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CLIMATE RISK ASSESSMENT

A Pilot study in Kullu, Himachal Pradesh

Imprint

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CLIMATE RISK ASSESSMENT

A PILOT STUDY IN KULLU, HIMACHAL PRADESH

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FACULTÉ DES SCIENCES
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भारतीय प्रौद्योगिकी संस्थान तिरुपति
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The data and information used for preparing this report have been sourced from secondary sources including state government departments, published sources of Government of India, and climate change assessment made by the consultants. While due care has been taken to ensure authenticity of the data and other information used, any inadvertent wrong data or information used is regretted. We are not liable to any legal or penal responsibilities arising from this and also from the use of this report by anyone.

Chief Secretary
Himachal Pradesh,
Shimla-2.

MESSAGE

The Hindu Kush Himalayan region is one of the most hazard prone regions, of the world. Its fragility stems from its susceptibility to multiple hazards of geological as well as hydro meteorological origin such as earthquakes, landslides, floods, flash floods, droughts, wildfires, cloudbursts, etc. The physical and socio-economic characteristics of the Himalayan region combined with the changing risk factors such as environmental and climate change, population growth, and economic globalisation have rendered the region highly vulnerable.

In the recent past, there have been several episodes of cloudbursts affecting villages in the Himachal Pradesh. Climate-induced events have impacted the lives, assets, and livelihoods of the mountain communities of our State, especially traditional livelihood options like agriculture and animal husbandry. Decreased productivity of existing crops and the resultant changes in cropping patterns have commonly been observed in the region. It is most visible in the diminishing and productivity of apples in the lower reaches of the valleys of Shimla, Kullu and Kinnaur districts.

Changes in habitat caused by climate change induced disasters such as floods and droughts as well as changes in food supply are leading to decreased production of milk from livestock. There are loss of habitats, species extinction, depletion of pasture lands, diseases in wild animals, pest attacks, high turbidity in water bodies and waterborne epidemics.

In addition to the direct impact on crops and livestock, events such as landslides and flash floods resulted in economic losses due to disruption of transportation linkages with markets, leading to disruptions in supply chain of essential goods and food. Greater intensity and frequency of climate-induced events also discourage tourists, destroy natural resources and adversely impact hospitality infrastructure that are crucial to tourism industry.

Climate risk assessment and management of such risks gives an insight in designing appropriate interventions and building resilient communities. I am happy to learn that the State Department of Environment, Science & Technology with support of GIZ has undertaken Climate Risk Assessment through a pilot study of district Kullu. This is a timely call and will certainly help the local administration to better comprehend and manage the climate risks

(Anil Khachi)

Principal Secretary
(Environment, Science & Technology)
Government of Himachal Pradesh

MESSAGE

Climate change is real, it’s happening and is affecting our life. Land-use changes and degradation of natural resources, climate change impacts on natural systems due to extreme events and disasters is causing considerable challenges. Addressing climate change related risks calls for integrated, systemic approach aligned to national strategies and action plan on climate change.

It is very important to understand and assess losses and damages arising out of climate risk at local level for improving the knowledge base towards addressing climate risk at national and local levels.

While a number of approaches already exist in the field of short-term climate risk assessment and management, mainly in the field of extreme events, existing approaches often do not sufficiently address long-term, slow-onset changes due to climate change.

Ministry of Environment Forests & Climate Change (MoEFCC) being the nodal Ministry of National Action Plan on Climate Change has considered reduction of damage and losses due to climate change impacts as a key concern. In this context, National Institute of Disaster Management (NIDM) in technical cooperation with GIZ adopted the structured process building on a methodological framework to assess and develop various measures at both national as well as sub national level.

The current study is guided by the Climate Risk Management (CRM) Framework, applied in India as part of Climate Change Adaptation in Rural Areas of India (CCA-RAI) project and operationalized for the selected study regions in Himachal Pradesh.

"Climate Risk Assessment- A Pilot Study" in District Kullu is an effort to assess and design remedial interventions at local level. I hope that the outcomes of the report would be useful in taking proactive steps by the stakeholders to mitigate adverse impacts of climate change in Kullu district.

(Kamlesh Kumar Pant, IAS)

Director
(Environment, Science & Technology)
Government of Himachal Pradesh

FOREWORD

It gives me immense pleasure to bring in the pilot study report 'Climate Risk Management (CRM) – a pilot study in Kullu, Himachal Pradesh' carried out under 'Climate Change Adaptation in Rural Areas-India (CCA-RAI)' project with support of GIZ. As part of Indo-German Technical Cooperation on Climate Change and funded by German Federal Ministry of Economic Cooperation and Development (BMZ), GIZ India is implementing CCA-RAI project in partnership with the Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India. The programme intends to integrate climate adaptation measures into the national and state development and strengthen the capacities of key actors for financing, planning, implementing and monitoring of climate change adaptation measures in four project partner States including Himachal Pradesh.

The Climate-related risks needs to be systematically identified, new climate risk indicators need to be standardized, and relevant data (including internal data) on climate related risks must be incorporated into risk management systems. Forward-looking methods, including scenario analyses, should be applied more frequently, and the climate change should be factored into existing risk models.

At the local level practitioners and stakeholders need to start by establishing broad-level governance and ownership models for this sector. Given the nature of the risk, establishing an internal cross-disciplinary working group that can help bring together different sectors of the region to start identification and assessment of climate related risks.

The impacts, scenarios highlighted in this report provide a broad overview and context, before focusing on the specific risks affecting a particular area or sector. Distinguishing physical and transition risks can be helpful in identifying areas of impact. Moreover, prioritizing action, programmes and sectors that are high risk can improve focus on the most material areas of concern. Developing in-house expertise on development of scenarios is also important, not only for risk management but also for its disclosure and its management. Though it is a beginning and much work is still to be done before climate risk management becomes embedded in day-to-day operations.

The efforts put in by Sh. Ashish Chaturvedi, Dirctor (CC), Sh. Kirtiman Awasthi, Sr. Policy Advisor, Ms. Somya, Ms. Monika Sharma from GIZ are highly appreciable. The hard work of other experts and professionals - both external and from within the State Government Departments and organizations, all those associated in finalizing this document are acknowledged thankfully.

The Climate Risk Assessment, a pilot study, carried out in District Kullu is a step forward towards climate resilience of communities. I hope the assessment will help the local decision makers for ensuring better adaptation and mitigation practices.

(Sudesh Kumar Mokhta, IAS)

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ABBREVIATIONS

AHP	Analytical hierarchy process
BL	Baseline
CCA	Climate Change Adaptation
CCA-RAI	Climate Change Adaptation in Rural Areas-India
CORDEX	Coordinated Regional Climate Downscaling Experiment
CRIDA	Central Research Institute for Dryland Agriculture
CRM	Climate Risk Management
DDMA	District Disaster Management Authority
DEST	Department of Environment, Science and Technology
DRR	Disaster Risk Reduction
EH	Extremely High
GHNP	Great Himalayan National Park
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
H	High
HI	Heat Index
HP	Himachal Pradesh
I	Intermediate
IHCAP	Indian Himalayas Climate Adaptation Programme
INHI	Infrastructure Hazard Index
INR	Infrastructure Risk
INRI	Infrastructure Risk Index
INRM	Integrated Natural Resources Management
IPCC	Intergovernmental Panel on Climate Change
L	Low
LHI	Livelihood Hazard Index
LHI	Livelihood Hazard Index
LR	Livelihood Risk
LRI	Livelihood Risk Index
MC	Mid-century
MME	Multi Model Ensemble
MSE	Madras School of Economics
NAPCC	National Action Plan on Climate Change
NEM	North East Monsoon
NGOs	Non-Governmental Organizations
NV	Normalized value
RCP	Representative Concentration Pathways
RI	Risk Index
SAPCC	State Action Plans on Climate Change
SWAT	Soil and Water Assessment tool
SWM	South West Monsoon
THI	Temperature Humidity Index
VA	Vulnerability Assessment
VCA	Vulnerability Capacity Assessment
VH	Very High
VL	Very Low

EXECUTIVE SUMMARY

A novel and innovative 6-step risk-centered framework has been implemented to assess current and future climate change impacts in Kullu district of Himachal Pradesh, Northern India, and to identify appropriate risk management options. Following from an initial scoping stage, guided through stakeholder discussions and consultation, comprehensive indicator-based risk analyses were undertaken, considering underlying components of hazard, exposure and vulnerability. Separate risk indices were established for rural infrastructure (roads, hospitals, and education facilities) and rural livelihoods (as related to agriculture), and the assessment considered both slow onset events (drought, extreme heat, and water stress), and rapid onset events (heavy rain, landslides, and floods).

The risk assessment has shown that heavy rainfall, related flood discharge, and landslides are all projected to increase across the district by mid-century (under RCP 4.5 and 8.5), increasing the threat to livelihoods and infrastructure, and compounding the effects of water scarcity, heat stress, and drought. These finding are in line with community perceptions that have highlighted significant and increasing impacts relating to flooding, cloudbursts, and plant diseases (as linked to rising temperature and water stress). Considering risks to livelihoods, highest risk levels under both current and future conditions are seen in the blocks of Kullu and Nirmand, while risk to infrastructure is highest in the block of Anni and Nirmand.

In order to expand beyond standard risk approaches, to evaluate risk tolerance levels, potential losses were calculated in monetary terms for key climate impacts. The economic analyses drew on information coming out of community surveys and focus group meetings, complimented with data on losses observed during past disasters, including within neighbouring states. All values were scaled according to the results of the composite risk assessment, recognizing likely higher (lower) potential losses in high (low) risk zones respectively. While representing an idealised approach, the analyses could demonstrate that in the absence

of suitable adaptation measures, house reparation costs and/or loss of income due to crop damages can be expected to increase in the order of 20 – 30% across the different blocks under RCP 8.5 by mid 21st century, causing a shift from tolerable to intolerable risk levels for many households. Considering damages to infrastructure, tolerance levels for communities will be seasonably variable, as for example damage to critical transportation corridors are more critical during the harvesting season, preventing crops from reaching economic markets.

Given the increasing climate risk to Kullu, urgent adaptation strategies that draw across the traditional domains of climate change adaptation and disaster risk reduction are needed to minimize potential losses. While a basket of potential options have been presented, ranging from incremental, through to fundamental and transformative approaches, the communities themselves have identified four areas in which government support is expected. This includes increasing access to cheap seeds for diversifying crops and recovering from disasters, climate-proofing of water infrastructure, improvements in transport and basic community infrastructure, and provision of subsidies to improve farm profitability. Uptake of insurance and other risk transfer mechanisms remain very low in the district, although are highlighted under district disaster management plans.

Core challenges remain in assessing future changes in vulnerability and exposure, including how the outcomes from existing and future development programmes and adaptation strategies can be accounted for in the risk assessment. However, despite these uncertainties, it is clear that timely implementation of well-conceived adaptation strategies have the potential to significantly reduce future losses, and thereby increase risk tolerance levels for rural communities. It is anticipated that the learnings and experiences from this study will help inform local decision-making, and will guide further studies of climate risk in other regions.

CLIMATE RISK ASSESSMENT

A Pilot study in Kullu, Himachal Pradesh

Introduction

The framing of the climate change challenge has evolved over the past decade, beginning with emergence of climate risk as a key concept in the science-policy dialogue (as for example arising out of IPCC SREX and AR5). Both climate science and the international climate negotiations stress an urgent need to develop and implement effective climate risk assessment and management approaches in order to avert, minimize and address loss and damage (L&D). While a number of approaches already exist in the field of short-term risk assessment and management (with focus on extreme events), existing approaches do not sufficiently address long-term, slow-onset changes due to climate change, and composite risks associated with these changes. Further, risk and vulnerability assessments often do not meet the information needs of policy-makers and local governments in order to manage the risks of climate change and associated L&D effectively. 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, and provide the basis for designing adaptation strategies.

Across the Indian sub-continent, climate change is recognized as a key threat to sustainable development, exacerbating other socio-economic and environmental pressures. Potential impacts of climate change in India extend from the high Himalayan states to the coastal zones, are transboundary in nature, and multi-sectoral. Recognizing these challenges, state governments have been proactive in their development of State Action Plans on Climate Change (SAPCC) that identify key vulnerabilities and risks. Due to its importance for sustaining livelihoods and serving as a backbone to economic development, the rural sector in particular is considered highly vulnerable to the adverse effects of climate change. Given these challenges, the Climate Risk Management (CRM) framework developed under GIZ offers exciting potential to inform decision-making and adaptation actions that may minimize or avoid weather and climate-related L&D. The CRM framework is comprehensive, iterative, demand-driven, and synergistic, as an interface between science and policy. There are of course immense challenges, as CRM aims at synergy between three different streams (DRR, CCA and L&D). Such a synergy necessitates a careful understanding of existing well-established institutional arrangements with regard to DRR, and the emerging institutional structure for CCA (e.g., as in the context of SAPCC), to explore where and how L&D fits into the existing institutional structure.

Climate change has been recognized as one of the key challenges for India together with increasing population, poverty alleviation and environmental degradation. The economy of India especially livelihood of rural population is dependent on climate-sensitive sectors like agriculture, forest, animal husbandry which are highly vulnerable to the impacts of climate change.

Severe floods, storms, droughts and heat waves as well as land and forest degradation and salinization of groundwater resources that are already seen today are often viewed as a foretaste of climate change interacting with other anthropogenic impacts on the environment. Mitigating climate change by reducing greenhouse gas emissions is one way of lessening the adverse effects of a more variable and changing climate. However, even if a radical reduction of global greenhouse gas emissions were possible today it would

not completely prevent significant changes in the world's climate. Therefore, societies and economies at all levels and on every continent have to prepare for and adapt to the potential impact of climate change. Climate change is one of the biggest environmental and developmental challenges that the natural ecosystems and socio-economic systems face.

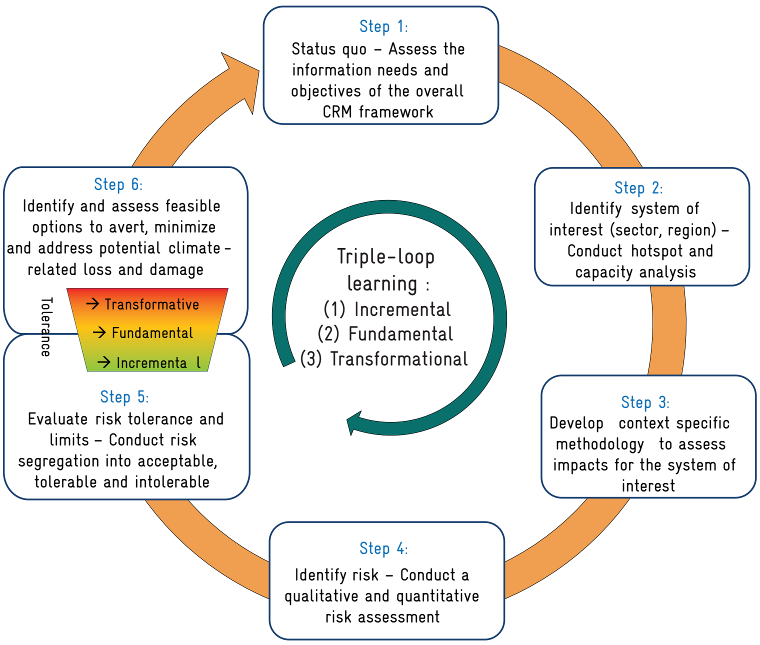
Further, climate change in the coming decades is likely to intensify, thereby adversely impacting food production, water resources, biodiversity and health. The impact or risk of climate change is the result of interaction of climatic hazards, exposure and vulnerability of the communities and systems, and various climate adaptation mechanisms address one or more of these components. According to IPCC 2014, the "first step towards adaptation to future climate change is reducing vulnerability and exposure to present climate variability", and a comprehensive risk assessment provides the required basis for related decision making. With various global-scale studies identifying India as one of the countries in the world most threatened by climate change[1], there is an urgent need for understanding climate risk at state level and subsequently devising options for adaptation planning and risk management. Climate Change Adaptation in Rural Areas-India (CCA-RAI), with partner states intends to prioritize high impact climate change adaptation issues and implement measures to address the challenges arising due to climate change.

Against this background and scope, the overall aim of this study is to test a risk-based approach to climate change adaptation for managing both the current and future risks associated with a spectrum of extreme weather events (rapid-onset) and slow-onset events. Taking a comprehensive risk approach, underlying drivers of hazard, exposure and vulnerability are to be assessed, considering how climate change and other social and institutional dimensions can influence these drivers. This study is expected to support decision makers and researchers in developing policy-relevant climate information and anticipatory planning and thus support the existing climate risk management measures in Indian states. More specifically, the results will be targeted towards decision-makers at the district level, while overall findings and methodological approaches must remain relevant also at the state level (as a basis for potential up scaling in the future). The study focused not only on conventional adaptation actions but also at the array of instruments from DRR and CCA as well as measures to address residual risk (risk transfer – insurance, social protection).

Applying the Climate Risk Management (CRM) Framework

The study is guided by the Climate Risk Management (CRM) Framework, applied in India as part of Climate Change Adaptation in Rural Areas of India (CCA RAI) project and operationalized for the selected study regions of Himachal Pradesh. The main considerations, methodological approach and results are therefore presented systematically in this report according to the 6-step CRM process.

Figure 1: Climate risk management (CRM) process from GIZ: 6 Step Framework



1 Muccione V, Allen SK, Huggel C, Birkmann J. 2016. Differentiating regions for adaptation financing: the role of global vulnerability and risk distributions. Wiley Interdisciplinary Reviews: Climate Change. DOI: 10.1002/wcc.447.

Table 1: Climate risk management (CRM) steps

CRM Steps	Core considerations	Tools/methods
1. Define status quo	Climate vulnerability and risk profile. DRR and CCA institutional context, establishing what data is available and identifying stakeholders and their information needs.	Desk-based review of science and policy documents and data. Stakeholder mapping.
2. Identify system of interest	Data coverage and availability. Climate risk hotspots. Needs and expectations of local stakeholders. Project timeframe and associated limitations.	Desk-based review and analyses of existing data (compiled under step 1). Inception workshop and round table discussion.
3. Develop context-specific methodology	Information and data collected through steps 1 and 2. Need for forward-looking climate risk analyses including new climate scenarios.	Based on methods and tools outlined in the *GIZ Risk Supplemented to Vulnerability Sourcebook*, and other best practices.
4. Identify climate change risks	Integrated concept of climate risk consisting of: Hazard: Slow and rapid onset events. Vulnerability: Block and village level. Exposure: Livelihoods and infrastructure	Hydrological and landslide susceptibility models; future scenarios driven by downscaled climate models. Indicator-based socioeconomic assessment (census India); focus group meeting to undertake VCA. Remote sensing-based mapping; census data; participatory surveys.
5. Evaluate risk tolerance and limits to adaptation	Capacities of affected systems to reduce and adapt to risks. Categorization of risks as acceptable, tolerable, and intolerable.	Evaluate existing capacities; learning from experiences and losses (focus group meeting) in the past. Expert judgment and evaluation.
6. Identify feasible options to address potential loss and damage	Evaluation of a basket of adaptation and CRM options in line with stakeholders needs. Consideration of incremental, fundamental, and transformative actions.	Focus Group Meetings to identify community expectations. Prioritization and ranking exercise during final technical exchange workshop.

Step 1: Define status quo

Objectives of the study

A main function of step 1 is to define/refine the objectives of the study and thereby, establish how the CRM framework will be applied, and the data/methods that will be required.

The specific objectives of this study are:

- To contribute towards comprehensive climate risk management in India by piloting the 6 step Climate Risk Management (CRM) Framework within a selected district of Himachal Pradesh.
- Inform state level climate risk and adaptation management processes by conducting an integrated risk assessment for:
  - Rural infrastructure
    - Roads, hospitals, and education facilities
  - Rural livelihoods
    - Impacts to agricultural land and related earnings, demography, and standard of living

On this second objective, it is crucial to take on board the information needs of stakeholders who are engaged in risk management and adaptation processes in the region of interest. Hence step 1 should be viewed as an iterative process coupled with step 2, characterized by extensive (and ongoing) stakeholder discussions to refine their information needs relating to the mutually agreed system of interest.

Context for the study

Based on the objectives outlined above, a comprehensive desk-based review was undertaken focusing on scientific literature and studies, existing scientific data, and policy documents to establish the context for the study and to determine further information needs. The desk-based review was focused in two areas:

a) Climate Vulnerability and Risk Profile

The starting point for establishing the baseline conditions in Himachal Pradesh are two studies namely Climate Impacts and Vulnerability Assessment[2], and the Integrated Climate Vulnerability, Hazards and Risk study undertaken in Himachal Pradesh[3]. The former study gave results as the district level for the entire state of Himachal Pradesh and was framed by the older (IPCC 4th Assessment) concept of climate vulnerability, whereas the latter study was framed by the concept of climate risk and focused at the block level for Kullu district. These studies build on further information contained in the State Action Plans on Climate Change, Disaster Management Plans, and other published academic literature from these states. From these studies an overview of the status quo, existing data availability, and information needs in terms of hydro-climatic and socio-demographic baseline data was generated

b) DRR/ CCA Institutional and Legislative Context

To ensure that the assessment results make a substantial contribution to on-ground adaptation action a comprehensive overview of the existing DRR and CCA institutional context is required, identifying linkages between key institutions, ongoing programmes and strategic plans. By identifying gaps or shortcomings, adaptation and risk management options can be tailored accordingly (see Step 6).

The strategic and legislative context for CCA and DRR in Himachal Pradesh are laid out in the *State Strategy and Action Plan on Climate Change* (DEST 2012), and *Himachal Pradesh State Disaster Management Plan* respectively (Department of Revenue 2012). These documents identified a series of climate and water related threats to the region including:

- Floods
- Heat Wave and Cold Wave
- Thunder and Lightning
- Hailstorm
- Snow Avalanches
- Change in crop and apple productivity
- Cloud Burst
- Droughts
- Increasing pests and diseases

In addition, geotechnical or geological disasters that are strongly influenced by weather and climate in the region include:

- Landslides and Mudflows
- Dam Failures/ Dam Bursts

2 INRM. 2017. Climate Impacts and Vulnerability Assessment in the State of Himachal Pradesh. Summary Report, GIZ, Delhi.

3 IHCAP. 2016. Climate Vulnerability, Hazards and Risk: An Integrated Pilot Study in Kullu District, Himachal Pradesh (Synthesis Report). Indian Himalayas Climate Adaptation Programme (IHCAP), Delhi.

