



SCIENCE BRIEF:
FLOOD RISK AND EARLY
WARNING SYSTEMS



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About IHCAP

The Indian Himalayas Climate Adaptation Programme (IHCAP) is a project under the Global Programme Climate Change and Environment (GPCCE) of the Swiss Agency for Development and Cooperation (SDC), and is being implemented in partnership with the Department of Science and Technology (DST), Government of India. IHCAP is supporting the implementation of the National Mission for Sustaining the Himalayan Ecosystem (NMSHE) as a knowledge and technical partner. The overall goal of IHCAP is to strengthen the resilience of vulnerable communities in the Himalayas and to enhance and connect the knowledge and capacities of research institutions, communities and decision-makers.

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INTRODUCTION

In Himachal Pradesh (HP), floods are the most frequent and prevalent natural disaster caused due to intense rainfalls during the monsoon season. Demographic pressure coupled with development of human settlements and infrastructure in the most exposed locations further aggravates the problem.

Each year, extreme floods occur in mountain catchments upstream causing economic losses as well as fatalities in the inhabited valleys downstream. The causes of flood disasters in HP include (i) long-duration monsoon rainfall (ii) cloudburst phenomena due to localized, intense downpours (iii) glacier lake outburst floods (GLOFs) caused by the sudden outburst of glacier lakes¹ and/or (iv) landslide lake outburst floods (LLOFs) caused by the outburst of lakes formed by landslides. Flash floods (especially from cloudbursts) and monsoon floods are the most common processes, and hence, the focus of this science brief.

Since the mid-20th century, more than 5,000 casualties have been reported as a result of floods in HP. The recorded flood events point to Kullu district as the most affected area in the state (Randhawa et al., 2016). Most of the inhabited valleys in the Indian Himalayan Region (IHR) have high risk of floods (Ballesteros-Canovas et al., 2017). The situation is unlikely to improve, and more such events could be expected over the next decades due to developmental pressure, related land-use changes (in terms of urbanization and tourism), and impacts of climate change and extreme events. These circumstances call for suitable adaptation measures and related policies based on robust scientific assessments.

However, the main challenge in IHR is the lack of historical flow records and high-quality data on past floods. This prevents the development of long-term, high-quality predictions of future flood trends. **This science brief focusses on the main results from the research conducted under the Indian Himalayas Climate Adaptation Programme (IHCAP), a project of the Swiss Agency for Development and Cooperation (SDC) on flood processes. The aim of the research was to develop innovative and sustainable approaches for regional flood risk assessments and adaptation planning in Kullu district.**

The technical results from the research have been simplified and presented in a comprehensive manner to deliver key messages for policymakers.

This document presents:

- (1) a summary of the frequency of flood events in Kullu district
- (2) an analysis of elements-at-flood risk used as a basis for flood hazard zonation

¹A lake outburst can be triggered by several factors such as ice or rock avalanches, the collapse of the moraine dams due to the melting of ice buried within, earthquakes or sudden inputs of water into the lake e.g. through heavy rains or drainage from lakes further up the glacier. GLOFs lead to sudden release of large volumes of water in very short interval of time resulting in flooding in the downstream areas.



FREQUENCY OF FLOOD DISASTERS IN KULLU DISTRICT



Floods in Kullu district (i.e. Beas, Parvati, Sainj and Tirthan Rivers) have taken place repeatedly (Figure 1) with at least 66 floods since 1965, defining an average frequency of 1.1 events per year (Ballesteros-Canovas et al., 2017). This average flood frequency is based on the existing flow discharge records and on the paleoflood reconstruction² using tree-rings³. The analysis was carried out at six different river reaches in the catchments of Upper Beas, Lower Parvati River, Tirthan River at up and downstream Gushaini; and Sainj River upstream Telara Dam (Figure 2, Labels 1-6). In most cases, reconstructed events in the recent five decades have matched with those recorded downstream by flow gauges. Overall, as per the flow gauge records, 17 flooded years have been observed since 1956, whereas tree-rings have provided evidence of 22 past flooding events since 1910. The comparison between both records suggests that > 40 percent of the reconstructed events were recorded by the flow records during last decades. Yet, the 60 percent of events were not previously observed, and therefore indicate the add value of the gathered flood reconstruction.



Figure 1

Embankment of the Beas River at the main Kullu-Manali road destroyed during the 2005 flood event. Source: <http://hillpost.in/2014/07/muck-dumping-a-threat-to-beas-river-valley/99667/>

²Paleofloods reconstruction refers to floods previously not recorded and such reconstruction of the magnitude and frequency of recent, past, or ancient floods is done using geological evidence (Baker, 2008; Kochel and Baker, 1982).

