Environmental Science and Policy 87 (2018) 1–10

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

Translating the concept of climate risk into an assessment framework to inform adaptation planning: Insights from a pilot study of flood risk in Himachal Pradesh, Northern India

Allen S.K.[a,b,*], Ballesteros-Canovas J.[a,c], Randhawa S.S.[d], Singha A.K.[e], Huggel C.[b], Stoffel M.[a,c]

[a] Institute for Environmental Sciences, University of Geneva, Switzerland
[b] Department of Geography, University of Zurich, Switzerland
[c] Department of Earth Sciences, University of Geneva, Switzerland
[d] Himachal Pradesh State Centre on Climate Change, State Council for Science, Technology and Environment, Shimla, India
[e] CTRAN Consulting, Bhubaneswar, Odisha, India

ARTICLE INFO

Keywords:
Flood
Hazard
Risk
Climate adaptation
Himalaya

ABSTRACT

Climate risk assessments provide the basis for identifying those areas and people that have been, or potentially will be, most affected by the adverse impacts of climate change. They allow hot-spots to be identified, and serve as input for the prioritization and design of adaptation actions. Over recent years, at the level of international climate science and policy, there has been a shift in the conceptualization of vulnerability toward emergence of 'climate risk' as a central concept. Despite this shift, few studies have operationalized these latest concepts to deliver assessment results at local, national, or regional scales, and clarity is lacking. Drawing from a pilot study conducted in the Indian Himalayas we demonstrate how core components of hazard, vulnerability, and exposure have been integrated to assess flood risk at two different scales, and critically discuss how these results have fed into adaptation planning. Firstly, within a state-wide assessment of glacial lake outburst flood risk, proxy indicators of exposure and vulnerability were combined with worst-case scenario modelling of the outburst hazard. At this scale, first-order assessment results are coarse, but have guided the design of monitoring strategies and other low-regret adaptation actions. Secondly, an assessment of seasonal monsoon and cloudburst-related flood risk was undertaken for individual mapped elements exposed along the main river valleys of Kullu district, drawing on innovative techniques using dendrogeomorphology to reconstruct potential flood magnitudes. Results at this scale have allowed specific adaptation strategies to be targeted towards hot-spots of risk. A comprehensive risk assessment must integrate across disciplines of physical and social science, to provide the necessary robust foundation for adaptation planning.

1. Introduction

Robust scientific assessment of the present and future impacts of climate change is a cornerstone of both national and international climate policy, providing the basis for adaptation planning and resource mobilisation (Huggel et al., 2015). At the international level funding instruments are called to target those potentially most affected by climate change, as highlighted recently, for instance, under Article 7 of the Paris Agreement of the Conference of Parties of the United Nations Framework Convention on Climate Change (UNFCCC). However, diversities across the different concepts and approaches used in climate impact studies have limited the ability of science to clearly inform policy. As a consequence, the allocation of adaptation funding (e.g., Green Climate Fund) remains controversial and challenging (Muccione et al., 2016). Similarly, at the national level, authorities are tasked with disentangling the multitude of socio-physical driving processes to identify regions most affected by climate change, and thereby target adaptation planning and strategies accordingly. With the recent emergence of climate risk as a key concept in the science-policy dialogue, led by the Intergovernmental Panel on Climate Change (IPCC 2014), these socio-physical processes are at least theoretically more clearly distinguished. Yet, this concept has rarely been applied in an assessment context (Muccione et al., 2016). As a consequence, there is a lack of clarity over how the concept of climate risk – increasingly favoured by policy and decision makers – should guide the scientific assessment of climate change impacts, at national, state, or district scales, and thereby provide the fundamental basis for adaptation planning.

The Indian Himalayan Region (IHR) faces particular challenges in

* Corresponding author at: Institute for Environmental Sciences, University of Geneva, Switzerland.
E-mail address: simon.allen@unige.ch (S.K. Allen).

https://doi.org/10.1016/j.envsci.2018.05.013
Received 22 September 2017; Received in revised form 5 April 2018; Accepted 17 May 2018

view of coping with the adverse effects of climate change, exacerbating other physical (e.g., topographic, geological) and anthropogenic (e.g., land-use practices, socio-economic) stressors (Hofer, 1993; Pande, 2006; Sati et al., 2011; Sati and Gahalaut, 2013). The IHR stretches across 12 states and is home to an estimated 72 million people, providing hydrological resources and ecosystems services to more than 900 million people living downstream upon the fertile grounds of the transnational Indo-Gangetic Plain. Recognising this challenge, the Indian government established in 2008 its National Action Plan on Climate Change (NAPCC), identifying eight core missions in the context of adaptation and mitigation planning (see Awasthi et al., 2016 for a comprehensive overview). This included the National Mission for Sustaining the Himalayan Ecosystem (NMSHE), calling specifically for scientific assessment of the vulnerability of the Himalayan ecosystem to variability in weather and climate, considering physical, biological and socio-cultural dimensions. With an emphasis on evidence-based policy measures, the NMSHE supports the Himalayan state governments in the planning and implementation of climate impact assessments, which serve as a basis for their State Action Plans for Climate Change (SAPCC). To this end, a need was identified for a homogenous assessment framework to be developed, drawing on the latest international concepts and allowing results to be compared across states and sectors.