Figure 2: Sectoral vulnerability assessment for Himachal Pradesh under baseline conditions. From the Climate Impacts and Vulnerability Assessment in the State of Himachal Pradesh (INRM 2017).

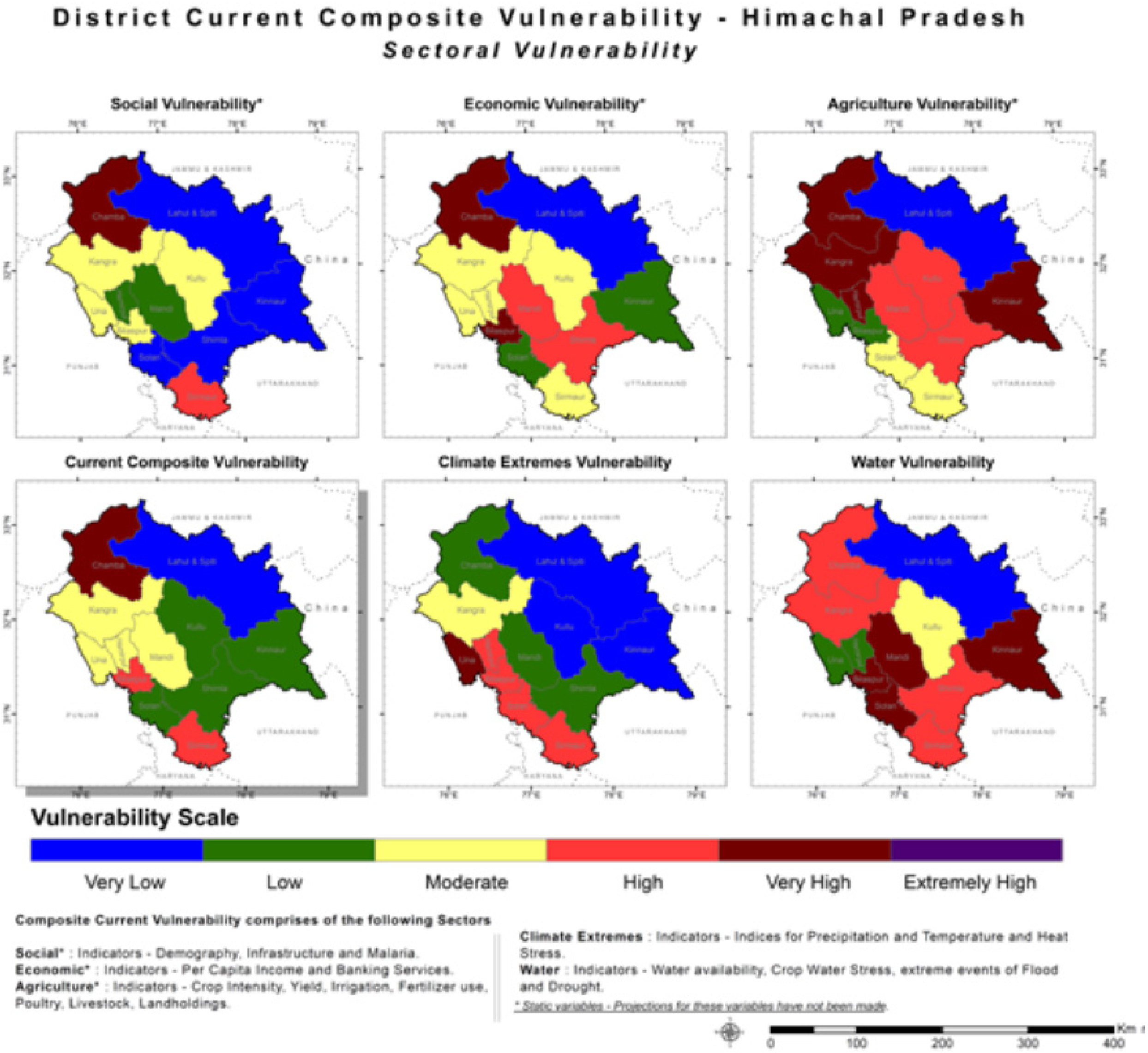
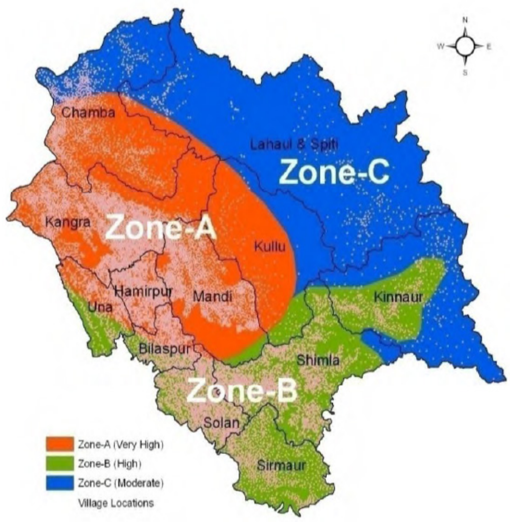
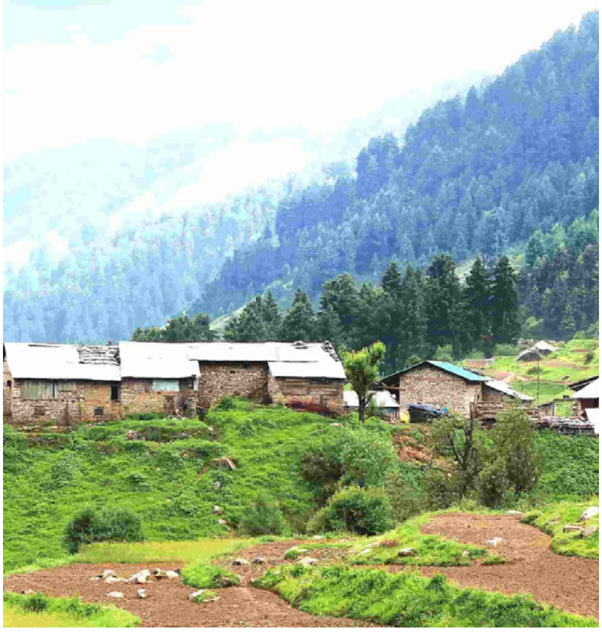


Figure 3: Composite risk zones for Himachal Pradesh, considering seismic, landslide, flood, and drought risk. From Himachal Pradesh State Disaster Management Plan respectively (Department of Revenue 2012)





From a sectoral perspective, agriculture has been highlighted as particularly threatened by climate change and related disasters (see figure 2), and many government led interventions are focusing on strengthening the rural economy and reducing vulnerabilities in this sector. Apple cultivation, which is of great economic importance for Kullu district in particular, is benefiting from training and awareness around technology to improve productivity, and replantation schemes to replace old low yielding varieties with higher yielding alternatives. Diversification is also being encouraged, through schemes that subsidize the building of polyhouses for indoor horticulture and promote organic farming.

Creating an enabling environment that encourages organic farming is seen as a way of promoting sustainable agricultural production, reducing greenhouse gas emissions, limiting the use of chemical fertilizers, and reducing irrigation requirements. In the area of animal husbandry, the government has been providing soft loans of up to INR 15,00,000 for investments that increase the income of farmers or provide self-employment opportunities, while the Bhed Palak Samridhi Yojana scheme provided subsidized loans for purchasing of livestock.

The state is also encouraging alternative forms of income, through promotion of eco-tourism and home stay schemes, generating employment opportunities and adding economic values in remote, rural areas. Similarly, there are efforts to make Himachal Pradesh the "herbal state", exploiting the potential of medicinal herbs and plants for income generation. The Indian cropping season is classified into two main seasons. The kharif cropping season is from July –October during the south-west monsoon and the Rabi cropping season is from October-March (winter). The crops grown between March and June are summer crops. Crop insurance schemes were first introduced by the state government in 1999 for the Rabi season only, but beginning in 2016 additional insurance schemes is also being provided for the Kharif (monsoon) season. The different stages of risk leading to crop loss due to prevention of sowing, post-harvest losses, localized calamities and losses to standing crops (from sowing to harvest) have been covered under this new scheme.

Table 2: Sector specific approach and processes for reconstruction, rehabilitation and recovery (from the District Disaster Management Plan for Kullu – 2017)

Sector	Approach	Process
Public assets: Roads and bridges Culverts, Public buildings like hospitals and schools	❖ Multi hazard resistant construction to be followed while reconstruction of public assets, for example, Hazard resistant buildings to be made with the help of certified engineers. ❖ Use of non-shrinking mortar ❖ Evacuation plans to be made for the public buildings ❖ Non-structural mitigation measures to be taken into consideration ❖ Risk sensitive development will be ensured in each of the reconstruction programmes. for example: landslide and flood zone mapping to be implemented ❖ Detailed geological survey of the land to be used for reconstruction.	❖ Detailed damages and needs assessment: Multi sectoral/ multi-disciplinary teams are to be made which can do a detailed damage and need assessment of the entire area. ❖ Develop a detailed recovery plan through multi departmental participation. Specific recovery plan through consultative process of different line department to be made. ❖ Arrange for funds from Central government, state government, multi-lateral agencies (World Bank or ADB) ❖ Multi sectoral Project Management Unit to be made. ❖ The process of monitoring and manipulation is to be done by SDMA.

The state disaster management plan also outlines the threat to critical infrastructure. In education, the statewide literacy rate of 84% (as per 2011 census) is higher than the national average, owing to a network of nearly 11,000 primary schools, 2300 middle schools, 2100 high and secondary schools, and 88 colleges. However, according to the state disaster management plan, up to 59% of these institutions are situated in the very high risk zones (considering a range of potential natural calamities – Figure 3), and a further 38% are in the high risk zone. Similarly, out of 605 medical institutions, some 48% are situated in the very high risk zones, and a further 44% are in the high risk zone. Information on the risk level to the states 34,000 km of roading, and 1400 km of bridges, is however not reported. Overall Kullu is classified as the district with the highest levels of infrastructural risk across the state. As such, the District Disaster Management Plan for Kullu (2017) places heavy emphasis on the reconstruction, rehabilitation and recovery phase for critical infrastructure (Table X). Importantly, the concept of "building-back-better" is evident within district planning, with the reconstruction phase highlighted as an opportunity to utlise latest building codes, best design practices, and zoning regulations.

In pursuance to the National Action Plan on Climate Change (NAPCC), a State Centre on Climate Change was established under the aegis of the State Council for Science Technology & Environment, Department of Environment, Science & Technology. The core mission of the state center is to understand climate change and its impact on the Himalayan Eco-System and to develop and implement mountain specific strategy, mitigation and adaptation plans based on vulnerability, risk scenario analysis and by enhancing capacity of all stakeholders to combat the threat of climate change. Specific objectives of the state center include:

- To strengthen capacity building in disaster management.
- To formulate policies and input to the state government in the field of disaster management and climate change

Hence, it is clear that disaster management is recognized by the state government as a top priority to reduce the risk associated with climate change, and authorities are working to strengthen preparedness levels so that impacts (loss and damage) can be reduced. Recent and ongoing actions of the state in this area include:

- Completion of state level hazard, risk and vulnerability assessment.
- Formulation of State and District level disaster management plans.
- Establishment of state and district level disaster management authorities, and state executive committee to coordinate disaster response efforts.
- Capacity building and awareness programmes.
- Strengthening of capacities for emergency response and search and rescue.
- Flood protection measures, such as embankments to protect critical infrastructure and flood prone areas.

From an institutional perspective, a range of key players support government authorities in climate change adaptation and disaster risk reduction, including academic institutions, community organizations, and Non-Governmental Organizations (NGOs). NGO's are recognized as a most effective means of achieving an efficient communication link between authorities and the affected community. There are different types of NGOs working at the advocacy as well as the grass roots levels in the state, helping with preparedness, relief and rescue, rehabilitation and reconstruction, and also in monitoring and feedback.

The increasing awareness of the linkages between climate change adaptation and disaster risk management, is clearly evident in the State Disaster Management Plan, which calls for priority to be given to promoting understanding of climate change adaptation strategies. Section 2.15.11 of the plan is specifically focused on vulnerability of the state to climate change, and acknowledges an increase in frequency of hydrometeorological hazards such as floods, droughts, landslides and avalanches as a key outcome of projected future climate change across the state.

Under the plan, the Department of Environment, Science and Technology DEST is recognized as the primary agency for research and development on climate change impact and adaptation activities for the State, and as such, DEST is required to provide inputs to the State Disaster Mitigation Committee. The State Disaster management plan specifies that during non-disaster time, DEST should undertake (among other activities) research on climate change impacts and recommend adaptation strategies.

Step 2: Identify system of interest

The selection of the study region was finalized through a rapid scoping study within the inception phase of the project, drawing on information compiled under Step 1.

Given the fact that a key objective is to test a methodological framework, a high priority was placed upon identifying a study area where the project team had already a good level of familiarity and access to high quality data. The criteria for selection of the study region thus considered:

- Previous experience and familiarity of the project team in the region
- Availability of data
  - Primary data (community surveys, focus groups)
  - Secondary data (hydro-meteo data, Census India, hazards mapping etc.)
- Current status of knowledge on risk and vulnerability
- Accessibility
- Stakeholder engagement and motivation based on past experiences from workshops and exchanges in the region.

Based on positive fulfilment of the criteria listed above, Kullu district, was selected as the priority region for the project.

To ensure that the assessment results will make a substantial contribution to on-ground adaptation action and meet the expectations of local stakeholders, a core component of Step 2 was a scoping process between science and decision- makers, facilitated through an inception meeting with stakeholders. Stakeholder mapping was undertaken to identify a range of actors and institutions from state-district-local levels. The subsequent inception meeting jointly with key stakeholders served as an opportunity to assess the state or district level priorities and explore key risks and adaptation needs of the different sectors. The selected region, and the justification for the selection was presented at the stakeholder inception meeting, with an opportunity given for discussion and refinement.

Priority region: Kullu district, Himachal Pradesh

Key findings of the state level Climate Impacts and Vulnerability Assessment (INRM 2017) included:

- Projected increase in monsoon rainfall and runoff (16% to 41% under RCP8.5).
- Projected increase in heat stress.
- The vulnerability of the water sector in Kullu district is projected to increase during the 21st century, due to increase in exposure to drought weeks and flood discharge and sensitivity to seasonal crop water stress.
- High vulnerability in the agricultural sector.

For primary data collection, participatory surveys focused on villages within the blocks of Anni and Banjar, where highest vulnerability in the agriculture sector has previously been identified in the University of Geneva led study.

Figure 4: Priority region

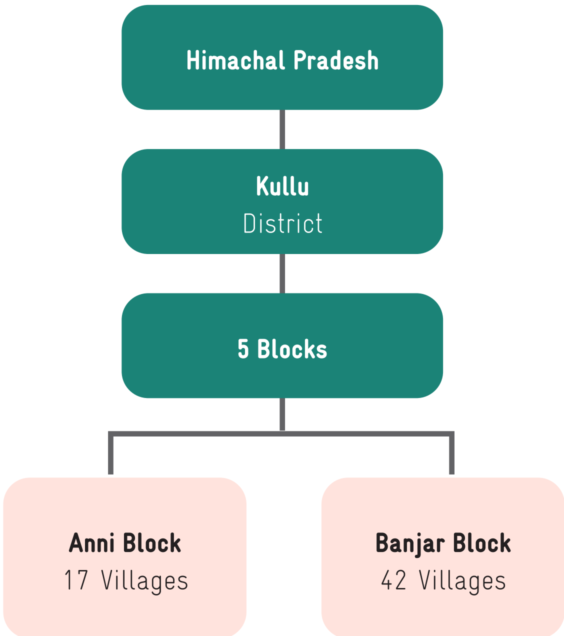
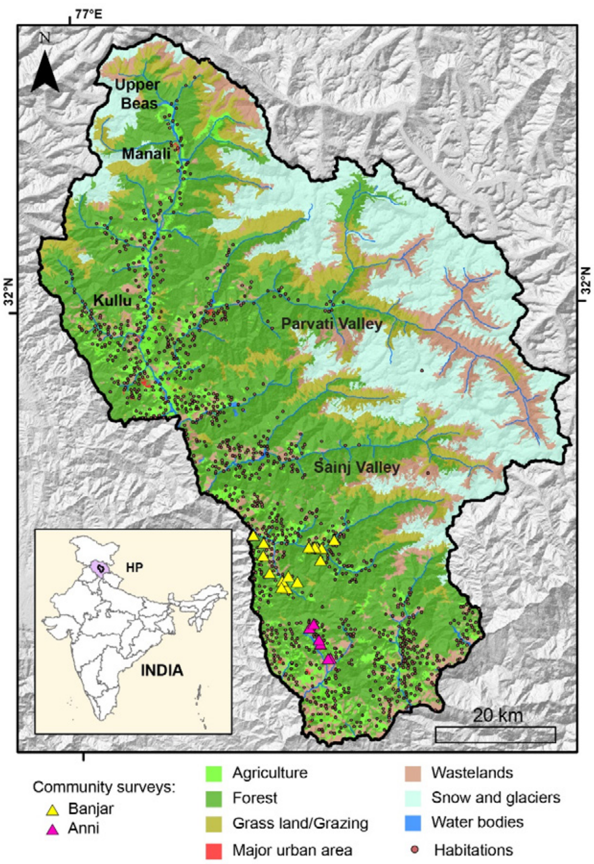


Figure 5: Overview of Kullu district showing major land use and land cover classes and habitations. Villages where the field survey (community participatory surveys) were undertaken within the Blocks of Ani and Banjar are indicated.



Kullu district

Kullu district (5,503 sq km) is centered along the north-south axis of the Kullu Valley formed by the Beas River, in central Himachal Pradesh. The district stretches from the village of Rampur in the south to the Rohtang Pass in the North. The largest valley in the district is called the Kullu Valley, which is also known as the Valley of the Gods. There is also a town called Kullu which sits on the banks of the Beas River in the central part of the valley. Major urban settlements include Manali, Kullu and Bhuntar. A unique feature of the Kullu Valley is the broad U-shaped profile, relative to many other more deeply entrenched river valleys of the Himalaya. The wide, gently sloping valley floor supports well-developed soils that in turn provide a rich agricultural resource to maintain a significant component of the local economy. The three major crops that are widely cultivated on this soil are wheat, apples and maize. In total, the climate-sensitive agricultural sector provides direct employment to about 70 per cent of the total population (Census of India 2011). According to the 2011 census Kullu district has a population of 437903, and out of the total population, urban population is 41391 (9.5%) while rural population is 396512 (90.5%). The district has a population density of 79 inhabitants per square kilometer. Its population growth rate over the decade 2001-2011 was 14.65%. Kullu has a sex ratio of 942 females for every 1000 males, and a literacy rate of 80.14%. Approximately 35 % of the district is under forest cover, giving way to alpine tundra at higher elevations. The largest mountain peaks extend above 6500 m above sea level, with numerous glaciers and snowfields feeding the Beas catchment. The district includes the Great Himalayan National Park (GHNP), one of the world's most significant areas of biodiversity.

The overall climate regime of the Kullu district is considered to be sub-tropical monsoon characterized by cool, snowy winters at higher elevations; a warm, dry spring and autumn; and a warm, wet monsoonal summer. Since the onset of the most recent unrest in Kashmir, Manali and the Kullu Valley in general, have become important destinations for tourists escaping the summer heat of India.

Anni Block

As per Census 2011, Anni's population is 56917, consisting of 12292 households. This block has 6119 children in the age bracket of 0-6 years. Literacy ratio in Anni block is 69%. Among males the literacy rate is 77% while female literacy rate is 62%. The working population is 63.7% while rest is unemployed. According to the 2016 University of Geneva led study, Anni Block is situated within the highest risk zones for both flooding and landslides, and has the second highest level of risk in the agriculture sector (behind Banjar).

Banjar Block

As per Census 2011, Banjar's population is 62390, consisting of 12361 households. This block has 8061 children in the age group of 0-6 years. Literacy ratio in Banjar block is 69%. In males the literacy ratio is 76% whereas female literacy rate is 61%. The working population is 67.2% while rest is unemployed. According to the 2016 University of Geneva led study, Banjar block has the highest level of risk in the agriculture sector, and moderate to high level of risk for flooding and landslides.

Box 1: Case Study Landslide Experiences in Himachal Pradesh

Landslides are the downslide movement of soil, debris or rocks, resulting from natural cause, vibrations, overburden of rock material, removal of lateral supports, and change in the water content of rock or soil bodies, blocked drainages etc. The mass movement varies in magnitude from soil creep to landslides. In the hilly terrain of Himalayas, landslides have been a major and widely spread natural disaster and often affect life and property and occupy a position of major concern.

Looking in to the past history of landslides within Kullu has shown that large part of its territory is prone to hazard of landslides especially during the rainfall and snowfall months of the year.

Area	Date	Damage
Luggar Bhatti	12.09. 1995	65 persons (35 as per official record) were buried alive during the slide
Manali	5.03.2011	Roads were blocked, electricity Supply dismantled, a four story traditional house collapsed due to weight of four-foot snow in Malana village.
Manali	26.02.2011	Collapsed terraced fields, uprooting and falling of trees, disrupting vehicular traffic at Raison, Dobhi, Alu Ground, Rangri and Manali.
Manali-Leh Highway	16.09.2012	Blocked Manali-Leh highway, leaving people stranded amidst Chaos and traffic bottlenecks.
Kullu-Anni	28.08 2013	Blocked the Kullu-Anni highway at two places and residents of hundreds of villages falling under 58 panchayats in Anni and Nirmand sub-divisions of Kullu had no connectivity with the District headquarter headquarters for about one week.
Manikaran Gurudwara-Kullu	18.08.2015	Damaged the 3 Rooms of Gurudwara building leaving 7 pilgrims dead and 11 injured with estimated loss of Rs. 29.10 lacs.
Pancha Manihar Road at Parbati HE Project, Stage-II, Kullu	02.09.2016	Total 9 persons (5 killed & 4 injured) were buried alive during the slide.