³Peak discharge reconstruction based on tree-rings is a scientific approach of estimating the flow discharge based on indicators such as the height of scars on trees caused during past floods (Ballesteros-Cánovas et al., 2015).

The occurrence of floods is not expected to decrease, and its consequences could become even worse in view of the ongoing climatic changes and increasing demographic pressure. Data indicates that the flood season in Kullu district normally lasts from June to September, with peaks in flood activity in July and August. The intensity of floods is the highest in the Upper Beas River (above Manali) (Figure 2, Label 1) and Sainj River (down to Telara Dam) (Figure 2, Label 2). The streamflow extremes observed in Sainj River (at Larji) (Figure 2, Label 3) was comparatively lower probably due to flow regulation by existing dams (Ballesteros-Canovas et al., 2017). The flood assessment for Kullu indicates variation in hazard levels for different catchments located in the district suggesting the need for local-level assessments in order to identify adaptation measures.

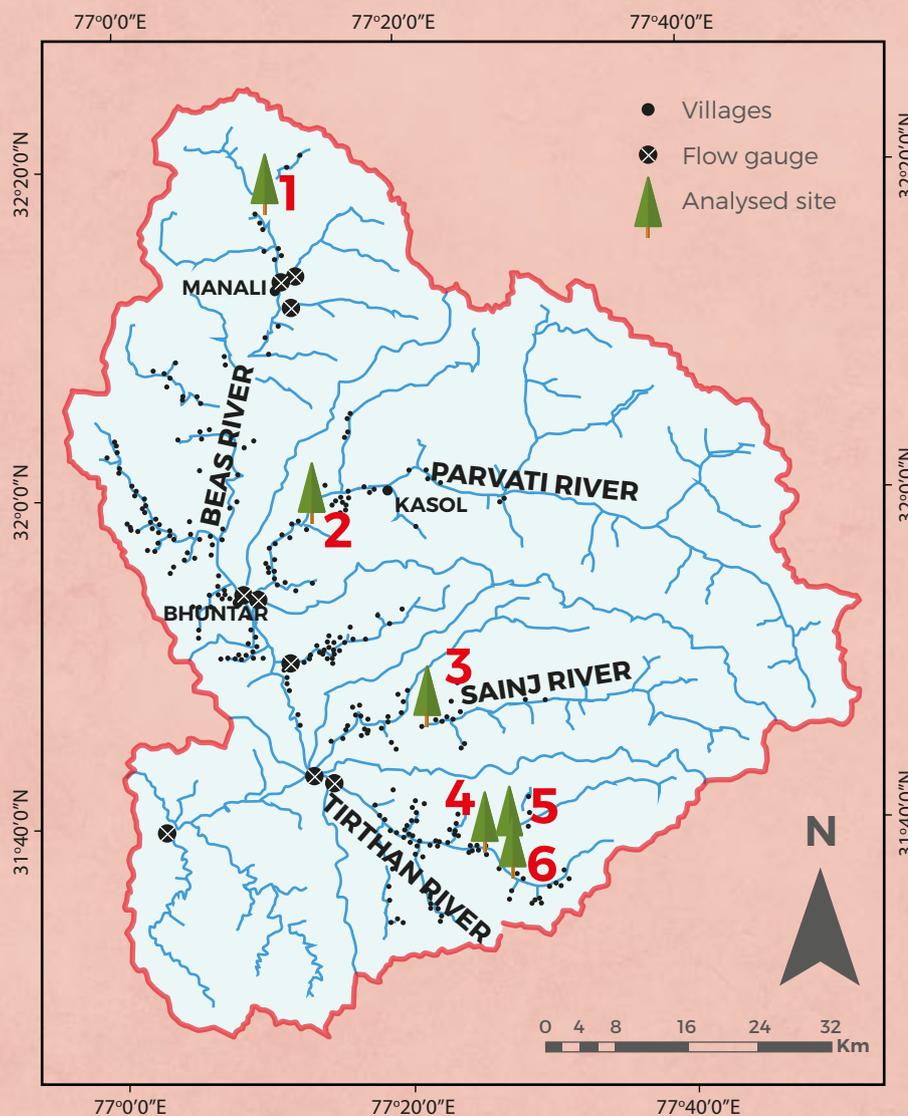


Figure 2 Map of Kullu district showing the studied catchment (border in red), the location of the available gauge stations (black dots with a cross) and all the paleoflood studied sites where reconstruction of ungauged flood events were conducted (Labels 1-6). The location of the examples related to man-made flood disaster sites correspond to the Labels: 1, 4 and 5 (See Box 1). Source: Juan Antonio Ballesteros Cánovas.



