). Kailash Sacred Landscape Conservation and Development Initiative (KSLCDI) Phase I report 2012-2017. International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.945.

b. Nepal, M., Das, S., Rai, R. K., Bhatta, L. D., Somanathan, E., Kotru, R., Khadayat, M. S., Rawal, R. S., & Negi, G. C. S. (2017). Valuation of Ecosystem Services in the Kailash Sacred Landscape; ICIMOD Research Report 2017/2. International Centre for Integrated Mountain Development (ICIMOD). Access here: https://lib.icimod.org/records/jbheg-v3796.
c. Bubb, P., Soesbergen, A. V., Bisht, N., Singh, G., Joshi, S., Aryal, K., Danks, F. S., Rawat, G. S., Bhuchar, S., Wu, N., Kotru, R., & Yi, S. (2017). Planning Management for Ecosystem Services: An Operations Manual. International Centre for Integrated Mountain Development (ICIMOD). Access here: https://lib.icimod.org/records/6ayrd-yfh98.
d. NA, . (2015). An Integrated Springshed Management Approach Linking Science, Policy, and Practice; Collaborative applied research in the Kailash Sacred Landscape (India and Nepal). International Centre for Integrated Mountain Development (ICIMOD). Access here: https://lib.icimod.org/records/c06pm-qce77.
e. Shi, P.-. li ., Duan, C., Wang, L., Wu, N., Kotru, R., & Gurung, J. (2021). Integrated landscape approaches to building resilience and multifunctionality in the Kailash Sacred Landscape, China. In Journal of Mountain Science (Numbers 08 April 2021). https://doi.org/10.1007/s11629-020-6500-x

2. The **Kailash Knowledge-based Information System (KBIS) and other data platforms** that support long-term monitoring and planning.
3. KSLCDI is built around **regional cooperation** among China, India, and Nepal and operationalized through multi-level partnerships linking governments, research institutions, civil society, communities, and the private sector.
4. **Capacity-building** has included community-based ecosystem management, responsible tourism, participatory NRM planning, agroforestry, transboundary forums and exchanges, and academic/research networking through Kailash CAFE.

Annex 6: Springshed Management for Sustainable Water Resources

Main partner organisations

- **Bhutan**: Ministries of Water Resources (Bhutan) Watershed Management Division and Department of Water; Department of Forests and Park Services (Bhutan)
- **India**: Ministries of Water Resources (India); GIZ India; Advanced Center for Water Resources Development and Management (ACWADAM); NITI Aayog; G.B. Pant National Institute of Himalayan Environment; Indian Institute of Technology (IIT) Roorkee; Local communities and local governments in India
- **Nepal**: Ministries of Water Resources (Nepal, India, Bhutan; Local Provincial Economic Development (LPED) project in Nepal; various local municipalities in Nepal (e.g., Kavre, Dhankuta); local NGOs (e.g., Nepal Water Conservation Foundation, Himalayan Grassroots Women's Network); Local communities and local governments in Nepal
- **Bangladesh**: Watershed Management Division
- **International**: ICIMOD (lead); Swiss Agency for Development and Cooperation (SDC); GIZ; FAO

Timeline: 2015–ongoing (initial pilot projects commenced in 2015, ongoing efforts for springshed management)

Geographic scope: Regional / multi-country. Over the spring dependent mountain systems across HKH, with documented work and outputs in Nepal, India, Bhutan and Bangladesh, and knowledge products framed for all ICIMOD regional member countries.

RSO research needs (A–E)

- Category C(a): Opportunities and challenges of implementing nature-based solutions in land systems in support of climate adaptation and mitigation. Focus on springs as critical water sources under threat from climate and land-use change, and on springshed restoration as a nature-based solution.
- Category C(d): Vulnerability of natural and human ecosystems and strengthening their resilience. Analysis of the vulnerability of coupled human–natural systems that depend on springs, and interventions to build resilience.
- Category B: Adaptation, loss and damage, and extreme events. Evidence on how springshed management can reduce water insecurity and associated climate risks in mountain communities.

Summary of research

Objective: The Springshed Management initiative aims to enhance community resilience to water scarcity by reviving and sustainably managing springsheds. This project focuses on restoring groundwater recharge, improving water quality, and promoting integrated water resource management practices in the HKH region, benefitting rural communities reliant on spring water.

Methodology: The initiative is built around a six-step protocol developed by ICIMOD and partners, combining spring inventory and mapping, hydrogeological assessment, analysis of social, gender and governance dimensions, recharge-area and springshed planning, and hydrological and socio-economic impact assessment to support evidence-based scaling. The protocol was developed through regional consultation and adapted to RMC contexts; implementation emphasises participatory science, local government engagement and women's participation in decision-making and technical training.

Main findings and conclusions: The initiative has generated a strong body of applied research and decision-support evidence. A 2021 ICIMOD working paper on Godavari, Nepal documented how high-discharge perennial springs are under stress from in-migration, rising demand, and long-term rainfall decline. A 2025 ICIMOD-linked citizen science dataset mapped spring sources in Kavre, Nepal and made them available for broader analysis and decision support. A 2023 Nepal-wide study found that springs had dried up in 74% of local government units, with medium to severe problems in 44%, and identified roads and infrastructure, earthquakes, and climate change as major drivers. A 2024 watershed study in far-west Nepal mapped 1,122 springs, found that 73% showed a continuous decline in flow and 2% had already dried up, and linked drying trends to land-use change, rising temperature, intense rainfall, population growth, and road expansion. A 2024 socioeconomic assessment found positive benefit-cost ratios in three of four scenarios, showing that spring revival can be economically justified under suitable local conditions. Research indicates that roughly 50% of springs in the Indian Himalayan Region have either dried up or show significantly reduced discharge due to climate change and land-use shifts.

The project contributes to SDG 6 (Clean Water and Sanitation) and supports national climate goals (NAPs) in Nepal, Bhutan, and India. The data is also relevant for IPCC assessments on mountain water cycles and groundwater depletion. The project aligns with global initiatives such as the Sustainable Development Goals (SDGs), particularly Goal 6 (Clean Water and Sanitation) and Goal 13 (Climate Action). It contributes to the objectives of the UN Framework Convention on Climate Change (UNFCCC) by promoting adaptive practices in vulnerable regions.

For more information on the project, please visit: https://www.icimod.org/initiative/rms/springshed-revival-and-management/.

Key outputs

1. ICIMOD's springs and springshed management work has produced practitioner manuals, technical and policy papers, peer-reviewed journal articles, datasets, and digital decision-support tools. Some major ones are as follows:
    a. Shrestha, R. B., Desai, J., Mukherji, A., Dhakal, M., Kulkarni, H., Mahamuni, K., Bhuchar, S., & Bajracharya, S. (2018). Protocol for reviving Springs in the Hindu Kush Himalayas: A Practitioner's Manual. International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/icimod.735.
    b. ICIMOD. (2021). Springshed management in the Himalaya: Ensuring water security and enhancing climate resilience. International Centre for Integrated Mountain Development (ICIMOD). Access here: https://lib.icimod.org/records/25d10-afz68.
    c. Dhakal, M. P., Khadka, K., Pokhrel, G., Desai, J., Kingsley, C., Barola, Y., & Bhuchar, S. (2021). Springs in the Godavari landscape, Nepal: Mapping, governance, and revival. Working paper. International Centre for Integrated Mountain Development (ICIMOD). Access here: https://lib.icimod.org/records/yg93x-7qz60.
    d. Thapa, S., Pandit, A., Bhuchar, S., & Dhakal, M. (2025). Citizen science approach for springshed management: A comprehensive community-driven mapping and dataset of spring sources in Kavre, Nepal. *Data in Brief; 60, Article 111466.* https://doi.org/10.1016/j.dib.2025.111466.
    e. Thapa, B., Bhattarai, C., Dahal, N., Tiwari, S., & Jacobsen, D. (2023). Drying of Springs in the Himalayan Region of Nepal: Perspectives of Local Government Leaders on Causes, Consequences, and Conservation Efforts. In Mountain Research and Development (Vol. 43, Number 4, pp. R9–R15). https://doi.org/10.1659/mrd.2023.00007.
    f. Pandit,A., Batelaan, O., Pandey, V.P., & Adhikari, S. (2024). Depleting Spring Sources in the Himalayas: Environmental Drivers or Just Perception? *Journal of Hydrology: Regional Studies; Vol. 53:101752*. https://doi.org/10.1016/j.ejrh.2024.101752.

