POLICY ANALYSIS EXERCISE

Increasing Access to Multi-Hazard Early Warning Systems

Promoting Climate Change Adaptation in the Hindu Kush Himalayan Region

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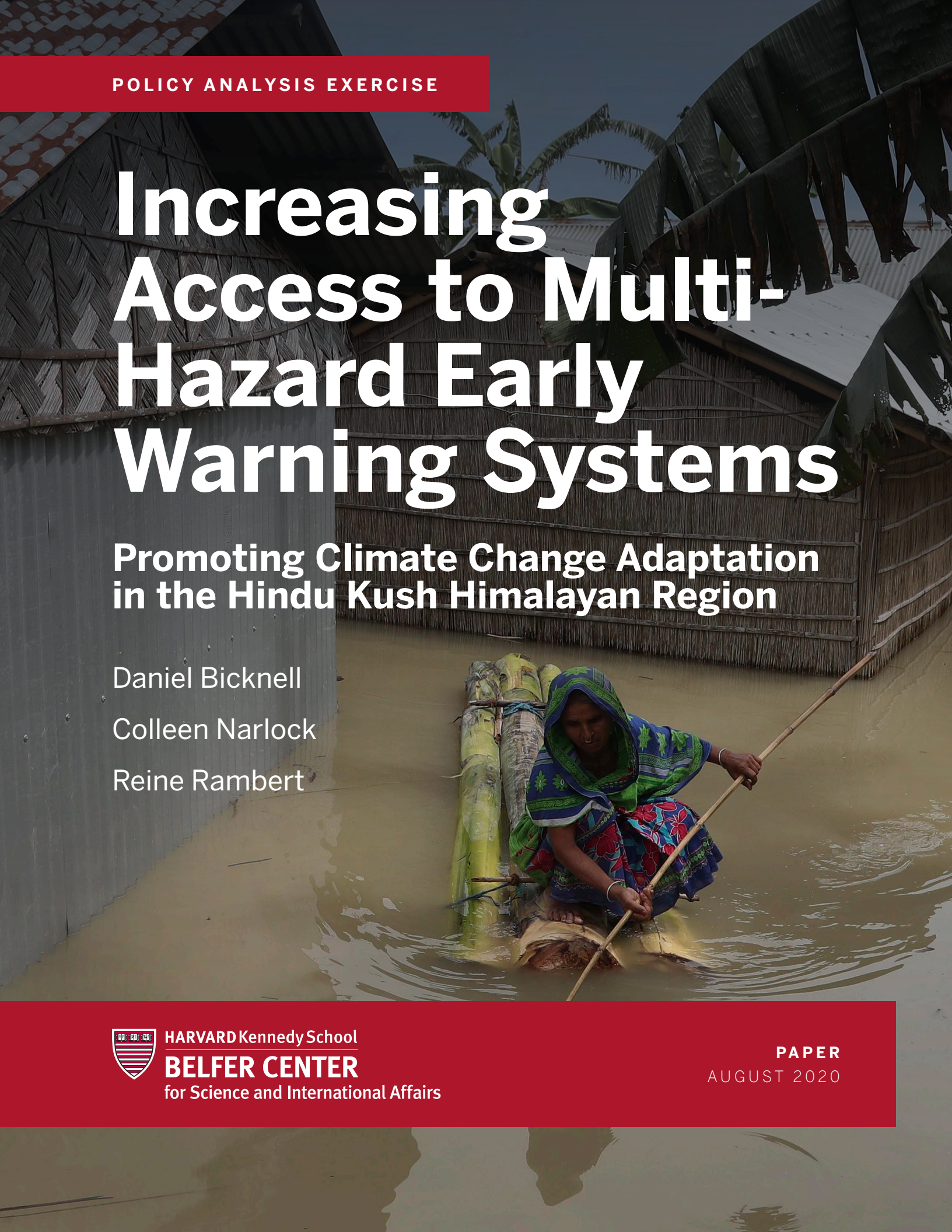

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This paper was completed as a Harvard Kennedy School Policy Analysis Exercise, a yearlong project for second-year Master in Public Policy candidates to work with real-world clients in crafting and presenting timely policy recommendations.

Cover photo: A woman rows a makeshift raft near her partially submerged house in Gagolmari village, Morigaon district, Assam, India, Tuesday, July 14, 2020. (AP Photo/Anupam Nath)

INCREASING ACCESS TO MULTI-HAZARD EARLY WARNING SYSTEMS: PROMOTING CLIMATE CHANGE ADAPTATION IN THE HINDU KUSH HIMALAYAN REGION

2020 POLICY ANALYSIS EXERCISE

HARVARD Kennedy School
JOHN F. KENNEDY SCHOOL OF GOVERNMENT

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Executive Summary

More than one billion residents of the Hindu Kush Himalaya (HKH) region will be at risk of exposure to increased frequency and intensity of natural hazards due to climate change and land-use changes.[1] Natural disasters not only take lives and disrupt livelihoods, but also compound the marginalization of women, lower castes, and other vulnerable groups. The International Centre for Integrated Mountain Development (ICIMOD), an intergovernmental organization representing the eight member countries of HKH (Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan), has been working at the nexus of climate change adaptation and disaster risk reduction to mitigate natural hazard threats.

Our Policy Analysis Exercise (PAE) aims to help ICIMOD, in partnership with the United Nations Framework Convention on Climate Change (UNFCCC), close a knowledge gap that serves as a barrier to climate adaptation: a lack of access to early warning systems for multiple hazards in the HKH region. This knowledge gap constitutes one of the sixteen knowledge gaps prioritized by the Hindu-Kush-Himalaya region for the Lima Adaptation Knowledge Initiative (LAKI).

Our research and interviews interrogated this knowledge gap through two main research questions:

1. ***What are the main barriers to access to multi-hazard early warning systems in HKH?***
2. ***What are potential solutions to such barriers, drawing from HKH and non-HKH real-world examples?***

We combined multiple research methods (e.g. literature review, desktop research, key informant interviews) to address this policy problem. We used ICIMOD's Community Based Flood Early Warning System (CBFEWS) as a lens to understand how ICIMOD overcame barriers to access in early warning systems for floods and flash floods. We conducted in-country interviews with more than 40 individuals involved in CBFEWS sites near the Nepal and India border to get first-hand knowledge of its mechanics, benefits, and challenges. Furthermore, we talked to subject-matter experts from ICIMOD and regional NGOs to gain insight into the most consequential barriers impacting access to early warning systems. Leveraging categories

[1] Philippus Wester et al., "The Hindu Kush Himalaya Assessment: Mountains, Climate Change, Sustainability and People" (Springer Open, 2019).

established by the UNDP, we identified and prioritized barriers to access to early warning systems (EWS) as follows:

1. Budget
2. Human resources and expertise
3. Technology, infrastructure, and forecasting capability
4. Response coordination and disaster preparedness
5. Legal and institutional arrangements
6. Public engagement, empowerment, and community outreach
7. Addressing impacts of climate change on disaster risks

Ultimately, we recommend that HKH stakeholders, who work with ICIMOD, expand their collaborative efforts focusing on floods to multiple natural hazards (i.e., droughts, landslides, debris flow, and earthquakes). **We recommend that HKH stakeholders work towards regional approaches to a coordinated multi-hazard early warning system**. This work would build off ICIMOD's community-based model and existing efforts with a regional or transboundary focus that ICIMOD has pioneered, including the disaster risk reduction work on the Koshi Basin Initiative and the HKH Hydrological Cycle Observing System (HYCOS) initiative.

Strategic Recommendation		
HKH stakeholders should expand focus from Community Based Flood Early Warning Systems to higher levels of governance and other natural hazards	»	HKH stakeholders should support research on early warning systems for a regional level (i.e. transboundary zones but sub-national areas) to increase the number of beneficiaries served in highly disaster-prone areas HKH stakeholders should consider expanding from a flood focus to other hazards, such as drought (e.g. landslide, debris flow, glacial lack outburst flooding (GLOF))

There are some immediate next steps that HKH stakeholders can take to address the barriers to effective, multi-hazard early warning systems. We propose short-term recommended actions for each enabling solution that HKH stakeholders could pursue. Each of these solutions addresses one or more barrier that emerged from our desktop research and community-based interviews.

Enabling Policy Recommendations: Solution	»	Barriers Addressed
1. Expand the Roles and Responsibilities of Private Sector Actors **1.1:** Convene a regional workshop on the role of private sector actors in EWS for multiple hazards **1.2:** Issue a Request for Information (RFI) for low-cost technologies for Early Warning Systems for multiple hazards		Technology, infrastructure, & forecasting capability; Public engagement, empowerment, & community engagement; Budget; Human resources & expertise
2. Explore Mechanisms for Financial Innovation **2.1:** Develop a target list of existing funders who offer additional financial assistance or new funders that can be pursued **2.2:** Conduct an Impact Assessment on CBFEWS sites where data is available to strengthen funding proposals		Budget
3. Improve Domestic and Regional Information Sharing and Coordination within HKH **3.1**: Establish a standardized "toolkit" to summarize and share aspects of CBFEWS that are transferable to other EWS **3.2:** Enter data-sharing agreements with actors that may have access to information about communities without EWS		Addressing impacts of climate change on disaster risks; Legal & institutional arrangements; Technology, infrastructure, & forecasting capability

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Acronym List

Acronym	Term
CBFEWS	Community Based Flood Early Warning System
CDEMA	Caribbean Disaster Emergency Management Agency
CSR	Corporate Social Responsibility
EM-DAT	Emergency Events Database
EWS	Early Warning System
FEMA	Federal Emergency Management Authority
GLOF	Glacial Lake Outburst Flooding
GPS	Global Positioning System
HKH	Hindu Kush Himalayan
HYCOS	Hydrological Cycle Observation System
ICG of IOTWMS	Intergovernmental Coordination Group of the Indian Ocean Tsunami Warning and Mitigation System
ICIMOD	International Centre for Integrated Mountain Development
IFRC	International Federation for the Red Cross
LAKI	Lima Adaptation Knowledge Initiative
MHEWS	Multi-hazard Early Warning System
NATO	North Atlantic Treaty Organization
NGO	Non-governmental Organization
PAE	Policy Analysis Exercise
RFI	Requests for Information
RFIS	Regional Flood Information System
SEE	Sustainable Eco Engineers
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollars

INTRODUCTION

A MULTI-HAZARD REGION

The Hindu Kush Himalayan (HKH) region includes Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. Nearly 1.9 billion people live in the HKH region and approximately 240 million live in the mountains and hills.[2] The mountains in the region are young and still rising, which increases vulnerability to erosion, earthquakes, and landslides, in addition to the other risks associated with being located in tectonically active zones. Regional experts have estimated that more than 1.0 billion people are at risk of exposure to the increasing frequency and intensity of natural hazards tied to both climate change and environmental degradation.[3] **Figure 1** uses data from the Emergency Events Database (EM-DAT) to convey the striking increase in disasters caused by natural hazards per year over time in the HKH region.

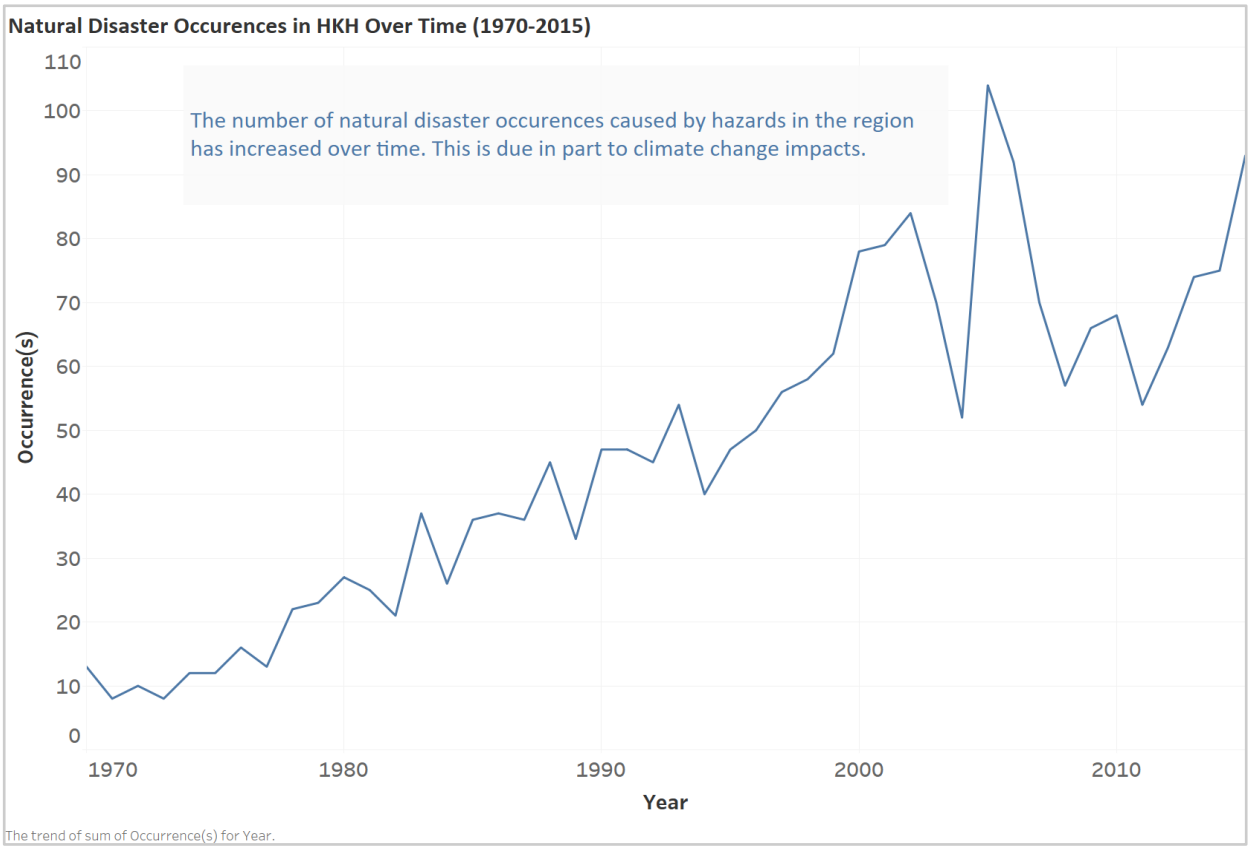

Figure 1: Natural Hazard Occurrences in HKH Over Time (1900-2015)

[2] Wester et al.
[3] "Natural Disasters and Impacts on Human Trafficking," ICF, February 20, 2019, https://www.icf.com/insights/disaster-management/trafficking-victims-in-disasters.

In addition to the human costs of lives lost, natural hazards also cause economic loss and traumatic displacement. As such, disaster risk reduction is an integral part of overall sustainable development efforts in the region, as natural hazards profoundly affect economic livelihoods, public health, and overall social well-being. Notably, women and other vulnerable groups are disproportionately and adversely impacted by natural hazards, compounding existing equity issues in the HKH region. Other adverse impacts include increases in human trafficking post-disaster events and other humanitarian challenges.[4] In conclusion, the HKH is a disaster-prone region and this reality affects the quality of life of nearly a quarter of the world's population.

Climate Adaptation Knowledge Gap

In 2014, the United Nations Framework Convention on Climate Change (UNFCCC), in partnership with the United Nations Environment Programme (UNEP), launched the first phase (2014-2018) of the Lima Adaptation Knowledge Initiative (LAKI).[5] LAKI serves as an action-oriented, global effort that identifies and prioritizes climate change adaptation knowledge gaps from six subregions (Andean, HKH, Indian Ocean Islands, North Africa, Southern Africa, and West Asia).

During the LAKI pilot phase, UNFCCC worked with the International Centre for Integrated Mountain Development (ICIMOD), a prominent intergovernmental organization of the eight HKH countries. ICIMOD's mission is "to enable sustainable and resilient mountain development for improved and equitable livelihoods through knowledge and regional cooperation." From October 20-22, 2016, UNFCCC and ICIMOD convened experts from the HKH subregion for a priority setting workshop to identify the main climate adaptation challenges.[6]

This policy analysis exercise aims to close Knowledge Gap Three identified in this priority-setting workshop. Knowledge Gap Three focuses on **the lack of access to early warning systems (EWS) for multiple hazards** in the Himalayas and downstream communities. This knowledge gap aligns with the Sendai Framework for Disaster Risk Reduction global target G. **Appendix B** provides more background on the knowledge gap and early warning systems.

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[4] Philippus Wester et al., "The Hindu Kush Himalaya Assessment: Mountains, Climate Change, Sustainability and People" (Springer Open, 2019).