The landslide Hotspot areas within district Kullu are:

Anni Sub-division – Bro, Jagat Khana, Sagofa, Sarga, Deem, Chayal, Gabal and Bakhun;

Banjar Sub-division – Neuli, Siund, Sainj, Bhyaliand Largi;

Manali Sub-division – Gulaba, Nehru Kund, Rangri to Aloo ground near Bahnu Bridge

Category	Area(sq km)	Area (per cent)
No Risk	23.22	0.42
Low-Moderate	1068.65	19.42
High	2650.19	48.16
Very High-Severe	1960.94	32
Total	5503	100

Source: ASTER DEM, LANDSAT ETM+ (2005); IRS P6 LISS III (2005)

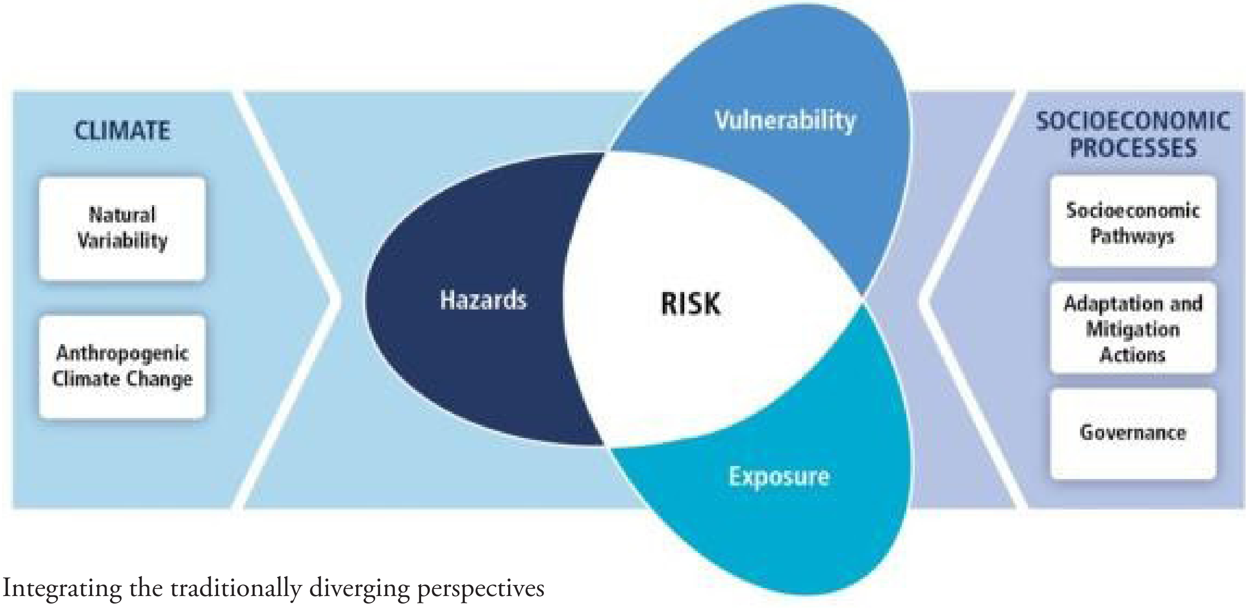
Step 3: Develop context-specific methodology

The general methodological approach for the core analytical and assessment steps (Table 1) was fine-tuned to the local context and for the two target sectors (rural infrastructure and rural livelihoods), based on feedback and discussion at the stakeholder inception meeting and the analyses coming out of Steps 1 and 2. As per the study requirements, the methodological approach was designed to include a forward-looking perspective, providing a detailed climate scenario-based risk analysis. Both top-down and bottom-up approaches have been incorporated into the risk assessment. However, it needs to be recognized that the short duration of the project restricted the level to which on-ground surveys and other participatory approaches could be implemented. The scope of the assessment was refined considering the information collected under steps 1 – 2 to focus on:

- Rural livelihoods: impacts to agricultural land and related earnings, demography, and standard of living.
- Rural infrastructure: impacts to roads, hospitals, and education facilities.

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 the risk assessment in Kullu district.

Figure 6: The risk assessment framework as conceived under IPCC AR5



Integrating the traditionally diverging perspectives from the disaster risk management and climate adaptation communities, the IPCC AR5 risk concept sees risk as a result of the interaction of **vulnerability, exposure, and hazard** (see Figure 6). In the subsequent sections core terminology and methodological approaches used to assess these three components at block and village level in Kullu district are introduced, and the integrated risk assessment is described in detail.

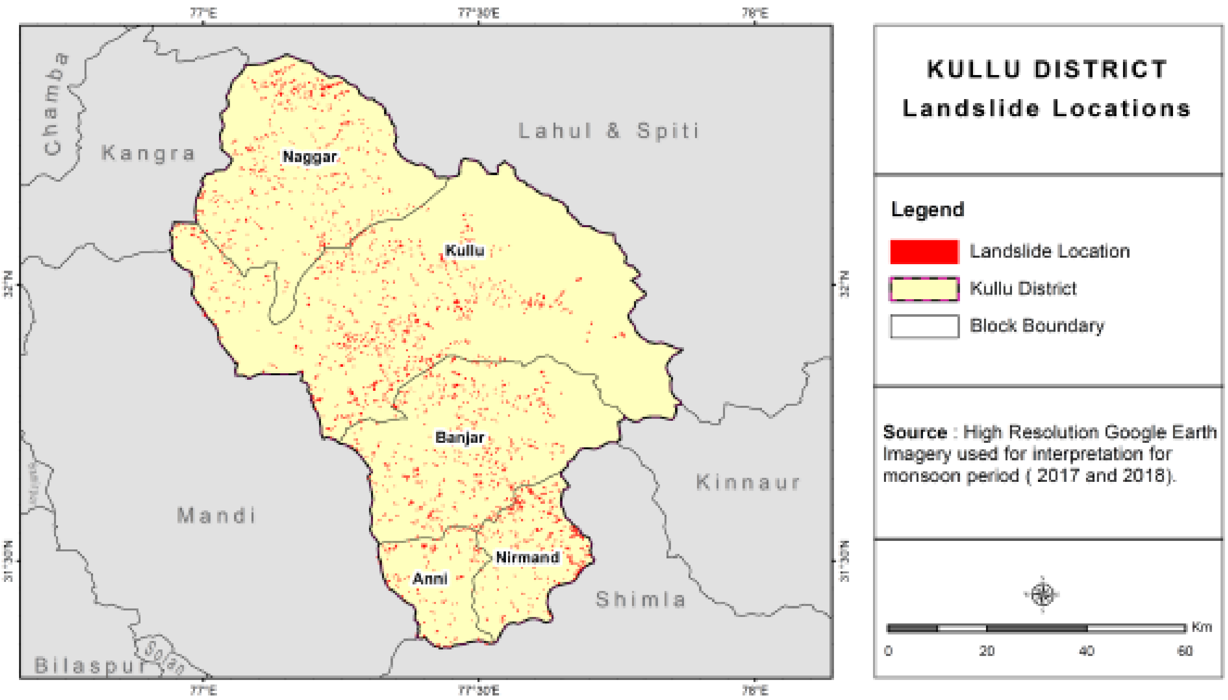
Climate related **risk** results from a physical event (**hazard**) intercepting with an **exposed** and **vulnerable** system (e.g., community or ecosystem).

Hazard

In the context of a climate risk assessment, it is assumed that a hazard is influenced by some external climate signal (e.g., change in rainfall triggering of landslides), which does not depend on exposure or vulnerability and can per se not be influenced by adaptation or other measures seeking to deal with climate-related loss and damage. 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.

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.'

Figure 7: Landslide location map for Kullu blocks identified from high resolution satellite imagery.



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. The initial scoping stage (steps 1 -2) resulted in the identification of several high priority slow onset and rapid onset hazards to be modeled and included in the risk assessment. A subset of these hazards was considered in this assessment in view of access to high quality baseline and projected data, and to keep the scope of the study manageable. Slow onset hazards considered in the risk assessment included **drought, extreme heat, and water stress, with related impacts on crops**. Rapid onset hazards considered were **floods and landslides,** as related to **heavy rainfall**.

For hydrological hazards (both flooding and droughts/water stress), catchment-scale modelling was undertaken using the Soil and Water Assessment tool (SWAT). For landslides, an inventory of 3200 landslides activated across Kullu district during the monsoon of 2017 was used as basis for landslide susceptibility modelling (Figure 7), considering also how heavy rainfall triggering events will increase landslide activity in the future. Future changes in temperature and precipitation were derived from downscaled CORDEX regional climate model output.

Vulnerability

As defined by IPCC 2014, vulnerability refers to 'The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.'

Vulnerability has two relevant elements:

Sensitivity

It is determined by those factors that directly affect the consequences of a hazard. Sensitivity may include physical attributes of a system (e.g. building material of houses, type of soil on agriculture fields), social, economic and cultural attributes (e.g. age structure, income structure).

Adaptive capacity

'The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences' (e.g. knowledge to introduce new farming methods).

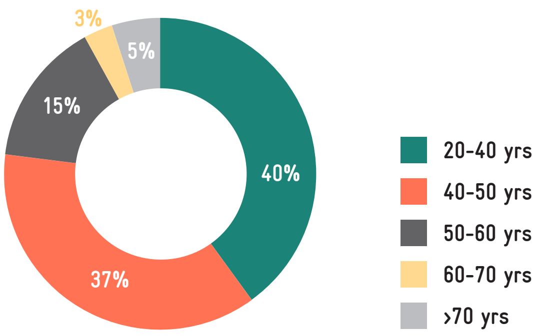
The vulnerability assessment in this study included two components:

- Indicator-based vulnerability assessment (secondary data)
- Community-level participatory field survey (primary data).

Details on the indicators used in the block/village-level indicator-based vulnerability (and risk) assessment using socio-demographic data from Census India (2011) are provided in Table A-3. The assessment follows approaches used in previous studies[4 5], where climate vulnerability is derived as a single generic index that characterizes a communities climate sensitivity, and ability to prepare, respond and recover from a climate impact, irrespective of what that specific impact might be (e.g., a flood or an extreme heat event).

The community participatory survey was undertaken during a 10 day field campaign. In total 100 surveys were undertaken in the blocks of Banjar and Anni, focusing on 15 different villages. Most participants were in the aged 20 – 50 years, and all had significant experience in the agriculture sector (Figure 8). The survey combined questions that explored underlying drivers of sensitivity and adaptive capacity, with broader questions on impacts and losses from past climate extremes in the region (as input to Steps 5 and 6). The structured questionnaire included classical element of a Vulnerability Capacity Assessment (VCA) such as historical timelines, impact rankings, and seasonal calendars[6]. The survey was led by scientists who are coming from the region, helping to establish an atmosphere of trust and openness with the participants.

Figure 8: Age of participants (n= 100) interviewed in the field survey



Exposure

As defined by IPCC 2014, exposure refers to 'The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.'

Exposure is therefore typically assessed based on an inventory of elements located within an area in which hazards or adverse effects of climate change may be expected to occur. At large scales, human exposure is difficult to directly quantify, and thus proxy indicators are used such as population density or housing density to provide an approximate indicator of the level of human exposure. It is assumed that higher population densities at the level of a block indicate an increased number of people exposed to weather and climate extremes.

Exposed elements or systems were determined using remotely sensed imagery and census data (Table A-2). For example, the number of people employed in agriculture is available at the village level from census data, net sown land area, and density of education facilities and hospitals. Roads exposed to floods or landslides were manually mapped using high resolution google imagery, and combined with available data from Open Street Map.

Scenarios of future population density were developed by extrapolating forward to the mid-21st century the linear trends in population change (at block and village levels) from 1991 – 2011. An alternative method using population trends from the SSP scenarios was explored, but the grid cell size was too coarse to give meaningful results in the context of this study.

4 Cutter SL, Finch C. 2008. Temporal and spatial changes in social vulnerability to natural hazards. Proceedings of the National Academy of Sciences (PNAS) 105: 2301–2306.

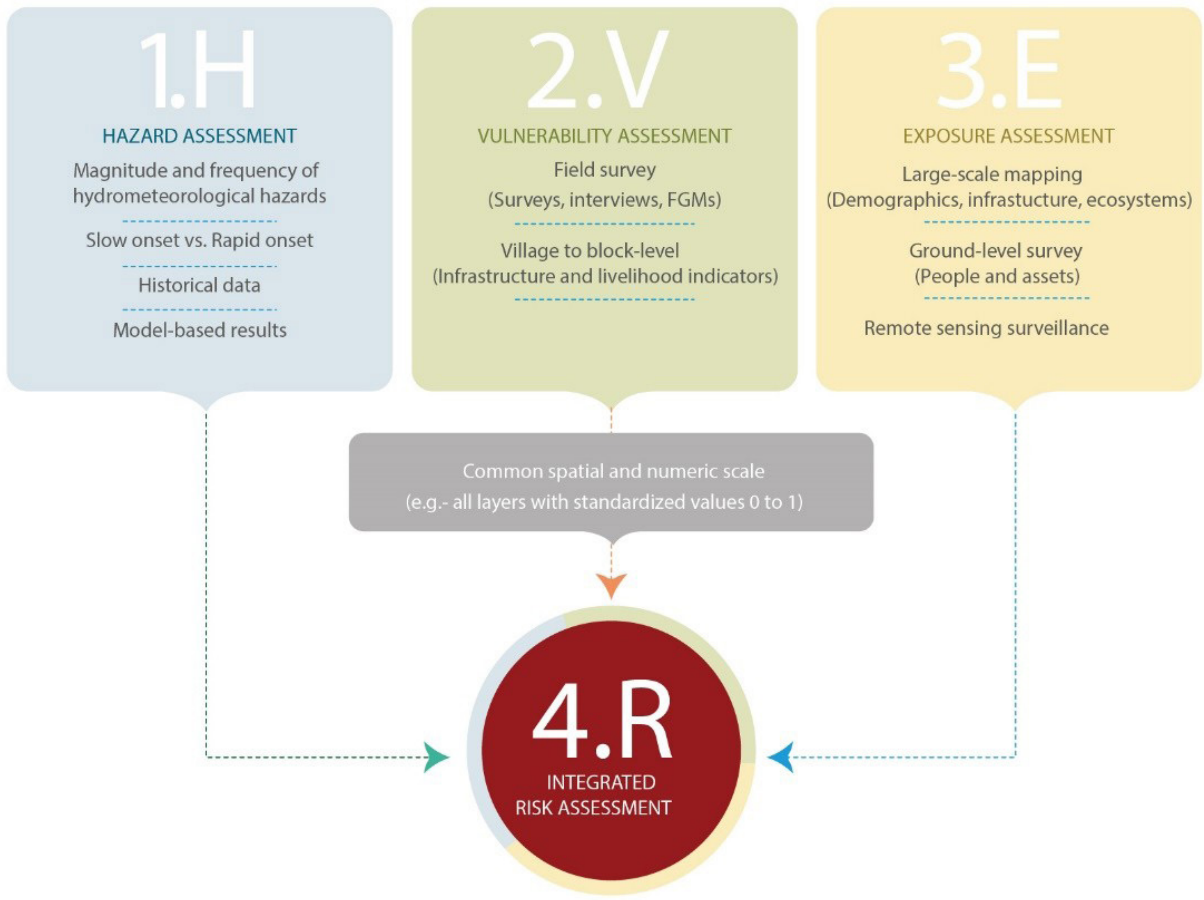
5 Birkmann J. 2014. Data, indicators and criteria for measuring vulnerability: Theoretical bases and requirements. In: Birkmann J (ed) Measuring Vulnerability to Natural Hazards: Towards Disaster Resilient Societies. United Nations University Press: New York, 55–57.

6 Maharjan SK, Maharjan KL, Tiwari U, Sen NP. 2017. Participatory vulnerability assessment of climate vulnerabilities and impacts in Madi Valley of Chitwan district, Nepal. Cogent Food & Agriculture 3(1). DOI: 10.1080/23311932.2017.1310078

Integrated risk assessment

Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk therefore results from the interaction of vulnerability, exposure and hazard (IPCC, 2014). These three components are governed by changes in climate system as well as socio-economic processes.

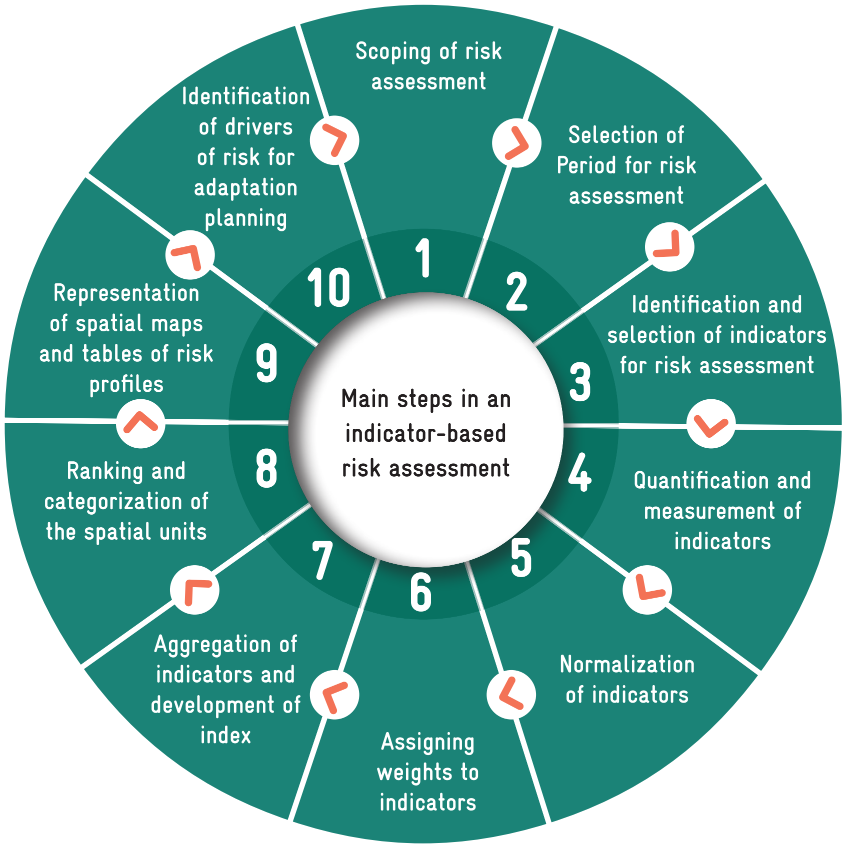
Figure 9: Schematic overview of the integrated climate risk assessment framework showing the key steps and component required



GIS was used to overlay the various hazard layers, with the vulnerability index, and exposure information to determine where people and their assets are at risk. This information provides a basis for establishing typical risk matrices, where a composite risk is categorized into easily communicated risk levels (e.g., purple, brown, red yellow, and green). For example, the overlay of information on hazard, exposure and vulnerability determines the likelihood and severity of an impact on rural infrastructure and livelihoods from multiple events such as droughts, flooding, and landslides, and the results are converted into pecuniary terms and then categorized based on the information collected from secondary sources and focus group discussions. An unweighted sum was used to combine the three components of risk: hazard, exposure and vulnerability (Figure 9).

The study used an indicator-based approach to assess the risk of blocks/villages of Kullu district. The risk assessment can be summarized within 10 steps, as described in Figure 10.

Figure 10: Main steps in an indicator-based risk assessment



Risk Assessment Step 1: Scoping

The scope and objective of the risk assessment within the broader CRM framework, was to identify and rank the blocks of Kullu and villages of Anni and Banjar according to composite levels of livelihood and infrastructure risk. Hence, a Livelihood Risk Index (LRI) and Infrastructure Risk Index (INRI) was developed using weighted average of individual components of risk, namely Hazard Index, Exposure Index and Vulnerability Index. The purpose was to develop both current and projected risk profiles at blocks/village level due to the current and projected climatic conditions. The indices would facilitate the identification of blocks and villages, which have high risk and needs to be identified for prioritization at the time of policy making for formulating adaptation planning and creating awareness.

Risk Assessment Step 2: Selection of the time period

The present assessment is done for current and mid-century between 2021– 2050 (2030s), for two RCP (4.5 and 8.5) scenarios, based on CMIP5 and CORDEX regional climate model outputs. The Multi Model Ensemble (MME) was used: 10 models averaged for the final analysis. Grid-resolution for the climate projections are 0.5°x 0.5°.

Risk Assessment Step 3: Identification and selection of indicators

This is one of the most crucial steps in risk assessment as the outcome will highly depend on the choice of indicators. While choosing the indicators, several things were considered, viz., type of indicator (i.e. whether it captures 'hazard', 'exposure' 'sensitivity' or 'adaptive capacity'), impact of indicator (i.e. whether it affects 'livelihood' or 'infrastructure,' etc.). The indicators for this study have been selected based on the availability of data across time and space (blocks/villages), literature research, consultation with state experts in the inception meeting and experiences drawn from previously carried out climate change vulnerability assessment for the Indian states of Tamil Nadu, Telangana, Punjab and Himachal Pradesh. Whereas hazard and exposure indicators were tailored and selected separately for the livelihood and infrastructure risk assessment respectively, generic indicators of climate vulnerability were used to arrive at a single climate vulnerability index. It should also be noted, that while some indicators had been used in previous studies (e.g., IHCAP 2016), the focus of the current study on a broader range of rapid and slow onset climate impacts, and finer spatial resolution of the current study (down to village level), required that a new grouping of indicators was evaluated.

A set of 43 indicators for the blocks of Kullu have been identified while 50 indicators for villages of Anni and Banjar blocks have been identified for the risk assessment. The selection and acquisition of common baseline data (climate, socio-economic and environmental) is the single most important element for an integrated climate vulnerability, hazard and risk assessment. This allows various contributing studies and assessed components to be brought together and synthesized to provide a robust scientific basis for climate adaptation and policy recommendations. Details of the list of identified indicators, their sources, spatial availability and time period for hazard, exposure and vulnerability assessment are given in Table A- 1, Table A- 2 and Table A- 3 respectively of Appendix I.

Risk Assessment Step 4: Quantification and measurement of indicators

Data was needed in quantifiable units to apply mathematical operations over it. For the vulnerability component, all socioeconomic data was extracted directly from Census India data portals, with exposure data coming from state published statistics.