g. Butte, G., Khadka, K., Aldinucci, A., Macaulay, B., & Bhuchar, S. (2024). Spring Revival in the Mid-Hills of the Himalaya: A Socioeconomic Assessment Using Benefit–Cost Analysis. In Mountain Research and Development (Vol. 44, Number 4, pp. R12–R25). https://doi.org/10.1659/mrd.2024.00020

2. The HKH Springs portal and decision-support system, which provides spatial and socio-economic information on springs to support planning and knowledge exchange.
3. The initiative is strongly collaborative and capacity oriented. It actively works with **local communities**, **local governments**, and sector agencies to mainstream springshed management into local climate-resilience planning.
4. Capacity-building has included practitioner manuals, field-based training, regional trainings for municipalities and institutions from India and Nepal, GESI-responsive trainings, and country-specific engagement in Bhutan with the Watershed Management Division and Department of Water. It has conducted regional training for over 125 practitioners on geohydrology and spring revival. Established "Community Resource Person" networks in 7 municipalities of Nepal to ensure sustained systematic observation at the local level. More recent regional cooperation also includes the HKH Springs Alliance, convened with IWMI, to align action for long-term water security and socio-ecological resilience.

Annex 7: Sustainable Management of High-Altitude Rangelands as Nature-based Solutions

Main partner organisations

- **Afghanistan**: Ministry of Agriculture, Irrigation and Livestock (MAIL);
- **Bhutan**: National Land Commission Secretariat (NLCS); Department of Livestock (DoL); and Department of Forests and Park Services (DoFPS); Bhutan Highland Development Programme
- **China**: Chengdu Institute of Biology, Chinese Academy of Sciences (CAS); Ministry of Agriculture and Rural Affairs of the People's Republic of China (MARA); National Forestry and Grassland Administration (NFGA); Sichuan Grassland Sciences Academy (SGSA); Lanzhou University; Tibetan Academy of Agricultural Animal Sciences; Institute of Geographical Sciences and Natural Sciences Research, CAS.
- **India**: G.B. Pant National Institute of Himalayan Environment and Development (GBPIHED); Wildlife Institute of India (WII), Government of Ladakh; Ashoka Trust for Research in Ecology and the Environment (ATREE)
- **Nepal**: Department of Livestock Services (DoLS); Department of National Parks and Wildlife Conservation (DNPWC); Nepal Agriculture Research Council (NARC); Nepal Yak Federation; Institute of Forestry, Tribhuvan University; Global Institute of Interdisciplinary Studies (GIIS);
- **Pakistan:** Pakistan Agricultural Research Council
- **International**: ICIMOD (Lead); FAO, IFAD, GIZ; IUCN

Timeline

- Regional Rangeland Programme (Phase I, II and III): 1999 –2011
- Transboundary Landscape Programmes: 2012 to 2022 (rangeland management was a component in all the transboundary landscape initiatives except HILIFE)
- 2023 – ongoing: ICIMOD formally launched this current intervention

Geographic scope: Regional / multi-country. The program works over HKH rangelands (~3.8M km^2) across 5 countries regional member countries: Afghanistan, Bhutan, China, India, Nepal, and Pakistan, with focused field action on high-altitude rangelands and agro-pastoral systems in Bhutan, Nepal, and Pakistan.

RSO research needs (A–E)

- Category C(a): Opportunities and challenges of implementing nature-based solutions in land systems in support of climate adaptation and mitigation. The project addresses this item through rangeland restoration, sustainable grazing NBS and fodder management systems enhancing the adaptive capacity.
- Category C(c): Emissions and removals from terrestrial ecosystems and information on ecosystems with high carbon reservoirs. Addresses it through taking rangelands as carbon sinks: quantifying soil organic carbon stocks in alpine/sub-alpine pastures and monitoring emissions from rangeland degradation/overgrazing.
- Category C(d): Vulnerability of natural and human ecosystems and strengthening their resilience. The project addresses this item primarily through work on improving pastoralist livelihoods, degradation tipping points, and developing climate-resilient rangelands.

Summary of research

Objective: The intervention addresses high-altitude rangelands and associated wetlands as critical socio-ecological systems that support biodiversity, ecosystem services, carbon functions, water regulation and the livelihoods and cultures of pastoralist and agro-pastoralist communities (around 20 million people in HKH rangelands). ICIMOD has prioritized rangeland management for multiple benefits as a core intervention to help HKH countries adopt inclusive policies and innovative practices to conserve, restore, manage, and sustainably use rangelands and wetlands and reverse their degradation. ICIMOD framing identifies three pillars: (i) generating robust data for policy support and advocacy, (ii) piloting innovative nature-based solutions for improved rangeland management, and (iii) strengthening national and regional networks of pastoralists and institutions through technology transfer, knowledge exchange, and capacity-building.

Methodology: The intervention combines policy and institutional analysis, participatory planning, geospatial monitoring and mapping, field-based restoration pilots and digital decision-support tools. National consultations in Nepal and Bhutan identify policy and institutional gaps and co-develop implementation plans. Key methodologies include piloting nature-based solutions (NbS) such as rotational grazing, "Landscape Journeys" for policy incentivization, and developing sustainable energy options (e.g., the DESER project) to reduce biomass pressure on fragile rangelands.

Main findings and conclusions: The intervention is producing actionable evidence on ecosystem condition, governance, and resilience. The program findings show that HKH rangelands are under pressure from climate change, environmental degradation, and socio-economic transformation, while pastoralists remain marginalized in policy processes. Its research confirmed that HKH rangelands (covering 60% of the land area) are warming at twice the global average. Piloted co-management models in Nepal and China demonstrated that community-led restoration can increase soil organic carbon and improve fodder availability by up to 20% within five years. ICIMOD's successful advocacy led to the inclusion of rangeland management in National Adaptation Plans (NAPs) and the formation of the Asian Highland Pastoralist Network. In Bhutan, ICIMOD-supported work has helped map and monitor tsamdros and herders, with the modified Tsamdro App and the dashboard that integrates grazing-area and mobility information for planning and monitoring.

The intervention also has wider science policy relevance. It provides critical data for the UNCCD on land degradation neutrality and the IPCC (AR6) on high-altitude ecosystem vulnerability, CBD (rangeland biodiversity), UNCCD (LDN targets), HKH Assessment, and Paris NDC support (NBS mitigation). ICIMOD is acting as the regional scientific hub for the UN International Year of Rangelands and Pastoralists (IYRP 2026). Through IYRP 2026, ICIMOD is using this work to elevate pastoralist voices in regional and global dialogues, support the formation of national yak herder federations in Bhutan and Nepal, and build toward a broader HKH Yak Network. This strengthens the role of Indigenous and local knowledge, peer exchange, and cross-border collaboration in resilient rangeland governance.

For more information on the intervention, please visit: https://www.icimod.org/ecosystems-landscapes/rangelands/.