[5] UNFCCC Secretariat, "The Lima Adaptation Knowledge Initiative | UNFCCC," The Lima Adaptation Knowledge Initiative, accessed February 8, 2020, https://unfccc.int/topics/adaptation-and-resilience/workstreams/nairobi-work-programme-nwp/the-lima-adaptation-knowledge-initiative.

[6] LAKI, "Workshop on Priority-Setting for the Hindu Kush Himalayan Subregion" (Sri Lanka, 2016), https://www4.unfccc.int/sites/NWPStaging/Documents/LAKI%20report%20on%20Hindu%20Kush%20Himalayan%20subregion%20(2).pdf.

For the purposes of our PAE, we rely on the following EWS definition: "the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities, and organizations threatened by hazards to take necessary preparedness measures."[7] A multi-hazard early warning system (MHEWS) addresses "several hazards and/or impacts of similar or different types in contexts where hazardous events may occur alone, simultaneously, cascading, or cumulatively over time." (In this PAE, we will use the phrase multi-hazard early warning system to also refer to 'early warning systems for multiple hazards.') **Figure 2** shows the four components of a single-hazard or multi-hazard early warning system.

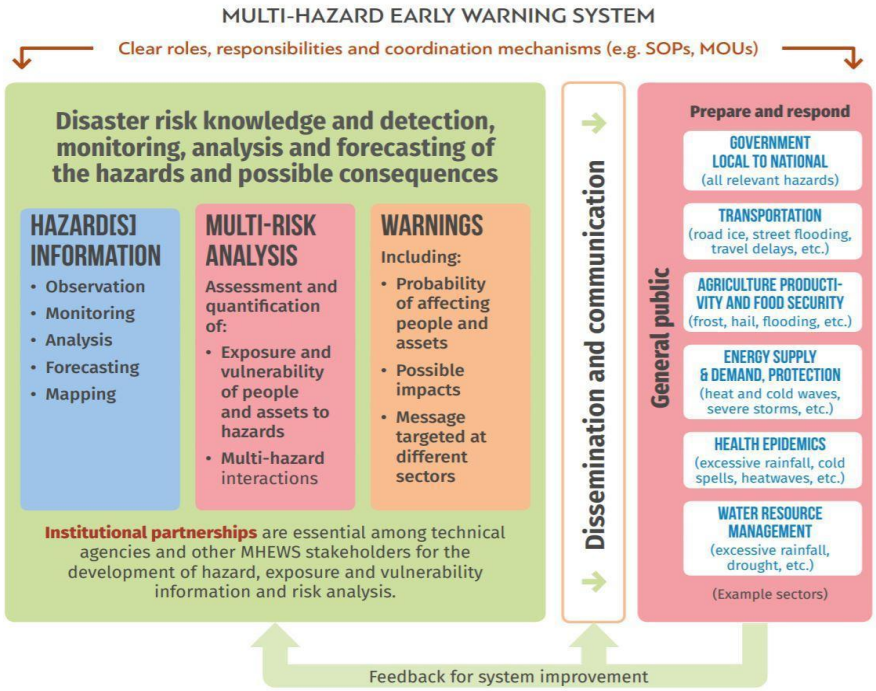


Figure 2: Multi-Hazard Early Warning System illustration from the World Meteorological Organization

Early warning systems contribute to far more than just disaster risk reduction. Effective EWS provide co-benefits that extend beyond traditional conceptions of preparedness because natural disaster events result not only in loss of life, but displacement, sanitation and health issues, and loss of livelihoods. Furthermore, the Paris Agreement explicitly includes EWS "as one of the major focus areas in order to enhance adaptive capacity, strengthen resilience and reduce vulnerability" associated with the detrimental effects of climate change. [8]

[7] Dipankar Shakya et al., "Community Based Flood Early Warning System Resource Manual - Revised Edition for Telemetry Based Instrumentation" (Kathmandu: International Centre for Integrated Mountain Development, April 2019), http://lib.icimod.org/record/34493/files/icimodCBFEWSResourceManual.pdf

[8] "Multi-Hazard Early Warning Systems A Checklist" (Multi-Hazard Early Warning Conference, Geneva, Switzerland: World Meteorological Organization, 2017), https://reliefweb.int/sites/reliefweb.int/files/resources/Multi-hazard_Early_Warning_Systems_A_Checklist.pdf.

To explore how ICIMOD could work with other HKH actors to address the lack of access to EWS for multiple hazards, we developed two research sub-questions.

1. **Baseline**: What are the current barriers to access to MHEWS in the HKH region?
2. **Options**: What can be done to overcome these barriers to access and/or improve existing EWS in the HKH region?

A Leading EWS: ICIMOD Community Based Flood Early Warning Systems

In 2010, ICIMOD developed a community-based flood early warning system (CBFEWS) to address flash floods. The sustainability of CBFEWS depends on the long-term sustainability technical, financial, institutional and social support. These factors need to be considered within a project life cycle so that the communities and other stakeholders can seamlessly take over the operations and maintenance of CBFEWS for which strong collaboration between upstream and downstream communities is required. Sustainability must be embedded in the four elements.

Figure 3 depicts the four elements that compose CBFEWS. The CBFEWS is an integrated EWS that leverages a "system of tools and plans managed by and for communities in order to provide virtually real-time early warnings on floods to reduce risks."[9] The system combines a low-cost water level monitoring instrument with a "caretaker" assigned to validate risk levels based on water level during impending floods. The caretaker works with locally tailored communications focal points to transmit early warnings to upstream and downstream communities.

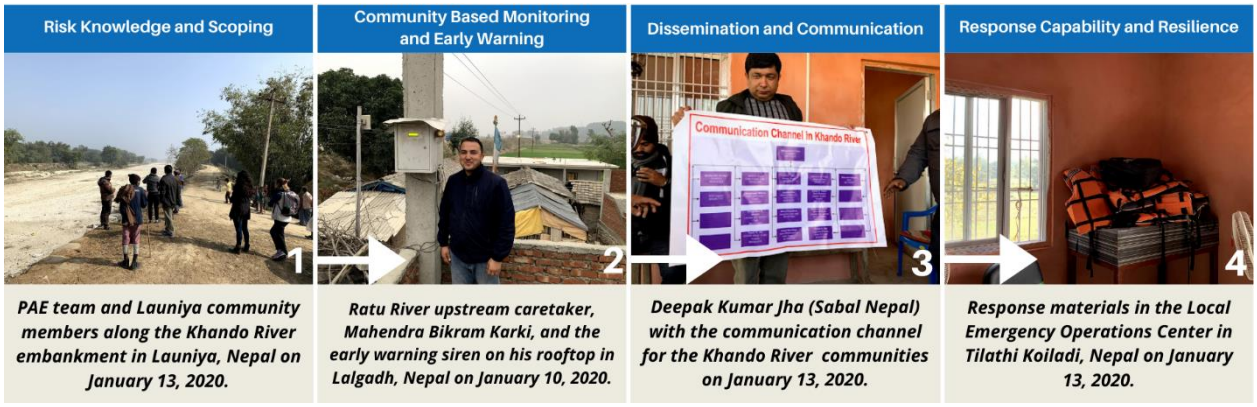


Figure 3: Four Elements of CBFEWS

[9] Shakya et al., "Community Based Flood Early Warning System Resource Manual - Revised Edition for Telemetry Based Instrumentation."

Four key aspects critical to CBFEWS effectiveness.[12]

1. **"People-centered**: *The system aims to include all members of vulnerable groups, in addition to traditional government agencies."*
2. **"Low-cost technology**: *Relative to alternative technologies, the cost of the wireless flood early warning instrument is relatively affordable (about $1,000 USD). The cost of a telemetry-based instrument is $3,800 USD."*
3. **"Near real-time information**: *Once the instrument is installed upstream of the beneficiary community, it reads and transmits water-level info in predetermined intervals."*
4. **"Multiple modes of disseminating early warning:** *The actual early warning may arrive in downstream villages via voice call, text, or internet group message from caretaker upstream or as a loud siren from the triggered alarm units. Key personnel will also receive email messages when pre-set danger thresholds are crossed by the monitored river.*

In 2014, the UNFCCC awarded ICIMOD and its partner organizations, Sustainable Eco Engineers (SEE) and Aaranyak, the Momentum for Change Lighthouse Award Activity under information and communication infrastructure for CBFEWS. Today, ICIMOD has deployed CBFEWS in four of the eight member countries: Afghanistan, India, Nepal, and Pakistan. Prior to these CBFEWS, many communities relied on a 'watch and warn' system (i.e. having a community member physically monitoring river water levels on or near the embankment or river).[10] In Pakistan communities, two to three people were appointed to watch the water from the highest point and beat a drum when a flood or debris flow was coming. Similarly, in Afghanistan, alternative communication methods were used including stone markers, mosque speakers, and a rifle shot to initiate food or debris flow warnings. [11] These precedents were both more labor intensive and dangerous than the formalized, end-to-end system established by CBFEWS implementation in these communities.

[10] Raj Kumar Mahato, Sone Lal Shah, and Sanjay Karns, Sarpallo Caretaker and Community Member Field Interview., January 11, 2020.
[11] Sayed Ahmad Sahim, Ahmad Fahim Shahab, and Rahman Baik Rahmani, Aga Khan Development Network Skype Interview., January 22, 2020.
[12] Shakya et al., "Community Based Flood Early Warning System Resource Manual - Revised Edition for Telemetry Based Instrumentation."

METHODOLOGY

Our research methodology relied on a combination of primary and secondary research collection including desktop research, a literature review, elite and community interviews, and qualitative data analysis. **Appendix C** provides a more detailed description of the interviews conducted for this report.

Secondary resources, including desktop research review, framed and motivated research questions to understand the LAKI knowledge gap. Peer-reviewed and grey literature research, in combination with interviews conducted within the Harvard community, focused on climate adaptation, disaster risk reduction (multi-hazard early warning systems), and disaster management.

We then conducted an in-depth review of ICIMOD's CBFEWS as an exemplary, locally driven innovation to address the lack of access to early warning systems. The focus on a flash flood early warning system aligned with the "water" theme from knowledge gap three. From January 2 - January 25, 2020, ICIMOD hosted our team at their headquarters office in Kathmandu, Nepal to conduct key informant and community-based interviews.

Our team dedicated a full week of in-depth interviews to CBFEWS' processes and procedures to understand its successful deployment in Nepal and in the three member countries (Afghanistan, India, Pakistan). Key informant interviews were conducted with ICIMOD, SEE and UNFCCC experts. Our team also visited ICIMOD's Godawari knowledge park to observe a scale model of a CBFEWS and gain an understanding of the system's process. We devoted an additional week to interviews with other stakeholders and partners of ICIMOD including Oxfam Nepal, Lutheran World Relief Nepal, World Wildlife Fund Pakistan, and the Aga Khan Agency for Habitat Afghanistan, to provide context on their understanding of regional barriers and solutions to increase access in the HKH region.

Our team also travelled to the Ratu and Khando rivers in Nepal to conduct in-depth community-based interviews. Interviews included those with the local community members (the beneficiaries of CBFEWS), caretakers, local government officials, and local partners.

Based on the interview data, we used two-stage qualitative coding analysis using predetermined codes and then emergent codes. Both the data collected in interviews and secondary literature sources supported the identification of barriers specific to the HKH region and ultimately framed our final recommendations. **Appendix D** contains a more detailed list of our assumptions and constraints.

LIMITATIONS

- We used CBFEWS as the main model to examine the lack of access to EWS in HKH. However, this meant that we focused a considerable portion of our analysis on community-based or bottom-up solutions and less time on analysis of national and regional infrastructure for top-down solutions.
- For the purposes of our PAE, we narrowed our analysis to MHEWS frameworks and flood EWS. We did not conduct as extensive research on other single-hazard EWS.
- We relied primarily on ICIMOD to identify and arrange the majority of our interviews in the HKH region; therefore, we were limited to the perspectives of stakeholders already in the ICIMOD network with availability during the time that we were in-country, potentially creating a selection bias.
- Given that no one on our team speaks Nepali or regional dialects, we depended on a professional translator for most interviews and recognized that nuances may have been in translation.

FINDINGS

KEY BARRIERS

Research Sub-Question 1: What barriers exist to accessing MHEWS in the HKH region?

Leveraging the insights from desktop research and both structured and semi-structured interviews, we identified several barriers preventing access to multi-hazard early warning systems. These barrier categories mirrored the seven categories of barriers identified by the United Nations Development Programme (UNDP) in a report entitled *Five Approaches to Build Functional Early Warning System.*[13] As a result, we relied on UNDP's seven categories based on their relative simplicity and comprehensibility to a general audience. We then prioritized the barriers based on our research and interview analysis.

While the barriers in the UNDP report apply broadly to developing nations, they fundamentally align with the regional insights in *The Hindu Kush Himalaya Assessment* and the barriers that

[13] Nicoletta Brazzola and Simon Helander, "FIve Approaches to Build Functional Early Warning Systems" (United Nations Development Programme, 2018), https://www.undp.org/content/dam/rbec/docs/UNDP%20Brochure%20Early%20Warning%20Systems.pdf.

emerged in our own qualitative interview coding analysis.[14] In order to combine this framework with the local insights from community-based interviews, we selected illustrative examples of the barriers to explain how these barriers are not just present at the regional or national level but also at the community level.

Budget

A financial budget is needed for every aspect of an EWS from funding the initial vulnerability scoping to the post-disaster evaluations. Budget barriers do not just exist within national level government authorities, but also among actors in different sectors and at multiple levels of governance. Barriers within this category include funding the acquisition and/or maintenance of an early warning instrument, conducting community outreach campaigns, compensating the labor required from local authorities to sustain an EWS, and acquiring weather and climate data.

Local Interview Example: Sabal Nepal, a CBFEWS implementing partner, said that getting the local governments to pay for the EWS served as the main barrier to increasing access along the Khando River.[15] Some of the funding needs included paying for the acquisition of the cost of the water-level monitoring instrument, compensating caretakers for their time, funding the operations and maintenance of the monitoring instrument, and purchasing response materials.

Human Resources and Expertise

Early warning systems rely on the knowledge and capabilities of personnel to maintain and operate the four different components of the system (as referred in **Figure 3**). In the HKH, this includes the capacities of the eight central governments to adopt EWSs, the local government capacity to implement training programs and oversee local operations, and the ability of local implementing partners to ensure that there are individuals with the expertise to maintain and operate monitoring equipment for the EWS. The Hindu Kush Himalaya Assessment identifies

[14] Wester et al., "Hindu Kush Himalaya Assessment."
[15] Juna Giri et al., Sabal Nepal Interview, January 12, 2020.

institutional capacity as the largest constraint to the implementation of climate adaptation goals and policies.[16]

Local Interview Example: According to Nanki Kaur, the Regional Programme Manager of Adaptation and Resilience building at ICIMOD, flood EWS need both climate and weather data; however, certain country-level partners do not have the same institutional and technological capacity in data collection that Nepal does.[17] As a result, varying levels of data availability and access make regional coordination and planning in HKH difficult.

Reine (left), Colleen (center), the local caretaker, Mahendra Bikram Karki (center right), and Hel Kumar (far right) in Lalgadh, Nepal. The Lalgadh, Nepal site can notify the downstream communities in India. (January 10, 2020)

Technology, Infrastructure and Forecasting Capability

There are both cost and access-related barriers to monitoring (e.g. remote sensing and ground data collection), forecasting (e.g. climate and hydrologic models), and warning dissemination technologies. This barrier can encompass a broad range of types of technologies, including a lack of access to the physical infrastructure and the related economic capacity needed to maintain such infrastructure.

[16] Arabinda Mishra et al., "Adaptation to Climate Change in the Hindu Kush Himalaya: Stronger Action Urgently Needed," in *The Hindu Kush Himalaya Assessment: Mountains, Climate Change, Sustainability and People*, ed. Philippus Wester et al. (Cham: Springer International Publishing, 2019), 457–90, https://doi.org/10.1007/978-3-319-92288-1_13.

[17] Kaur, Interview with Nanki Kaur, January 21, 2020.

Mohammad Salim, Ratu River upstream caretaker, showing our team part of the low-cost early warning instrument installed at his home in Rupani, Nepal on January 11, 2020.

Local Interview Example: Mandira Singh Shrestha (ICIMOD) noted difficulties with data sharing at the region, inter- and intra-governmental level.[18] She expressed that the lack of modernized data networks and systems to collect pertinent data, including weather and climate data, constituted a significant barrier.