For quantifying the hydrological-related hazard indicators, the Soil and Water Assessment Tool (SWAT) was used. The SWAT model[7] has been developed to predict the hydrological response of ungauged catchments to natural and anthropogenic perturbations. The major advantage of the SWAT model is that unlike the other conventional conceptual simulation models it does not require much calibration and therefore can be used on un-gauged watersheds (as is typically the case in Himalayan catchments). Input data for the model includes topography (DEM), landuse, soil, daily weather data (rainfall, maximum and minimum temperature, solar radiation, relative humidity and wind speed), cropping pattern, reservoirs and any man made structure with their characteristics and operation rules. Modelling was performed using a 30m Digital Elevation Model. As output, crop water stress, ground and surface water stress and flood data has been used as indicators in the current study.

Future projected climate variables as used for input to SWAT and for extreme analyses are based on CORDEX South Asia modelled data. Extreme heat indices, drought, and precipitation extremes have been analyzed for the baseline period (1981-2010) and mid-century (2021-2050). Climate data from three Regional Climate Models (RCM) of REMO (from MPI), RCA4 (from SMHI) and CCAM (from CSIRO) for RCP4.5 (moderate emission scenario) and RCP8.5 (a scenario of comparatively high greenhouse gas emissions) have been used to calculate the ensemble mean climate extremes indices.

Risk Assessment Step 5: Normalization of indicators

Different indicators are measured in different units (e.g., density of population in terms of persons per sq. km, literacy rate in percentage, Consecutive Dry Days in terms of number of days, etc.). As the risk assessment is about ranking, the indicators have to be brought into common units. In order to make the indicators unit-free, each indicator is normalized. This is also done to avoid one variable having an undue influence on the analysis. Normalized values always lie between 0 and 1. The normalization process varies, depending on the nature of relationship of that particular indicator with the risk (positive or negative relationship). The formulas are given in the Appendix.

Risk Assessment Step 6: Assigning weights to indicators

Weights were assigned to each indicator according to their importance in determining vulnerability of a system. To get reliable results, weights have been assigned to each indicator based on Lyengar and Sudarshan (1982) methodology (see Appendix II for details). It is a method to work-out a composite index from multivariate data and link the weight to variance across the indicators. The choice of the weights in this manner ensures that large variation in any one of the indicators does not unduly dominate the contribution of the rest of the indicators and distort the overall ranking of the blocks/villages. This methodology is statistically sound and well suited for the development of risk index to climate change also.

Risk Assessment Step 7: Aggregation of indicators and development of index

Aggregation of the different indicators is necessary to obtain a composite aggregated risk index or value for each block/village. The final livelihood an

7 Neitsch, S. L., J. G. Arnold, J. R. Kiniry, J. R. Williams, and K. W. King. 2002a. Soil and Water Assessment Tool - Theoretical Documentation (version 2000). Temple, Texas: Grassland, Soil and Water Research Laboratory, Agricultural Research Service, Blackland Research Center, Texas Agricultural Experiment Station

infrastructure risk indices were constructed by simply taking a summation of all the normalized scores of the sub-indicators (hazard, exposure, and vulnerability). No weightings were applied to the hazard, exposure and vulnerability indices, assuming that all components contribute equally to overall risk.

Risk Assessment Step 8: Ranking and categorization of the spatial units

Arrangement of the assessed Index values in decreasing or increasing order allows for ranking of units of study. Risk index values lie between 0 and 1, where 0 indicates least risk and 1 indicates most risk.

With respect to their respective degree of risk, all spatial units are categorized. Cluster analysis is done on the calculated indices to group them into six categories -very low (VL), low (L), intermediate (I), high (H), very high (VH) and extremely high.

Risk Assessment Step 9: Representation of spatial maps and tables of risk profiles

The obtained risk indices along with its components is represented with the help of tables and maps. Risk assessment and risk maps are key components of science-based climate change adaptation that provide the basis for risk reduction measures such as land use planning, early warning systems, preparedness and awareness-building activities.

Risk Assessment Step 10: Identification of drivers of risk for adaptation planning

Identifying the drivers of risk is crucial for adaptation planning. It enables the authorities to chalk out efficient and effective plans to reduce risk, that focus on the underlying risk components of hazard, exposure and vulnerability. A main advantage of the integrated risk assessment undertaken in this study, is that changes in underling index values for hazard, exposure and vulnerability can be teased out, and adaptation strategies designed accordingly. For example, a high risk level could result from extreme levels of vulnerability and moderate levels of hazard and exposure. In such a case, adaptation efforts may rather focus on strengthening local capacities to prepare, respond and recover from disasters. Such information coming out of the risk assessment feeds directly into Step 6 of the CRM framework, focusing on the design of adaptation options to address potential loss and damage.

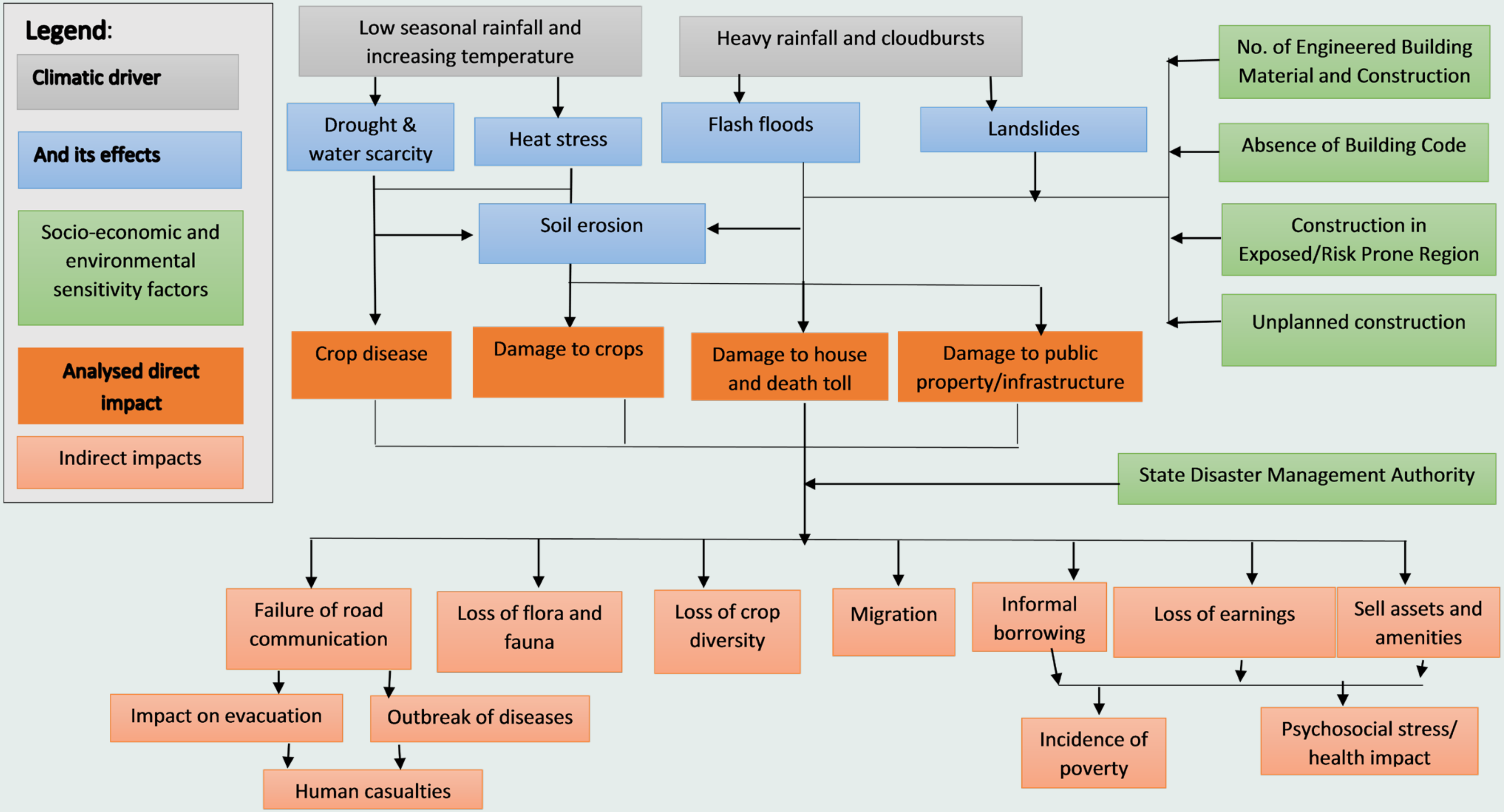
Step 4: Identify climate change risks

Using the indicator-based methodology, blocks of Kullu and villages of Anni and Banjar have been classified into various risk categories. It is seen that livelihood and infrastructure-based indicators vary across the blocks and the villages. In this section, the context for and results of the indicator-based methodology are presented, and complimented with analyses with information coming out of the field survey.

Impact-risk chain for rural communities in Kullu District

In order to synthesize the factors that influence risk in Kullu district, and thereby provide a context for the development of the indicator-based risk assessment and direction for the design of adaptation options, an impact-risk chain was developed based on the information collected during the field survey, combined with the expert judgement of the project team. The communities perceive increasing heavy rainfall and cloudburst events to be the main climate driver of sudden onset disasters (flooding and landslides) in the region. Meanwhile, decreasing seasonal rainfall and increasing warm days drive slow onset hazards of drought and water scarcity, leading to decreased agricultural productivity and increasing incidences of plant diseases. These perceptions are in line with climate models, that show increases in both heavy rainfall events, and drought over this region of the Indian Himalayas. In other words, overall seasonal rainfall amounts are expected to decrease, and the number of dry days increase, but when it does rain, these may be increasingly high intensity events. The impact-risk chain presented in Figure 11, focusses on the climatic hazards for which observations, climate models, and community perceptions all provide robust evidence of an increasing trend. Starting with increasing heavy rainfall and cloud burst events, increasing warm days, water scarcity and drought, leading to associated hazards of increasing flash floods, landslides, soil erosion, crop damage and plant diseases, the analyses from the field survey has identified several direct and indirect impacts to the communities. In addition, crucial institutional and regulatory factors that influence the exposure and vulnerabilities of the community to these impacts have been identified., and will be discussed further in the context of adaptation strategies developed under Step 6.

Figure 11: Impact chain for communities in Kullu district, considering both rapid onset and slow onset effects of climate change



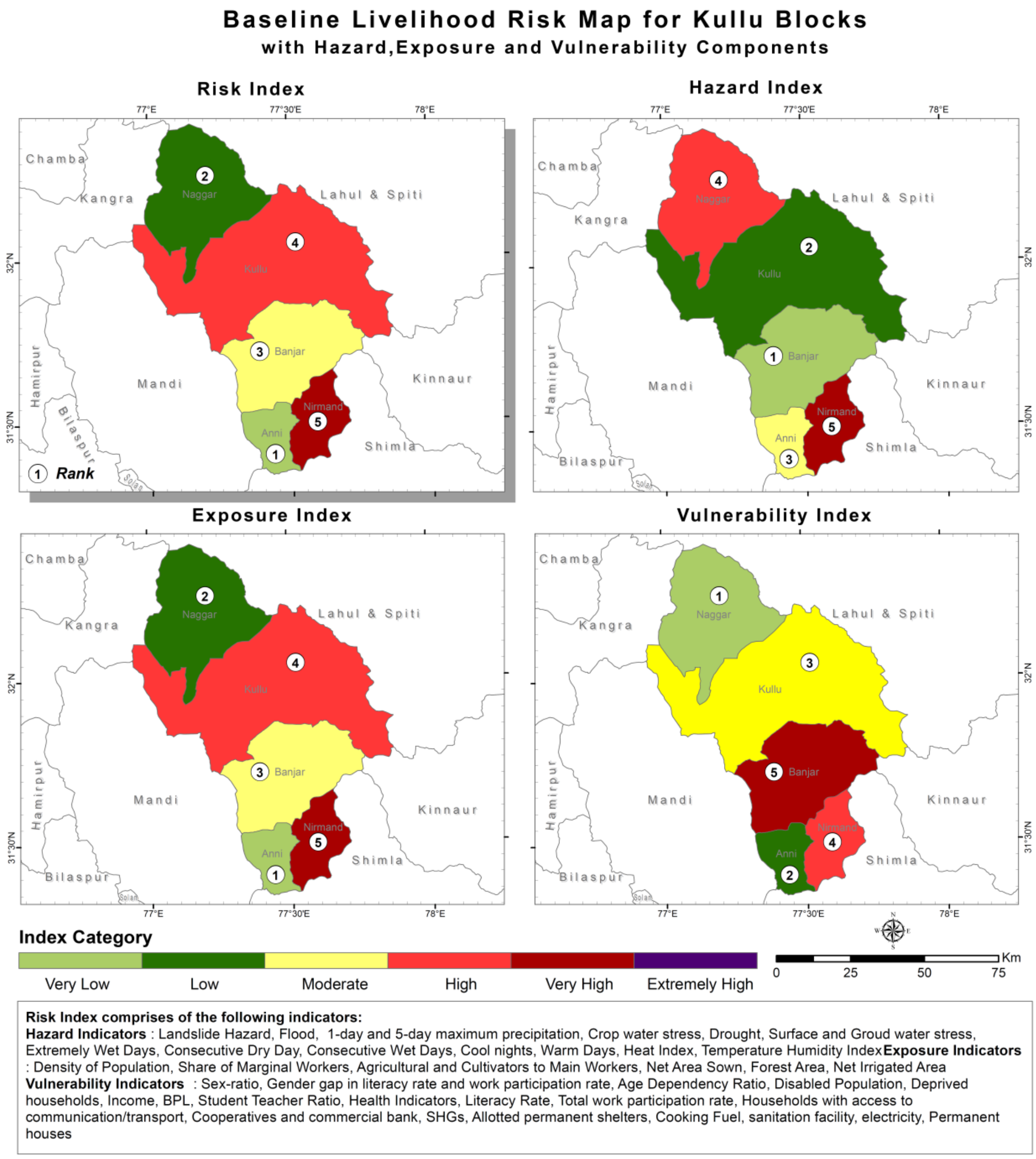
Risk Profiles of Blocks of Kullu

Livelihood Risk Index (LRI) and Infrastructure Risk Index (INRI) have been constructed across the 5 blocks of Kullu using identified indicators (Table A- 1, Table A- 2 and Table A- 3 Appendix I). Blocks are ranked based on the calculated index values. Higher index value represents high risk while lower index value represents low risk for the blocks. A rank value 1 indicates that the block has least risk to climate change and rank value 5 indicates that it has the most risk. The Livelihood Risk Index and Infrastructure Risk Index and the disaggregated Hazard, Exposure and Vulnerability analysis are presented in the following paragraphs. The indices would facilitate the identification of blocks and villages, which have high risk and need to be identified for prioritization at the time of policy making for formulating adaptation planning and creating awareness. Tables showing the block wise index values, ranks and category for current and projected risk for the indices individually are given from Table A- 4 to Table A- 10 in Appendix I.

Livelihood Risk Index

The Livelihood Risk Index (LRI) represents an overall view on the entire set of indicators considered at block level for Kullu (Himachal Pradesh). Risk Index is computed using weighted average of the hazard, exposure and vulnerability indicators given in Table A- 1, Table A- 2 and Table A- 3 of Appendix I. Table A- 1, Table A- 2 and Table A- 3 indicators are added together to arrive at an overall hazard, exposure and vulnerability index respectively for the blocks. The final risk classification (5 categories) provides a relative indication of the threat level across the district, identifying blocks where the risk is most pronounced.

Figure 12: Current Livelihood Risk Map for Kullu blocks with Hazard, Exposure and Vulnerability Components



Current situation

Nirmand located in South Eastern part of Kullu district with rank 5 is at very high risk under current climate. The block of Anni with rank 1, has very low overall levels of livelihood risk. Spatial representation of livelihood risk and its components category for blocks for the baseline is depicted in Figure 12. The major drivers of livelihood risk in all the 5 blocks of Kullu are presented in Table 3. while key hazard indicators are summarized for current and future conditions in Figure 13.

Table 3: Drivers of Livelihood Risk in different blocks of Kullu district

Rank (Category)	Blocks	Drivers of Risk		
		Hazard	Exposure	Vulnerability
5 (Very high)	Nirmand block falls in the very high side of livelihood risk index due to high levels of hazard, exposure and vulnerability (Figure 12).	Landslide hazard, flood, drought in SWM season and cool nights compared to the other blocks. It also has high 1-day and 5-day maximum precipitation, crop water stress in SWM season, Extremely Wet Days and Consecutive Dry Days.	The share of marginal workers, percentage of net area sown, forest area and net irrigated area is high	Lack of adaptive capacity mainly in terms of literacy rate, total work participation rate and higher sensitivity due to sex-ratio, gender gap in literacy rate, deprived households, and disabled population makes it fall under higher vulnerability relative to the other blocks.
4 (High)	Kullu block falls under high risk category mainly due to high exposure index and vulnerability	It has high surface water and ground water stress in SWM season, surface water stress in NEM season and high Temperature Humidity Index compared to the other blocks.	The density of population and net area sown is relatively high leading to increased exposure	Adaptive capacity is low as percentage of households having access to sanitation facility, communication/transport, cooperatives and commercial bank and access to drinking water source is low and the block has higher gender gap in work participation rate, age dependency ratio, deprived households and households using biomass for cooking relative to the other blocks.
3 (Intermediate)	Banjar stands almost at the middle of the ranking. Though block falls under very high vulnerability it has very low hazard risk and it is the combination which makes it fall under intermediate risk category	It has low hazard due to lower values of extreme climate indices, flood, landslide hazard, surface water and crop water stress.	The forest area and net irrigated area is relatively less thus the exposure to hazards is low.	Percentage of households with access to communication/ transport, cooperatives and commercial bank, drinking water source, electricity and households living in permanent houses is the least compared to other blocks while age dependency ratio, households using biomass for cooking and households with less income is high
2 (Low)	Naggar- For the large block of Naggar, where hazard levels are also comparatively high, very low levels of both exposure and vulnerability lead to low overall levels of risk.	It experiences high hazard levels due to high landslide hazard, 1-day and 5-day maximum precipitation, crop water stress and ground water stress in SWM season and extremely wet days.	The density of population, agricultural and cultivators to main workers and net area sown is the minimum thus the livelihood exposure index is low.	Literacy rate, population with access to cooperatives and commercial bank, sanitation facility and electricity as main source of lighting highlights the blocks adaptive capacity. Sex-ratio, households with less income, gender gap in literacy rate, age dependency ratio, disabled population, deprived households, households using biomass for cooking is low lowering its sensitivity making it least vulnerable.

Rank (Category)	Blocks	Drivers of Risk		
		Hazard	Exposure	Vulnerability
1 **(Very Low)**	Anni block, falls in the very low side of livelihood risk index due to very low exposure and low vulnerability though it experiences moderate hazard levels relative to the other blocks	Anni block has low values of 1-day maximum precipitation, ground water stress in SWM season, extremely wet days, Temperature Humidity Index, surface water stress in SWM season, cool nights and warm days. However, it has high crop water stress, surface water stress and ground water stress in NEM season, high Consecutive Dry Days and Consecutive Wet Days.	The share of marginal workers, percentage of net area sown, forest area and net irrigated area is relatively less thus the exposure of Anni block to hazards is low.	Households with access to communication/transport, cooperatives and commercial bank and drinking water source, households living in permanent houses are high increasing its adaptive capacity and gender gap in work participation rate, age dependency ratio, deprived households and households using biomass as fuel for cooking is low reducing its sensitivity. Thus, it is less vulnerable relative to the other blocks.

Projected situation

Spatial representation of current and projected LRI and LHI at block level for RCP4.5 and RCP 8.5 scenarios are depicted in Figure 14 Figure 15 respectively. Vulnerability is not projected for the future, and hence, the main driver of change in risk is the underlying change in hazard linked to climate warming, and increase in exposure (based on extrapolated trends in recent population change). Projected changes in key hazard indicators, relative to current conditions, are shown in Figure 13.

- The overall livelihood risk of all the Kullu blocks is projected to increase towards mid-century as compared to the baseline for both the IPCC AR5 climate scenarios. Block risk is likely to be almost the same under RCP4.5 and RCP8.5 scenario towards mid-century.
- The overall livelihood hazard and exposure of the blocks (population) is projected to increase towards mid-century as compared to the current conditions for both the emission scenarios.
- Landslides, flood discharge, drought weeks, extremely wet days, 1 day and 5-day maximum rainfall, warm days area all generally projected to increase towards the mid-century as compared to current conditions thus contributing to increase in the Livelihood Risk (LR) of the blocks.
- The largest driver of future risk is changes in heavy rainfall events, leading to flooding and landslides. Note that torrential flows triggered by cloudburst-type events are not well captured by the flood model used here, but can be expected to increase inline with the increase in extremely wet days.
- Drought conditions are expected to be worse under RCP 4.5 than 8.5 in most blocks, owing to differences in seasonal rainfall amounts between the two scenarios.
- Ground water stress shows variable results, depending upon the season and scenario, but general future changes are small relative to large model uncertainty.
- Notably all blocks fall within high to extremely high livelihood risk categories by the mid century.
- The blocks of Anni and Naggar are projected to fall under high livelihood risk by mid century, compared to current levels of very low and low risk respectively. Similarly, Banjar and Kullu are projected to fall under very high risk (currently intermediate and high respectively) while Nirmand is projected to move to extremely high levels of risk (currently very high risk).

Figure 13: Hazard indicator values (normalized from 0 – 1) for current and future conditions across the 5 blocks of Kullu, based on regional climate models and SWAT modelling.