Key outputs

1. ICIMOD's rangeland work has produced a mix of peer-reviewed papers, technical publications, governance/process documents, and digital decision-support tools. Some major publications include:
    a. Uddin, K., Shaoliang, Y., Shakya, B. *et al.* Monitoring spatio-temporal change of rangeland vegetation in Bhutan to inform sustainable rangeland management. *Discov Geosci* 4, 56 (2026). https://doi.org/10.1007/s44288-026-00434-4.

b. ICIMOD. (2026). Rangeland and wetland management in the Hindu Kush Himalaya: Compendium of best practices (p. 98). International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.1112.
c. Wangchuk, K., Wangdi, J. & Dorji, T. Governance of rangeland in Bhutan: Institutions and policy initiatives. *Pastoralism* 13, 20 (2023). https://doi.org/10.1186/s13570-023-00284-6.
d. Ning, W., Joshi, S., & Shaoliang, Y. (2025). Introduction: Pastoral resilience in a changing world in the Hindu Kush Himalaya. In Nomadic Peoples (Vol. 29, Number 1, pp. 1–11). Liverpool University Press (LUP). https://doi.org/10.3828/whpnp.63837646691062.
e. Verma, R., & Khadka, M. (2016). Gender and Pastoralism in the Rangelands of the Hindu Kush Himalayas: Knowledge, Culture, and Livelihoods at the Margins of the Margins. International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.633.

2. The Bhutan *tsamdro* and herder mobility dashboard and other geospatial tools that support grazing-area and mobility planning.
3. The intervention is explicitly built on regional cooperation, national policy engagement, and capacity strengthening. It has been supporting country consultations, policy harmonization, institutional coordination, and regional work planning; promotes technology transfer and knowledge exchange; and strengthens pastoralist and institutional networks.
4. Documented capacity-building elements include participatory planning workshops in Nepal and Bhutan, use of ecosystem-service planning tools, training on digital rangeland data collection, co-development of tsamdro management processes, and support for pastoralist federations and regional herder networks.
5. It has established the Nepal Yak Federation in Bhutan, India, and Nepal to enhance their capacity to raise their agenda, influence national policies, map grazing areas and empower local herders. These networks were also used as platforms for practical work such as grazing area mapping. It has Conducted regional training on Geo-informatics for Rangeland Resources Management for RMC government officials to improve systematic observation.

Annex 8: Disability and disaster in the HKH region- a cross-country analysis of disability patterns and disaster linkages in Bangladesh, India, Nepal and Pakistan

Timeline: July 2025-ongoing

Geographic scope: Pakistan, India, Nepal and Bangladesh

RSO research needs (A–E)

- Category B: Adaptation, loss and damage, and extreme events. Analysis of how climate-related disasters contribute to disability and multi-dimensional vulnerability.
- Category E: Cross-cutting issues. Intersectional analysis of disability, gender, poverty and geography, and implications for climate justice and inclusive adaptation.

Summary of research

Objective: The study compiles and analyses secondary data on the socio-economic characteristics of persons with disabilities (PwDs) in the HKH region and examines linkages between disability and disaster risk, with four specific objectives: to explore data availability and comparability; to assess data quality; to analyse socio-economic characteristics of PwDs; and to examine relationships between disaster exposure and disability in mountain contexts.

Methodology: The research adopts a comparative, cross-country analytical framework, drawing on nationally representative household surveys harmonised across four countries (Bangladesh HIES 2022; India NSS 76th Round 2018; Nepal NLSS-IV 2022–23; Pakistan DHS 2017–18 and Census 2023). To ensure comparability, the study applies the Washington Group Short Set (WG-SS) functional approach, defining disability as "some difficulty or worse" in at least one functional domain (seeing, hearing, mobility, cognition, self-care, communication). Analytical steps include construction of harmonised disability indicators, disaggregation by age, gender, literacy, wealth and rural–urban location, subnational analysis to capture mountain-specific disparities, and regression and correlation analyses linking disaster exposure to disability prevalence, including a Nepal case study on multi-hazard risk.

Main findings and conclusions: The main finding of the study reflects that disability is not randomly distributed: it is concentrated among older populations, individuals with low literacy and residents of remote, high-risk mountain areas where access to services is limited. Evidence from Nepal indicates that living in high-hazard districts is independently associated with higher disability prevalence, even after controlling for socio-economic factors, and that disaster-related damage to health systems, livelihoods and social protection structures contributes to the accumulation of disability over time. The study finds that gendered impacts are uneven across countries, that literacy is a key protective factor, and that the HKH region faces multi-hazard exposure, with landslides, floods and earthquakes playing distinct roles in disability outcomes. The conclusion is that climate-related disaster risk is a structural driver of inequality and that disability must be recognised as a climate justice and adaptation issue.

For policy and practice, the findings highlight the need to:

- Integrate disability inclusion into climate adaptation and disaster risk reduction frameworks
- Design inclusive early warning systems, evacuation protocols, and recovery programme
- Invest in education especially for women and girls as a resilience strategy
- Strengthen health and social protection systems in remote mountain regions

- Ensure that climate policies explicitly address intersectional vulnerabilities, including disability, gender, and geographic isolation

Overall, the study reinforces the urgency of embedding intersectional and inclusive approaches within climate research, policy, and finance mechanisms under the UNFCCC, particularly for high-risk regions such as the HKH

Key outputs

1. The report "Disability and Disaster in the HKH region- a cross-country analysis of disability and disaster linkages". As it is an ongoing report - close to completion, the plan for post dissemination is to share the findings across regional and global platforms including ICIMOD's Regional Member Countries and partners.

Annex 9: Thame Valley Glacial Lake Outburst Flood 2024 – Causes, impacts and future risks

Main partner organisations: National Disaster Risk Reduction and Management Authority (NDRRMA), Asian Development Bank (ADB), BGC Engineering, Khumbu Pasang Lhamu Rural Municipality, Sagarmatha Pollution Control Committee (SPCC)

Timeline: August 2024 event; field investigation November–December 2024; report published 2025

Geographic scope: Thame Valley, Dudh Koshi basin, Everest region, Solukhumbu district, Nepal (HKH)

RSO research needs (A–E)

- Category A(a), A(g): Near-term climate change and its prediction; advances and gaps in attribution science (event attribution, regional signals). Attribution of a specific GLOF event to a rock avalanche trigger under climate change.
- Category B(a), B(b), B(d): Evolution and dynamics of extreme events, early-warning systems and climate services; assessing adaptation progress; understanding complex, cascading and transboundary risks. Understanding extreme event dynamics, cascading (multi-lake) and transboundary risks
- Category C(b): Climate change impacts and risks for the cryosphere and related ecosystems. Climate change impacts on cryosphere and downstream hazards
- Category E(a), E(c): Synergies and trade-offs with SDGs; research supporting work under the Convention and Paris Agreement (e.g. Nairobi Work Programme). Supports Sendai Framework, SDGs (1, 6, 9, 11, 13), UNFCCC loss and damage mechanisms, the Nairobi Work Programme on impacts, vulnerability and adaptation and provides evidence for early warning system design and transboundary risk management in the HKH.

Summary of research

Objectives

- To investigate the causes and trigger mechanisms of the August 16, 2024 Glacial Lake Outburst Flood (GLOF) in Thame Valley, Nepal.
- To assess the cascading impacts of the flood on downstream communities, infrastructure (homes, schools, health post, hydropower plant), and geomorphology.
- To evaluate future risks from remaining glacial lakes in the watershed and provide recommendations for disaster risk reduction and climate adaptation.

Methodology

- **Satellite analysis**: Pre- and post-event high-resolution Planet satellite imagery (August 15, 16, 17, 31, 2024) to identify lake area changes, breach locations, and flood paths.
- **Field investigation (Nov 29 – Dec 8, 2024)**: Multi-disciplinary team (ICIMOD, NDRRMA, ADB, BGC Engineering) conducted visual inspections, differential GPS (dGPS) measurements, and geological/geomorphological assessments.
- **UAV survey**: Uncrewed Aerial Vehicle (drone) survey paired with dGPS to produce ultra-high resolution orthomosaic imagery of Thame village and downstream areas (UAV not feasible at lake site due to gusty winds).

- **Lake risk classification**: Based on dam type, freeboard, connectivity to glaciers, surrounding slope stability, and evidence of past/future hazards (rock/ice avalanches, landslides).