Response Coordination and Disaster Response Preparedness

Response coordination and disaster preparedness closely aligns with the fourth element of an early warning system (e.g. response capability and resilience in CBFEWS). Chronologically, disaster preparedness barriers impede efforts to reduce or mitigate the impacts of a disaster before they happen, and response coordination barriers impede efforts to respond to the disaster once it has occurred. Barriers within this category may include a lack of response capacity, risk awareness, warning notifications, and disaster simulations. Additionally, it could include a lack of material resources for response processes during and after a disaster.

[18] Mandira Singh Shrestha, Interview with Mandira Singh Shrestha, January 22, 2020.

Local Interview Example: Community member and local authority interviews stressed the importance of response materials and response capabilities at higher rates than provincial or national-level interview respondents. For example, when we asked community members in Sarpallo, Nepal about early warning system barriers, they referred to a lack of resources for response activities (e.g. search and rescue), response materials (e.g. life jackets and boats), and evacuation as one of their most pressing concerns.[19]

Community based interview with Raj Kumar Mahato (left) (Ratu River downstream caretaker) at the Ward 7 office in Sarpallo, Nepal on January 11, 2020.

Legal and Institutional Arrangements

Gaps exist in legal and institutional frameworks that prevent the streamlined and timely flow of risk information to decision-making authorities and to the community-level recipients of early warnings.[20] Delineated roles and responsibilities for relevant governmental actors remain critical for effective EWS operations; however, some roles and responsibilities are not clearly defined.[21] The Hindu Kush Himalaya Assessment highlights barriers in governance and in links between upstream and downstream communities as two main issues facing the HKH region, both of which correspond to these legal and institutional frameworks.[22]

[19] Mahato, Shah, and Karns, Sarpallo Caretaker and Community Member Field Interview
[20] Nicoletta Brazzola and Simon Helander, "FIve Approaches to Build Functional Early Warning Systems" (United Nations Development Programme, 2018), https://www.undp.org/content/dam/rbec/docs/UNDP%20Brochure%20Early%20Warning%20Systems.pdf.
[21] "Multi-Hazard Early Warning Systems A Checklist" (Multi-Hazard Early Warning Conference, Geneva, Switzerland: World Meteorological Organization, 2017), https://reliefweb.int/sites/reliefweb.int/files/resources/Multi-hazard_Early_Warning_Systems_A_Checklist.pdf.
[22] Ramesh Ananda Vaidya et al., "Disaster Risk Reduction and Building Resilience in the Hindu Kush Himalaya," in *The Hindu Kush Himalaya Assessment: Mountains, Climate Change, Sustainability and People*, ed. Philippus Wester et al. (Cham: Springer International Publishing, 2019), 389–419, https://doi.org/10.1007/978-3-319-92288-1_11.

A historical example in the HKH region is the lack of clearly delineated roles in transboundary flood management in Nepalese and Indian national and local government authorities revealed in the 2008 Kosi Floods. [23] In brief, an extensive case study of the 2008 Kosi Floods, which resulted in the displacement of over 3 million people and large agricultural loss, attributed the immense damage and lack of proper warning to ambiguities in the Kosi Treaty between the two nations about when, who, and how monitoring and maintenance of the embankments (i.e. flood control structures) would be conducted by respective authorities.[24]

Local Interview Example: Rajan Subedi of Oxfam noted issues with formal international coordination and information sharing between governmental entities in HKH.[25] In addition, Rakesh Kumar Shah (Lutheran World Relief) noted that neither Nepal or India are ready to adopt a transboundary EWS despite the fact that flooding impacts the border area.[26] He believes more cooperation is needed between the two nations. The National EWS protocol for floods in the region where he operates takes up to 48 hours to disseminate information to vulnerable communities across the border, whereas, the local EWS helps share flood-related information within 15-24 hours. The accompanying photo was provided by a community member to show us the intense seasonal flooding that occurs in the region of Nepal that borders India, demonstrating the need for transboundary coordination.

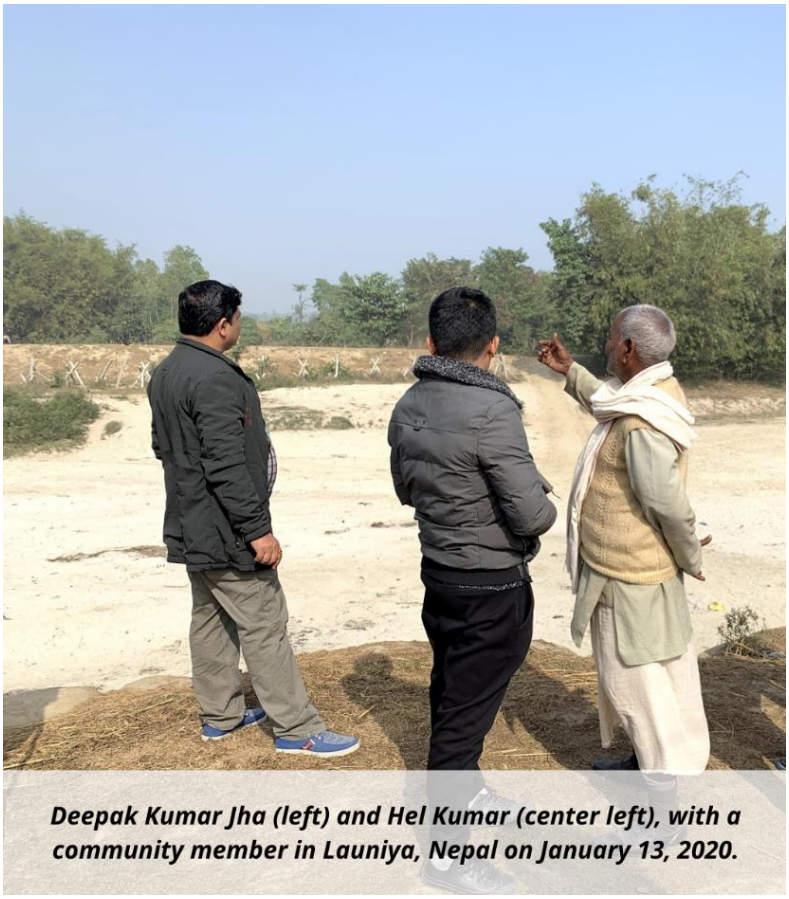
Photo of seasonal flooding taken by cellphone and provided by Sarpallo, Nepal community member.

[23] Rashmi Kiran Shrestha et al., "Institutional Dysfunction and Challenges in Flood Control: A Case Study of the Kosi Flood 2008," *Economic and Political Weekly* 45, no. 2 (2010): 45–53.
[24] Rashmi Kiran Shrestha et al., "Institutional Dysfunction and Challenges in Flood Control: A Case Study of the Kosi Flood in 2008," *Economic & Political Weekly*, January 9, 2020.
[25] Rajan Subedi, Oxfam Nepal Interview, January 21, 2020.
[26] Rakesh Kumar Shah, Lutheran World Relief Interview, January 21, 2020.

Public Engagement, Empowerment, and Community Outreach

Public engagement, empowerment, and community outreach transverse the four elements of EWS. Barriers within this category may include assigning roles to the public in flood monitoring, communicating actionable information in multiple languages, planning awareness workshops in disadvantaged communities, and creating communication chains that reach remote and vulnerable populations.

Local Interview Example: In our interview with the World Wildlife Fund-Pakistan, a CBFEWS implementation partner in Pakistan, they mentioned the challenges that they face in accessing remote populations.[27] In our interview with Lutheran World Relief, an EWS implementer, they emphasized the challenges they face reaching members that may be outside of their community grazing livestock when the warning notifications have been activated.[28]



Deepak Kumar Jha (left) and Hel Kumar (center left), with a community member in Launiya, Nepal on January 13, 2020.

Addressing Impacts of Climate Change on Disaster Risks

Historical data and trends need to be analyzed to forecast the impact that climate change will have on disaster risks in the HKH region. However, certain countries in the HKH region lack the

[27] Fazal Karim and Muhammad Mudassar, WWF Pakistan, January 22, 2020.
[28] Kumar Shah, Lutheran World Relief Interview.

technological infrastructure to collect reliable weather and climate data, and according to the UNDP, climate change is modifying the trends that have been historically used to produce such forecasts.[29] Under the status quo, HKH as a whole, is missing modernized monitoring networks, climate information databases and management systems, and locally customized climate change projections.

Local Interview Example: Rajesh Kumar Shah (Lutheran World Relief) discussed how improving climate and weather information systems, downscaling data, and customizing information to the end-users in a way that is understandable and actionable could help overcome current weather and data gaps.

Photo of HKH landscape in Sindhuli District, Nepal.

[29] Brazzola and Helander, "FIve Approaches to Build Functional Early Warning Systems."

Potential Solutions

Research Sub-Question 2: What can be done to overcome these barriers to access and/or improve existing EWS in the HKH region?

Table 1 summarizes the ways in which ICIMOD has already illustrated success in its contribution to overcoming the barriers to increase access to EWS for floods and flash floods in the HKH region.

Barrier	ICIMOD's Current Solution
Budget	**Financial Innovation:** Basket Fund model piloted in Tilathi Koiladi.
Human resources and expertise	**Partnerships and Involvement of Private Sector:** Works with SEE and local government offices to provide technical trainings for caretakers and other personnel.
Technology, infrastructure, and forecasting capability	**Involvement of Private Sector:** Partnerships with SEE in Nepal and BIS in Pakistan to develop cheap and easy-to-use technology for monitoring and alerts.
Response coordination and disaster preparedness	**Partnerships**: Works with local organizations and government line agencies who conduct preparedness training.
Legal and institutional arrangements	**Improve Information Sharing**: The community-based model links upstream and downstream communities without the need for formal legal and institutional arrangements. ICIMOD is also working with partners and local government line agencies to integrate CBFEWS in the annual disaster management plans at the local level.
Public engagement, empowerment, and community outreach	The community-based model engages and empowers the community.
Addressing impacts of climate change on disaster risks	**Improve Information Sharing:** Coordination with the HKH-HYCOS and Regional Flood Information System to improve hydrometeorological data.

ICIMOD's successful CBFEWS utilize many easily transferable aspects which we believe can help to increase access to MHEWS in the HKH region. To expand on ICIMOD's work, we generated potential **"enabling solutions"** which aim to overcome at least one barrier identified in our analysis. Each enabling solution plays an indirect, or supportive role, to the overall mission. These solutions contribute to the creation of an *enabling environment* where MHEWS are effectively enhanced, scaled, or developed.

We grounded each enabling solution in a combination of real-world examples in the region (*i.e. internal*) and examples outside of the region (*i.e. external*) to demonstrate the feasibility of the solution. This narrowed the number of potential solutions to those that we deemed the most realistic and tangible based on the existing capabilities and role attributes of ICIMOD. These potential solutions build off ICIMOD's existing core competencies and potential areas of focus.

In addition, we identified **"strategic solutions"** that HKH stakeholders could take to expand access to EWS. These strategies are intended to guide how HKH stakeholders could allocate its resources and concentrate its capacity with the goal to increase access to MHEWS. ICIMOD cannot achieve this goal alone as it requires the mobilization of actors from the household to the regional level to create resilient early warning systems for multiple hazards. Nonetheless, ICIMOD is uniquely positioned to mobilize action from national governments, civic organizations, local governments, non-state actors, etc. to increase access in densely populated urban regions as well as in the last mile of connectivity in rural municipalities.

Enabling Solutions

These solutions focus on creating the proper ***enabling environment*** (i.e. supportive processes, norms, and tools) for improving access to EWS. The solutions do not singularly increase access, rather they enable the expansion of access to EWS. These are not mutually exclusive options but are intended to complement one another. The *Hindu Kush Himalaya Assessment* highlights four enabling factors for scalability: resources, partnerships, knowledge management, and understanding of the local context.[30] The recent community-based climate adaptation literature has identified three enabling conditions —participatory approaches, social processes, and multiple scales—and initiatives focused on experimentation and learning as the most successful

[30] Mishra et al., "Adaptation to Climate Change in the Hindu Kush Himalaya."

ways to overcome the barriers.[31] Therefore, we consider three enabling solutions that integrate these considerations and aim to improve access to MHEWS in the HKH region.

1. ***Expand the roles and responsibilities of private sector actors***
2. ***Explore mechanisms for financial innovation***
3. ***Improve domestic and regional information sharing and coordination within the HKH***

1. Expand the Roles and Responsibilities of Private Sector Actors

Key barriers addressed:

In the HKH region, the private sector is not fully integrated into EWS plans, processes, and infrastructure. In other countries, such as the U.S., the private sector plays an indispensable role in driving technological advancements the monitoring and early warning and the communications and dissemination components of a MHEWS. The private sector, if more heavily involved, could offer financial and non-financial resources (e.g. human capital) that could strengthen regional EWS infrastructure.

Hel Kumar of SEE (right) demonstrating the CBFEWS along the Khando River at the Sabal Nepal office in Rajbiraj with Colleen Narlock (left) and Deepak Kumar Jha of Sabal Nepal (center). January 12, 2020

Real World Example: Internal (Nepal and Pakistan): We know this solution to be feasible to the region, because ICIMOD has already leveraged private sector participation in order to develop and sustain early warning systems. For example, it worked with private sector actors, Sustainable Eco Engineering (SEE)

[31] Karen Elizabeth McNamara and Lisa Buggy, "Community-Based Climate Change Adaptation: A Review of Academic Literature," *Local Environment* 22, no. 4 (April 3, 2017): 443–60, https://doi.org/10.1080/13549839.2016.1216954.

in Nepal and Buraq Integrated Solutions (BIS) in Pakistan, to manufacture and maintain the technology. SEE's technology was instrumental in ICIMOD's award-winning CBFEWS in Nepal.

***Real World Example: External (United States of America)*:** In the U.S., the Federal Emergency Management Authority (FEMA), a federal government agency, runs the Integrated Public Alert and Warning System (IPAWS) that functions as the national EWS for all hazards, natural and manmade.[32] FEMA collaborates with radio and television broadcast agencies in order to create a multi-layer approach to disseminating warnings through subscription and non-subscription-based services. It also collaborates with 462 unique wireless providers. FEMA tries to remain on the cutting edge of technology by issuing Request for Information (RFIs) to private technology vendors to learn about emerging or cutting edge solutions to problems or obstacles that they have, regularly attending private exhibitions and trade shows for various technologies (e.g. consumer electronics), and sending representatives to conferences, such as those by the International Association of Emergency Managers.[33] FEMA also maintains connections to multilateral institutions in the international community (e.g. International Telecommunications Union, NATO, etc.) to stay up to date on the latest developments in technologies, standards, and events around the world. This collaboration for the private sector means FEMA takes a key regulatory and coordinating role but does not have to singlehandedly develop new technologies, build new infrastructure, and finance all components of the system. Instead, FEMA leans on the private sector so that there is mutually beneficial collaboration. This, of course, is not possible in all HKH countries. Nevertheless, there are incremental ways in which ICIMOD can facilitate more cross-pollination from private sector actors.

Real World Example: External (Asia Pacific): A common critique of using examples of high-income industrialized nations is that it is not truly a peer-to-peer comparison because of the dissimilar economic contexts. However, there are compelling examples of private sector collaboration in Asia as well. The Early Warning Broadcast Initiative, for example, informed broadcasters and media about the need for improved communication systems between government authorities and the public.[34] This resulted in the training of overall 500 broadcasters and standardized procedures for disaster warning (i.e. Standard Operating Protocols) to create

[32] Antwane Johnson, Interview with U.S. Federal Emergency Management Authority (FEMA) on Integrated Public Alert and Warning System (IPAWS), February 28, 2020.
[33] Johnson.
[34] Brazzola and Helander, "FIve Approaches to Build Functional Early Warning Systems."

a "culture of early warning and preparedness" in Malaysia, Thailand, China, Philippines, Vietnam, Cambodia, and Indonesia.

2. Explore Mechanisms for Financial Innovation

Key barriers addressed: 

In local interviews, desktop research, and conversations with ICIMOD, it was apparent that financial resources are a limiting factor in developing early warning systems and investing in disaster risk reduction more broadly. This solution focuses ICIMOD's activities on diversifying and expanding potential sources of funding to include novel sources of funding, such as newly created funds, and also developing partnerships with organizations or private actors that could potentially unlock funding for investments in multi-hazard early warning systems or non-financial resources that enable cost savings. We think this is in line with current ICIMOD priorities, because the HKH Assessment report already noted insurance, a financial mechanism to transfer risk and thus better manage risk, as a key barrier to improving overall disaster risk reduction in the region.[35]

Real World Example: Internal: The Tilathi Koiladi rural municipality chairman worked with the Corporate Social Responsibility division of a local bank to get it to contribute to a specialized fund for CBFEWS. In addition to raising money from the localities that would benefit from the system and combining this with the bank's funding, he negotiated a high enough interest rate at the bank to create a self-sustaining fund that could cover the annual costs of CBFEWS (i.e.