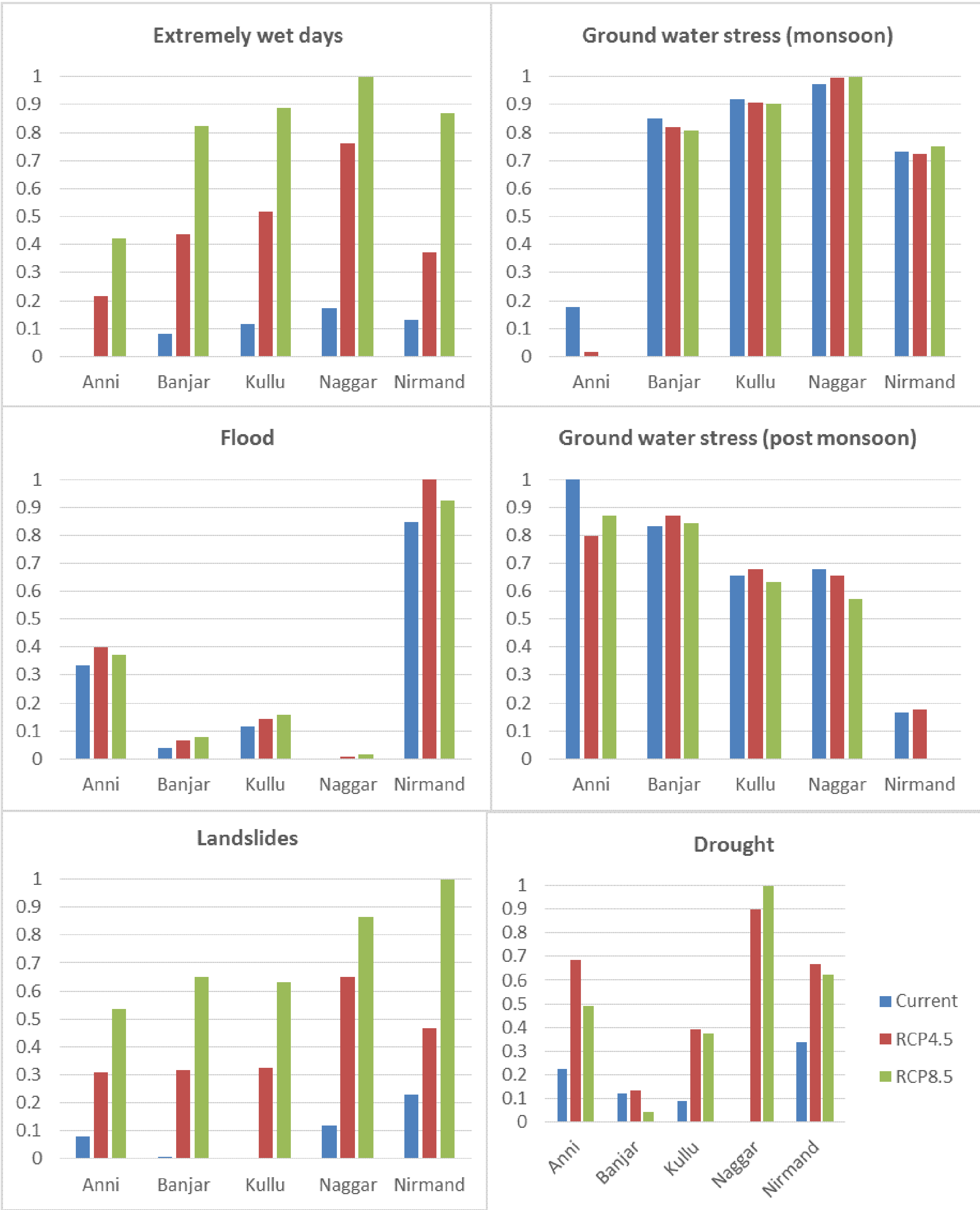
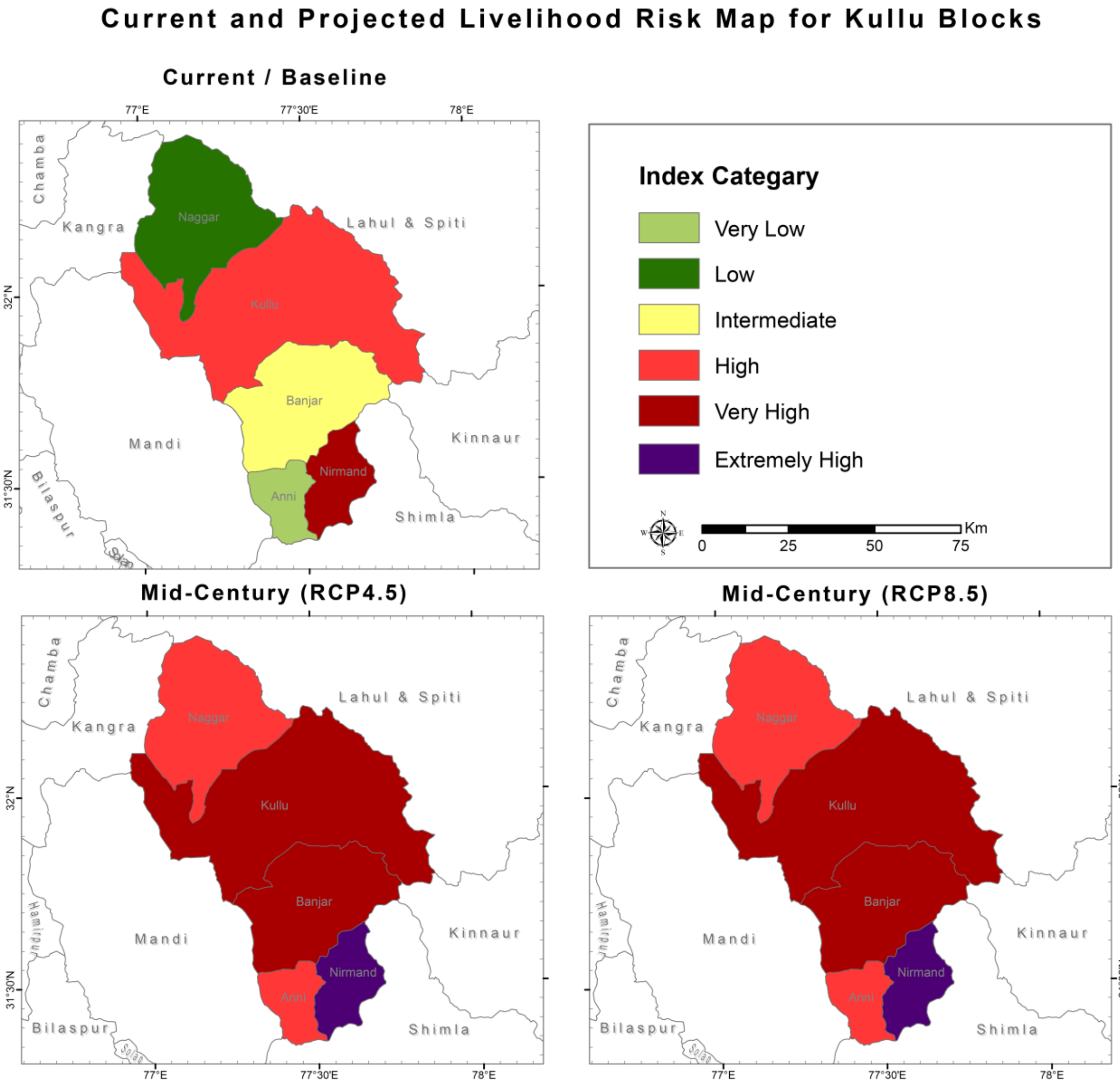
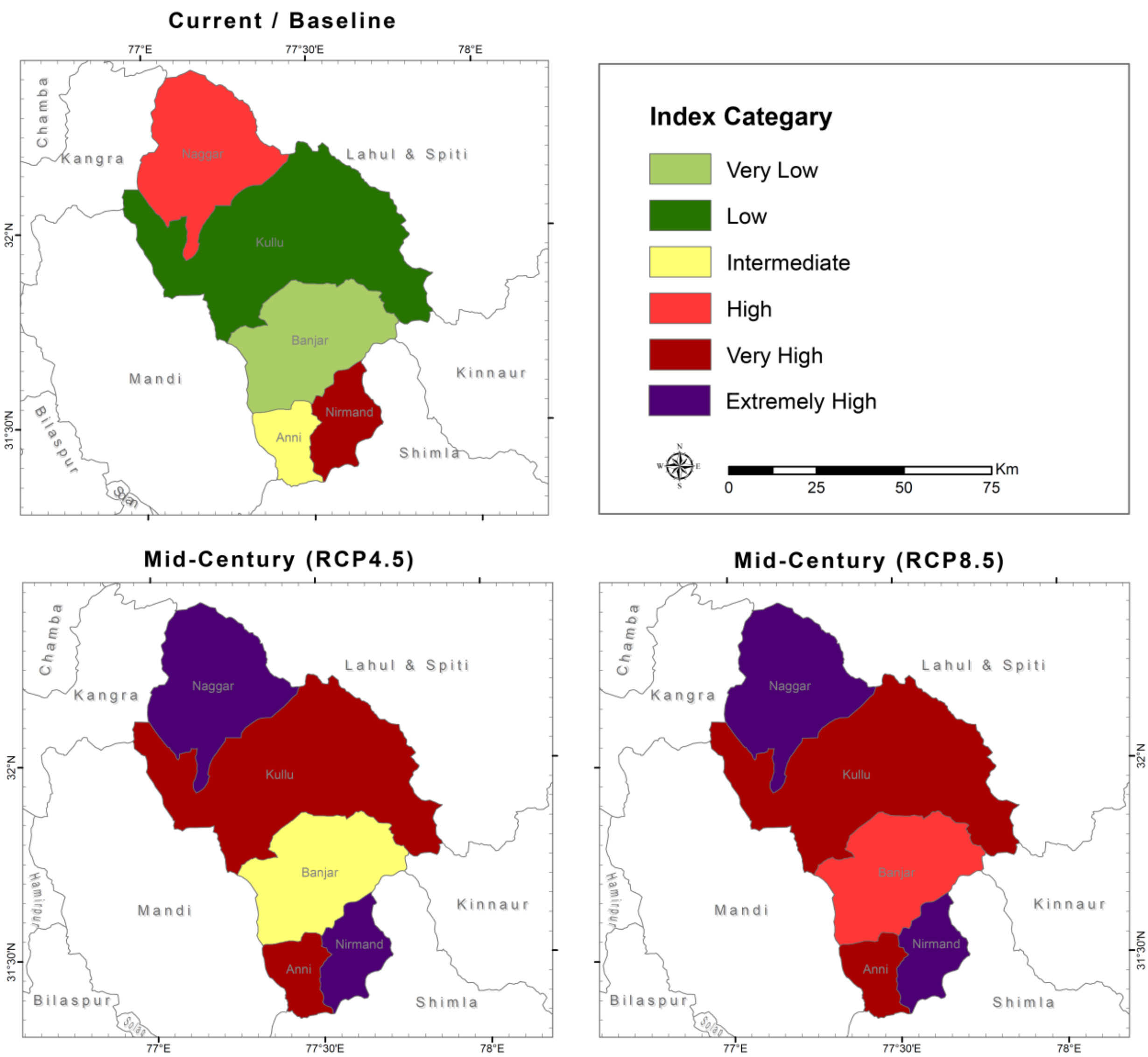


Figure 14: Current and Projected Livelihood Risk Map for Kullu Blocks, under RCP scenarios 4.5 and 8.5.



Risk Index comprises of the following indicators:
Hazard Indicators : Landslide Hazard, Flood, 1-day and 5-day maximum precipitation, Crop water stress, Drought, Surface and Groud water stress, Extremely Wet Days, Consecutive Dry Day, Consecutive Wet Days, Cool nights, Warm Days, Heat Index, Temperature Humidity Index **Exposure Indicators** : Density of Population, Share of Marginal Workers, Agricultural and Cultivators to Main Workers, Net Area Sown, Forest Area, Net Irrigated Area**Vulnerability Indicators** : Sex-ratio, Gender gap in literacy rate and work participation rate, Age Dependency Ratio, Disabled Population, Deprived households, Income, BPL, Student Teacher Ratio, Health Indicators, Literacy Rate, Total work participation rate, Households with access to communication/transport, Cooperatives and commercial bank, SHGs, Allotted permanent shelters, Cooking Fuel, sanitation facility, electricity, Permanent houses

Figure 15: Current and Projected Livelihood Hazard Map for Kullu blocks, under RCP scenarios 4.5 and 8.5.



Hazard Indicators - Landslide Hazard, Flood, 1-day and 5-day maximum precipitation, Crop water stress, Drought, Surface and Groud water stress, Extremely Wet Days, Consecutive Dry Day, Consecutive Wet Days, Cool nights, Warm Days, Heat Index, Temperature Humidity Index

Infrastructure Risk Index

The Infrastructure Risk Index (INRI) is computed using weighted average of the hazard, exposure and vulnerability indicators given in Table A- 1, Table A- 2 and Table A- 3 of Appendix I. Spatial representation of Infrastructure risk and its components category for blocks for the baseline is depicted in Figure 16. The vulnerability indicators used for INRI is common as the LRI. Notably, the hazard indicators considered for INRI include flood and landslide only, as these are considered capable of causing direct impacts to infrastructure.

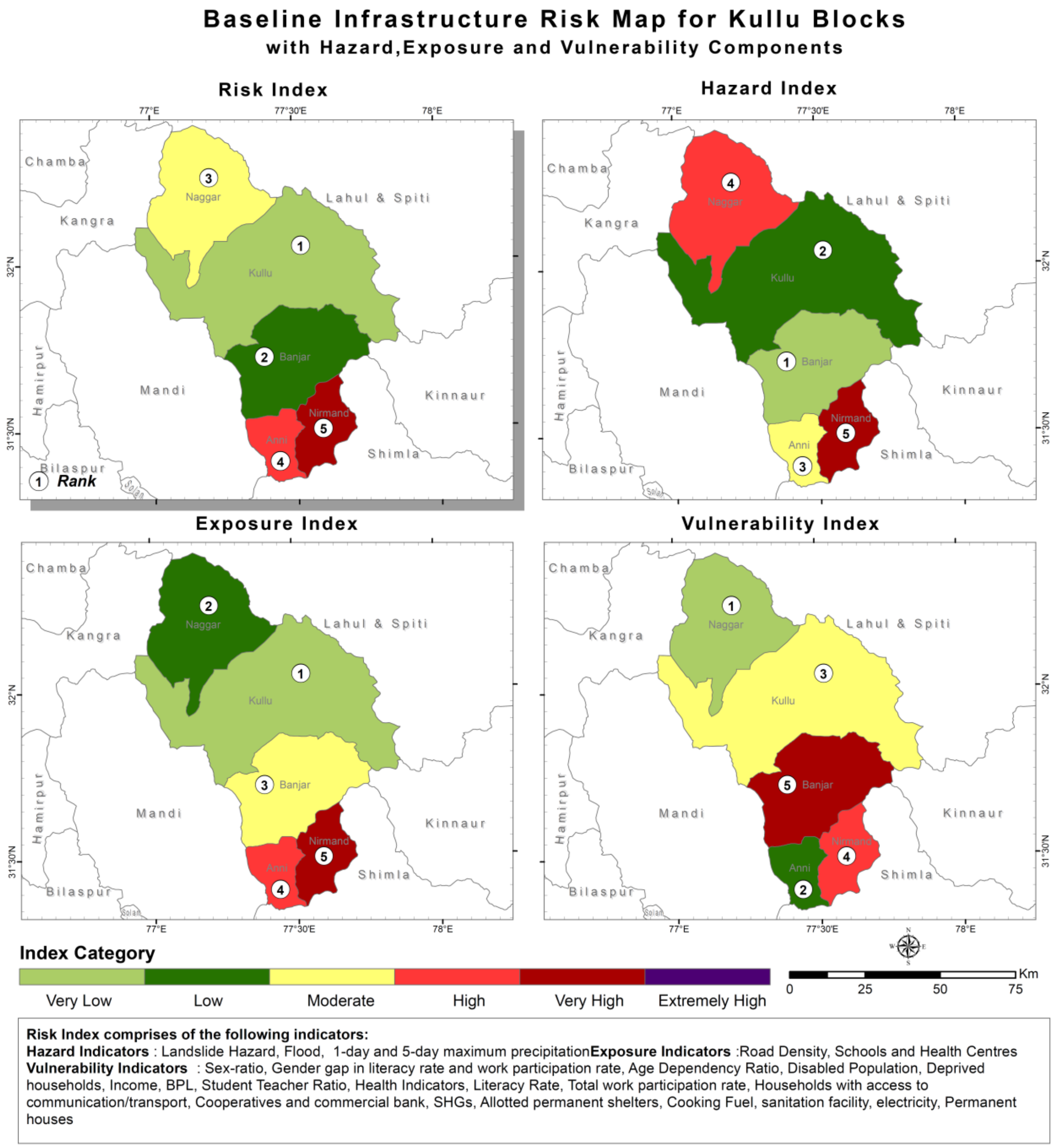
Current situation

Nirmand block, with rank 5 is at very high risk under current climate. The block of Kullu with rank 1, has very low overall levels of Infrastructure risk. The major drivers of Infrastructure risk in all the 5 blocks of Kullu are presented in Table 4.

Table 4: Drivers of Infrastructure Risk in different blocks of Kullu district

Rank (Category)	Blocks	Drivers of Risk		
		Hazard	Exposure	Vulnerability
5 (Very high)	Nirmand block falls in the very high side of Infrastructure risk index due to very high levels of hazard, exposure and vulnerability (Figure 16).	The major drivers of risk are maximum landslide hazard, flood, high 1-day and 5-day maximum precipitation as compared to the other blocks.	Road density, number of educational and medical institutions per capita is more which leads to increased exposure.	The indicators contributing to higher vulnerability have been discussed in the livelihood risk above.
4 (High)	Anni block falls in the high side of Infrastructure risk index due to high exposure and moderate hazard levels.	The main contributing factors for its high risk include flood hazard.	High road density and higher number of medical institutions per capita.	
3 (Intermediate)	Naggar: For the large block of Naggar, where hazard levels are also comparatively high, low levels of both exposure and vulnerability lead to low overall levels of risk.	It experiences high hazard levels due to high landslide hazard, 1-day and 5-day maximum precipitation.	The number of medical institutions is the least thus the Infrastructure exposure index is low.	
2 (Low)	Banjar block has low infrastructure risk due to very low hazard levels though it experiences very high vulnerability.	It has low hazard due to low risk of flood, landslide hazard, and 1-day and 5-day maximum precipitation.	The road density is the least.	
1 (Very Low)	Kullu block falls in the very low side of infrastructure risk index due to very low exposure and low hazard though it experiences moderate vulnerability levels relative to the other blocks (Figure 16).	It has the least risk of landslide hazard and low 5-day maximum precipitation.	The road density, number of educational and medical institutions in the block is less comparatively leading to reduced exposure	

Figure 16: Current Infrastructure Risk Map for Kullu blocks with Hazard, Exposure and Vulnerability Components



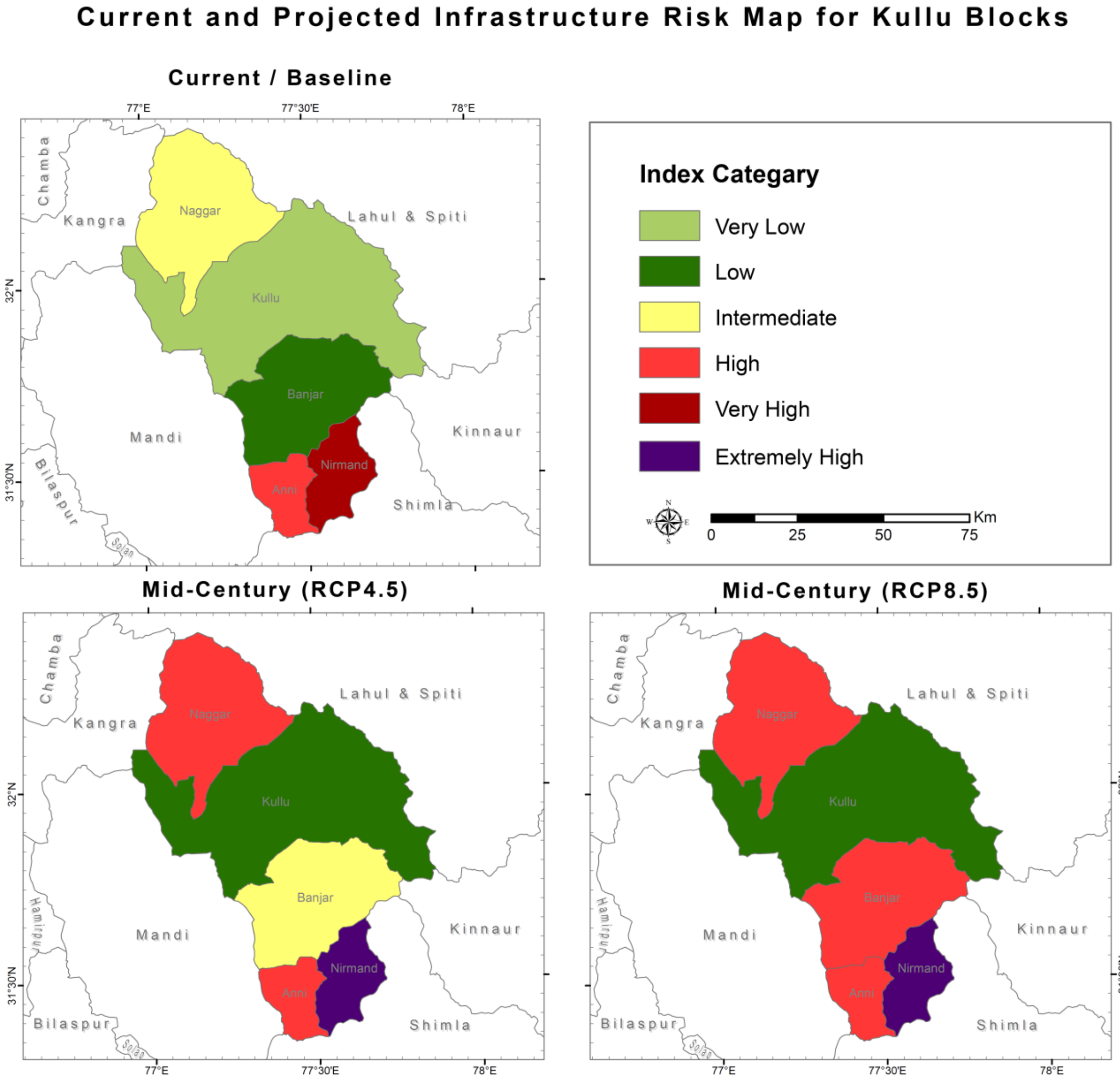
Projected situation

Spatial representation of current and projected LRI and LHI category for blocks for RCP4.5 and RCP 8.5 scenarios are depicted in Figure 17 and Figure 18 respectively. Vulnerability and exposure are not projected for the future, and hence, the main driver of change in risk is the underlying change in hazard linked to climate warming. A full consideration of future risk would need to include (if available) data on planned infrastructural developments over the next 20 – 30 years.