Main findings and conclusions

- **Trigger and cause**: A rock avalanche from a steep (~200 m high) hillslope on the left flank of Upper Ngole Cho (GL-5) generated a displacement wave, eroding 4.5 m of moraine on the bedrock dam. This released ~1.56×10^5 m^3 of water, which then caused a cascading breach of Lower Ngole Cho (GL-4), releasing an additional ~3.03×10^5 m^3 and eroding a 22 m deep, 51 m wide breach.
- **Cascading impacts**: The flood transformed into a hyper-concentrated flow, eroding moraines, forming a temporary pond at Thyanbo outwash plain, and then breaching again – intensifying downstream destruction. It destroyed 25 homes/guesthouses, a school, a health post, a bridge, and the intake of Khumbu hydropower plant, displacing 135 people.
- **Future risks**: Upper Ngole Cho remains moderate-to-high risk (rock/ice avalanches, but bedrock outlet reduces outburst probability; overflow remains a threat). Rindhi Cho (GL-1) is classified as high-risk (no visible outlet, ice-cored moraine, seasonal fluctuations). Homey Cho (GL-2) is moderate-risk. Lower Ngole Cho and Parchemuche Cho (GL-3, GL-4) are low-risk.
- **Conclusion**: The Thame GLOF highlights the cascading, multi-hazard nature of cryospheric disasters in the HKH. Urgent measures include filling tension cracks, riverbank protection, channelisation, installation of hydrological monitoring and early warning systems, and detailed geophysical surveys of high-risk lakes.

Key outputs

1. Maharjan, S. B., Sherpa, T. C., & Shrestha, A. B. (2025). Thame Valley Glacial Lake Outburst Flood 2024: Causes, impacts and future risks. International Centre for Integrated Mountain Development (ICIMOD); National Disaster Risk Reduction & Management Authority (NDRRMA). https://doi.org/10.53055/ICIMOD.1101.
2. ICIMOD GLOF database of High Mountain Asia. https://doi.org/10.26066/RDS.1973283.
3. UAV orthomosaic and dGPS data: Available from ICIMOD Cryosphere Initiative
4. Strong multi-institutional collaboration: ICIMOD, NDRRMA (Nepal), ADB, BGC Engineering, KPLRM (local rural municipality), SPCC.
5. Capacity building of local authorities and communities through field engagement and knowledge sharing.
6. Use of high-resolution satellite imagery (Planet) accessed via NASA SERVIR HKH Program, demonstrating operational use of Earth observation for disaster response.
7. Recommendations for installation of hydrological/meteorological monitoring stations and early warning systems, directly building local and national capacity for GLOF risk reduction.
8. The report provides a replicable methodology for post-disaster GLOF investigation (satellite + field + UAV + risk classification) applicable across the HKH region.

Annex 10: Changing dynamics of glaciers in the Hindu Kush Himalayan region from 1990 to 2020

Main partner organisations: General Directorate of Water Resources and National Water Affairs Regulation Authority (Afghanistan); Central Department of Geology and Central Department of Hydrology and Meteorology (Tribhuvan University, Nepal); Department of Geology, Tri-Chandra Multiple Campus, Nepal

Timeline: Data studied from 1990 – 2020; Report published 2026.

Geographic scope: HKH region across Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan, covering 10 major river basins and 16 mountain sub-ranges.

RSO research needs (A–E)

- Category A(a), A(f), A(g): Near-term climate change; high-resolution regional climate and cryosphere information; advances and gaps in attribution science.
- Category B(a), B(b), B(d): Dynamics of cryosphere-related extremes and risks; adaptation progress; complex and transboundary risks.
- Category C(b): Climate change impacts and risks for cryosphere-dependent ecosystems.
- Category E(a), E(c): Synergies with SDGs; evidence for UNFCCC and Paris Agreement processes (e.g. NAPs).

Summary of research

Objectives

- To develop and refine the first comprehensive, multi-decadal (1990–2020) glacier change dataset for the entire Hindu Kush Himalaya (HKH) region using consistent data sources and methods.
- To analyse the influence of topographic parameters (elevation, slope, aspect) and glacier size on spatial distribution and retreat patterns.
- To provide scientifically robust evidence base for water resource planning, climate adaptation, disaster risk reduction, and transboundary cooperation.

Methodology

- **Data sources:** Consistent Landsat satellite imagery (target years 1990, 2000, 2010, 2020; ±1 year) and SRTM digital elevation model (DEM).
- **Approach:** Semi-automatic object-based image classification combining automated algorithms (e.g., NDSI for clean ice) with extensive manual validation and correction, particularly for debris-covered glaciers, shadows, and low-contrast areas.
- **Validation:** Cross-checked with high-resolution Google Earth imagery and compared against global/regional inventories (RGI, GAMDAM, Chinese Second Glacier Inventory). Uncertainty estimated at 2–3% of total area.
- **Parameters:** Glacier ID, area, elevation (min/mean/max), slope, aspect, hypsometry; ice reserves estimated via area–thickness empirical relation.

Main findings and conclusions

- **Status (2020)**: 63,761 glaciers covering 55,782 km^2 with estimated ice reserves of 5,736 km^3. Small glaciers (<0.5 km^2) dominate in number (74%) but large glaciers (≥10 km^2) hold 40% of ice reserves.
- **Decadal change (1990–2020)**: Total glacier area decreased by 12% and ice reserves by 9%, with the rate of loss accelerating markedly after 2010 (4.9% area loss in 2010–2020 vs. 3.2% in 1990–2000).
- **Regional patterns**: Highest absolute losses in Indus, Ganges, Brahmaputra basins (e.g., Ganges –21%). Highest percentage losses in eastern basins (Salween –33%, Yangtze –23%). Karakoram showed stability (–0.9%, "Karakoram anomaly").
- **Topographic controls**: Greatest area loss at 4,500–5,500 masl, on slopes of 20–30°, and on NE, E, and SE aspects (higher solar radiation).
- **Fragmentation**: Number of smallest glaciers (<0.5 km^2) increased due to fragmentation of larger glaciers, even as their total area continued to shrink.
- **Conclusions**: Accelerating glacier retreat threatens dry-season water availability, increases risks of GLOFs and other cascading hazards, and demands urgent climate action, basin-specific adaptation, and transboundary water cooperation. The dataset also serves as a training resource for AI-based automated glacier monitoring. Supports IPCC reports (e.g., SROCC), SDGs 6, 13, 15, Sendai Framework for DRR, and Paris Agreement by providing open-access, standardized evidence for climate adaptation, disaster risk reduction, and transboundary water planning in the HKH region.

Key outputs

1. Maharjan, S. B., & Sherpa, T. C. (2026). Changing dynamics of glaciers in the Hindu Kush Himalayan region from 1990 to 2020. International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.1122.
2. Decadal glacier changes dataset. https://doi.org/10.26066/vds.1973447. The dataset is available in electronic form at www.icimod.org/himaldoc.
3. The project involved extensive collaboration with national partners in Afghanistan (GDWR, NWARA) and academic institutions in Nepal (Tribhuvan University). The standardized, basin-wide dataset serves as a crucial resource for training automated monitoring systems using satellite imagery and artificial intelligence, thereby building regional capacity for continuous and responsive glacier tracking.

Annex 11: HKH Glacier Outlook 2026: Insights from 50 years of Himalayan glacier monitoring

Main partner organisations: World Glacier Monitoring Service (WGMS); Geological Survey of India; national monitoring agencies in India, Nepal, Pakistan, Bhutan and China

Timeline: 1974 – 2026 (50 years of monitoring); Report published 2026

Geographic scope: Hindu Kush Himalaya (HKH) region, with specific focus on western Himalaya (India), central Himalaya (Nepal), and underrepresented regions including Karakoram, Sikkim, Zanskar, and Bhutanese Himalaya.