EXAMPLES OF MAN-MADE FLOOD DISASTERS IN KULLU DISTRICT

BOX 1

Human activities in the floodplains have sometimes been the cause of flood disasters in Kullu district.

A) Human activities near a river channel can cause flood disaster. This is indicated by the example of construction at Palchan village on the banks of Beas River (Figure 2, Label 1). At this site, the construction of a new bridge connecting Palchan with Solang resulted in major modifications in the river channel. As a consequence, during the moderate flood of July 2012, the local school, the hydropower plant as well as bridges located further downstream were seriously damaged (Figure 3a).

B) Lack of hazard zonation enhances future flood risk for infrastructure. During the flood of July 2005, a combination of flood in the main Tirthan River and an intense debris flow in a nearby tributary system resulted in major changes in the river channel upstream of Gushaini village (Figure 2, Label 4). Large amounts of sediment (with boulders up to 2 m in diameter) came downstream and changed partially the river corridor at Gushaini village, where severe damage was reported. Despite the occurrence of this major event, a new school and other infrastructure have been constructed in the now-abandoned channel (Figure 3b).

C) Lack of risk perception and land management will result in future disasters. This is indicated by the example of construction work at an elevated section of Tirthan River formed due to deposition of sediments, ca. 10 km downstream of Gushaini village (Figure 2, Label 5). The section was significantly flooded during July 2005. Despite the flood disaster, massive construction work for tourist facilities started within this section in 2006 (Figure 3c).

Figure 3



Figure 3a

Severe damage at the primary school located at Palchan village after the 2012 flood in Beas River.



Figure 3b

School constructed in the abandoned channel of Tirthan River upstream of Gushaini village after the flood in 2005.



Figure 3c

Tourist facility constructed at a section of Tirthan River after it was flooded in 2005. The scars on the trees show the minimum water level during the 2005 flood event.

Source: Juan Antonio Ballesteros Cánovas.

2



FLOOD HAZARD ASSESSMENT: ELEMENTS-AT-RISK⁴ IN KULLU DISTRICT

In Kullu district, more than 1,300 (around 70 percent of the total analysed) elements and infrastructure have been categorized as being at very high and high flood risk, stressing the need to carry out more detailed assessments as well as mitigation measures.

The flood hazard assessment based on existing stream gauge records in Kullu district is insufficient. Hence, a regional flood frequency analyses was carried out to estimate the flood discharge of each river (Ballesteros-Canovas et al., 2017). Data on peak discharges was reconstructed based on tree-ring reconstructions and merged with existing flow records to understand the past flood characteristics within Kullu. The analysis conducted in Kullu has demonstrated that flood hazards have been systematically underestimated in the past. Short flow records and the highly fragmented stream gauge series, both in space and time, cannot be used in an efficient way for flood analyses, and may even have potential negative effects when it comes to the design of climate change adaptation and disaster risk reduction strategies.

The new data on floods, gathered as part of IHCAP study, was used to assess elements-at-risk in Kullu district. The flood hazard analysis to assess the risk was done using estimated stream discharge evaluated at each km along all major rivers. The exposure analysis is based on distance from the channel and differences in altitude between all digitized infrastructure (i.e. houses, bridges, road reaches, hydropower dams and airport) and the channel morphology (i.e. concave-shape channel-to-flat floodplain). Flood risk for a total of 1,958 existing infrastructure in Kullu district was analysed using this approach and accordingly categorization of zones in five classes was carried out (Table 1). Overall, 70 percent of all infrastructure was categorized at very high or high flood risk (Ballesteros-Canovas et al., 2016). This information can be used directly to prioritize adaptation plans. For this reason, a database of all elements-at-risk, including information about their geographical position, catchment area upstream, slope, channel morphology and flood hazard and exposure levels constitutes a valuable document for implementing disaster risk reduction strategies, especially Early Warning Systems (EWS).

⁴Elements-at-risk designates any kind of infrastructure exposed to flood processes.

On 18 August 2015, ten people were killed and many injured after a landslide hit the famous Manikaran Sahib gurudwara, situated on Parvati River in Kullu district, Himachal Pradesh. A massive boulder (shown in the picture) tore through its complex and hit the gurdwara's langar hall (community kitchen) and serai (accommodation) wing.