- The overall Infrastructure hazard of the blocks is projected to increase towards mid-century as compared to the current conditions for both the emission scenarios.
- Landslides, flood discharge, 1 day and 5-day maximum rainfall are projected to increase towards the mid-century as compared to current conditions thus contributing to increase in the Infrastructure Risk (INR) of the blocks (see also Figure 11, left panels).

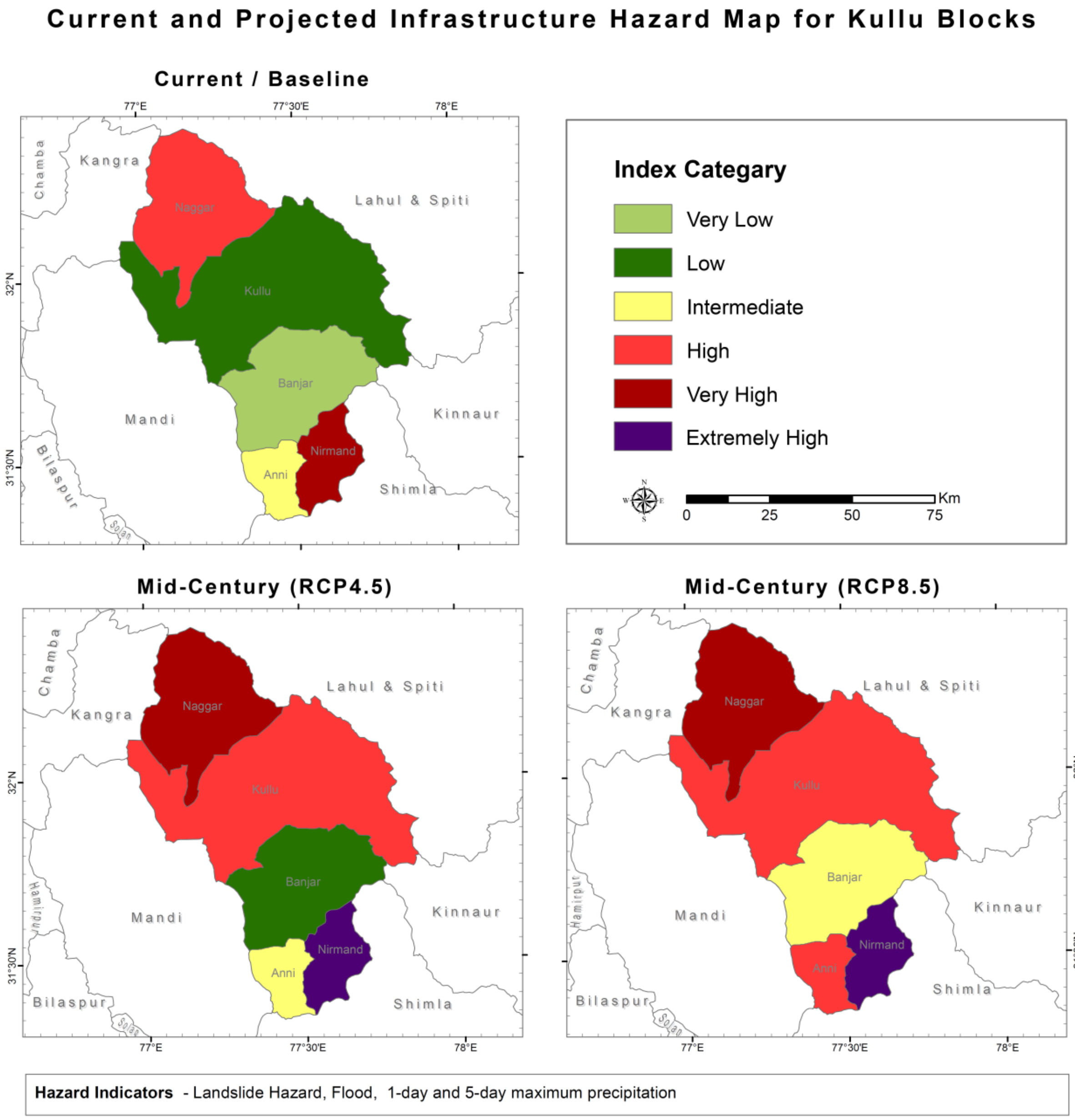
- The overall Infrastructure risk for all the Kullu blocks is projected to increase towards mid-century as compared to the baseline for both the IPCC AR5 climate scenarios. Block risk is likely to be almost the same under the two scenarios, except for Banjar.
- Infrastructure Risk of block Banjar is projected to increase to intermediate under RCP4.5 mid-century and to high under RCP 8.5 mid-century as compared to low under current risk. This is because heavy rainfall and associated landslide hazard is expected to increase towards RCP4.5 and RCP8.5 mid-century scenario as compared to the current conditions.
- Kullu is projected to fall under low infrastructure risk (currently at very low risk). Similarly, Banjar and Naggar are projected to fall under high risk from current low and intermediate categories while Nirmand is projected to move to extremely high from very high risk in the baseline.

Figure 17: Current and Projected Infrastructure Risk Map for Kullu Blocks, under RCP scenarios 4.5 and 8.5.



Risk Index comprises of the following indicators:
Hazard Indicators : Landslide Hazard, Flood, 1-day and 5-day maximum precipitation**Exposure Indicators** :Road Density, Schools and Health Centres**Vulnerability Indicators** : Sex-ratio, Gender gap in literacy rate and work participation rate, Age Dependency Ratio, Disabled Population, Deprived households, Income, BPL, Student Teacher Ratio, Health Indicators, Literacy Rate, Total work participation rate, Households with access to communication/transport, Cooperatives and commercial bank, SHGs, Allotted permanent shelters, Cooking Fuel, sanitation facility, electricity, Permanent houses

Figure 18: Current and Projected Infrastructure Hazard Map for Kullu Blocks, under RCP scenarios 4.5 and 8.5.



Risk Profiles of Village of Anni

Livelihood Risk Index (LRI) and Infrastructure Risk Index (INRI) have been constructed across the 17 villages of Anni using identified indicators (Table A- 1, Table A- 2 and Table A- 3 Appendix I). Villages are ranked based on the calculated index values. Tables showing the village wise index values, ranks and category for current and projected risk for the indices individually are given from Table A- 11 to Table A- 17 in Appendix I. It is noted that limitations at this scale relate primarily relate to uncertainties in the downscaled climate model data. On the other hand, socioeconomic data, as used for the vulnerability and exposure indices likely becomes more representative at the village scale. Figure 19 shows the villages of Anni blocks for reference.

Livelihood Risk Index

The Livelihood Risk Index (LRI) represents an overall view on the entire set of indicators considered at village level for Anni. The final risk classification (5 categories) provides a relative indication of the threat level across the block, identifying villages where the risk is most pronounced. Spatial representation of livelihood risk and its components category for village for the baseline is depicted in Figure 20.

Current situation

Villages namely, Karshaigad and Bishla Dhar located in North Western part of Anni block with ranks 17 and 16 respectively are at very high risk under current climate. The villages of Soidhar, Beongal and Palehi (South eastern part of the district) with ranks 1, 2 and 3 respectively have very low overall levels of livelihood risk. The major drivers of livelihood risk in all the villages of Anni are presented in Table 5.

Projected situation

Spatial representation of current and projected LRI and LHI category for villages of Anni block for RCP4.5 and RCP 8.5 scenarios are depicted in Figure 21 and Figure 22 respectively.

- The overall livelihood risk of most of the Anni villages is projected to increase towards mid-century as compared to the baseline for both the

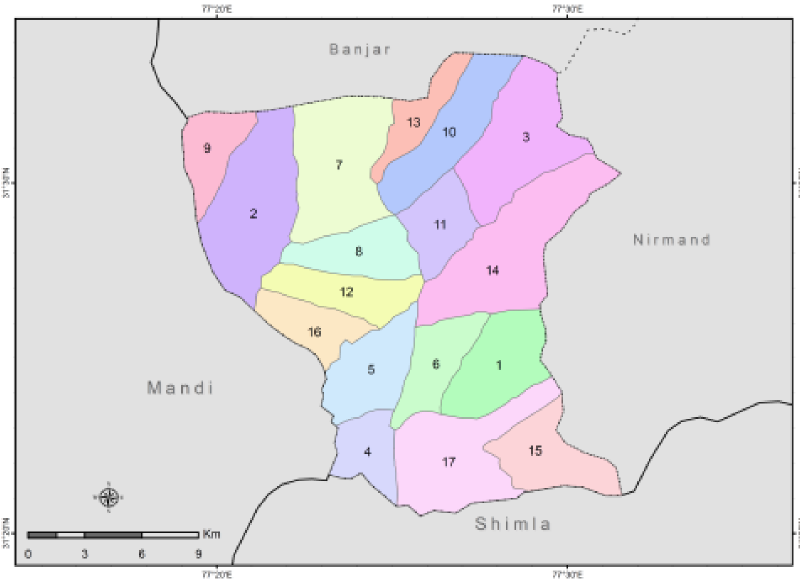
Table 5: Drivers of Livelihood Risk in Anni Villages

Category	Villages	Drivers of Risk		
		Hazard	Exposure	Vulnerability
Very high	Karshaigad and Bishla Dhar: Karshaigad fall in the very high side of livelihood risk index due to high levels of exposure and vulnerability while Bishla Dhar due to high levels of hazard and vulnerability (Figure 20).	The major drivers of risk are maximum landslide hazard, and low surface water availability compared to the other villages.	The share of marginal workers is high for Bishla Dhar while density of population for Karshaigad leading to increased exposure.	Lack of adaptive capacity mainly in terms of literacy rate, banking services, access to drinking water, communication and transport and electricity and higher sensitivity due to sex-ratio, gender gap in literacy rate, and disabled population makes **Bishla Dhar** fall under higher vulnerability. **Karshaigad** has lack of adaptive capacity mainly in terms of literacy rate, communication, transport, electricity, access to drinking water, lack of agriculture credit societies and higher sensitivity due to biomass cooking, gender gap in literacy rate, age dependency ratio, deprived households and disabled population.
High	Karad, Manjha Desh, Lajheri, Franali, Shilhi, Kohila and Kungash .	Karad, Manjha Desh, Lajheri, Franali, Shilhi, Kohila and Kungash villages with ranks 15, 14, 13, 12, 11, 10 and 9 respectively falls under high risk category. Karad mainly due to high exposure index and higher sensitivity coupled with lower adaptive capacity relative to the other village while Manjha Desh has high hazard coupled with high vulnerability.		
Intermediate	Buchair, Dingi Dhar and Karana	Three villages namely, Buchair, Dingi Dhar and Karana fall under intermediate risk category. They are depicted in yellow colour in Figure 20.		
Low	Khani and Jaban villages with ranks 5 and 4 respectively fall under low risk	Khani and Jaban villages with ranks 5 and 4 respectively fall under low risk. Khani has low hazard risk and vulnerability. Jaban has very low vulnerability along with very low exposure to hazards.		
Very Low	Palehi, Beongal and Soidhar	Soidhar, Beongal and Palehi with ranks 1, 2 and 3 respectively falls in the very low side of livelihood risk index due to low hazard levels, exposure and vulnerability relative to the other village (Figure 20)		

IPCC AR5 climate scenarios. Villages risk is likely to be almost the same under RCP4.5 and RCP8.5 scenario towards mid-century except for Soidhar and Beongal. Soidhar and Beongal are projected to move to low risk under RCP4.5 scenario while intermediate risk under RCP8.5 scenario from current very low risk category in the baseline.

- The overall livelihood hazard of the villages is projected to increase towards mid-century as compared to the current conditions for both the emission scenarios.
- Landslides, flood discharge, drought weeks, extremely wet days, consecutive dry days, 1 day and 5-day maximum rainfall and warm days are projected to increase while cool nights are projected to decrease towards the mid-century as compared to current conditions thus contributing to increase in the Livelihood Risk (LR) of the villages.

Figure 19: Anni Block Map showing its villages



Anni Block (Kullu)	
S.No.	Village Name
1	Beongal
2	Bishla Dhar
3	Buchair
4	Dingi Dhar
5	Franali
6	Jaban
7	Karad
8	Karana
9	Karshaigad
10	Khani
11	Kohila
12	Kungash
13	Lajheri
14	Manjha Desh
15	Palehi
16	Shilhi
17	Soidhar

Figure 20: Current Livelihood Risk Map for Anni villages with Hazard, Exposure and Vulnerability Components

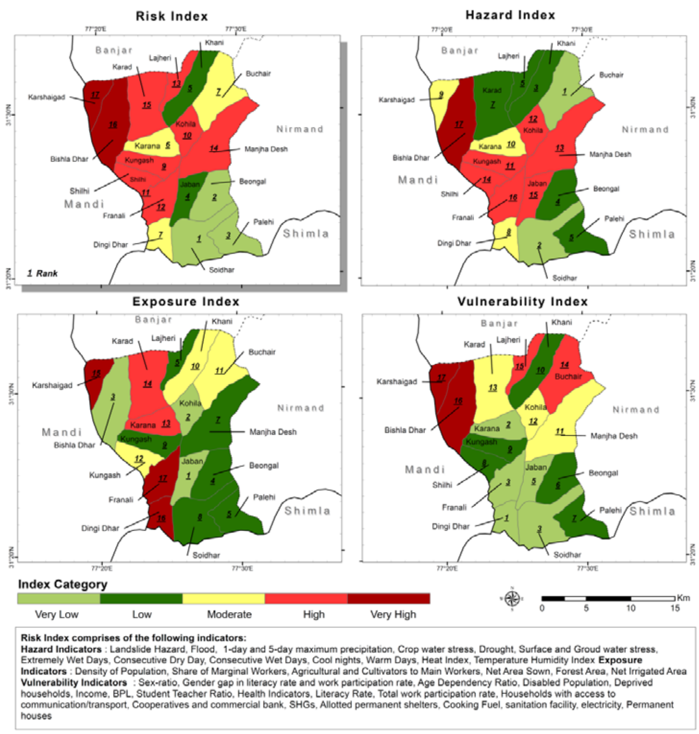
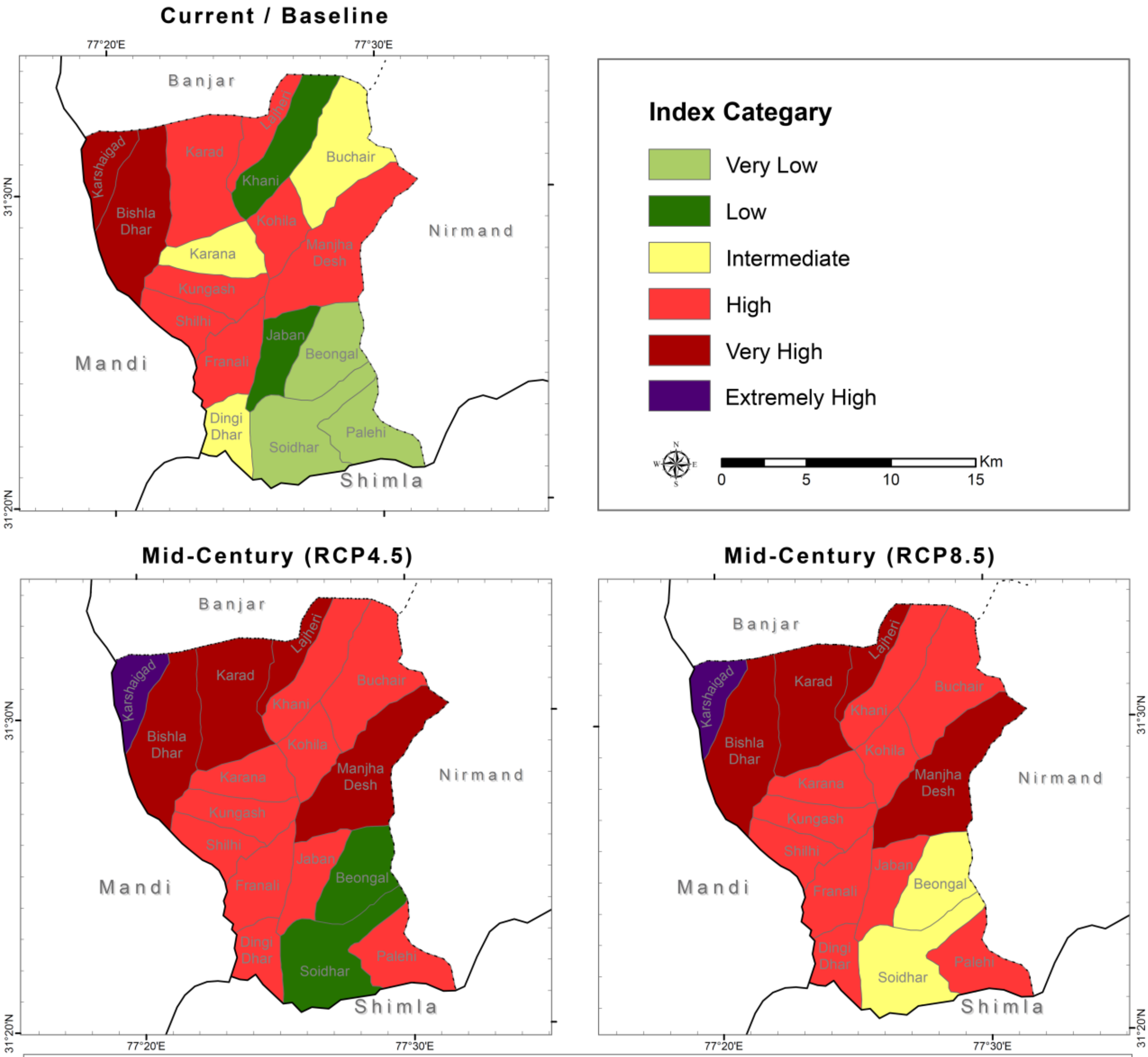
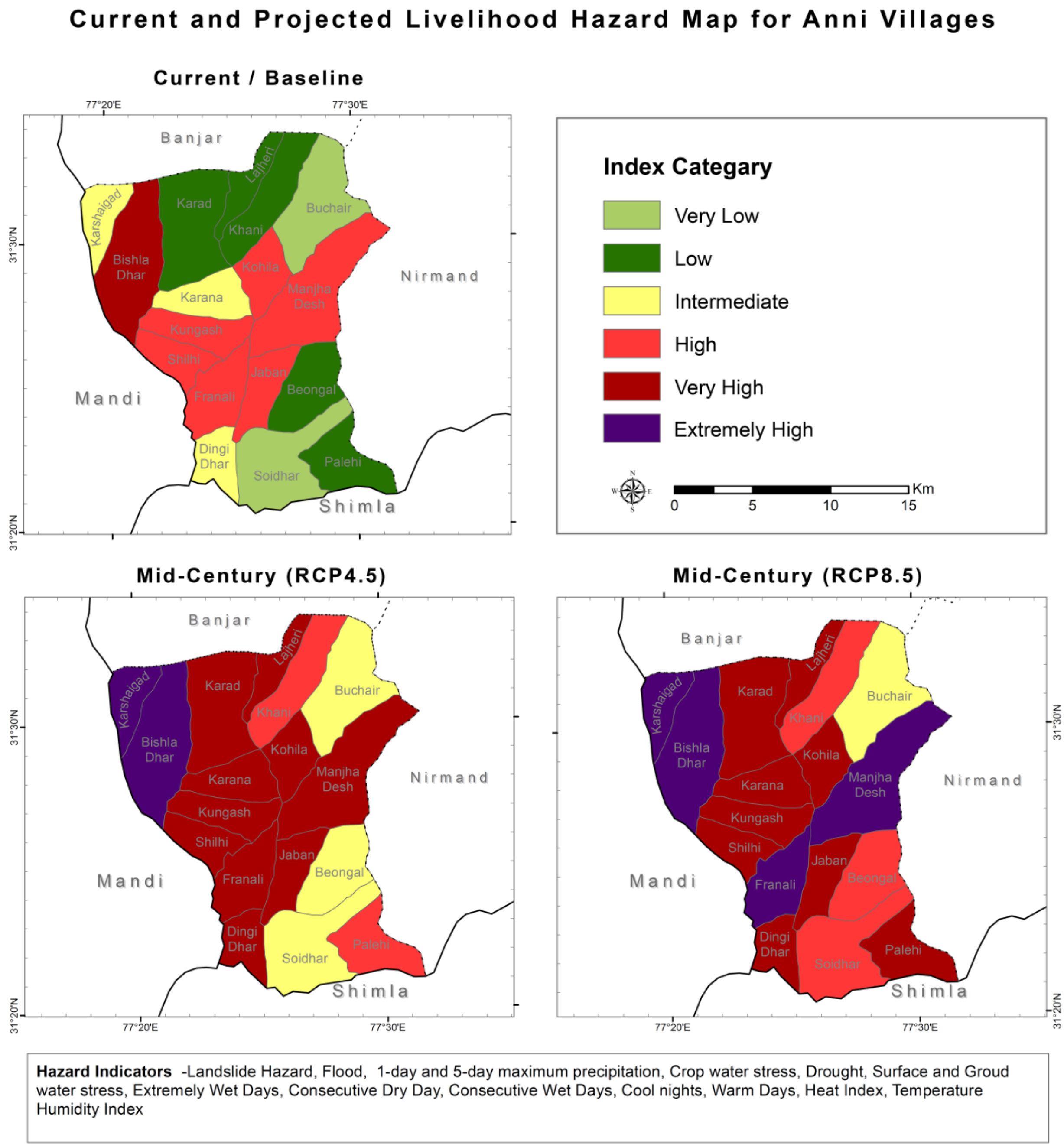


Figure 21: Current and Projected Livelihood Risk Map for Anni villages, under RCP scenarios 4.5 and 8.5.