RSO research needs (A–E)

- Category A(a), A(g): Near-term climate change and attribution of glacier mass loss.
- Category B(a), B(b), B(d): Data for early-warning and risk assessment (e.g. GLOFs), adaptation planning and transboundary water risk.
- Category C(b): Climate impacts on cryosphere and related ecosystems.
- Category E(a), E(c): Supporting SDGs 6 and 13 and UNFCCC/Paris Agreement adaptation and loss-and-damage processes.

Summary of research

Objectives

- To present an updated overview of glacier status in the HKH based on five decades (1974–2026) of field-based mass balance monitoring.
- To identify monitoring achievements, gaps, and priority actions for strengthening cryosphere observation networks.
- To inform ministers, development partners, and regional institutions about the evidence base for glacier change and to highlight where coordinated support is most urgently needed, particularly during the International Year of Glaciers' Preservation (2025) and the Decade of Action for Cryosphere Science (2025–2034).

Methodology

- Compilation and analysis of all available glacier-wide mass balance measurements conducted in the Himalaya since September 1974.
- Data from 38 glaciers, comprising 302 annual observations (32 positive, 270 negative mass balance years).
- Identification of WGMS benchmark glaciers (minimum 10 years of continuous observations): Mera, Pokalde, Rikha Samba, West Changri Nup, Yala (central Himalaya, Nepal), Chhota Shigri and Hoksar (western Himalaya, India).
- Representativeness assessment: systematic comparison of field-based glaciological measurements with satellite-based geodetic estimates of glacier mass balance to evaluate how well benchmark glaciers represent broader regional trends.

Main findings and conclusions

- **Mass balance trends**: 89% of annual observations (270 out of 302) showed negative mass balance, indicating widespread and persistent glacier mass loss over 50 years.
- **Monitoring gaps**: Out of approximately 63,700 glaciers in the HKH, only 38 have been monitored in the field. Observations are unevenly distributed, with major gaps in Karakoram, Sikkim, Zanskar, and Bhutanese Himalaya. Seventeen mass balance series have been discontinued.
- **Benchmark glaciers**: Only seven glaciers currently qualify as WGMS benchmark glaciers. Mera and Rikha Samba are representative of the central Himalaya; Chhota Shigri represents the western Himalaya.
- **Way forward**: Priority actions include expanding monitoring to underrepresented regions, sustaining long-term observations of benchmark glaciers, standardising methodologies, and sharing data with WGMS to improve global representation of Himalayan glacier response to climate change.
- **Conclusion**: Sustained long-term glacier monitoring is essential climate infrastructure for hydrological forecasting, GLOF risk assessment, transboundary water cooperation, and climate-resilient development. The IYGP 2025 and Decade of Action for Cryosphere Science provide a strategic framework for mobilising investments and regional collaboration.

Key outputs

1. Azam, M. F. (2026). HKH Glacier Outlook 2026: Understanding Change Through 50 Years of Field Observation (p. 14 p.). International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.1123.
2. Azam, M. F. (2026). Fifty years of Himalayan glacier mass-balance monitoring: Recommendations in honour of IYGP 2025. *Journal of Glaciology*, *72*, e43. https://doi.org/10.1017/jog.2026.10151
3. Shared mass-balance datasets via ICIMOD and WGMS, built on long-term collaboration with national agencies.
4. The report builds on five decades of collaboration between ICIMOD, national monitoring agencies (Geological Survey of India, Nepal, Bhutan, Pakistan), and the World Glacier Monitoring Service (WGMS). It identifies priority regions (Karakoram, Sikkim, Zanskar, Bhutan) for expanding field monitoring networks, which will require capacity building and technology transfer.
5. Recommends standardisation of monitoring methodologies and data sharing with WGMS to enhance global representation and regional comparability. Aligns with the International Year of Glaciers' Preservation (2025) and the Decade of Action for Cryosphere Science (2025–2034), providing a strategic framework for mobilising investments and enhancing collaboration among HKH member countries.

Annex 12: HIGRID – Building capabilities for green, climate-resilient and inclusive development in the Lower Koshi River Basin

ICIMOD Action Area: DRR Intervention, HIGRID project

ICIMOD focal point: Saswata Sanyal, HIGRID Project Coordinator and DRR Intervention Manager

Main partner organisations: Australian Government (funder); 28 municipalities across Koshi and Madhesh provinces; organisations of persons with disabilities; Indigenous groups; community-based organisations; entrepreneurs and local leaders.

Timeline: Ongoing (as of 2025).

Geographic scope: Lower Koshi River Basin in eastern Nepal (Terai lowlands, mid-hill and high-hill districts).

RSO research needs (A–E)

- Category A(a), A(f): Near term climate information and high resolution local climate data for action.
- Category B(a), B(b), B(d), B(e): Evolution and dynamics of extreme events and early warning systems; assessing adaptation progress; understanding cascading water related risks; climate risks for vulnerable groups (including persons with disabilities and women).
- Category E(a), E(c): Synergies between mitigation, adaptation and SDGs; inclusive research and practice supporting UNFCCC adaptation and loss and damage work.

Summary of research

Objectives

- To support municipalities in integrating Disaster Risk Reduction (DRR) approaches into planning and budgeting that are responsive to Gender Equality, Disability and Social Inclusion (GEDSI).
- To scale up GEDSI-responsive innovative DRR solutions and enterprises based on green, climate-resilient, and inclusive development (GRID).
- To enhance community resilience to "Too Much and Too Little" (TMTL) water challenges (floods, droughts, and other water-induced hazards) in the Lower Koshi River Basin.

Methodology

- Strengthening inclusive DRR governance: Partnering with local governments to integrate GEDSI principles into DRR plans, ensuring responsiveness to disadvantaged groups (women, persons with disabilities).
- Solutions to tackle TMTL water: Building capacity of communities and decision makers to scale innovative solutions, including Nature based Solutions, responsible tourism, sustainable watershed management, and Community Based Flood Early Warning Systems (CBfEWs).
- Developing GRID value chains: Developing and integrating GRID based value chains (vegetable, mango, Mithila art) to diversify income sources and promote entrepreneurship for disadvantaged communities (women, youth).
- Ensuring inclusive gender responsive budgeting: Enhancing capacity of local governments to implement mandated Gender Responsive Budgeting (GRB) in 11 municipalities to ensure fair resource allocation and GEDSI inclusive decision making.

Main findings and conclusions

- The Lower Koshi River Basin (LKRB) is home to nearly 8 million people at risk from climate induced changes to the hydrological cycle (altered precipitation, evaporation, and increased frequency/intensity of floods and droughts).
- A large proportion of the population relies on water intensive agriculture, making them highly vulnerable to TMTL water challenges.
- Disadvantaged groups, particularly organisations of persons with disabilities, face even higher risks.
- The project is delivering three key outputs: 3 GRID based solutions, 5 municipalities incorporating GEDSI inclusive DRR plans, and 7 TMTL water value chains.
- **Conclusion**: Integrating GEDSI into DRR governance, scaling Nature based Solutions and early warning systems and developing inclusive value chains are effective strategies for building climate resilience in the LKRB.
- This project also supports the Sendai Framework for Disaster Risk Reduction (Targets A, B, C, D, E – inclusive DRR), UN Sustainable Development Goals (SDG 1 – poverty, SDG 5 – gender equality, SDG 10 – reduced inequalities, SDG 11 – sustainable cities and communities, SDG 13 – climate action, SDG 17 – partnerships), and the Paris Agreement (adaptation and resilience). Also contributes to National Adaptation Plans (NAPs) and local climate action in Nepal.