Within this context, research collaboration between Indian and Swiss scientists was initiated under the Indian Himalayan Climate Adaptation Program (IHCAP). The overall goal of the joint research activities was to implement a pilot study of climate vulnerability, hazard, and risk, focussing upon Kullu district, Himachal Pradesh, within an integrative assessment framework that could be upscaled to other districts and states of the IHR or elsewhere. The research covered diverse climate-related threats ranging from landslides, avalanches and floods, to impacts on biodiversity and the agriculture-horticulture sector (IHCAP, 2016). Drawing on experiences gained through this pilot study, here we focus on how the IPCC concept of climate risk was operationalised to guide our assessment in Kullu, highlight key considerations, challenges and approaches used, and then critically reflect on how the results from these studies have informed local adaptation planning. Hence, we provide a rare end-to-end case study and analysis of science-based climate adaptation in action. We specifically focus on flood risk, as floods represent a key climate-related threat not only within the IHR, but also across many other mountainous regions of the world (e.g., Jongman et al., 2012; Peduzzi et al., 2009; Singh and Kumar, 2013). Our assessment in Kullu considers floods related primarily to seasonal monsoon rainfall and cloudburst events (for simplicity referred herein as monsoon floods) and Glacial Lake Outburst Floods (GLOFs).

2. Kullu District, Himachal Pradesh

Kullu district (population 437,900; land area 5500 km^2) within the north-west Indian state of Himachal Pradesh was selected as the focus region for the pilot study. The district is centred along the north-south orientated valley of Beas river, and provides a significant national transportation corridor. Major urban settlements and tourism hot-spots located along the broad, highly fertile floodplains of the U-shaped valley include Manali, Kullu and Bhuntar. The main tributary rivers of the Parvati, Sainj, and Tirthan are characterized by narrow side valleys, where villages are located on steep slopes or on the limited, yet often flood-prone, flatter reaches. Approximately 35 per cent of the district is under forest cover, giving way to alpine tundra and glacial landscapes at higher elevations, where the largest mountain peaks extend up to 6500 m a.s.l. The climate regime of the Kullu district is considered to be sub-tropical monsoon characterized by cool, snowy winters at higher elevations; as well as warm, dry spring and autumn; and a warmer, wetter monsoonal summer. An increase in mean annual air temperature of 1.6 °C has been measured across the northwestern Himalayan region during the past century, which is far in excess of mean global warming (Bhutiyani et al., 2007). Demographically the district has seen significant growth recently in urban population, with a 35 per cent increase recorded between 2001 and 2011 (Census India). Floods are the major threat to the district, triggered primarily by seasonal monsoon rain and cloud-burst events, often associated with significant bank erosion and landslide activity (Ballesteros-Cánovas et al., 2017). The formation and bursting of landslide dammed lakes has also been responsible for flood events in the region (Ruiz-Villanueva et al., 2016). The potential for GLOFs is thought to be increasing significantly as glaciers melt and lakes expand (Allen et al., 2016), while hydropower plants and other infrastructure being built at higher altitudes closer to the glacier lakes is increasing the associated risk (Schwanghart et al., 2016).

3. Components of climate risk

The recent emergence of climate risk as a key integrative concept arising out of the IPCC's fifth assessment cycle (IPCC, 2014) provided a logical framing for pilot studies in Kullu. Integrating the traditionally diverging perspectives from the disaster risk management and climate adaptation communities, climate risk is conceptualised by IPCC as a physical event (hazard) intercepting with an exposed and vulnerable system (e.g., community or ecosystem) (Fig. 1). In the subsequent sections we introduce core terminology and methodological approaches used to assess these three components of flood risk in Kullu district, and across the surrounding state.

3.1. Hazard

As defined by IPCC 2014, hazard refers to *"the potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources"*. Within the framework of the risk assessment, identifying and quantifying the hazard determines what it is that communities or systems are exposed and vulnerable to. Hazards in this context include both slow onset processes (e.g., increase in mean temperature or decrease in rainfall leading to impacts such as species changes or extinction, vegetation change or ground water shortages) and sudden onset events (e.g., flooding, heatwaves, landslides). Hazards are often associated with unusual or extreme hydro-meteorological events, but non-extreme events also can lead to disasters where other physical or societal factors precondition such an outcome (Seneviratne et al., 2012).

For the hazard assessment, information is required on both the intensity of the event (or magnitude), and the probability of occurrence (or frequency). Where there is reliable historical data and observations these quantities may be relatively simple to establish based on a catalogue of past events. However, in the context of flood hazard assessment in Kullu two fundamental problems arose which are indicative of the challenges researchers face working in many of the worlds mountain regions:

i Stream-gauge records are sparse and incomplete, and are often damaged during the most extreme (and important) events.
ii GLOFs are a rapidly evolving flood threat in many glaciated mountain catchments, and historical records are therefore often completely lacking or of limited value.

3.1.1. Dendrochronology to reconstruct hazard baseline

In an effort to overcome the lack of historical data, analyses of tree rings (dendrochronology) have been widely used to reconstruct the timing and magnitude of hydrogeomorphic hazards, including floods, debris flows, landslides, and snow avalanches (see Stoffel et al., 2010 for a comprehensive review). The approach is based on the concept that trees affected by hydrogeomorphic processes will conserve information