Risk Index comprises of the following indicators:
Hazard Indicators : Landslide Hazard, Flood, 1-day and 5-day maximum precipitation, Crop water stress, Drought, Surface and Groud water stress, Extremely Wet Days, Consecutive Dry Day, Consecutive Wet Days, Cool nights, Warm Days, Heat Index, Temperature Humidity Index **Exposure Indicators** : Density of Population, Share of Marginal Workers, Agricultural and Cultivators to Main Workers, Net Area Sown, Forest Area, Net Irrigated Area**Vulnerability Indicators** : Sex-ratio, Gender gap in literacy rate and work participation rate, Age Dependency Ratio, Disabled Population, Deprived households, Income, BPL, Student Teacher Ratio, Health Indicators, Literacy Rate, Total work participation rate, Households with access to communication/transport, Cooperatives and commercial bank, SHGs, Allotted permanent shelters, Cooking Fuel, sanitation facility, electricity, Permanent houses

Figure 22: Current and Projected Livelihood Hazard Map for Anni villages, under RCP scenarios 4.5 and 8.5.



Infrastructure Risk Index

The Infrastructure Risk Index (INRI) is computed using weighted average of the hazard, exposure and vulnerability indicators. Spatial representation of Infrastructure risk and its components category for village for the baseline is depicted in Figure 23. The vulnerability indicators used for INRI is common as the LRI.

Current situation

Village namely, Soidhar located in Southern Kullu of Anni block with rank 17 is at very high risk under current climate. The villages of Khani, Buchair, Manjha Desh and Lajheri (North Eastern part of Kullu) with ranks 1, 2, 3 and 4 respectively have very low overall levels of infrastructure risk. The major drivers of infrastructure risk in all the villages of Anni are presented in Table 6.

Table 6: Drivers of Infrastructure Risk in Anni Village

Rank (Category)	Village	Drivers of Risk		
		Hazard	Exposure	Vulnerability
5 (Very high)	Soidhar village falls in the very high side of Infrastructure risk index due to very high hazard risk and exposure (Figure 23).	The major drivers of risk are maximum, flood and ground water stress as compared to the other village.	Number of communities, primary and sub health centres per capita are more which leads to increased exposure.	The work participation rate is low while gender gap in work participation is also high.
4 (High)	Palehi, Bishla Dhar, Shilhi and Kungash	Palehi, Bishla Dhar, Shilhi and Kungash villages with ranks 16. 15, 14 and 13 respectively falls under high risk category. Palehi, Shilhi and Kungash mainly due to high exposure index and high hazard risk while Bishla Dhar has high hazard risk and higher sensitivity coupled with lower adaptive capacity relative to the other village.		
3 (Intermediate)	Kohila, Beongal, Jaban, Dingi Dhar and Karana	Five villages namely, Kohila, Beongal, Jaban, Dingi Dhar and Karana fall under intermediate risk category. They are depicted in yellow colour in Figure 19.		
2 (Low)	Karad, Franali and Karshaigad	Karad, Franali and Karshaigad villages fall under low risk. Karshaigad has low hazard risk and exposure. Franali has very low vulnerability along with low hazard risk comparatively.		

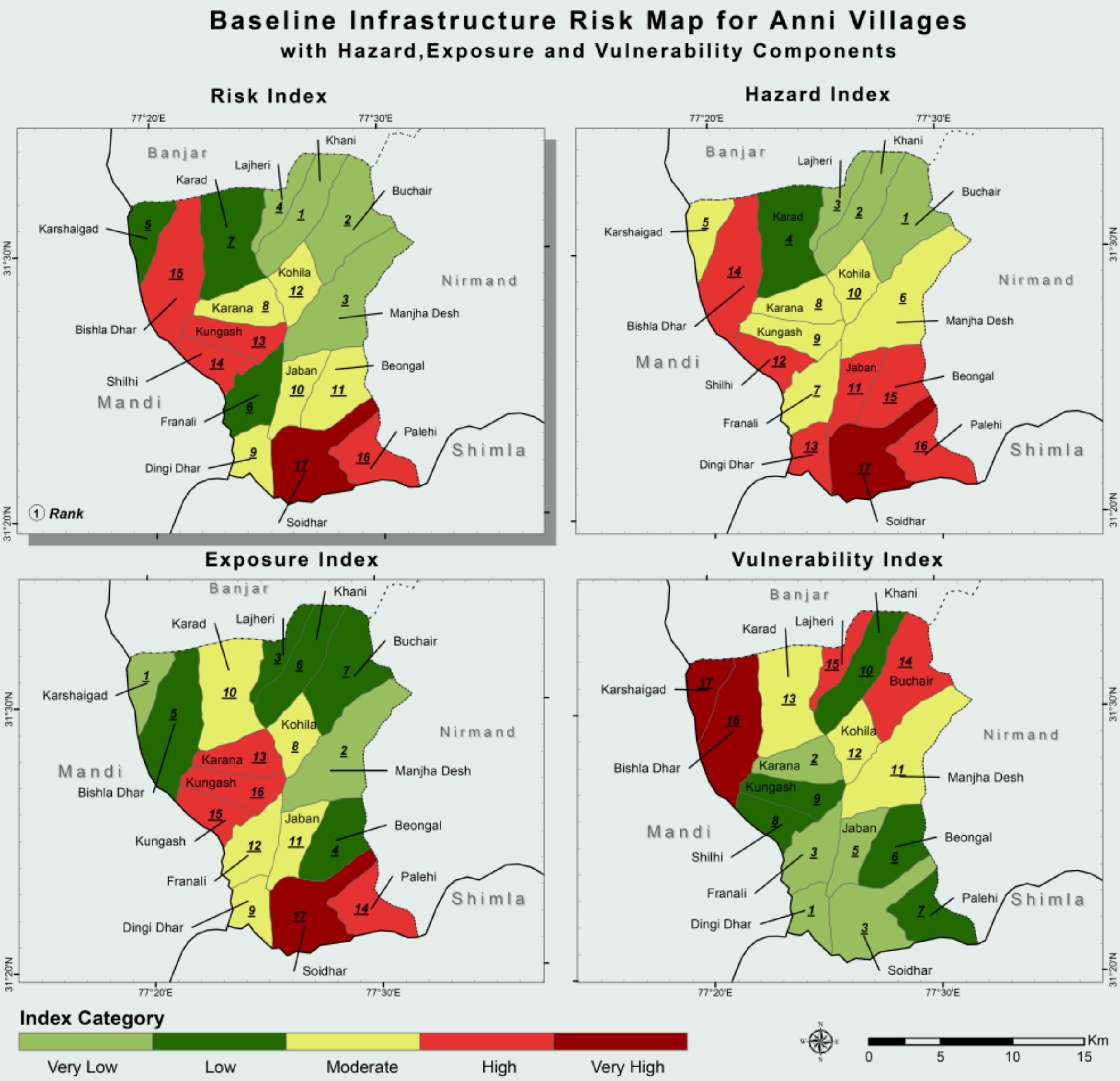
Spatial representation of current and projected LRI and LHI category for villages of Anni block for RCP 4.5 and RCP 8.5 scenarios are depicted

Projected situation

Spatial representation of current and projected LRI and LHI category for villages of Anni block for RCP4.5 and RCP 8.5 scenarios are depicted in Figure 24 and Figure 25 respectively.

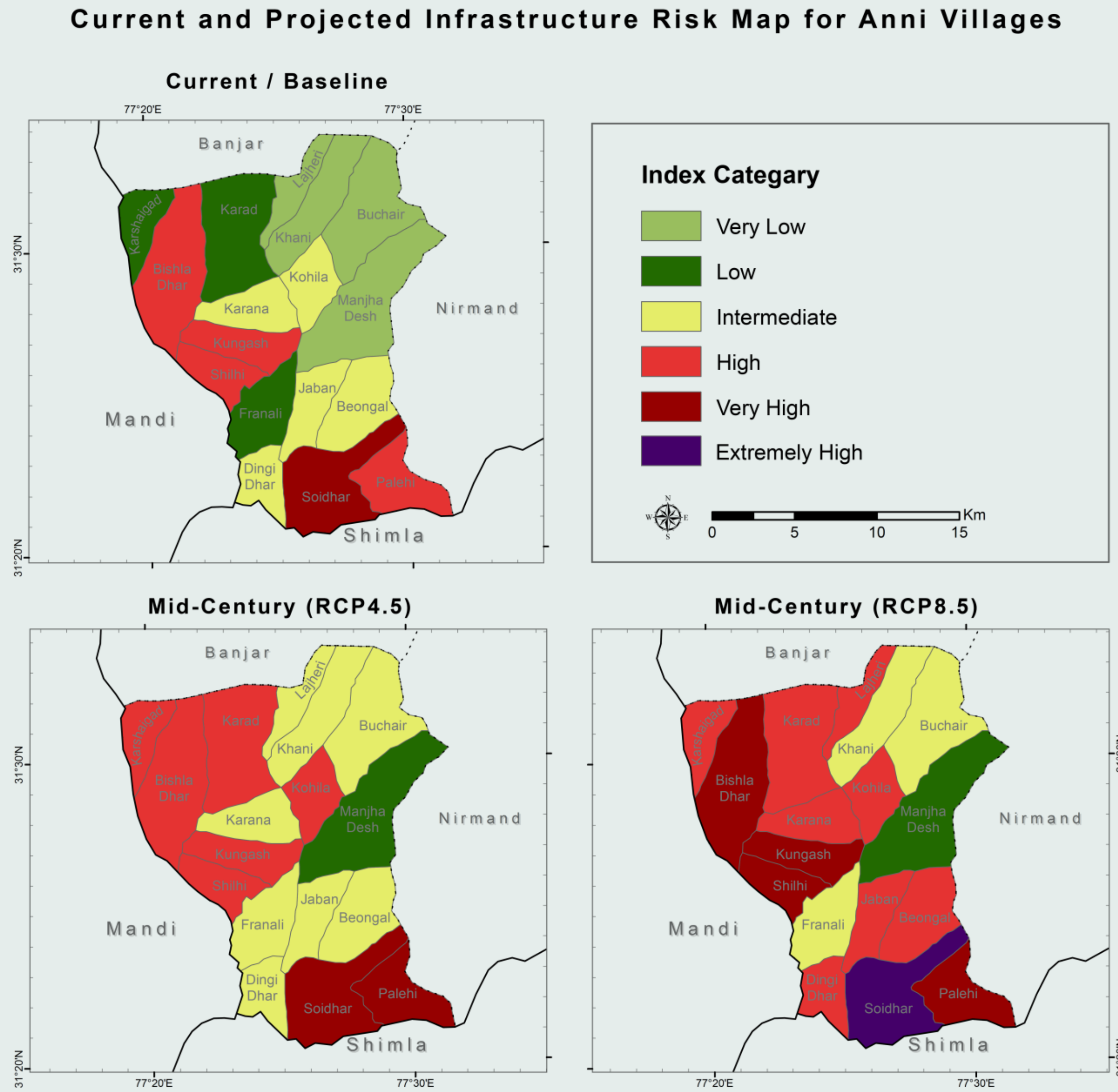
- The overall infrastructure risk of all the Anni villages is projected to increase towards mid-century as compared to the baseline for both the IPCC AR5 climate scenarios. Villages risk is likely to be further exaggerated under RCP8.5 as compared to RCP4.5 mid-century scenario.
- The overall infrastructure hazard of the villages is projected to increase towards mid-century as compared to the current conditions for both the emission scenarios.
- Landslides, flood discharge, 1 day and 5-day maximum rainfall are projected to increase towards the mid-century as compared to current conditions thus contributing to increase in the Infrastructure Risk (INR) of the villages.

Figure 23: Current Infrastructure Risk Map for Anni villages with Hazard, Exposure and Vulnerability Components



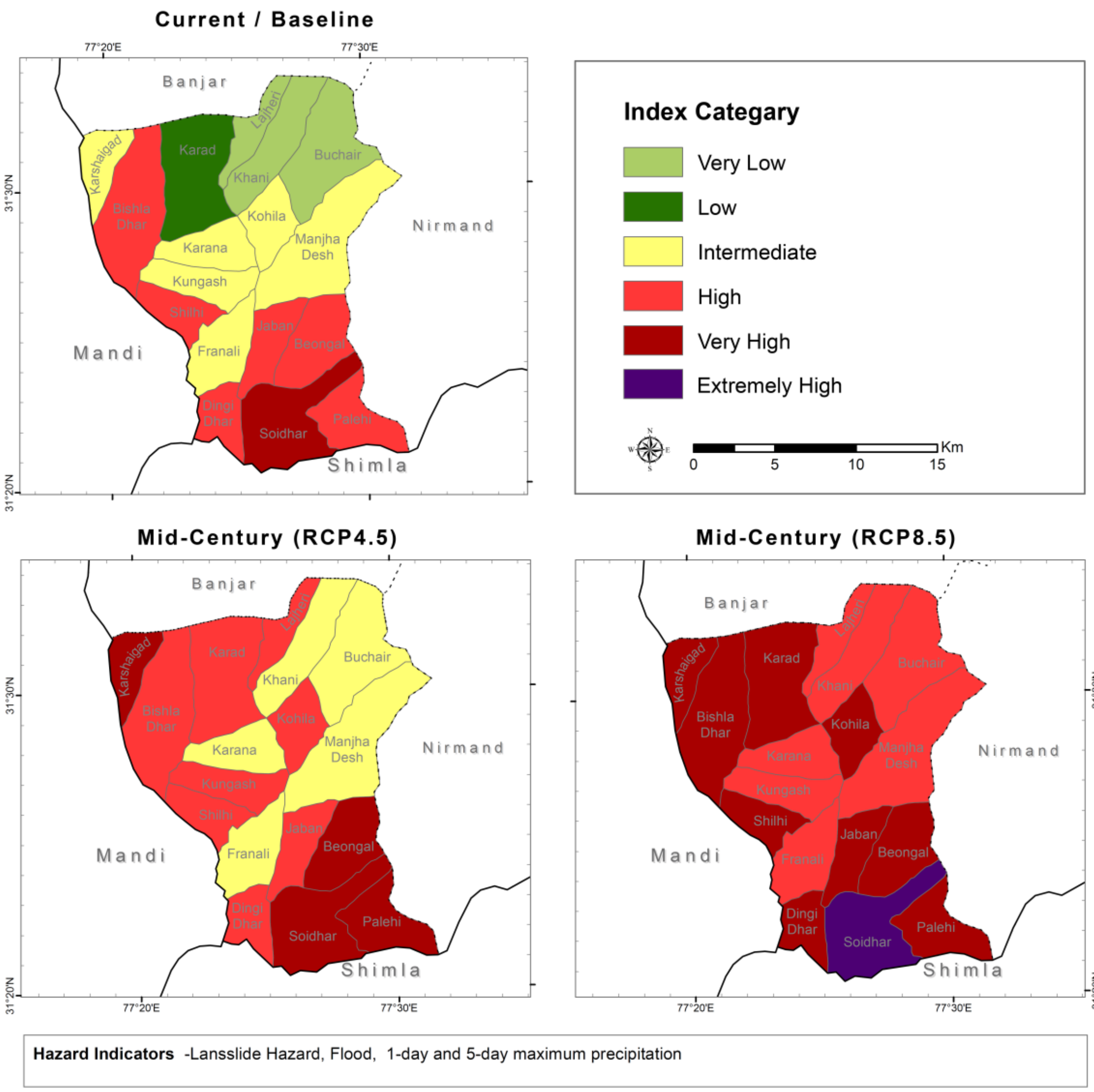
Risk Index comprises of the following indicators:
Hazard Indicators : Landslide Hazard, Flood, 1-day and 5-day maximum precipitation**Exposure Indicators** :Road Density, Schools and Health Centres
Vulnerability Indicators : Sex-ratio, Gender gap in literacy rate and work participation rate, Age Dependency Ratio, Disabled Population, Deprived households, Income, BPL, Student Teacher Ratio, Health Indicators, Literacy Rate, Total work participation rate, Households with access to communication/transport, Cooperatives and commercial bank, SHGs, Allotted permanent shelters, Cooking Fuel, sanitation facility, electricity, Permanent houses

Figure 24: Current and Projected Infrastructure Risk Map for Anni villages, under RCP scenarios 4.5 and 8.5.



Risk Index comprises of the following indicators:
Hazard Indicators : Landslide Hazard, Flood, 1-day and 5-day maximum precipitation**Exposure Indicators** :Road Density, Schools and Health Centres**Vulnerability Indicators** : Sex-ratio, Gender gap in literacy rate and work participation rate, Age Dependency Ratio, Disabled Population, Deprived households, Income, BPL, Student Teacher Ratio, Health Indicators, Literacy Rate, Total work participation rate, Households with access to communication/transport, Cooperatives and commercial bank, SHGs, Allotted permanent shelters, Cooking Fuel, sanitation facility, electricity, Permanent houses

Figure 25: Current and Projected Infrastructure Hazard Map for Anni villages, under RCP scenarios 4.5 and 8.5.



Risk Profiles of Village of Banjar

Livelihood Risk Index (LRI) and Infrastructure Risk Index (INRI) have been constructed across the 42 villages of Banjar using identified indicators (Table A- 1, Table A- 2 and Table A- 3 Appendix I). Villages are ranked based on the calculated index values. Tables showing the village wise index values, ranks and category for current and projected risk for the indices individually are given from Table A- 18 to Table A- 24 in Appendix I. Figure 26 shows the villages of Banjar blocks for reference.

Livelihood Risk Index

The Livelihood Risk Index (LRI) represents an overall view on the entire set of indicators considered at village level for Banjar (Kullu). The final risk classification (5 categories) provides a relative indication of the threat level across the block, identifying village where the risk is most pronounced. Spatial representation of livelihood risk and its components category for village for the baseline is depicted in Figure 27.

Current situation

Villages namely, Gara Parli and Karshai Gad-II of Banjar block with ranks 42 and 41 respectively are at very high risk under current climate. The village of Bini with rank 1 has very low overall levels of livelihood risk. The major drivers of livelihood risk in all the villages of Banjar are presented in Table 7.

Table 7: Drivers of Livelihood Risk in Banjar Village

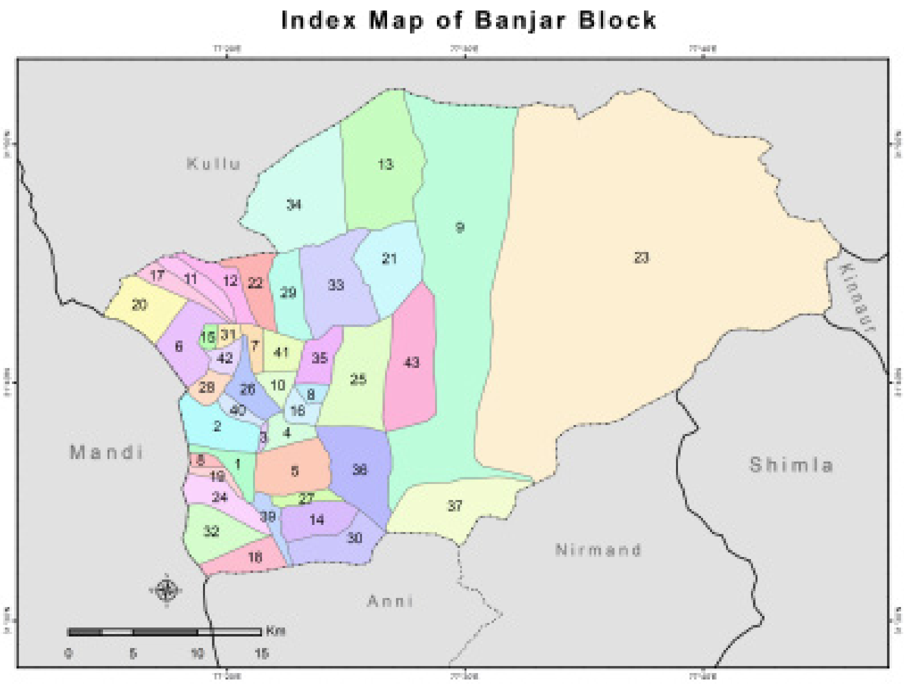
Category	Villages	Drivers of Risk		
		Hazard	Exposure	Vulnerability
Very high	Gara Parli and Karshai Gad-II: Gara Parli fall in the very high side of livelihood risk index due to high levels of hazard and vulnerability while Karshai Gad-II due to high levels of exposure and vulnerability though has very low hazard risk (Figure 27).	The major drivers of risk for Gara Parli are maximum landslide hazard, drought, crop water stress and ground water stress as compared to the other villages..	The net sown area and density of population is high for Karshai Gad-II leading to increased exposure.	Lack of adaptive capacity mainly in terms of literacy rate, Anganwadi Centre, permanent houses, communication and transport and electricity and higher sensitivity due to age dependency ratio, biomass cooking, deprived households, and low income makes **Gara Parli** fall under higher vulnerability relative to the other village. Lack of adaptive capacity mainly in terms of access to electricity, sanitation facility and total work participation rate and higher sensitivity due to gender gap in literacy rate and work participation rate, low income and disabled population makes **Karshai Gad-II** fall under higher vulnerability.
High	Dusharh, Sachen, Chippni, Manyashi, Mashyar, Pakhari, Shangarh, Siri Kot, Shilhi, Khabal	10 villages namely, Dusharh, Sachen, Chippni, Manyashi, Mashyar, Pakhari, Shangarh, Siri Kot, Shilhi and Khabal with ranks 40 to 31 in order fall under high risk category. Dusharh and Sachen mainly due to high exposure index and high hazard levels. Chippni has high hazards and higher sensitivity coupled with lower adaptive capacity relative to the other village.		
Intermediate	Shapnil, Mohni, Thani Char, Shanshar, Chakurtha, Seraj, Sharchi, Chethar, Rashala, Lapah, Sajwar, Thati Bir, Tinder, Ghiaghi, Jauri, Chanon, Deotha, Bala Gad, Tandi	19 villages fall under intermediate risk category. They are depicted in yellow colour in Figure 27.		
Low	Kanon, Dhaugi, Kotla, Tarangali, Bihar, Bahu, Kalwari, Sehuli, Ratwah, Palach	10 villages namely, Kanon, Dhaugi, Kotla, Tarangali, Bihar, Bahu, Kalwari, Sehuli, Ratwah, Palach with ranks 2 to 11 in the same order fall under low risk. Kanon has very low vulnerability. Dhaugi, Kotla, Tarangali have low vulnerability along with low exposure to hazards. Bihar has low risk of hazards as well as low vulnerability relative to others.		
Very Low	Bini	Bini with rank 1 falls in the very low side of livelihood risk index due to low hazard levels, exposure and vulnerability relative to the other village (Figure 27)		

Projected situation

Spatial representation of current and projected LRI and LHI category for villages of Banjar block for RCP4.5 and RCP 8.5 scenarios are depicted in Figure 28 and Figure 29 respectively.