Key outputs

1. International Centre for Integrated Mountain Development (ICIMOD). (2025). HI-GRID: Building Capabilities for Green, Climate-Resilient and Inclusive Development in the Lower Koshi River Basin. International Centre for Integrated Mountain Development (ICIMOD). Access here: https://lib.icimod.org/records/9txrr-ks753.
2. **Tools**: Community Based Flood Early Warning Systems (CBfEWs); Gender Responsive Budgeting (GRB) frameworks; GRID value chain development guides (vegetable, mango, Mithila art).
3. Strong **multi stakeholder cooperation**: Australian Government (funder), ICIMOD (implementer), 28 local municipalities, organisations of persons with disabilities, indigenous groups, community members, entrepreneurs, and municipality leaders.
4. **Capacity building** for local governments on GEDSI inclusive DRR planning, gender responsive budgeting, and watershed management. Community based flood early warning systems empower local communities to manage risks and adapt to changing climate conditions.
5. Promotion of inclusive entrepreneurship (value chains) for women, youth, and disadvantaged groups, contributing to livelihood diversification and climate resilience.

Annex 13: 2025 drought in Nepal's Madhesh Province: A rapid situational analysis

Main partner organisations: Ministry of Agriculture and Livestock Development (MoALD), Nepal; Australian Embassy in Nepal

Timeline: 2025 drought event; analysis and report in 2025.

Geographic scope: Madhesh Province in the south-eastern Terai region of Nepal.

RSO research needs (A–E)

- Category A(a), A(f), A(g): Near-term climate change; high-resolution local climate information; attribution of monsoon failure and drought persistence.
- Category B(a), B(b), B(d), B(e): Evolution of slow-onset extreme events and cascading risks; adaptation progress and impacts; climate risks for vulnerable groups (including women and smallholder farmers).
- Category E(a), E(c): Synergies with SDGs 1, 2, 5, 6 and 13; evidence for UNFCCC adaptation and loss-and-damage work and the Nairobi Work Programme.

Summary of research

Objectives

- To conduct a rapid situational analysis of the 2025 drought in Nepal's Madhesh Province following its declaration as a "disaster crisis zone" (23 July 2025).
- To assess meteorological, hydrological, and agricultural drought conditions, including impacts on groundwater, drinking water, and paddy cultivation.
- To estimate potential rice production shortfalls and associated food security risks.
- To provide short-term and long-term recommendations for drought mitigation, adaptation, and policy interventions.

Methodology

- **Rainfall analysis**: Analysis of observed and forecasted rainfall data from Nepal's Department of Hydrology and Meteorology (DHM) and University of California's Climate Hazard Center (CHC), including winter (Dec 2024–Feb 2025) and monsoon (Jul–Sep 2025) rainfall anomalies.
- **Satellite-based remote sensing**: Use of Sentinel 2 imagery to compare cropland greenness (vegetation cover) on 15 July 2024 vs. 18 July 2025; use of MODIS-derived Vegetation Condition Index (VCI) and Standardised Precipitation Index (SPI) to identify drought stress and vegetation stress concentration.
- **Ground data integration**: Reports from Ministry of Agriculture and Livestock Development (MoALD) on rice transplantation rates (as of 27 July 2025) and field observations on groundwater levels and borehole status.
- **Impact estimation**: Assessment of rice area under drought stress (percentage and spatial distribution) and estimation of potential production shortfall (metric tons) based on satellite-derived stress levels and historical production data.

Main findings and conclusions

- **Meteorological drought**: Prolonged dry conditions began with below-normal winter rainfall (Dec 2024–Feb 2025), followed by erratic monsoon onset and weak progress in July 2025, with forecasts indicating continued dry spells through August.
- **Hydrological drought**: Groundwater levels critically low; >30% of community boreholes reportedly dried up; hand pumps non-functional in Parsa and Bara districts; acute drinking water crisis with disproportionate burden on women and girls.
- **Agricultural drought**: Rice transplantation rate stood at only 52% as of 27 July 2025, compared to 92% during the same period in 2024. An estimated 35–40% of rice growing area is under extreme drought stress, rising to 60–78% in Mahottari, Dhanusha, and Siraha districts. Potential rice production shortfall of 400,000–450,000 metric tons (~10% of national rice supply).
- **Conclusion**: The drought represents a cascading crisis – from meteorological to hydrological to agricultural – with severe implications for food security, rural livelihoods, gender equity, and the national economy. Immediate relief and long term adaptation (e.g., direct seeding, crop diversification, groundwater recharge, completion of Sunkoshi Marin Diversion Project) are urgently needed.
- The project also provides evidence for National Adaptation Plans (NAPs) and early warning systems for slow onset hazards in South Asia.

Key outputs

1. Shrestha, S., Shrestha, S., Dulal, B., & Khadgi, V. R. (2025). 2025 Drought in Nepal's Madhesh Province: A rapid situational analysis. International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.1097.
2. **Tool**: National Agriculture Drought Watch Nepal (dynamic, science based drought monitoring for early warning and decision support) – maintained by ICIMOD.
3. **Data sources**: Sentinel 2 and MODIS satellite imagery; DHM rainfall data; CHC forecasts.
4. **Capacity building** for local institutions and farmers on climate resilient farming practices (direct seeding, crop diversification, nature based solutions for groundwater recharge).
5. ICIMOD provided technical support for satellite based drought monitoring (SPI, VCI) and risk communication and continues to update the National Agriculture Drought Watch Nepal.

Annex 14: Himalayan Climate Change Adaptation Programme (HICAP)

Main partner organisations

Regional Member Country Institutions: Institute of Water Modelling (IWM), Bangladesh; Asia International Rivers Centre (AIRC)/Yunnan University; China, Chengdu Institute of Biology (CIB), China; Ecological Environment Protection Research Centre, Yunnan Institute of Environmental Science, China; Institute of Geographic Sciences and Natural Resources Research (IGSNRR), China; Kunming Institute of Botany (KIB) – including Centre for Mountain Ecosystem Studies (CMES), China; Social Development Institute, Sichuan University, China; Women and Development Research Centre (WAD), Yunnan Academy of Social Sciences (YASS), China; Aaranyak, India; Indian Institute of Technology (IIT) Delhi, India; Indian Institute of Sciences (IISc) Bangalore, India; Centre for Environmental and Agricultural Policy Research, Extension and Development (CEAPRED), Nepal; Koshi Victim Society (KVS), Nepal; South Asian Network of Environmental Economists (SANDEE), Nepal; Nepal Development Research Institute (NDRI), Nepal; World Wide Fund for Nature (WWF) , Nepal; Women Organizing for Change in Agriculture and NRM (WOCAN), Nepal; Aga Khan Rural Support Programme (AKRSP), Pakistan; International Water Management Institute (IWMI), Pakistan; Pakistan Agriculture Research Council (PARC), Pakistan; and World Wide Fund for Nature (WWF), Pakistan.

International Institutions: ICIMOD; Bjerknes Centre for Climate Research (BCCR), Norway; FutureWater, the Netherlands; International Institute of Social Studies, The Hague, Netherlands; University of Sussex, United Kingdom; CICERO [Promoter Organization]; and GRID-Arendal [Promoter Organization].

Timeline: 2011–2017, with some activities continuing into 2018.

Geographic scope: HICAP research spans across five sub-basins of major Himalayan river systems: two sub-basins of the Brahmaputra and one each of the Indus, Ganges, and Salween-Mekong [Upper Indus (Pakistan), Koshi Sub-basin (Nepal), Eastern Brahmaputra (India), Upper Brahmaputra (Tibetan Autonomous Region, China), Upper Salween-Mekong (China)].

RSO research needs (A–E)

- Category A(f): High-resolution local and regional climate and water-scenario information.
- Category B(b, d, e): Assessing adaptation progress; understanding complex, cascading and transboundary risks; climate risks for vulnerable groups including women and the poor.
- Category C(a): Opportunities and challenges for implementing NbS, including ecosystem-based approaches.
- Category E(a, b, c): Synergies and trade-offs with SDGs; integrating gender and equity; research supporting UNFCCC work including NAPs, NDCs and the Nairobi Work Programme.