The Basket Fund

In December 2019, Tilathi Koiladi Rural Municipality Chairman Satish Singh initiated the process to generate sustainable CBFEWS financing. ICIMOD, Sabal Nepal. ICIMOD, Sabal Nepal, Ideal Society Saving and Credit Co-operative Limited, Tilathi Koiladi rural municipality, Rajbiraj municipality, Rupani municipality, and Prabhakar Yadav (a district-level governing body) created a local basket fund to sustain the operation and maintenance of the CBFEWS along the Khando River, Nepal in their communities. The municipalities contributed initial investments and the local cooperative provided a higher than market interest rate. This basket fund overcomes funding challenges that inhibit sustained access to early warning systems.

[35] Wester et al., "Hindu Kush Himalaya Assessment."

compensation of the caretaker, Operations and Management, etc.), while accruing interest to grow from year to year.

Real World Example: External (Indonesia): In 2013, Zurich Insurance Company committed up to 22.7 million USD to support a model that promotes flood resilience with the International Federation of Red Cross and Red Crescent Societies.[36] The initiative financed pre-event mitigation measures, targeting low-income communities and successfully implemented a mobile application (Z-alert) in Indonesia, to provide notifications on fire, typhoons, and tsunamis. There is also a feature for private citizens to add and verify warnings. This example demonstrates that private companies, such as insurance companies, have shared interests with inter-government agencies like ICIMOD, to reduce risks and disseminate more effective, multi-hazard early warning systems. Likewise, the private sector has financial resources and specialized technical capacity that can be invaluable in these contexts.

3. Improve Domestic and Regional Information Sharing and Coordination within the HKH

Key barriers addressed: 

Obstacles and inefficiencies in the standard processes for sharing raw data, especially data regarding water availability, prevent effective coordination on EWS in the HKH. This can be attributed to differences in levels of capacity between national governments in the HKH region, as well as differences in sub-national agencies, some of which are newly created, as in Nepal, which recently underwent federalization. Early warning systems cannot effectively function without streamlined and timely information sharing for all four system elements between relevant actors and stakeholders. ICIMOD has already made this a priority and driven progress in this area suggesting its willingness to potentially continue to work in this realm.

Real World Example: Internal (HKH region): ICIMOD is working on improving information sharing and coordination with the HKH-HYCOS, which works with the World Meteorological Organization to improve hydrometeorological data collection, transmission, analysis, and dissemination for early warning systems. It has also worked on the Regional Flood Information System for the same regional initiative, which has the additional benefit of involving capacity-building/training activities for pertinent stakeholders (e.g. employees of disaster management

[36] Brazzola and Helander, "Five Approaches to Build Functional Early Warning Systems."

authorities, emergency response, etc.). However, there is more that can be done at the national and subnational levels to improve integration and dissemination of information.

Real World Example: External (The Intergovernmental Coordination Group (ICG) of Indian Ocean Tsunami Warning and Mitigation System) An intergovernmental institution (ICG of IOTWMS) launched an effort aiming to enhance awareness and implementation of procedures for risk assessment and effective MHEWS among its member countries.[37] The initiative analyzes both slow onset and rapid hazards, including tsunami, sea level rise, coastal erosion, oil spills, windstorms, and flooding. Increasing "last mile" connectivity to the community level is a stated priority of the group and it is leveraging information, data, and subject matter expertise from governmental and non-governmental collaborators. For example, the initiative has formed partnerships with 15 higher education institutes across Europe and Asia, as well as representatives of the member countries governments (Indonesia, Maldives, Myanmar, Philippines, Sri Lanka).[38] The group had previously established 24 tsunami warning centres in the Indian Ocean to increase the number of sea level gauges and deep ocean tsunameters for data sharing. Like ICIMOD, which has focused on floods, it focused first on a single hazard, tsunamis, before expanding activities to other hazards through institutionalized processes and agreements. The IOTWMS, also piloted a new Severe Weather Forecasting Demonstration Project to strengthen regional infrastructure for the forecasting elements of EWS. By building institutional infrastructure (e.g. a regional framework, formal partnerships with government, academic, and non-government actors, pilot projects, etc.), the group is moving towards better regional integration and expanded focus on new hazards.

[37] Richard Haigh, Dilanthi Amaratunga, and Kinkini Hemachandra, "A Capacity Analysis Framework for Multi-Hazard Early Warning in Coastal Communities - ScienceDirect," *Procedia Engineering* Volume 212 (2018): 1139–46.
[38] Haigh, Amaratunga, and Hemachandra.

STRATEGIES

In addition to the enabling solutions described above, we identified five strategies that HKH stakeholders (ICIMOD and implementing partners) could follow to increase access to MHEWS. These strategies describe pathways through which ICIMOD can channel resources and focus action. We see five potential strategies that vary based on ownership level and hazard type.

- Expansion Strategy 1: **Enhance existing CBFEWS sites**
- Expansion Strategy 2: **Expand CBFEWS at the community level**
- Expansion Strategy 3: **Expand CBFEWS to Multi-Hazard focus at the community level**
- Expansion Strategy 4: **Expand to Multi-Hazard focus at the regional level**
- Expansion Strategy 5: **Expand to Multi-Hazard focus at the national level**

Table 2: Strategic pathways to increase access to EWS for multiple hazards in HKH

	Ownership Level			Hazard Type				
	Local (Community)	Regional (District/ Province)	National	Flood	Landslide	Debris Flow	Drought	GLOF
1	x			x		*		*
2	x			x		*		*
3	x			x	+	+	+	+
4		x		x	+	+	+	+
5			x	x	+	+	+	+

(x) *Standard components of the envisioned expansion strategy.*

(*) *ICIMOD currently focuses CBFEWS on flood hazards. In Pakistan, CBFEWS is used for debris flow and glacial lake outburst flooding (GLOF) at two sites.*

(+) *While options represent a transition from CBFEWS to a multi-hazard system, these strategies could involve addressing all hazards or any additional hazards that CBFEWS does not currently address.*

The following section describes the five strategic solutions that ICIMOD could pursue along with the advantages and disadvantages of each solution.

1. ICIMOD and implementing partners could enhance the reach of CBFEWS within existing communities

Description: ICIMOD could make improvements to existing EWS (e.g. CBFEWS) to ensure universal access within existing locations. ICIMOD could identify shortcomings and obstacles of existing systems through systematic evaluations and impact assessments to improve upon existing plans, processes, and infrastructure.

Advantages and Disadvantages: Though improvements to existing EWS would certainly increase their impact, this strategy would not lead to a drastic increase in the number of beneficiaries. Additionally, without data from a thorough impact assessment of their existing sites, we cannot estimate the number of additional beneficiaries if Strategy 1 were pursued.

***Example**: One shortcoming of CBFEWS identified in field research and interviews is the fact that caretakers, critical players in the upkeep and functioning of the system, are not all financially compensated. While many caretakers reported a sense of personal gratification and pride in their voluntary work, all caretakers interviewed in the field referenced a desire for some form of compensation. Most caretakers have other jobs to sustain themselves financially, the additional role can create stress on the individual and their family. In Afghanistan, there was also an instance of a caretaker moving away without proper notification to find a job, suggesting that the lack of compensation could lead to issues with system sustainability.[39] ICIMOD has already begun to explore and implement successful sustainability models to remedy this shortcoming in certain CBFEWS sites. Developing a viable mechanism for seasonal compensation across all existing and future CBFEWS sites could support local caretakers and potentially boost the long-term viability of the model.*

[39] Sahim, Shahab, and Rahmani, Aga Khan Development Network Skype Interview.

2. ICIMOD and implementing partners could expand CBFEWS to new communities

Description: ICIMOD and implementing partners could continue to identify new locations for their existing CBFEWS model (i.e. prerequisites: appropriate geographical sites and sufficient stakeholder buy-in). This could mean scaling the Community Based Flood Early Warning System to other regions within Afghanistan, India, Nepal, and Pakistan or introducing it to Bangladesh, Bhutan, China, and Myanmar.

Advantages and Disadvantages: ICIMOD would increase the additional number of beneficiaries of EWS in the HKH by expanding to communities that did not previously have any access. However, the political and financial barriers associated with expanding to new communities would be greater than those of Strategy 1. Additionally, Strategy 2 does not expand EWS to other natural hazards and remains focused on flash floods.

***Example**: To overcome the barriers to geographical expansion, one potential pathway to scaling access could involve developing standardized criteria for scaling CBFEWS to another location. While ICIMOD has already developed certain technical feasibility criteria for scaling CBFEWS, it can develop holistic criteria for determining the socio-political readiness of another geographic location for CBFEWS expansion. This could involve developing relations with new implementing partners (e.g. NGOs) in other regions or other HKH nations to ensure there is community desire and will to maintain the system. It could also include training and capacity-building, similar to efforts that ICIMOD has already done in Pakistan and Afghanistan to scale out from India and Nepal. Lastly, there could be certain predetermined checks for analyzing potential ways to align the CBFEWS with other national systems if they exist in the given locality.* [40]

[40] International Federation of Red Cross and Red Crescent Societies, "Community Early Warning Systems: Guiding Principles" (Koninklijke Brill NV, 2012), https://doi.org/10.1163/2210-7975_HRD-9813-2015012.

3. ICIMOD and implementing partners could expand effective aspects of CBFEWS to community-based early warning systems for multiple natural hazards

Description: ICIMOD could identify the transferable aspects of CBFEWS for EWS adoption including, but not limited to, cheap and easy to use technologies, mock drills, training, and coordination procedures with the Local Emergency Operations Centers. These aspects can be turned into a toolkit to be used by other ICIMOD natural hazard initiatives or by other implementing partners' EWS.

Advantages and Disadvantages: Like Strategy 2, Strategy 3 would increase the additional number of beneficiaries with access to EWS more than Strategy 1 by expanding to communities that did not previously have any access. It shares the similar constraint of having greater political and financial barriers than Strategy 1. To compare Strategy 3 to Strategy 2, additional data is needed regarding the political capital available in the targeted communities, necessary capacity development requirements, initial financial investments, and anticipated timeline.

***Example**: ICIMOD's successful partnership with SEE illustrates the benefit of utilizing cheap and easy-to-use technology for CBFEWS. This aspect of CBFEWS can be easily transferred to MHEWSs. Though we recognize that ICIMOD does not have the capacity to work everywhere we believe that the implementation of the Springshed Management Program and SERVIR illustrate that ICIMOD does have the capacity to branch into the development of EWS for other natural disasters. ICIMOD also does extensive work on disaster risk reduction related to multiple natural hazards. This could perhaps set the groundwork for a new area of work that develops EWS infrastructure for non-flood hazards. Alternatively, other implementing partners (i.e. Oxfam Nepal, Red Cross and Red Crescent Societies, and Lutheran World Relief) could utilize transferrable aspects of CBFEWS for community based EWS for other hazards as well.*

4. ICIMOD and implementing partners could explore initiating a Regional Multi-Hazard Early Warning System and/or supporting existing regional multi-hazard early warning systems

Description: Currently, ICIMOD supports a model of an EWS that focuses on the community level and primarily addresses one natural hazard (i.e. flooding). ICIMOD and implementing partners could expand on existing efforts to explore MHEWS that operate on the regional level, within a country or within an area that encompasses a transboundary zone. The rationale for this approach is that certain types of resource, such as bodies of water tied to hydrological natural hazards impact more than one locality or municipality, and instead impact large regions where residents could potentially pool resources and/or coordinate to mitigate related risks.

Advantages and Disadvantages: Working across countries or across cities within a country for a regional focus requires political will, meticulous coordination, and broad stakeholder buy-in (e.g. cooperation from civil society and private citizens in addition to government). While

Example: *Recognizing that natural resources or topographical features do not fall neatly within jurisdictional boundaries, ICIMOD launched the Koshi Basin Initiative and the Koshi Disaster Risk Reduction Knowledge Hub. The Koshi Basin Initiative aims to improve water resource management in the Koshi River basin and cryosphere by enabling evidence-based decision making and regional cooperation across China, India, and Nepal.[41] The Initiative already includes transboundary working groups for droughts, floods, glacial lake outburst floods (GLOF), and landslide and sedimentation.[42] The Initiative has an online information system that includes gender disaggregated indicators relevant to water, food, energy, climate change, and disaster risk management.[43] A feasible extension of this Initiative could be to expand the working groups focused on flood and community-based disaster risk reduction with multiple stakeholder organizations while utilizing the already established online Koshi Basin Initiative Information System, which collects relevant hydrometeorological data and disaster data.*

[41] "Koshi Basin Initiative – ICIMOD," accessed March 29, 2020, https://www.icimod.org/initiative/koshi-basin-initiative/.
[42] "Koshi DRR Knowledge Hub – ICIMOD," accessed March 29, 2020, https://www.icimod.org/initiative/koshi-drr-knowledge-hub.
[43] "Koshi Gender Portal – ICIMOD," accessed March 29, 2020, https://www.icimod.org/koshi/gender-portal/.

a regional MHEWS could be very impactful in terms of the number of beneficiaries covered and the types of hazards addressed, it poses logistical challenges in terms of financing, design, implementation, and continued operations and management. It would take considerably more capacity than the other expansion strategies (e.g. 1-3). Nonetheless, the HKH Assessment found that "local initiatives are not adequately supported through subnational and national governance systems," so interventions at this level could build capacity at these levels as well.[44]

5. ICIMOD and implementing partners could expand national government multi-hazard early warning systems

Description: ICIMOD supports member countries by increasing access to research innovations, databases, and technical experts—all of which all support existing national government EWSs. ICIMOD and implementing partners could expand existing efforts and initiate new efforts that enhance MHEWS operations at the national level. The expansion could focus on incorporating new hazards into existing systems, expanding the reach of national systems, or connecting national systems to regional and local systems.[45]

Advantages and Disadvantages: Expanding at the national level could enable ICIMOD and implementing partners to address a large number of beneficiaries and coordinate with

***Example**: Bindeshor Yadab, Sub-Inspector Nepal Police, and Khem Raj Katwal, Sub-Inspector Armed Police Force mentioned that they receive early warning notifications from the new Sapta Koshi monitoring site at Chatara station. The Nepal Department of Hydrology and Meteorology operates this station through the Flood Forecasting Section. The HKH HYCOS Regional Flood Information System can complement and strengthen systems such as the Flood Forecasting Section's flood discharge measurement stations and other EWS elements operated by the national government. Similarly, ICIMOD could identify actors that exist within multiple systems and focus attention on co-developing system elements. For example, ICIMOD could work with the Nepalese Department of Hydrology and Meteorology (DHM) to understand how the Khando River CBFEWS sites and the Sapta Koshi at Chatara station could broaden their area of coverage.*

[44] Hemant Raj Ojha et al., "Governance: Key for Environmental Sustainability in the Hindu Kush Himalaya," in *The Hindu Kush Himalaya Assessment: Mountains, Climate Change, Sustainability and People*, ed. Philippus Wester et al. (Cham: Springer International Publishing, 2019), 545–78, https://doi.org/10.1007/978-3-319-92288-1_16.
[45] Bindeshor Yadab and Khem Raj Katwal, Nepal Police and Armed Field Interview, January 13, 2020.

scientific and technical agencies that traditionally play a lead role in EWS development (e.g. DHM, Geological Agencies, Ocean Observing Agencies, etc.). If EWS development is a priority of political leadership, ICIMOD would face relatively lower political and institutional barriers because they would be operating jointly with national governments. Nevertheless, national EWSs are less conducive to community ownership. Similarly, due to resource scarcity and capacity constraints, national-level systems may not be able to center the most marginalized communities to the same extent as regional and community-based systems.

KEY CONSIDERATIONS

With finite resources, both in terms of human capital and finance, ICIMOD and implementing partners have limited capacity to pursue all five of the strategies to increase to MHEWS. As such, **Table 3** synthesizes some key trade-offs of the respective pathways. **Appendix E** contains a matrix with the detailed rationales behind each criterion's assessment.