Table 1. Typology of elements at risk in Kullu district

TYPE	VERY HIGH	HIGH	MODERATE	LOW	LOWER
Houses	317	928	270	220	21
Bridges	7	48	12	15	6
Road reaches	12	55	23	18	0
Hydropower dam	0	3	0	2	0
Airport	1	0	0	0	0
Total	337	1,034	305	255	27

Considering the high number of elements-at-flood risk, it is imperative to implement adaptation strategies to improve the resilience of the population against future hydrological-related disasters. Installation of Early Warning Systems based on the acquired knowledge during IHCAP research may help to mitigate future losses and fatalities in Kullu district in the short term (See Box 2). This can be complimented by a long-term monitoring system of hydro-meteorological conditions.



EXAMPLES OF ADAPTATION CONCEPT: REDUCING FLOOD RISK IN PARVATI VALLEY

BOX 2

Parvati valley has been identified as a major risk hotspot for monsoon floods, cloudburst events and potential GLOFs. Development of an integrated monitoring and early warning system to deal with flood risk would therefore be an adaptation response. The integrated system would include implementation of the state-of-the-art catchment-scale long-term monitoring system to assess hydro-meteorological conditions in Parvati valley, and the implementation of modern EWS with the goal to protect the identified “risk hotspots” along the valley.

The long-term monitoring of hydro-meteorological conditions would facilitate early detection of relatively slowly evolving as well as rapid onset flood threats and warning of the subsequent risk to downstream areas. It would also help in providing agro-meteorological advisories in the short term. The EWS would comprise of three components aimed at warning the population in the most critical risk hotspot areas in Parvati valley. The approach would include establishing monitoring system (flow and rain gauge stations); a data management centre; and warning systems along with raising awareness.

Figure 4 shows the schematic hydrological information about Parvati valley, highlighting the three components of EWS. Two of the components are for the warning of flash floods in small torrent catchments above the villages of Shat (EWS 1) and Kasol (EWS 2). The third component (EWS 3) is aimed at flood warnings along the main Parvati River channel. Apart from the technical measures, the intervention would ensure last mile connectivity with local communities to enhance preparedness towards flood events. The proposed EWS would be integrated into the existing Disaster Response System of the District Disaster Management Centre of Kullu.