Summary of research

Objectives

- Increase understanding of uncertainties influencing climate change scenarios and water availability and demand projections for parts of major river basins, and to encourage the use of the knowledge thus created.
- Enhance capacities to assess, monitor, communicate, prepare for, and undertake actions to respond to challenges and opportunities from impacts of climate change and other drivers of change.
- Make concrete and actionable proposals on strategies and policies (with particular reference to women and the poor) for uptake by stakeholders, including policy makers.

Methodology: HICAP an interdisciplinary, transdisciplinary approach combining natural and social science. It connects the thematic components of Climate change scenarios; Water availability and demand scenarios; Ecosystem services; Food security; Vulnerability and adaptation; Gender and adaptation; Communications and outreach. All HICAP research has been based on the three concepts of salience, credibility and legitimacy, while ensuring stakeholder engagement, with work being organised under four pillars, namely science, action research, piloting and communication. Lastly, action research was undertaken research to systematically test adaptation practices on ground, with pilot projects such as Resilient Mountain Villages and Community-Based Flood Early Warning Systems to demonstrate and promote adaptation approaches. Policy champions were also identified to advocate for research uptake.

Main findings and conclusions

- The region is warming, especially in winter and at higher altitudes, leading to more extreme and unpredictable weather, increased glacial melt, increased community vulnerability, and challenges for ecosystems and agriculture. The total annual water availability is not changing.
- The concept of 'flexibility' has emerged as a key notion and includes local empowerment, agro-diversity, social security and gender-friendly diversification of livelihoods. Smart planning can help adaptation and create new opportunities.
- Although initially focused on climate change, research has also clearly established that it is a combination of multiple drivers – which differ across the region and socioeconomic scales – that influences vulnerability and adaptation needs.
- There is a need for more holistic and upstream–downstream solutions, embracing different approaches in different situations and regions. These may include Payment for Ecosystem Services approaches or cost-effective Ecosystem Based Adaptation incorporating local knowledge and practices. However, different agroecological zones may have different solutions, which must be analysed individually.
- Improved communication with policymakers, and community capacity-building (particularly for women) are two ways of minimizing risks and vulnerabilities.
- Regional key messages include the need for a greater focus on water stress and adaptation in Nepal; greater emphasis on gender in livelihood diversification and risk management in India; and greater integration of adaptation, gender, migration and other social factors in adaptation strategies in China. Global lessons point to the connections between mountain areas in the regional (upstream–downstream) and global context, with a need for cross-learning between mountain regions.
- The knowledge generated from HICAP science, action research and piloting has contributed to the understanding of how 15 of the 17 Sustainable Development Goals can be achieved in the Hindu Kush Himalayas, to a greater or lesser extent. Contribute to the UNFCCC and Nairobi Work Programme. HICAP results and approach has been integrated into 6 national/state-level development policies and plans making use of HICAP work.
- The Himalayan Climate and Water Atlas was launched at UNFCCC COP-21 in Paris (2015) (downloaded over 10,000 times) and the CB-FEWS won the UNFCCC "Momentum for Change – Lighthouse Award" (2016).

Key outputs

1. HICAP has led to 87 (41 peer-reviewed) publications, with some major ones highlighted below:
    a. Agrawal, N. K., Alfthan, B., van Oort, B., Leikanger, I., & Schoolmeester, T. (2017). Adaptation in the Himalayas: Knowledge, Action and Results; Highlights from the Himalayan Climate Change Adaptation Programme (HICAP), 2012–2017. International Centre for Integrated Mountain Development (ICIMOD). Access here: https://lib.icimod.org/records/ka6xg-ae059.

b. Aase, Tor H. (ed.), *Climate Change and the Future of Himalayan Farming* (Delhi, 2017; online edn, Oxford Academic, 19 Sept. 2019), https://doi.org/10.1093/oso/9780199475476.001.0001.
c. Quincey, D.J. (2017). The Himalayan Climate and Water Atlas. In Mountain Research and Development (Vol. 37, Number 1, pp. 155–156). https://doi.org/10.1659/mrd.mm197.
d. Gerlitz, J.-V., Banerjee, S., Hoermann, B., Hunzai, K., Macchi, M., & Tuladhar, S. (2014). Poverty and Vulnerability Assessment – A survey instrument for the Hindu Kush Himalayas. International Centre for Integrated Mountain Development (ICIMOD). Access here: https://lib.icimod.org/records/zya8h-x3304.
e. ICIMOD. (2016). Gender in Water Management; Considerations for Nepal's Koshi River Basin. International Centre for Integrated Mountain Development (ICIMOD). Access here: https://lib.icimod.org/records/aegav-h9p30.

2. HICAP has generated household-level poverty and vulnerability assessment datasets for Eastern Brahmaputra sub-basin in India, Koshi sub-basin in Nepal, Upper Brahmaputra sub-basin in China and Upper Indus sub-basin in Pakistan.
3. Cooperation and capacity-building elements include training for 19 communities and 18 institutions; training 47 journalists (leading to around 70 articles and news stories); ten investigative journalism grants (resulting in 37 investigative stories); and strong co-design of pilots and research with local communities and strategic partners.

Annex 15: Himalayan Adaptation, Water and Resilience (HI-AWARE) Research on Glacier and Snowpack Dependent River Basins for Improving Livelihoods

Main partner organisations

Consortium Partners: ICIMOD (lead); Bangladesh Centre for Advanced Studies (BCAS), Bangladesh; The Energy and Resources Institute (TERI), India; and Climate Change, Alternate Energy and Water Resources Institute of the Pakistan Agricultural Research Council (CAEWRI-PARC), Pakistan

International Partner: Alterra – Wageningen University and Research, the Netherlands.

Strategic Partners: Megh Pyne Abhiyan ("Cloud Water Campaign"), India; The Mountain Institute India, India; The Centre for Ecology, Development and Research (CEDAR), India; Practical Action – South Asia Office; and LEAD Pakistan.

Timeline: 2014–2018.

Geographic scope: HI-AWARE research spans across four study basins: the Indus, Upper Ganga, Gandaki and Teesta focus in 12 sites that represent a range of climates, altitudes, hydro-meteorological conditions, rural-urban continuums, and socio-economic contexts. The research sites encompass four countries, namely Bangladesh, India, Nepal, and Pakistan.

RSO research needs (A–E)

- Category A(f): High-resolution local and regional climate information and projections.
- Category B(b, d, e): Assessing adaptation progress; understanding complex, cascading and transboundary risks; climate risks for vulnerable groups.
- Category C(a, b, c): NbS and ecosystem-based approaches; climate impacts on cryosphere-linked ecosystems; emissions and removals from terrestrial systems and high-carbon reservoirs (through land and water interventions).
- Category E(a, b, c): Synergies between adaptation, mitigation and SDGs; equity and gender; research supporting UNFCCC processes, including NAPs and NDCs, and the Nairobi Work Programme.

Summary of research

Objectives

- Generate scientific knowledge on the biophysical, socio-economic, gender, and governance conditions and drivers leading to vulnerability to climate change
- Develop robust evidence to improve understanding of the potential of adaptation approaches and practices, with an explicit focus on gender and livelihoods
- Develop stakeholder-driven adaptation pathways based on the up- and out-scaling of institutional and on-the-ground adaptation innovations
- Promote the uptake of knowledge and adaptation practices at various scales by decision-makers and citizens
- Strengthening the interdisciplinary expertise of researchers, students, and related science-policy-stakeholder networks

Methodology: HI-AWARE adopted a comparative, participatory, cross-scalar trans-disciplinary. gender-inclusive and integrative approach looking into the short and long-term climate trends, physical and social vulnerabilities, and adaptation strategies at various scales. The research areas included water, energy, food

security, human health, water-induced hazards (such as floods, landslides and droughts) and extreme weather events. The program conducted research and pilot interventions, capacity building and policy engagement on climate resilience and adaptation in the mountains and flood plains of the Indus, Ganges, and Brahmaputra river basins. The sub-basins for the research and pilot interventions were selected through stakeholder consultation.