Table 3: Strategic pathway comparison analysis

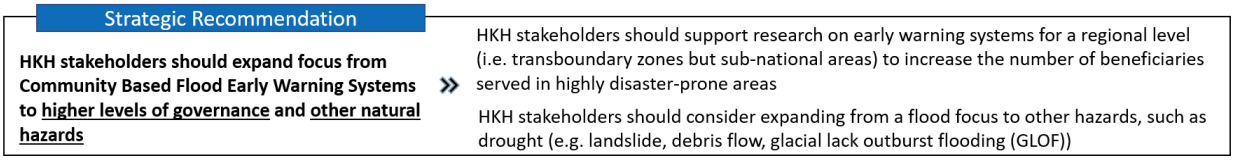
Strategic Solutions/ Criteria	Financial feasibility (e.g. financial cost)	Technical feasibility (e.g. time and capacity needed to implement)	Political feasibility (e.g. political capital / will needed to implement)	Number of Total Beneficiaries	Procedural equity*	Distributive Equity**
1 - Enhance Impact	High feasibility (i.e. Low Cost)	High	High	Low	High	High
2 - Expand Geographically	Medium feasibility (i.e. Medium/High cost)	Uncertain	Uncertain	Medium	High	High
3- Explore community-based MHEWS	Medium feasibility (i.e. Medium/High cost)	Medium/high	Medium	Medium	Uncertain	High
4 -Expand Regional MHEWS	Low/Medium feasibility (i.e. Medium/High cost)	Uncertain	Uncertain	High	Low	Uncertain
5 - Expand National MHEWS	Low/Medium feasibility (i.e. Medium/High cost)	Uncertain	Uncertain	High	Low	Uncertain

***Procedural equity** - "Emphasizes the extent and robustness of public and community participation planning and decision making"[46]
****Distributive equity** - "Emphasizes disparities across social groups, neighborhoods, and communities in vulnerability, adaptive capacity, and the outcomes of adaptation actions" [47]

[46] Sheila Foster et al., "New York City Panel on Climate Change 2019 Report Chapter 6: Community-Based Assessments of Adaptation and Equity," *Annals of the New York Academy of Sciences* 1439, no. 1 (2019): 126–73, https://doi.org/10.1111/nyas.14009.
[47] Foster et al.

RECOMMENDATIONS

After analyzing the tradeoffs, disadvantages, and advantages of the five proposed strategies**, we recommend that implementing partners within the HKH region in partnership with member governments of ICIMOD pursue strategy four: expanding from a single-hazard focus (i.e. CBFEWS) to a multi-hazard focus and expanding at the regional level.**



This approach should be complimentary to existing, successful efforts. For example, this does not mean that ICIMOD should abandon its innovative and impactful CBFEWS model. ICIMOD successfully increases access to early warning systems at the community-level. The hands-on workshops demonstrate success of existing sites and encourage adoption by new authorities. The interventions to build social connection and institutional arrangements between upstream and downstream communities develop critical local capacity. Rather, ICIMOD should continue to facilitate knowledge sharing about CBFEWS-related insights, so that it is not the sole "social catalyst" of the CBFEWS model.

Generally, the more community-based an EWS is, the more tailored its design can be, and the more procedural equity and community ownership it can incorporate. However, the larger the coverage of the EWS, the more people it can protect in order to maximize impact. As the coverage and technological sophistication of a system increases, the costs and logistical challenges increase as well. Nevertheless, EWS infrastructure with a larger geographic coverage undoubtedly yields more societal benefits. While our analysis is limited by incomplete access to information and certain assumptions, we were still able to compare the major trade-offs between the strategies.

RECOMMENDED POLICY STRATEGY: EXPAND ACCESS TO MHEWS IN HKH BY FOCUSING ON REGIONAL MHEWS

Why a Regional Focus?

The need for a regionally focused EWS was particularly evident during our field visit to the Nepal-India border adjacent to the Indian state of Bihar. Indian and Nepali authorities jointly manage some of the physical infrastructure for flood management (e.g. dams/embankments) along the Kosi River and these physical interventions impact both sides of the border. We discovered that there were clear interdependencies related to information-sharing and early warning among first responders and private citizens in the borderland region.

Figure 4 shows the impact of monsoon-induced floods and landslides in northern India and southern Nepal and Bangladesh.[48] It illustrates that natural hazard preparedness necessitates transboundary and/or regional coordination, because natural hazards cause fatalities, displacement, and other detrimental effects in areas that are not contained in conventional, geo-political boundaries. Countries in the HKH also share certain distinct geographical and topographical features that create shared risks and vulnerabilities for unevenly distributed clusters of residents

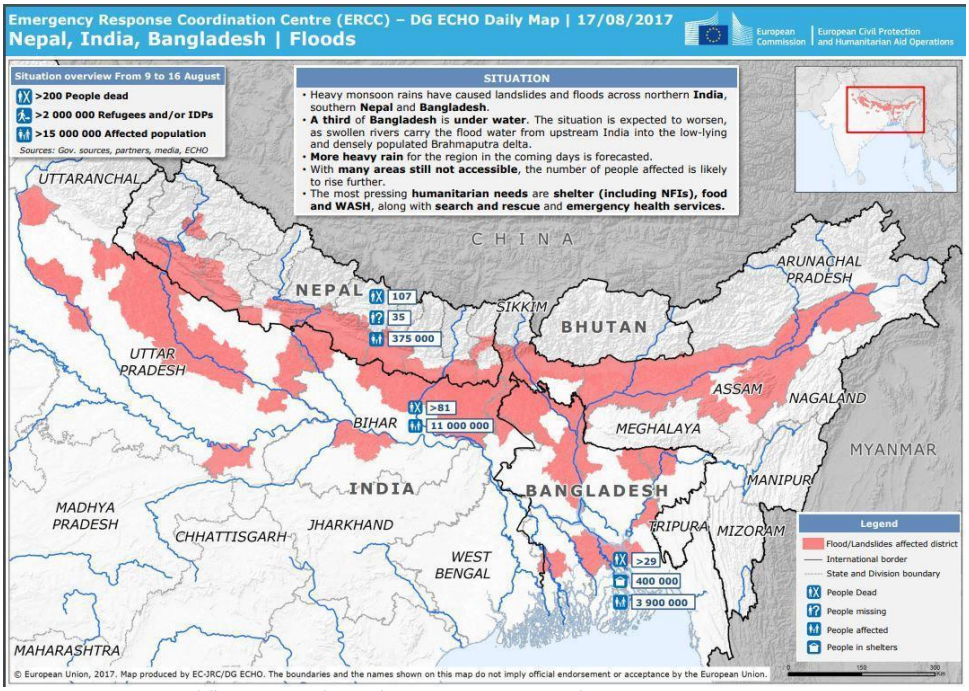


Figure 4: Impact of floods and landslides in India, Nepal, and Bhutan

[48] "Nepal, India, Bangladesh | Floods - Daily Map," ReliefWeb, August 17, 2017, https://reliefweb.int/map/india/nepal-india-bangladesh-floods-dg-echo-daily-map-17082017.

Why a Multi-hazard Focus?

ICIMOD's current focus on CBFEWS is appropriate, given that floods are the most frequent type of natural hazard in the HKH region and have caused the most economic damage, in aggregate, over the past century. **Figure 5,** generated with data from the Emergency Events Database (EM-DAT), shows a tree map of all economic damage attributable to natural hazards in HKH by hazard type and further affirms the importance of flood early warning systems.[49] However, droughts and other natural hazards, while *less frequent, can be* as destructive or more destructive on average per occurrence.

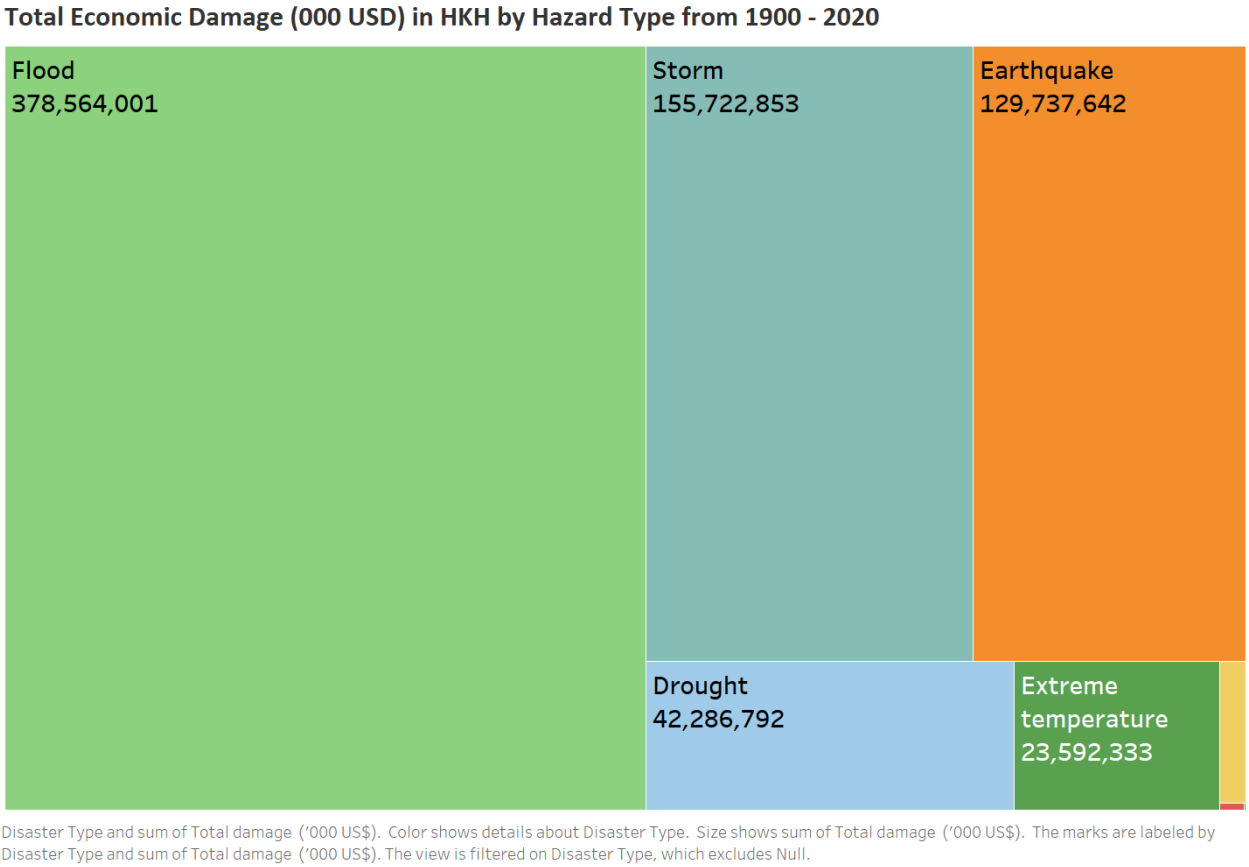


Figure 5: Tree map of economic damage attributed to natural hazards in the HKH subregion

[49] The International Disaster Database (EM-DAT), 1900 - 2020, Total Economic Damage, filtered to HKH countries. Data archive, http://emdat.be.

Figures 6 and 7 show the average number of fatalities and economic damage per event by disaster type for the same range of dates in HKH. These data points are instructive but imperfect; for example, GLOF is not included as a distinct hazard type. In addition, the categories do not reveal cascading hazards (e.g. floods can trigger landslides). Nevertheless, as the figures show, drought events kill more people and cause more economic damage, on average, than flooding.

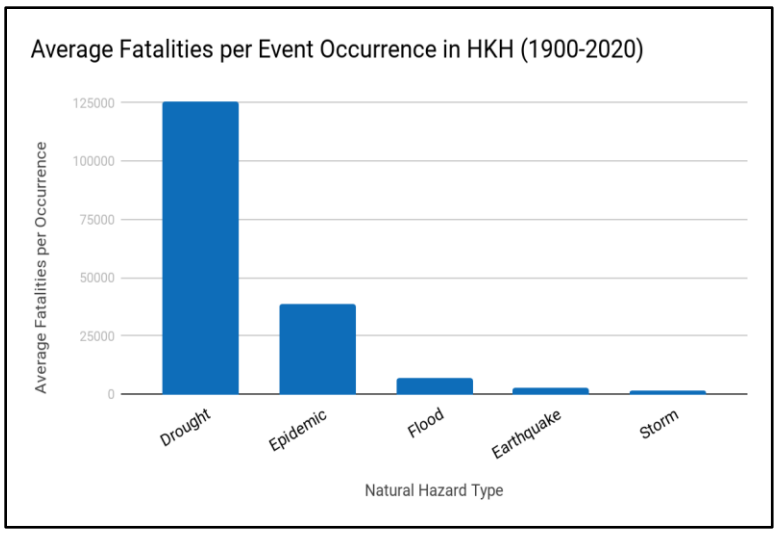


Figure 6: Average fatalities per event occurrence in HKH (1900-2020)

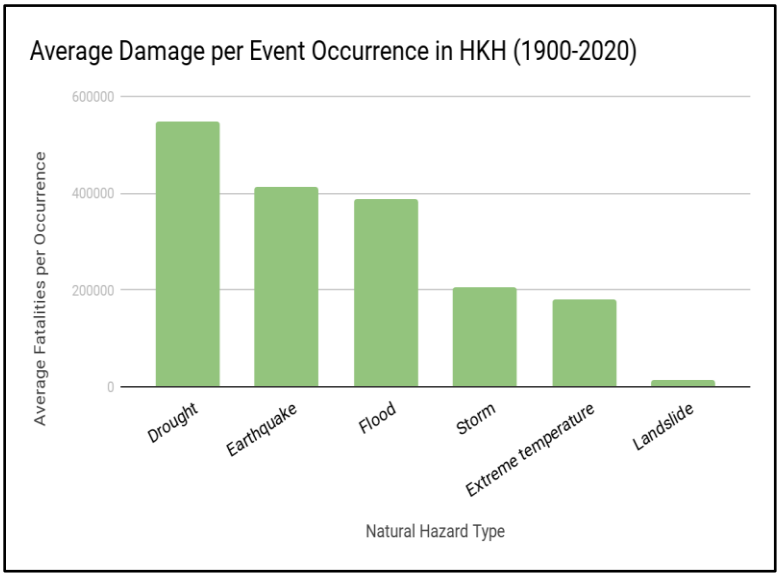


Figure 7: Average damage per event occurrence in HKH (1900-2020)

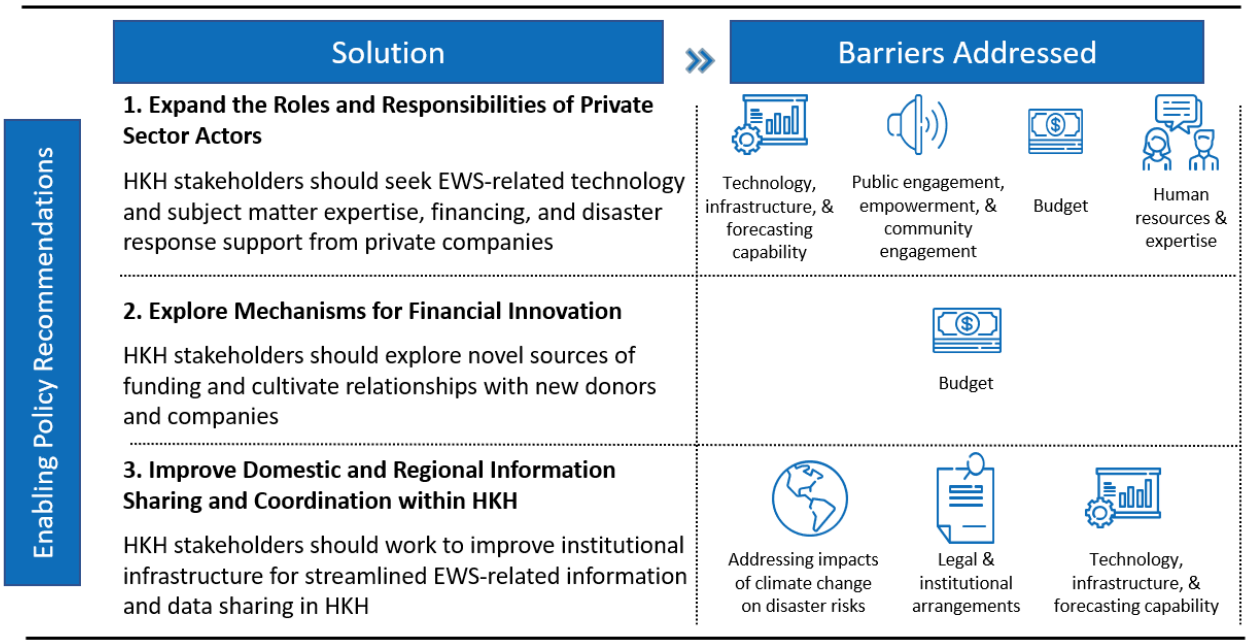
According to the same dataset, drought has killed more people than any other hazard type over the past century in the HKH region. ICIMOD's SERVIR Hindu Kush Himalaya and Climate Services for Resilient Development Initiatives helped to establish a regional agricultural drought monitoring and early warning system at regional, national, and district levels.[50] Nonetheless, Shesh Kanta Kafle from the Disaster and Climate Change Study Centre assessed the status of MHEWS in Nepal and found high interventions for floods but low interventions for droughts.[51]

[50] ICIMOD, "Drought Monitoring and Early Warning System for the Hindu Kush Himalaya," 2018, https://lib.icimod.org/record/34333.
[51] Shesh Kanta Kafle, "Disaster Early Warning Systems in Nepal: Institutional and Operational Frameworks," *Journal of Geography & Natural Disasters* 07, no. 02 (2017), https://doi.org/10.4172/2167-0587.1000196.