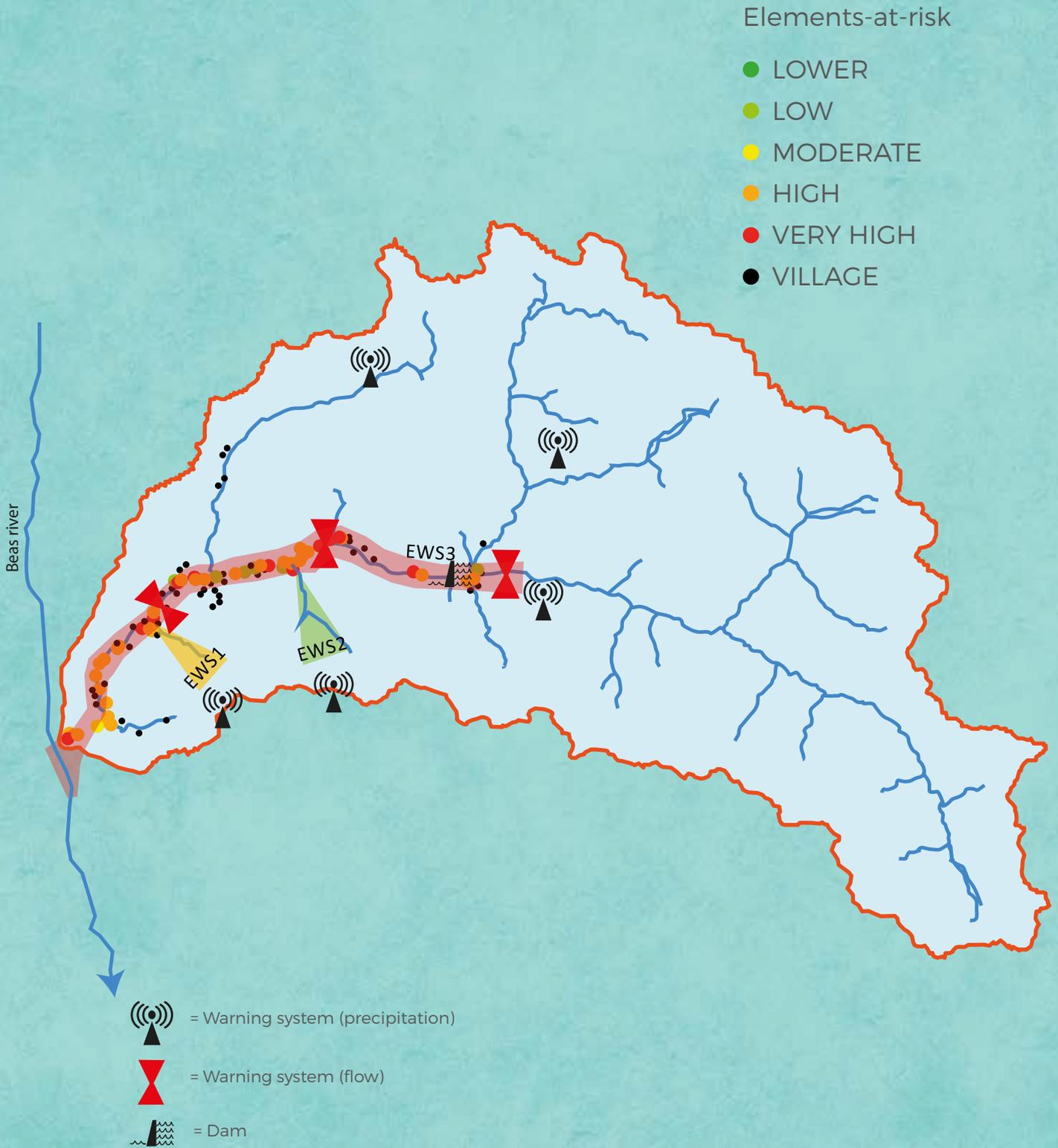


Figure 4 Example of the design of an integrated Monitoring-cum-EWS in Parvati valley. Concept and design by Juan Antonio Ballesteros Cánovas.

RECOMMENDATIONS:

The research on flood risks carried out under IHCAP points to a need to implement flood hazard zonation and warning strategies in Kullu district to improve flood adaptation and mitigation over the next decades. **This assessment presents an example for evidence-based adaptation planning to reduce flood risks in mountain regions. A similar approach can be used to increase resilience towards future flood risks across the Indian Himalayan Region.** Some specific recommendations emerging from the assessment are:

- **Enhanced Preparedness:** In contexts such as Kullu with high frequency of floods and a large number of elements-at-risk, **the most urgent adaptation action involves preparedness of the government agencies to alert and rescue local people.** This action should be planned and implemented at all organizational and societal levels. For instance, in Kullu, this can be linked to the existing Himachal Pradesh Disaster Management Authority (HP-DMA). **Timely information with last mile connectivity for the communities will be crucial to mitigate impacts and to limit casualties.** Long-term monitoring and EWS could be developed for the most vulnerable valleys. In addition, capacity building and specialized training of communities on appropriate response mechanisms, including the identification of shelters and evacuation paths, should be developed at the local level.
- **Robust database:** A major risk in operating an EWS involves the possibility of false alarms (often induced by rather limited knowledge of antecedent environmental conditions and flood behaviour in general). **Historical records and flood reconstructions need to be improved and applied to other regions/sectors in the area (and beyond) for a dynamic learning process and an improved understanding of how floods act in the wider IHR.**
- **Spatial risk and hazard mapping: A flood hazard zonation is desirable to reduce the number of elements-at-risk in regions facing flood risks** such as in Kullu district. This will limit the use of flood plains for construction, and through the implementation of specific measures, will control flood-related problems such as network disruption, erosion and landslide and potential pollution sources.
- **Flood-resilient construction:** Based on the knowledge of flood risk, appropriate design parameters can be adopted while constructing houses and infrastructure especially in areas exposed to flood hazards. Building guidelines and their enforcement can help in facilitating such construction.
- **Knowledge dissemination: The dissemination of information and training related to hazard zones, elements-at-risk and best practices will empower authorities and local citizens.** Informed people will have a different risk perception.



Evidence-based planning and implementation of adaptation measures is a pre-requisite for building resilience of mountain communities and ecosystems in the Indian Himalayan Region (IHR). Recognizing the pervasive and complex challenge that the communities face in IHR, the Swiss Agency for Development and Cooperation (SDC) together with the Department of Science and Technology (DST), Government of India, initiated the Indian Himalayas Climate Adaptation Programme (IHCAP). Under IHCAP, a pilot study was done for Kullu district, Himachal Pradesh in coordination with the Department of Environment, Science and Technology (DEST), Government of Himachal Pradesh, to provide an integrated assessment of climate vulnerability, hazards and risk for climate adaptation planning. This series of Science Briefs on specific topics represents the key messages drawn from the outcomes of the Indo-Swiss scientific studies for Kullu in simplified language to inform decision making.

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