The program design focussed on:

- **Generating Knowledge**: five interlinked Research Components focusing on knowledge generation on climate change impacts, the causes that lead to vulnerability, and adaptation practices and policies.
- **Research into Use**: systematically promote the uptake of knowledge and adaptation practices at various scales by practitioners and policymakers, to reduce vulnerabilities of communities and build livelihood resilience.
- **Strengthening Expertise**: build the capacity of researchers, students, and science and policy stakeholder networks to do interdisciplinary research on climate change vulnerability, resilience, and adaptation.

Main findings and conclusions

- The Indus, Ganges and Brahmaputra river basins are extremely susceptible to temperature increase. Higher elevation will experience an even greater wetter conditions in the future and increases in extreme precipitation. The projected temperature increases for the basins (3.5 and 6 °C by 2100 under the more likely climate change scenario) exceed the global target 1.5 -2 °C. events, indicating that the 1.5 and 2 °C scenarios are not suitable for adaptation planning in South Asia
- Heat waves are expected to increase in intensity and duration in South Asia, especially in the cities. Poor people are especially vulnerable due to living in dense built-up neighbourhood. Individual solutions are not sufficient, concerted efforts are needed in the urban landscape both at community and individual level to address urban heat in South Asia.
- Robust region-specific climate change projections developed by HI-AWARE for the Indus, Ganges and Brahmaputra (IGB) river basins indicate that extreme precipitation events, the main driver of flood, will likely increase in frequency and severity in the coming decades. However, floods need not result in tragedy if planning and management are inclusive
- 130 million farmers in the downstream plains of the Indus and the north-western part of the Ganges basin depend on water originating from glacier and snow melt from the mountains. Any changes in the future availability of meltwater or further groundwater depletion will therefore impact agriculture. Understanding the links between sources of water demand and sources of water supply is important for developing appropriate adaptation measures
- Mean annual water availability is likely to increase by 36-42%, 37-46% and 17-46% in the IGB, however, the water consumption in downstream areas of the IGB basins is projected to increase by 24%, 42% and 107%, respectively, during the 21st century. Socio-economic development leading to increase in water demand will become the main driver of the future water gap, not climate change.
- There is a high dependence on springs (ranging between 50-100%) for water supply in three-fourths of the urban areas of the Himalaya. A holistic approach to manage water that includes springshed management along with planned adaptation is of the utmost importance for securing safe water supply in the urban Himalaya.
- Vulnerabilities are shaped by the interaction of both climatic stresses and socio-economic drivers and conditions in the local context. Relevant policies, strategies and plans should address differential vulnerabilities. Greater resources allocations are to be made for the climate affected HKH region and the most vulnerable communities and groups.
- HI-AWARE has contributed to global scientific discourse on climate change adaptation through a plethora of knowledge products including peer-reviewed, reports, simulations, datasets and media

products. HI-AWARE project framework and findings are also designed to directly support national reporting and policy process. The localized climate data and adaptation pathways provided evidence base that directly helps member countries formulate National Adaptation Plans (NAPs).

- 9 HI-AWARE researchers were directly involved in development of IPCC report (IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC), IPCC Special Report on Climate Change and Land (SRCCL), IPCC Sixth Assessment Report (AR6).
- More outputs and information can be found here: https://hi-aware.org/.

Key outputs and cooperation

1. HI-AWARE has produced over 28 papers in leading peer-reviewed journals, 21 working papers and two special issues (including on gendered vulnerability and urban water). Some major ones include:
    a. HI-AWARE. (2018). Himalayan Adaptation, Water and Resilience Research (HI-AWARE); Highlights 2014-2018. International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.722.
    b. Lutz, A., Immerzeel, W., Biemans, H., Maat, H., Veldore, V., & Shrestha, A. (2016). Selection of Climate Models for Developing Representative Climate Projections for the Hindu Kush Himalayan Region; HI-AWARE Working Paper 1. International Centre for Integrated Mountain Development (ICIMOD). Access here: https://lib.icimod.org/records/hwdbs-j8c53.
    c. Lutz, A. F., & Immerzeel, W. (2016). Reference Climate Dataset for the Indus, Ganges, and Brahmaputra River Basins; HI-AWARE Working Paper 2. International Centre for Integrated Mountain Development (ICIMOD). Access here: https://lib.icimod.org/records/rjdcz-ktt36.
    d. Dasgupta, P. (2016). Assessing Costs and Benefits of Climate Change Adaptation; HI-AWARE Working Paper 3. Himalayan Adaptation, Water and Resilience (HI-AWARE). Access here: https://lib.icimod.org/records/yh811-hgk89.
    e. Kraaijenbrink, P. D. A., Bierkens, M. F. P., Lutz, A. F., & Immerzeel, W. W. (2017). Impact of a global temperature rise of 1.5 degrees Celsius on Asia's glaciers. *Nature, 549*(7671), 257–260. https://doi.org/10.1038/nature23878.
    f. Biemans, H. & Siderius, Christian & Lutz, Arthur & Nepal, Santosh & Ahmad, Bashir & Hassan, Tagraid & Von Bloh, Werner & Wijngaard, René & Wester, Philippus & Shrestha, Arun & Immerzeel, W. (2019). Importance of snow and glacier meltwater for agriculture on the Indo-Gangetic Plain. Nature Sustainability. 2. 594-601. https://doi.org/10.1038/s41893-019-0305-3.
    g. Vij, S., Moors, E., Ahmad, B., Uzzaman, A., Bhadwal, S., Biesbroek, R., Gioli, G., Groot, A., Mallick, D., Regmi, B., Saeed, B. A., Ishaq, S., Thapa, B., Werners, S. E., & Wester, P. (2017). Climate Adaptation Approaches and Key Policy Characteristics: Cases from South Asia. Environmental Science and Policy 78, 58-65. http://dx.doi.org/10.1016/j.envsci.2017.09.007
    h. Maharjan, A., Hussain, A., Bhadwal, S., Ishaq, S., Saeed, B. A., Sachdeva, I., Ahmad, B., T., H. S. M., Tuladhar, S., & Ferdous, J. (2018). Migration in the Lives of Environmentally Vulnerable Populations in Four River Basins of the Hindu Kush Himalayan Region; HI-AWARE Working Paper 20. International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.729.
2. Key datasets include high-resolution reference climate data for the Indus, Ganges and Brahmaputra. Some of these include:
    a. Lutz, A. F., ter Maat, H. W., Biemans, H., Shrestha, A. B., Wester, P., & Immerzeel, W. W. (2016). Selecting representative climate models for climate change impact studies: An advanced envelope based selection approach. International Journal of Climatology. http://doi.org/10.1002/joc.4608.
    b. Novel high-quality and high-resolution reference climate covering the IGB river basins with a particular focus on improved representation of high-altitude precipitation, covering from

1 January 1981 to 31 December 2010. This dataset was used for the downscaling of the 8 GCMs (4 GCM each for RCP4.5 and 8.5) to analyse future projections for the period of 2016-2045 (representing 2030s) and 2036-2065 (representing 2050s) for the National Adaptation Plan process of Nepal.

   c. Survey of 1,987 households (A sample size of 402 households was determined using Cochran's sample size formula for each river basin) examining the patterns of migration, and its role in building adaptive capacities of households in four critical sectors – agriculture, livestock, forests, and water.

3. Capacity-building highlights include support to about ten PhD and 28 master's candidates, research institutes and NGOs from the region for conducting interdisciplinary research on climate change vulnerability, adaptation and resilience.
4. Gender-sensitivity training sessions and climate change vulnerability and adaptation workshops in the study sites for stakeholders to foster common understanding of critical Hi-AWARE issues, including challenges and opportunities.
5. Science-Policy Dialogue brought together key stakeholders, including researchers and policymakers, working on climate change adaptation.