Because HKH is a disaster-prone region and subject to multiple hazards, not just flooding, it is important for HKH stakeholders to expand its EWS initiatives to explore and integrate other hazards. Additionally, hazards often occur cascadingly (i.e. triggering one another) or exacerbate one another necessitating a multi-hazard approach. ICIMOD has the scientific and technical expertise to meaningfully contribute to EWS for non-flooding hazards and is already working on disaster risk reduction at the Koshi Basin level. For this reason, HKH stakeholders branching out to non-flood early warning systems would be a feasible extension of its existing work. **Appendix F** provides potential implementation actions that ICIMOD could pursue related to this strategy.

Recommended Enabling Policy Solutions

We recommend the following actionable and feasible enabling solutions to increase access to MHEWS in the immediate future. We outline actions that ICIMOD and other HKH implementing partners could take to achieve the overall strategy of regional and multi-hazard early warning expansion.



Policy Recommendation 1: Integrate private sector actors more holistically into early warning systems.

Even if consensus exists on the importance of private sector participation in early warning system infrastructure, questions may persist on how increased private sector participation might be possible on a tactical level. We believe that various sectors could be relevant to early warning system work, depending on which of the four EWS components is being targeted for support. The following provide examples of partners for each component:

- *Disaster risk knowledge/detection:* Hydropower companies in Nepal or greater HKH, companies using satellite monitoring, Garmin or other companies with high-quality GPS technologies
- *Monitoring, analysis, and forecasting of hazards*: Technology vendors focusing on actual design/manufacturing of monitoring devices relevant to natural hazards in HKH or around the world, agricultural technology companies
- *Dissemination & communication:* Mobile service providers in Nepal, India, or greater HKH depending on regional focus
- *Preparedness & response:* Mobile application companies, supply and logistic companies

In the U.S., private sector participation looks fundamentally different, focusing primarily on consumer electronics and mass communications for early warning procedures; however, ICIMOD and implementing partners can work to tailor a private sector engagement strategy for what is appropriate for the HKH context.

1.1 Recommended Action: Convene a regional workshop on the role of private sector actors in MHEWS.

***1.2 Recommended Action*:** Issue an RFI for low-cost technologies for EWS.

Policy Recommendation 2: Explore mechanisms for financial innovation

Finding new sources of funding could help sustain existing EWS, invest in new early warning systems, and bolster investments in the human capital that is at the heart of all systems. First, the Alliance for Hydromet Development, formed in December 2019, and the Climate Risk Early Warning System Initiatives are two potential sources of funding that HKH stakeholders could explore, if no relationships with the efforts already exist. Both efforts include at least some existing funders/partners of ICIMOD's work, but greater involvement in the efforts could potentially lead to new sources of funding.

Secondly, ICIMOD and implementing partners can explore more formal relationships/contact with Corporate Social Responsibility departments in prominent HKH private companies and/or ICIMOD could explore partnering with private companies, such as Zurich Insurance, to increase access to funding and other resources. Zurich Insurance was both referenced in our research on other regional solutions, for its work in Indonesia, and in the Lutheran World Relief interview. We are uncertain of the status of ICIMOD's working relationship with the insurance company, but think it is something worth pursuing if not previously explored. Furthermore, the HKH Assessment, written by regional experts identified insurance as one of the key barriers to improving Disaster Risk Reduction, indicating that this is already a recognized priority.[52]

Additionally, performance metrics demonstrating the valuable work that ICIMOD has done to date could strengthen potential funding proposals. We have seen extensive evidence that ICIMOD's CBFEWS model minimizes economic loss in vulnerable communities and saves lives. A systematic statistical analysis of losses before/after CBFEWS implementation (i.e. impact assessment) can give ICIMOD and implementing partners leverage when sourcing financial or operational support from governments, private companies, or non-profit organizations.

2.1 Recommended Action: Develop a target list of existing funders who offer additional financial assistance or new funders that can be pursued and prioritize targets based on feasibility, funding availability, and proposal deadlines.

2.2 Recommended Action: Conduct an Impact Assessment on CBFEWS sites where data is available.

[52] Vaidya et al., "Disaster Risk Reduction and Building Resilience in the Hindu Kush Himalaya."

Policy Recommendation 3: Improve Domestic and Regional Information Sharing and Coordination within HKH

ICIMOD and its implementing partners can play a significant role in overcoming the obstacles to streamlined and efficient coordination and information sharing necessary for timely end-to-end EWS functioning. One of the most distinctive elements of its CBFEWS model was the clear delegation of roles and responsibilities in each component of the early warning system. It leveraged clear communication maps, tailored trainings, process maps, and other tools to delineate each stakeholder's role in CBFEWS. ICIMOD should share the successful and transferable attributes of its CBFEWS through the development of a toolkit which can be utilized by regional governments and other stakeholders to implement MHEWS across the HKH. An example of an EWS guiding toolkit can be found here. This was developed by the Caribbean Disaster Emergency Management Agency (CDEMA) in partnership with the International Federation for the Red Cross and Red Crescent Societies (IFRC) and the UNDP. ICIMOD could pursue a similar partnership with UNDP and NGOs such as Oxfam Nepal, with whom ICIMOD already has working relationships.

Additionally, we recognize that actors such as ICIMOD are not the only stakeholders interested in climate and weather data. As referenced above, many private sector companies rely on similar information for their operations. Companies, such as ClimaCell, have emerged to help companies across sectors acquire the necessary climate and weather data for their day-to-day operations. Data-sharing agreements with individual companies or organizations like ClimaCell which collect, monitor, and share climate and weather information for multiple sectors, could greatly improve domestic and regional information sharing and coordination within the HKH.

3.1 Recommended Action: Establish a standardized "toolkit" to summarize and share aspects of CBFEWS that are transferable to other MHEWS.

3.2 Recommended Action*:* Enter data-sharing agreements with actors that may have access to information about communities without EWS (e.g. ClimaCell, satellite monitoring companies, Garmin, commercial transportation companies, and agriculture device companies).

CLOSING KNOWLEDGE GAP 3

ICIMOD is uniquely positioned to help the HKH region increase access to MHEWS. These proposed strategic and enabling recommendations align with existing frameworks. For example, **Table 4** places these recommendations within the behavioral change framework from the HKH Assessment. This is not an exhaustive list of existing or potential initiatives that fit within this framework, but an illustration of the compatibility of our recommended solutions in this report with the existing DRR framework. We recognize that ICIMOD and implementing partners must mobilize actors across communities, governance jurisdictions, and cultures to close knowledge gap three. Nonetheless, we believe that these proposed recommendations can help ICIMOD and the region get closer to increasing access to MHEWS in the HKH to save money and more importantly lives.

Table 4: How our recommended enabling solutions align with the existing DRR and behavior change framework from the HKH Assessment

	Information	*Infrastructure*	*Institutions*	*Insurance*
Command and control Mechanisms			Institutionalize private sector actor participation	Partner with insurance companies for EWS investment
Incentives		Solicit RFI for low-cost monitoring instruments		
Persuasion	Ensure regional access to impact assessments and standardized 'toolkit' for EWS expansion / advocacy		Work with private sector actors with mutual interest in DRR	
Nudging	Access new funding source information and opportunities to incentivize EWS investment		Enter into data-sharing agreements	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Appendix A: Ethics and Transparency Statement

Although we conducted research in communities that experience heightened impacts from natural disasters, we did not intentionally put ourselves in a natural disaster to conduct research. We interacted with vulnerable populations to surface lived experiences and realities of the individuals on the frontlines of the natural hazards. We did not visit during monsoon season, which would have distracted from prevention and preparedness activities. We were mindful to observe local customs when entering local communities and households. Furthermore, we made sure to communicate that we were students conducting research for our Master in Public Policy degree and that their participation did not signify an increase in resources for their community.

Funding

The Harvard Kennedy School's Belfer Center for Science and International Affairs provided us $5,000 to conduct in-country research. In addition, the Belfer Center's Environment and Natural Resources Program provided $3,000 for PAE travel and research. ICIMOD provided in-kind assistance, such as arranging our site visit, coordinating interviews, providing workspace during our visit, dedicating staff hours to our project, and coordinating other logistics of our site visit. The Nepalese company, Sustainable Eco Engineers, (SEE) provided technical and translation support during our site visit and was compensated by our grant funding.

APPENDIX B: EWS BACKGROUND

LAKI Knowledge Gap

Table 5: Knowledge Gap Three [53]

Rank	3
Theme	Water
Category	Lack of access
Gap description	Lack of access to awareness-raising products and early warning systems for multiple hazards (drought, landslide, debris flow, flooding, glacier lake outburst flood) in the Himalayas and downstream communities
Expression of interest	Focus Humanitarian Assistance (Pakistan)
Possible deliverables	As part of the existing DRR programme by Focus Humanitarian Assistance, good practices in the form of case studies and reports could be shared Timeline: December 2018 Country: Multi-country
Tentative partners	Aga Khan Agency for Habitat (AKAH), United Nations Development Programme (UNDP), ICIMOD

Sendai Framework for Disaster Risk Reduction 2015-2030

Global target G: Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030.

KEY TERMINOLOGY

While there are multiple definitions of what an **early warning system** is, in this context, we rely on the UN International Strategy for Disaster Reduction definition: "the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities, and organizations threatened by hazards to take necessary preparedness measures and act appropriately in sufficient time to reduce possibility of harms or losses."[54]

[53] LAKI, "Workshop on Priority-Setting for the Hindu Kush Himalayan Subregion."
[54] Shakya et al., "Community Based Flood Early Warning System Resource Manual - Revised Edition for Telemetry Based Instrumentation."

A **natural hazard** refers to "naturally occurring physical phenomena caused by rapid or slow onset events which can be geophysical, hydrological, climatological, meteorological, or biological [55]. The fact that natural hazards often do not occur alone, but instead cascading or cumulatively over time, creating interrelated effects, necessitates a **"multi-hazard" approach** to preparedness planning and early warning system design [56]. For this reason, there is an emphasis on "multiple hazards" in the knowledge gap language and on **"**multi-hazard early warning systems" in literature on leading practices in disaster risk reduction (DRR). The table below defines the key natural hazards mentioned explicitly in knowledge gap three, but it is not an exhaustive list of all hazards impacting the HKH region.

Table 6: Natural Hazard Definitions

Natural Hazard	Definition
Drought	"Drought is defined as a deficiency of rainfall over an extended period--a season, a year, or several years --relative to the statistical multi-year average for the region [57]."
Landslide	"The term landslide is used in its broad sense to include downward and outward movement of slope forming materials (natural rock and soil. It is caused by heavy rain, soil erosion and earth tremors and may also happen in areas under heavy snow." [58]
Debris flow	"Fast-moving flows of mud and rock, called debris flows or mudslides, are among the most numerous and dangerous types of landslides in the world." [59]
Flood	"A flood is any relatively high streamflow overtopping the natural or artificial banks in any reach of a stream. Floods occur for many reasons, such as long-lasting rainfall over a broad area, locally intense thunderstorm-generated rainfall, or rapid melting of a large snowpack with or without accompanying rainfall [60]."
Glacial Lake Outburst Flood	Glacial Lake Outburst Floods (GLOFs) refer "a sudden release of a significant amount of water retained in a glacial lake, irrespective of the cause" [61].

[55] "Types of Disasters - IFRC," accessed February 8, 2020, https://www.ifrc.org/en/what-we-do/disaster-management/about-disasters/definition-of-hazard/.
[56] "Multi-Hazard Early Warning Systems A Checklist."
[57] "Drought - IFRC," accessed February 9, 2020, https://www.ifrc.org/en/what-we-do/disaster-management/about-disasters/definition-of-hazard/drought/.
[58] "Floods - IFRC," accessed February 9, 2020, https://www.ifrc.org/en/what-we-do/disaster-management/about-disasters/definition-of-hazard/floods/.
[59] Lynn Highland et al., "Debris-Flow Hazards in the United States" (United States Geological Survey), accessed February 9, 2020, https://pubs.usgs.gov/fs/fs-176-97/fs-176-97.pdf.
[60] "Floods and Recurrence Intervals," United States Geological Survey (USGS), 2019, https://www.usgs.gov/special-topic/water-science-school/science/floods-and-recurrence-intervals?qt-science_center_objects=0#qt-science_center_objects.
[61] Adam Emmer, "Glacier Retreat and Glacial Lake Outburst Floods (GLOFs)," *Oxford Research Encyclopedia of Natural Hazard Science*, April 26, 2017, https://doi.org/10.1093/acrefore/9780199389407.013.275.

Whether a multi-hazard early warning system or a single-hazard early warning system, generally four main components are included in any early warning system.[62] The United Nations conceptualized the four elements as: 1) disaster risk reduction 2) detection, monitoring, analysis and forecasting of the hazards and possible consequences 3) warning dissemination and communication 4) preparedness and response capabilities.[63] ICIMOD mirrors these components in CBFEWS: 1) risk knowledge and scoping 2) community based monitoring and early warning 3) dissemination and communication 3) response capability and resilience.[64]

ICIMOD has led the development of a locally-tailored framework on disaster risk reduction for the Hindu-Kush-Himalaya that builds off of existing knowledge of global frameworks (e.g. The Hyogo Framework for Actions 2005-2015 and the Sendai Framework for Disaster Reduction 2015-2030). The framework, published in *The Hindu Kush Himalaya Assessment: Mountains, Climate Change, Sustainability and People,* identified four, central pillars that need to be enhanced or invested in to overcome existing barriers:

1. **Information** - "Sharing hazard information between upstream and downstream communities, ensuring communication about cascading hazards."
2. **Infrastructure** - "Adapting to climatic and seismic risks, investing to enhance connectivity"
3. **Institutions** - "Addressing gender and governance dimensions and developing mechanisms to connect national institutions, policies, and actions with local ones"
4. **Insurance** - "Insuring, or transferring risk, to build resilience to residual disaster risks (those that may not be eliminated)"

[62] Villagran uses a three-phase model and Basher proposes an integrated model.
[63] "Multi-Hazard Early Warning Systems A Checklist."
[64] Shakya et al., "Community Based Flood Early Warning System Resource Manual - Revised Edition for Telemetry Based Instrumentation."

Additionally, the report identifies four broad categories of strategies for interventions to rectify the identified barriers (See Table 7).

Table 7: Disaster risk reduction elements and behavioral change strategies (Table 11.10 in Chapter 11 of the Hindu Kush Himalaya Assessment)[65]

	Information	Infrastructure	Institutions	Insurance
Command-and-control Mechanisms	Zoning and Building Code Enforcements	Infrastructure development projects, Technical design standards, Building codes and Land use plan/zoning	Institutionalization of formal and informal institutions	
Incentives		Rural housing reconstruction program (RHRP); financial support for seismic-resistant housing and Budget for infrastructure development		Subsidizing insurance premium that farmers pay for index-based weather crop insurance
Persuasion	Providing Hazard Maps	Technical guidelines and dissemination training by engineers regarding infrastructure development	Support from formal and informal institutions	Engaging NGOs as social mobilizers to raise awareness of market insurance for crops
Nudging	Community - Based Flood Early Warning Systems (CBFEWS)	Promoting retrofitting with nudges to consider traditional and cultural preferences	Institutional arrangement for CBFEWS; Revival of drying springs	Encouraging self-insurance through personal savings motivated by a clearly visible purpose such as loss of crops due to floods

[65] Vaidya et al., "Disaster Risk Reduction and Building Resilience in the Hindu Kush Himalaya."

Existing Initiatives on Early Warning Systems in the HKH

In addition, to the research and thought-leadership related contributions of ICIMOD, there are several tangible, regional efforts that seek to build capacity in this domain and pilot some of the interventions in Table 6.

Hindu-Kush-Himalaya-Hydrological Cycle Observing System (HKH-HYCOS) – HKH-HYCOS was an effort between ICIMOD and the World Meteorological Organization (WMO) that aims to overcome issues providing end-to-end flood early warning systems in the region by improving data collection, transmission, analysis, and dissemination of hydrometeorological data. The program is working to establish a framework for regional cooperation that facilitates information-sharing about hydrological information systems and transboundary flood management in the Indus river basins.[66]

Regional Flood Information System (RFIS) – As part of HKH-HYCOS, a regional flood information system (RFIS) has been established in order to enable transboundary exchange of real-time and near-real-time data, best practices, and subject matter expertise related to flood management (includes Bangladesh, Bhutan, Nepal, Pakistan as member countries; India and China are observers). Thirty upgraded hydro-meteorological stations in four HKH countries (Bangladesh, Bhutan, Nepal, Pakistan) were installed as part of this effort. There was also extensive capacity-building and training activities of pertinent stakeholders (e.g. employees of disaster management authorities, emergency response, etc.).[67]

Gender Disparity Studies of Flood Early Warning Systems in HKH Countries – ICIMOD has undergone analysis of flood early warning systems from "a gendered perspective" to more holistically analyze the issues and opportunities for enhanced gender and social inclusion. The study focuses first on four countries in HKH and analyzes institutional arrangements, key stakeholders, legal provisions, coordination and linkage mechanisms, and the four key elements of early warning systems.[68] Previous studies have attributed the fact that women are at higher risk of dying in disaster than men to "women's lack of information, mobility, decision-making power, and access to resources and training, as well as gender-based social/cultural norms and

[66] "Hindu Kush Himalayan-HYCOS | HydroHub."
[67] Organization (WMO) and International Centre for Integrated Mountain Development, *Establishment and Operation of a Flood Information System in the Hindu Kush Himalayas "Making Information Travel Faster than Floods", HKH HYCOS User Phase 2015-2019*.
[68] "Flood Early Warning Systems in Nepal."

barriers, conventional gender responsibilities, and high rates of male out-migration."[69] The work of ICIMOD seeks to provide actionable means of addressing this reality through the design and implementation of more gender inclusive early warning systems.

Community-based Flood Early Warning Systems (CBFEWS) - An early warning system that combines a "people-centered, timely, simple and low-cost technology" that monitors water levels with related tools and plans managed by and for communities.[70] The Community-Based Flood Early Warning System (CBFEWS) developed by ICIMOD is an award-winning approach to increasing preparedness and reducing harm that has been scaled to four of the eight HKH countries: India, Nepal, Pakistan, and Afghanistan.

[69] "Flood Early Warning Systems in Nepal."
[70] "Community Based Flood Early Warning Systems – ICIMOD."

Appendix C: Interviews

Exploratory Conversations

Prior to the field visit, we met with Harvard faculty to develop our research methodology and learn more about the region and disciplines.

- **Professor Dan Schrag**, Harvard University Sturgis Hooper Professor of Geology; Professor of Environmental Science and Engineering; Director, Harvard University Center for the Environment
- **Professor Rob Stavins**, Harvard University A. J. Meyer Professor of Energy and Economic Development
- **Professor Sheila Jasanoff**, Harvard University Pforzheimer Professor of Science and Technology Studies
- **Professor Hanna Reema**, Harvard University Professor of South-East Asia Studies
- **Professor Juliette Kayeem**, Harvard University Belfer Senior Lecturer in International Security
- **Professor Dutch Leonard**, Harvard University George F. Baker, Jr. Professor of Public Management
- **Professor John Holdren**, Harvard University Teresa and John Heinz Professor of Environmental Policy
- **Professor Bill Clark**, Harvard University Harvey Brooks Professor of International Science, Public Policy and Human Development, PAE advisor
- **Professor Dara Cohen**, Harvard University Ford Foundation Associate Professor of Public Policy, PAE seminar advisor

In addition, we met with the following external resources:

- **Maria Ignacia Arrasate**, Representative of GeoAdaptive LLC, a global consulting and strategy company that specialized in solving complex, economic, environmental, and social problems in a variety of territories, industries, and scales.
- **Antwane Johnson**, Director of the Integrated Public Alert & Warning System (IPAWS) at the United States Federal Emergency Management Authority (FEMA)

In-Country Interviews

We attempted to replicate the people-centered approach of CBFEWS in our interviews. The existing grey and peer reviewed literature generally relied on regional, national, and international-level actors.

Table 8: Summary of in-country interviews conducted

Participants	Time	Location
January 3, 2020		
• Neera Shrestha Pradhan, ICIMOD • Vijay Khadgi, ICIMOD • Shailendra Shakya, ICIMOD	9:00 - 10:00 AM (1 hour)	ICIMOD office, Nepal
• Arun Bhakta Shrestha, ICIMOD • Neera Shrestha Pradhan, ICIMOD • Shailendra Shakya, ICIMOD	10:00 - 10:30 AM (30 minutes)	ICIMOD office, Nepal
• Ajaz Ali, ICIMOD	10:51 - 11:30 AM (39 minutes)	ICIMOD office, Nepal
• Mahendra Man Shakya, SEE • Hel Kumar Shrestha, SEE • Yuke Maharjan, SEE • Narendra Bajracharya, ICIMOD • Shailendra Shakya, ICIMOD	2:00 - 3:00 PM (1 hour)	ICIMOD office, Nepal
• Nishikant Gupta (ICIMOD)	3:15 - 3:35 PM (20 minutes)	ICIMOD office, Nepal
January 7, 2020		
• Kanchan Shrestha, ICIMOD	9:30 - 10:00 AM (30 minutes)	ICIMOD office, Nepal
• Neera Shrestha Pradhan, ICIMOD	10:00 - 11:00 AM (1 hour)	ICIMOD office, Nepal
• Neera Shrestha Pradhan, ICIMOD • Vijay Khadgi, ICIMOD • Hel Kumar Shrestha, SEE	12:30 - 3:30 PM (3 hours)	ICIMOD Knowledge Park demonstration in Godavari, Nepal
January 9, 2020		
• Neera Shrestha Pradhan, ICIMOD • Vijay Khadgi, ICIMOD	2:30 - 3:15 PM (45 minutes)	ICIMOD office, Nepal
Site Visit Day 1: January 10, 2020		

• Mahendra Bikram Karki (Caretaker)	5:00 – 5:30 PM (30 minutes)	Mahendra Bikram Karki's home, Lalgadh, Nepal
Site Visit Day 2: January 11, 2020		
• Raj Kumar Mahato (Caretaker) • Sone Lal Shah (Ward 7 Chairman) • Indra Kumar Mahato, DRR member • Parikshan, DRR member • Sonkot, DRR member • Cahdran Kussah, Sarpallo village community member • Sanjay Karns, village farmer	10:20 AM – 12:00 PM (1 hour and 40 minutes)	Ward 7 Office, Sarpallo, Nepal
Site Visit Day 3, January 12, 2020		
• Juna Giri – Sabal Nepal Board of Director Chairperson • Deepak Kumar Jha – Executive Director • Rajesh Jha (DRR focal person) • Ashok Kumar Sah, Program Coordinator, Sabal Nepal • *Four unidentified individuals*	10:41 – 11:40 AM (1 hour)	Sabal Nepal, Rajbiraj, Nepal
• Rajesh Jha (DRR Focal Person)	11:45 AM – 12:05 PM (20 minutes)	Sabal Nepal, Rajbiraj, Nepal
• Juna Giri (Sabal Nepal)	12:10 – 12:18 PM (18 minutes)	Sabal Nepal, Rajbiraj, Nepal
• Mohammad Salim (Caretaker/Farmer) • Deepak Jha (Sabal Nepal) • Akbar Salim, professional driver • Mohammad Salim's mother • Idris, labor worker • Three unidentified individuals	2:35 – 3:19 PM (45 minutes)	Mohammad Salim's home, Rupani, Nepal
Site Visit Day 4: January 13, 2020		
• Bindeshor Yadab, Sub-Inspector Nepal Police • Khem Raj Katwal, Sub-Inspector Armed Police Force	10:49 – 11:10 AM (20 minutes)	Nepal Police Station, Sagarmatha, Nepal
• Kishor Kumar Jha, Administration • Deepak Mandal, Public Health Inspector (rural municipality)	11:45 AM – 12:30 PM (45 minutes)	Local Emergency Operations Center, Tilathi Koiladi, Nepal

• Bijay Kumar Sha, Public Health (ward)		
• Shiba Sharan Mandal (Launiya) community member	12:50 – 1:05 PM (15 minutes)	Launiya, Nepal
• Satish Kumar Singh (Tilathi Koiladi Chairperson)	8:00 – 8:30 PM (30 minutes)	Hotel Durbar, Lahan, Nepal
Site Visit Day 5: January 14, 2020		
• Mahendra Bikram Karki (caretaker) • Bisnu Kumar Shrestha, ward member • Bed Maya, member of the community • Subna Karki • Paibati Duhkel • Biswu Adhikar, APF • Menuka Timalsina • Kanxa Ram Thokar • Pgul Maya Karki	9:02 – 9:42 AM (40 minutes)	Mahendra Bikram Karki's home, Lalgadh, Nepal
January 20, 2020		
• Sanjay Pandey, Yugantar • Nishikant Gupta, ICIMOD • Shailendra Shakya, ICIMOD	1:45 – 2:37 PM (52 minutes)	ICIMOD office, Noshaq Hall, Nepal
• Dr. Ramesh Ananda Vaidya, ICIMOD • Neera Shrestha Pradhan, ICIMOD • Shailendra Shakya, ICIMOD	3:00 – 4:00 PM (1 hour)	ICIMOD office, Nepal
January 21, 2020		
• Rajan Subedi, Oxfam • Shailendra Shakya, ICIMOD	10:20 – 11:02 AM (42 minutes)	Oxfam office, Patan, Nepal
• Rakesh Kumar Shah, Lutheran World Relief • Shailendra Shakya, ICIMOD	11:27 – 12:07 PM (40 minutes)	Lutheran World Relief Office, Patan, Nepal
• Nanki Kaur, ICIMOD • Neera Shrestha Pradhan, ICIMOD • Shailendra Shakya, ICIMOD	3:35 – 4:34 PM (59 minutes)	ICIMOD office, Nepal
January 22, 2020		
• Fazal Karim, WWF Pakistan	10:00 – 11:10 AM	ICIMOD office, Noshaq Hall, Skype

• Muhammad Mudassar, ICIMOD Pakistan Country Office • Ajaz Ali, ICIMOD • Shailendra Shakya, ICIMOD	(1 hour and 10 minutes)	
• Mandira Singh Shrestha, ICIMOD • Neera Shrestha Pradhan, ICIMOD • Shailendra Shakya, ICIMOD	11:32 AM – 12:22 PM (50 minutes)	ICIMOD office, Noshaq Hall
• Sanjeev Bhuchar, ICIMOD • Shailendra Shakya, ICIMOD	2:05 – 2:45 PM (40 minutes)	ICIMOD office, Noshaq Hall
• Sayed Ahmad Sahim, Program Officer, AKAH • Ahmad Fahim Shahab, Program Assistant/Engineer, AKAH • Rahman Baik Rahmani, Engineer, AKAH • Neera Shrestha Pradhan, ICIMOD • Shailendra Shakya, ICIMOD	3:00 – 3:50 PM (50 minutes)	ICIMOD office, Noshaq Hall, Skype
January 23, 2020		
• Rojina Manandhar, UNFCCC • Neera Shrestha Pradhan, ICIMOD • Shailendra Shakya, ICIMOD	1:45 – 2:45 PM	ICIMOD, Skype

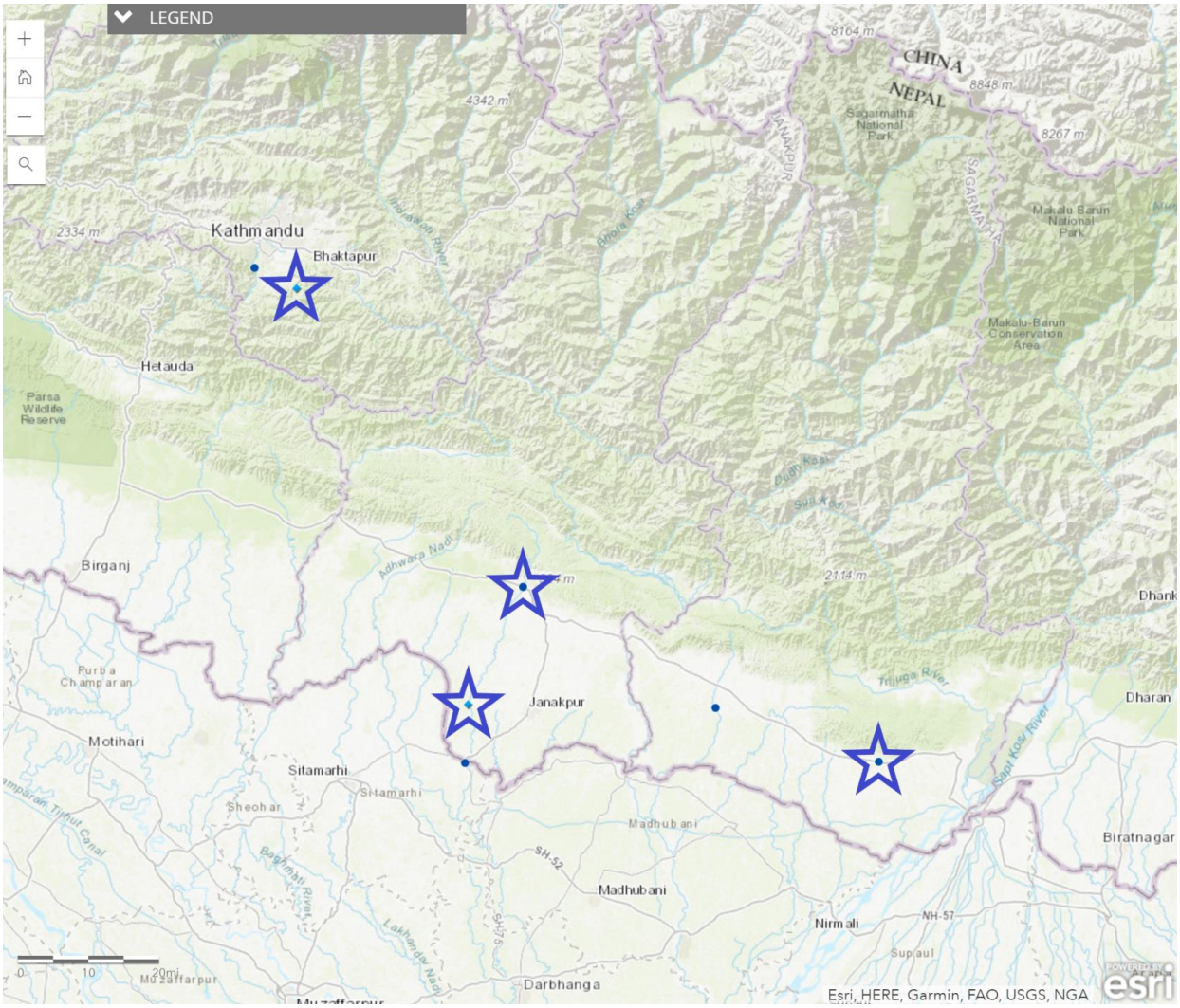

Figure 8: CBFEWS sites visited during in-country interviews[71]

[71] ICIMOD, "Story Map Basic: CBFEWS Map," accessed April 2, 2020, https://www.arcgis.com/apps/StoryMapBasic/index.html?appid=d040ad8b4fcb4ca992e549ea5073fbd7.

Interview Questions

We primarily conducted semi-structured interviews. The general interview structure contained questions relevant to the individual(s)' background, access to early warning systems, their role in the early warning system (if applicable), barriers to accessing early warning systems, and their recommendations for methods to increase access.

Most of our community interviews were conducted in Nepali. Hel Kumar Shrestha (SEE) served as our translator and technical support.

Each interview included a version of our two research sub-questions:

1. **Baseline**: What are the current barriers to access to early warning systems and awareness-raising products for multiple hazards in the HKH region?
2. **Options**: What can be done to overcome barriers to access and/or improve existing early warning systems in the HKH region?

For example, we prepared the following interview guide for the two CBFEWS caretakers in the Ratu River and the Khando River upstream communities.

Background Information

1. How did you become your community's caretaker?
    a. How long have you been the caretaker?
2. What were you doing prior to taking on this role?

Caretaker Role

3. How has your role in your community changed?
4. Please describe any challenges you have had to face in being your community's caretaker.
5. Were these challenges expected?

2017 Monsoon

6. Please tell us about your experience as the caretaker during the Aug. 2017 monsoon.
    a. What went well?
    b. Did you encounter any unanticipated challenges?
    c. How could the CBFEWS system (or improved community preparation) be improved for an even better outcome next time?

2019 Floods

7. Please tell us about your experience as the caretaker during the 2019 floods.
    a. What went well?
    b. Did you encounter any unanticipated challenges?
    c. How could the CBFEWS system (or improved community preparation) be improved for an even better outcome next time?

Access to information

8. How do you get information?
9. Are there formal institutions to get information? Any informal? Social networks?
10. How would you like to receive information? What would be best for outreach?
11. What would be the enabling environment that would allow them to access information easily from central ministries and information. How CBFEWS has allowed them to get information?
12. Has getting the access to information supported other social community relations like in Assam?
13. Do you really need CBFEWS or not? What is the value addition or not?

Community Interactions

14. How do you communicate with the downstream communities? (i.e., whatsapp, SMS, VIBER)
    a. Are there any challenges with the current form of communication?
15. How has your interaction with the downstream community changed since the implementation of the CBFEWS?
16. Have there been any challenges sharing information with downstream communities? With downstream communities across the border?

Training

17. Can you please describe your CBFEWS training experience facilitated by ICIMOD?
    a. How did your training compare to a real flood warning?
18. Is there anything we have not asked you about your role as a caretaker you wish to share with us?

Institutional Support

19. What type of institutional support do you need?

Interview Coding Analysis

Coding: The two-step coding analysis integrates both the CBFEWS-focused and multi-hazard early warning system interviews.

1. Step 1: Using predetermined codes (barriers and potential solutions) we sorted the relevant, compiled interview data.
2. Step 2: Using emergent codes, we then sorted the data sub-categories to surface barriers and solutions revealed during interviews.

Appendix D: Assumptions and Constraints

Assumptions

- We assumed that the frameworks, statistics, and general information obtained in our desktop research and literature information were reliable and accurate, given that the sources appeared credible.
- We assumed that information provided by community-based field interviews was accurate and somewhat representative of the challenges found at other Community-Based Flood Early Warning sites. We cross-checked interview data with literature sources when possible.
- We assumed that the integrity of content from the translated interviews (i.e. Nepali to English or local Dialect to Nepali to English) was maintained, although some nuances were undoubtedly lost.
- We assume that the recent COVID-19 pandemic did not fundamentally change the priority to increase access to MHEWS in the HKH region in the near-term.

Constraints

- Most of our information came from either community-level stakeholders or ICIMOD staff. Hence, we were not able to get information from many active, national government officials in the region (e.g. Nepal Department of Meteorology and Hydrology), representatives of other aid agencies (e.g. United States Agency for International Development), or other relevant UN entities (e.g. United Nations Development Programme).
- Our community-based interviews were not always gender-diverse but instead male-dominated at times. Additionally, there were also social hierarchical dynamics in semi-structured group interviews, where the most senior official would lead or dominate the conversation.
- Our interviews were almost entirely arranged by our client, ICIMOD, except for Harvard faculty, GeoAdaptive, and FEMA interviews. This means we were primarily accessing information from entities already within their network.
- We interviewed individuals in the four HKH countries (i.e. Nepal, India, Afghanistan, and Pakistan) with CBFEWS. This means we were not able to touch base with stakeholders

in China, Bhutan, Myanmar, and Bangladesh, who undoubtedly face context-specific issues related to early warning systems that would have been pertinent to our analysis.

- When considering the five expansion strategies, we did not have access to sufficient information/data to assess operational, financial, or political feasibility to provide granular quantitative analysis, so we relied on relative orders of magnitude and our own intuition from the information that we did obtain.

APPENDIX E DECISION RATIONALE

Table 9: Options table with decision rationale

Strategic Solutions/ Criteria	Financial feasibility (e.g. financial cost)	Technical feasibility (e.g. time and capacity needed to implement)	Political feasibility (e.g. political capital / will needed to implement)	Number of Total Beneficiaries	Procedural equity	Distributive Equity
1 - Enhance Impact	High feasibility (i.e. Low Cost) Making an incremental improvement to an existing CBFEWS site would be relatively low-cost because the major upfront costs are already paid. Hence, this strategy has high financial feasibility.	High Technology for CBFEWS is already established and would only require incremental upgrades, improvements, or complementary additions (e.g. improvements to cell phone access or communications channels).	High Strengthening existing CBFEWS would require little political capital, because most existing CBFEWS have some connectivity with local government agencies or political figures already. As such, this strategy has high political feasibility.	Low An incremental improvement would only ensure the sustainability of an existing system. Thus, it would either not add new beneficiaries or add a negligible # of those overlooked by the local system.	High The community has localized management/ control over the EWS.	High More vulnerable subsets of the community are likely to be included in the community-level planning.
2 - Expand Geographically	Medium feasibility (i.e. Medium/High cost) Establishing a new CBFEWS site requires upfront costs of equipment, technical assistance for training/capacity-building activities, and labor for installation and O&M. It thus has relatively medium financial feasibility compared to the low-cost option of strengthening an existing site.	Uncertain Feasibility depends on the new site (whether it is a new location within a country that already has CBFEWS or an HKH country without CBFEWS). There are also technological barriers to importing/exporting the technology if it is a new HKH country.	Uncertain The expansion of CBFEWS to new sites (within a country that already has CBFEWS or in the HKH countries without CBFEWS) would require differing levels of feasibility. As such, this is uncertain and needs ICIMOD input.	Medium feasibility (i.e. Medium/High cost) A new CBFEWS site could add a modicum number of new beneficiaries. For example, if expanded in a municipality comparable to Tilathi Koiladi, it could reach up to 35K new beneficiaries.	High The community has localized management/ control over the EWS.	High More vulnerable subsets of the community are likely to be included in the community-level planning.

3- Explore community-based MHEWS	Medium feasibility (i.e. Medium/High cost) Establishing an entirely new EWS requires either development or acquisition costs for new infrastructure and technology. Alternatively, it could also mean labor/technical assistance to build off an existing CBFEWS site but adds a new hazard-focus. It has the highest costs of the three strategies and thus lowest feasibility.	Medium feasibility (i.e. Medium/High cost) There are existing technologies (some open-source and some with proprietary protection) that could be used to complement CBFEWS or add another hazard to an existing EWS. If operating in an HKH country with CBFEWS already, such as Nepal. This could have medium feasibility.	Medium Given that MHEWS expansion would take place in communities where CBFEWS may already be present, there could be existing political will/ connections.	Medium A new EWS with a level of subnational or national integration has the potential to add many more beneficiaries than a community-based system (such as CBFEWS). An EWS run through major cell service providers, for example, could reach up to millions depending on the level of cell phone penetration. It depends entirely on the type of EWS and the technology enabling technology used.	Uncertain If the integrity of the community-based system is maintained, then there is potential for high distributive equity (if there is ample community input). However, that is uncertain.	High More vulnerable subsets of the community are likely to be included in the community-level planning.
4 -Expand Regional MHEWS	Low/Medium feasibility (i.e. Medium/High cost) This would be significantly more costly relative to the other options, because you are adding geographic coverage and more beneficiaries.	Uncertain This depends on which hazard(s) are chosen for expansion and whether there is existing technology that can be easily adapted or acquired for the given region.	Uncertain The adoption of a new EWS would require a wholly uncertain level of feasibility depending on its location, timing, and the political environment at the moment of proposed adoption/ implementation	High The system would benefit many more people than a community-based system	Low There will be little to no availability for meaningful community input if the system is designed and implemented primarily by regional actors.	Uncertain Depending on how the system's design incorporates vulnerability of different subsets of the population, it could have high or low distributive equity.
5 - Expand National MHEWS	Low/Medium feasibility (i.e. Medium/High cost) This would be significantly more costly relative to the other options, because you are adding geographic coverage and more beneficiaries.	Uncertain This depends on which hazard(s) are chosen for expansion and whether there is existing technology that can be easily adapted or acquired for the given country.	Uncertain The adoption of a new EWS would require a wholly uncertain level of feasibility depending on its location, timing, and the political environment at the moment of proposed adoption/ implementation	High The system would benefit many more people than a community-based system	Low There will be little to no availability for meaningful community input if the system is designed and implemented primarily by national actors.	Uncertain Depending on how the system's design incorporates vulnerability of different subsets of the population, it could have high or low distributive equity.

Procedural equity – "Emphasizes the extent and robustness of public and community participation planning and decision making"[72]
Distributive equity – "Emphasizes disparities across social groups, neighborhoods, and communities in vulnerability, adaptive capacity, and the outcomes of adaptation actions" [73]

[72] Foster et al., "New York City Panel on Climate Change 2019 Report Chapter 6."
[73] Foster et al.

APPENDIX F: POTENTIAL STRATEGIC IMPLEMENTATION ACTIONS

We recommend that ICIMOD and regional partners focus at the regional (province and district) level to increase access to MHEWS in the HKH region. Figures 12 and 13 illustrate the ownership level of intervention that we recommend for the Nepalese and Pakistani context, as an example.

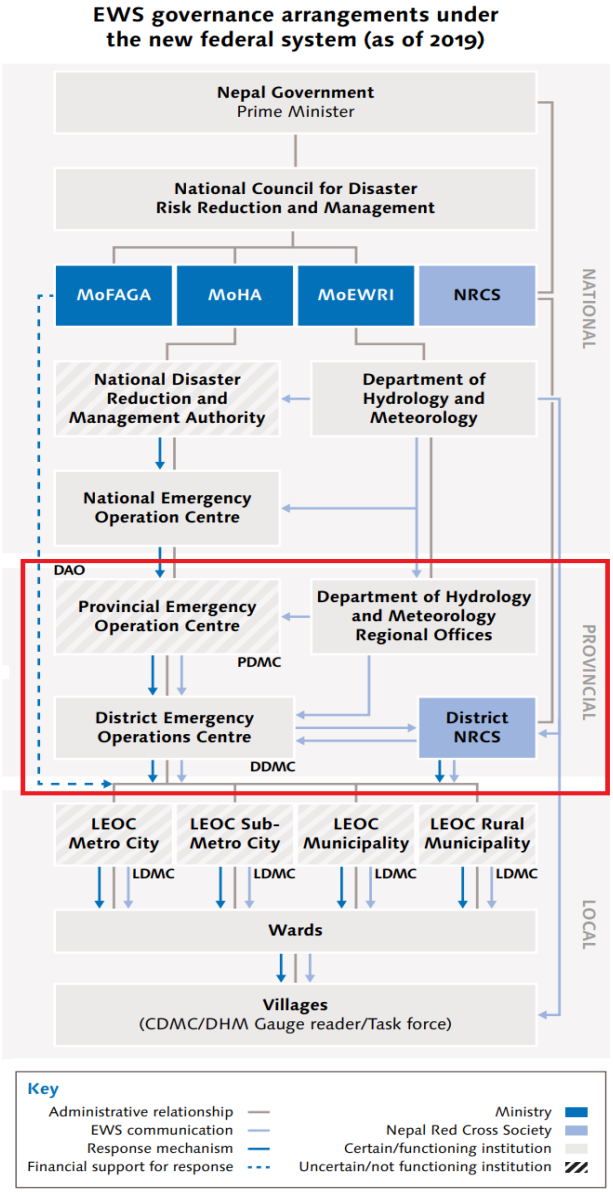

Figure 9: Recommended area of ownership level focus (red outline) for this strategic recommendation in Nepal. Figure adapted from Figure 2: Roles and Responsibilities pre- and post-federalisation.[74]

[74] Chinaporn Meechaiya et al., "The Governance of Nepal's Flood Early Warning System," 2019, 48.

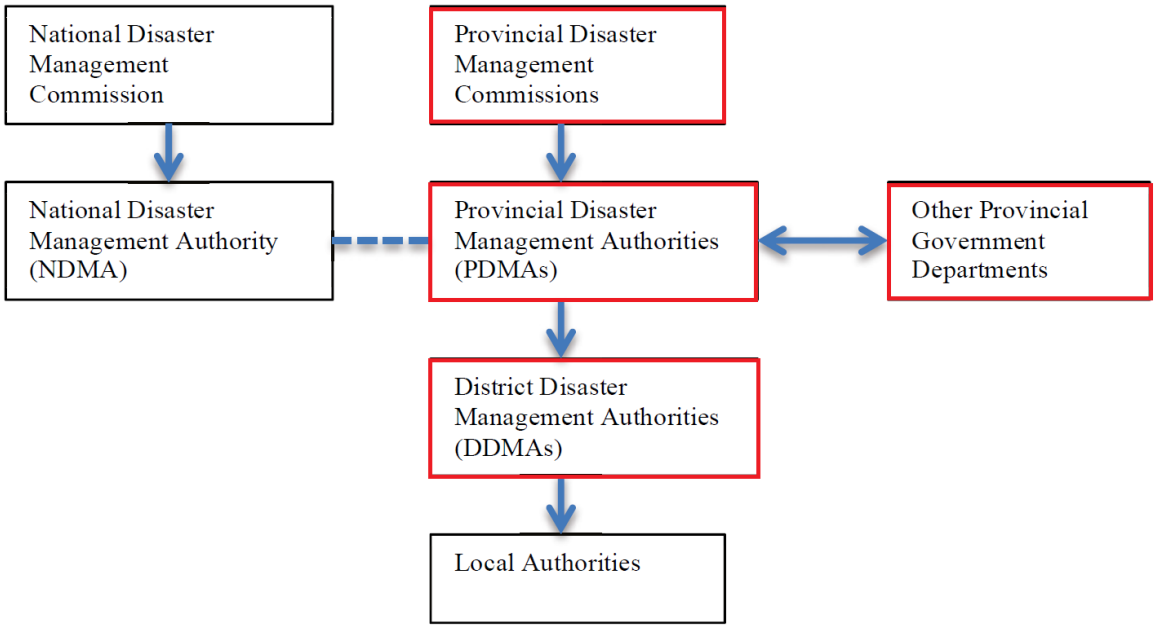

Figure 10: Recommended area of ownership level focus (red outline) for this strategic recommendation in Pakistan. Figure adapted from Figure-1: Institutional Model for Disaster Risk Management in Pakistan[75]

In the LAKI priority-setting workshop, stakeholders identified provincial planners and watershed managers as intended knowledge users of knowledge gap three.[76] ICIMOD and implementing partners engage regional-level actors, such as these provincial planners, in areas with CBFEWS. Thus, ICIMOD is well positioned to strengthen regional-level MHEWS in existing areas served by CBFEWS and expand into new areas without MHEWS access. In addition, ICIMOD and partner organizations can pursue any one of the three enabling recommendations with an emphasis on regional level interventions.

In terms of operationalizing this strategic recommendation, ICIMOD and other partner organizations could pursue any of the actions below to help close knowledge gap three.

- Potential Action: Engage Provincial Disaster Management Commission and Authorities in the Province of Punjab, Pakistan about their experience implementing Pakistan's National Multi-Hazard Early Warning Plan. [77]

[75] Rabiya Mukhtar, "Review of National Multi-Hazard Early Warning System Plan of Pakistan in Context with Sendai Framework for Disaster Risk Reduction," *Procedia Engineering*, 7th International Conference on Building Resilience: Using scientific knowledge to inform policy and practice in disaster risk reduction, 212 (January 1, 2018): 206–13, https://doi.org/10.1016/j.proeng.2018.01.027.
[76] LAKI, "Workshop on Priority-Setting for the Hindu Kush Himalayan Subregion."
[77] Rabiya Mukhtar, "Review of National Multi-Hazard Early Warning System Plan of Pakistan in Context with Sendai Framework for Disaster Risk Reduction," *Procedia Engineering*, 7th International Conference on Building

- Potential Action: Engage the Ministry of Environment Protection and Agriculture of Georgia to draw insights from their "Scaling-up multi-hazard early warning system and the use of climate information in Georgia" UNDP project for applicability in the HKH region.[78]
- Potential Action: Coordinate with other implementing partners, such as Red Cross and Red Crescent, Lutheran World Relief, and Oxfam to identify early warning system overlap at district and provincial levels.
- Potential Action: Explore potential transboundary collaboration between India and Bangladesh through ICIMOD's work with the Flood Forecasting and Warning Centre in Bangladesh.
- Potential Action: Explore how CBFEWS and SERVIR could build into regional MHEWS and integrate into national MHEWS.
- Potential Action: Engage provincial actors in the Gilgit-Baltistan region to understand their need for r or interest in a regional MHEWS in Pakistan through the ICIMOD Indus Basin Initiative.

Resilience: Using scientific knowledge to inform policy and practice in disaster risk reduction, 212 (January 1, 2018): 206–13, https://doi.org/10.1016/j.proeng.2018.01.027.

[78] UNDP, "Scaling-up Multi-Hazard Early Warning System and the Use of Climate Information in Georgia," 2018, /projects/scaling-multi-hazard-early-warning-system-and-use-climate-information-georgia.

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