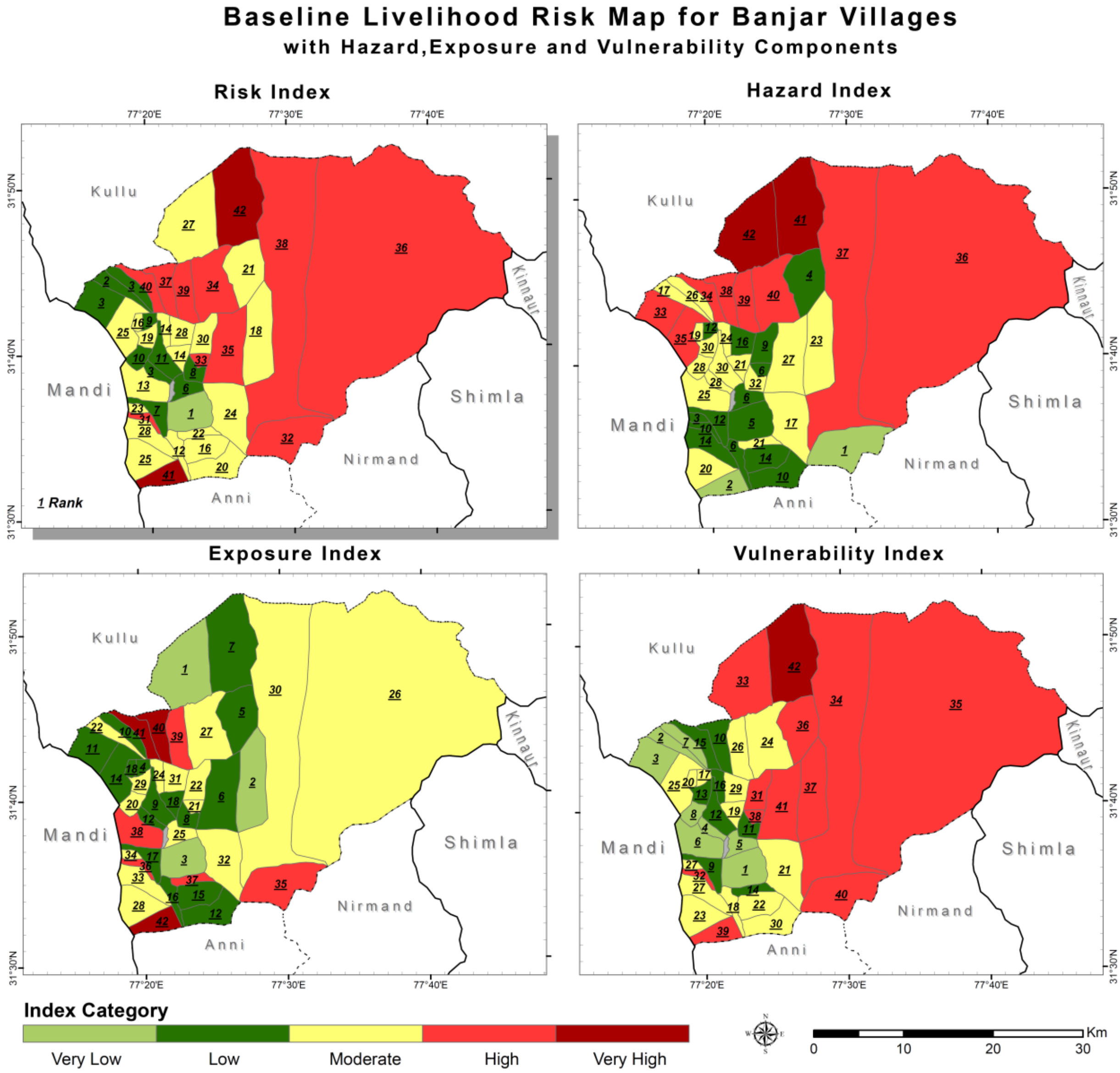
- The overall livelihood risk of the Banjar villages is projected to increase towards mid-century as compared to the baseline for both the IPCC AR5 climate scenarios. Villages risk is likely to be almost the same under RCP4.5 and RCP8.5 scenario towards mid-century except for Shilhi which is projected to move to very high risk under RCP8.5 scenario from current high-risk category in the baseline and. RCP4.5 scenario.
- The overall livelihood hazard of the villages is projected to increase towards mid-century as compared to the current conditions for both the emission scenarios.
- Landslides, flood discharge, 1 day and 5-day maximum rainfall, extremely wet days, consecutive wet days and warm days are projected to increase while cool nights are projected to decrease towards the mid-century as compared to current conditions thus contributing to increase in the Livelihood Risk (LR) of the villages.

Figure 26: Banjar Block Map showing its villages



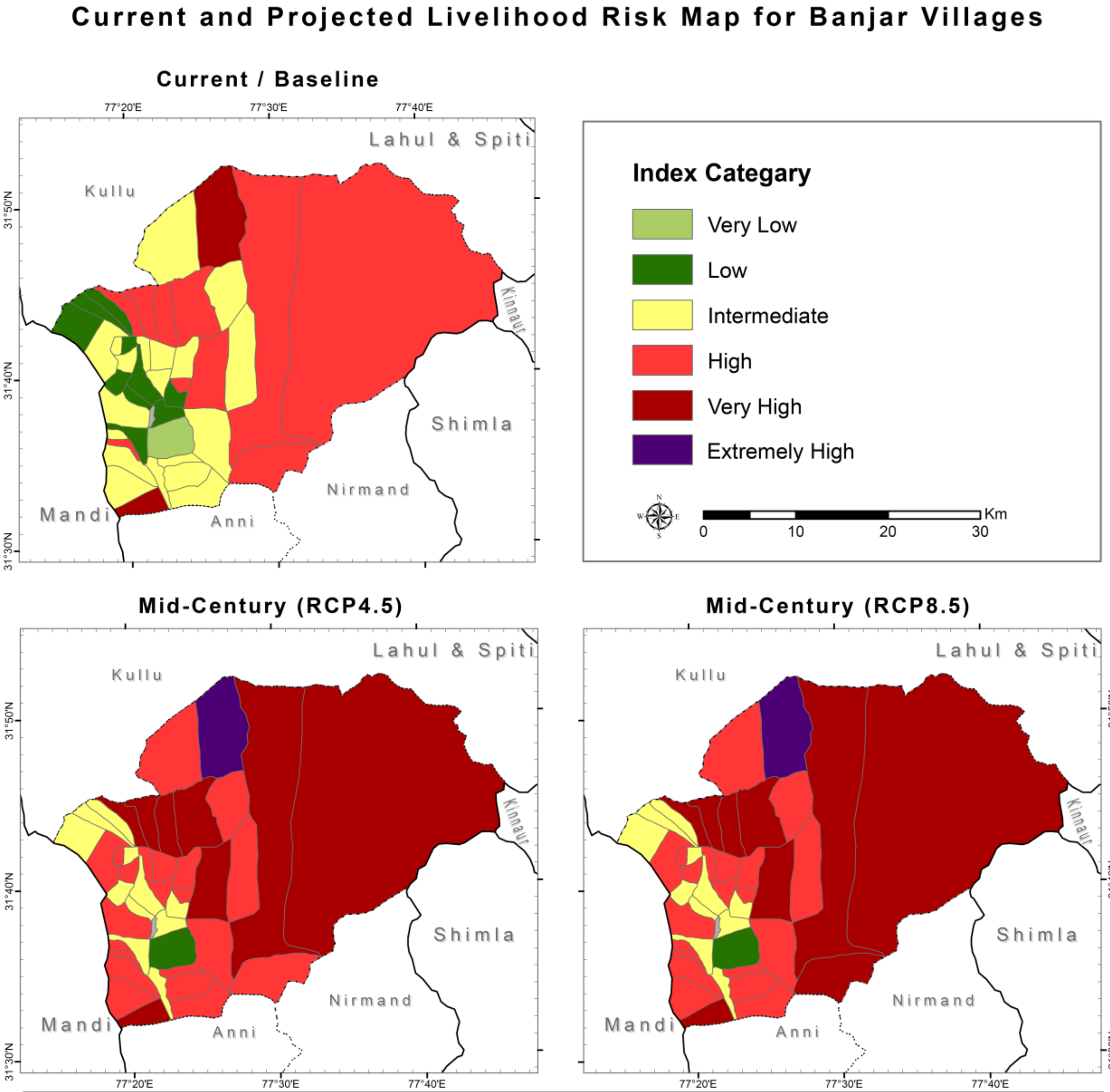
Banjar Block (Kullu)			
S.No.	Village Name	S.No.	Village Name
1	Bahu	23	Mashoor
2	Bala Gad	24	Mohni
3	Banjar (N.P.)	25	Pakhari
4	Bihar	26	Palach
5	Birri	27	Rashala
6	Chakurtha	28	Ratwah
7	Charain	29	Sachen
8	Chethar	30	Sajwar
9	Chippni	31	Sehuli
10	Deotha	32	Seraj
11	Dhaugi	33	Shangarh
12	Dusharh	34	Shanshar
13	Gara Parli	35	Shapnil
14	Ghiaghi	36	Sharchi
15	Jauri	37	Shilhi
16	Kalwari	38	Siri Kot
17	Kanon	39	Tandi
18	Karshai Gad-II	40	Tarangali
19	Khabal	41	Thani Char
20	Kotla	42	Thati Bir
21	Lapah	43	Tinder
22	Manyashi		

Figure 27: Current Livelihood Risk Map for Banjar villages with Hazard, Exposure and Vulnerability Components



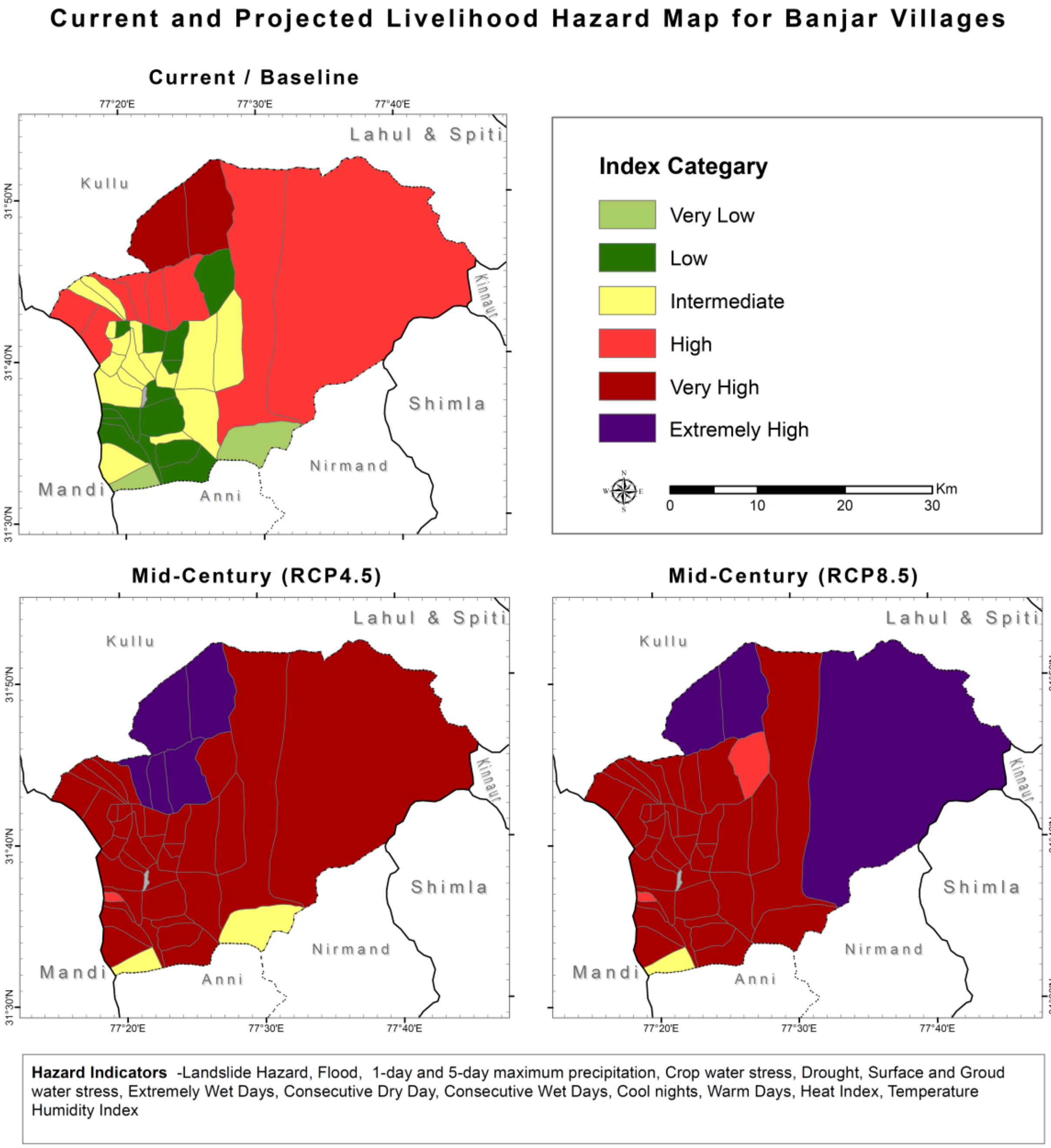
Risk Index comprises of the following indicators:
Hazard Indicators : Landslide Hazard, Flood, 1-day and 5-day maximum precipitation, Crop water stress, Drought, Surface and Groud water stress, Extremely Wet Days, Consecutive Dry Day, Consecutive Wet Days, Cool nights, Warm Days, Heat Index, Temperature Humidity Index**Exposure Indicators** : Density of Population, Share of Marginal Workers, Agricultural and Cultivators to Main Workers, Net Area Sown, Forest Area, Net Irrigated Area
Vulnerability Indicators : Sex-ratio, Gender gap in literacy rate and work participation rate, Age Dependency Ratio, Disabled Population, Deprived households, Income, BPL, Student Teacher Ratio, Health Indicators, Literacy Rate, Total work participation rate, Households with access to communication/transport, Cooperatives and commercial bank, SHGs, Allotted permanent shelters, Cooking Fuel, sanitation facility, electricity, Permanent houses

Figure 28: Current and Projected Livelihood Risk Map for Banjar villages, under RCP scenarios 4.5 and 8.5.



Risk Index comprises of the following indicators:
Hazard Indicators : Landslide Hazard, Flood, 1-day and 5-day maximum precipitation, Crop water stress, Drought, Surface and Groud water stress, Extremely Wet Days, Consecutive Dry Day, Consecutive Wet Days, Cool nights, Warm Days, Heat Index, Temperature Humidity Index **Exposure Indicators** : Density of Population, Share of Marginal Workers, Agricultural and Cultivators to Main Workers, Net Area Sown, Forest Area, Net Irrigated Area**Vulnerability Indicators** : Sex-ratio, Gender gap in literacy rate and work participation rate, Age Dependency Ratio, Disabled Population, Deprived households, Income, BPL, Student Teacher Ratio, Health Indicators, Literacy Rate, Total work participation rate, Households with access to communication/transport, Cooperatives and commercial bank, SHGs, Allotted permanent shelters, Cooking Fuel, sanitation facility, electricity, Permanent houses

Figure 29: Current and Projected Livelihood Hazard Map for Banjar villages, under RCP scenarios 4.5 and 8.5.



Infrastructure Risk Index

The Infrastructure Risk Index (INRI) is computed using weighted average of the hazard, exposure and vulnerability indicators. Spatial representation of Infrastructure risk and its components category for village for the baseline is depicted in Figure 30. The vulnerability indicators used for INRI is common as the LRI.

Current situation

Village namely, Mashyar and Shilhi of Banjar block with ranks 42 and 41 respectively is at very high risk under current climate. The villages of Manyashi, Chanon, Dusharh, Shangarh, Sachen and Bini with ranks 1, 2, 3, 4, 5 and 6 respectively have very low overall levels of infrastructure risk. The major drivers of infrastructure risk in all the villages of Banjar are presented in Table 8.

Table 8: Drivers of Infrastructure Risk in Banjar Village

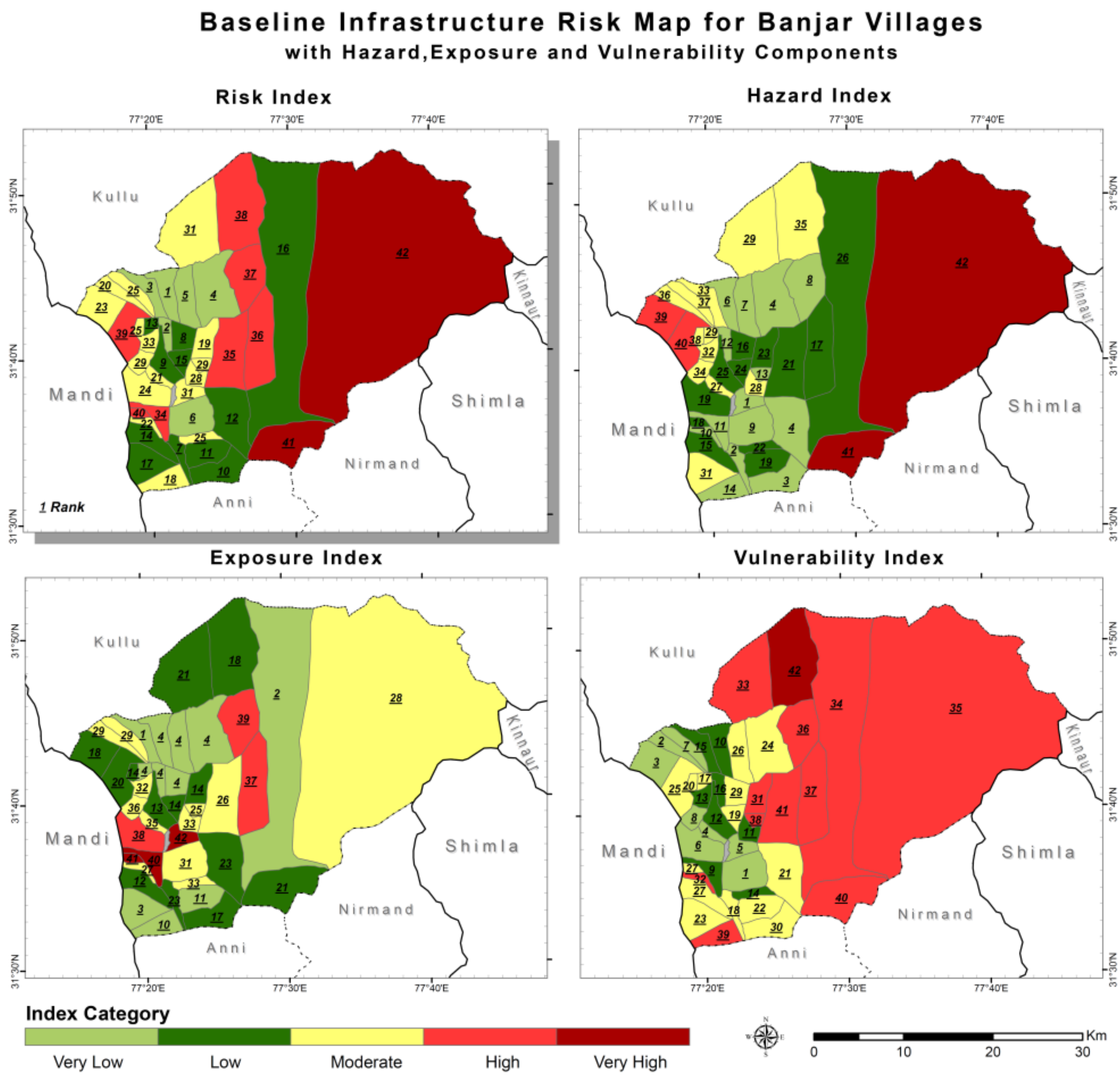
Rank (Category)	Village	Drivers of Risk		
		Hazard	Exposure	Vulnerability
5 (Very high)	Mashyar and Shilhi. They fall in the very high side of Infrastructure risk index due to very high hazard risk and vulnerability (Figure 30	The major drivers of risk are landslide hazard, 1 day and 5-day maximum rainfall as compared to the other village.	Number of communities, primary and sub health centres per capita are more along with population density which leads to increased exposure.	The literacy rate, access to banks, drinking water, sanitation facility and electricity is low while deprived households and age dependency ratio is high.
4 (High)	Chethar, Chakurtha, Gara Parli, Lapah, Tinder, Pakhari, Bahu	Chethar, Chakurtha, Gara Parli, Lapah, Tinder, Pakhari and Bahu villages with ranks 40 to 34 in order falls under high risk category. Chethar, Lapah, Tinder and Pakhari mainly due to high exposure index and high vulnerability while Chakurtha and Gara Parli has high hazard risk and higher sensitivity coupled with lower adaptive capacity relative to the other villages.		
3 (Intermediate)	Thati Bir, Bihar, Shanshar, Ratwah, Siri Kot, Kalwari, Dhaugi, Jauri, Rashala, Bala Gad, Kotla, Khabal, Tarangali, Kanon, Shapnil, Karshai Gad-II	Sixteen villages fall under intermediate risk category. They are depicted in yellow colour in Figure 30.		
2 (Low)	Tandi, Thani Char, Palach, Sajwar, Ghiaghi, Sharchi, Sehuli, Mohni, Deotha, Chippni and Seraj	12 villages fall under low risk. Tandi has very low hazard risk. Thani Char has very low exposure to infrastructure.		
1 (Very Low)	Manyashi, Chanon, Dusharh, Shangarh, Sachen and Bini	They fall in the very low side of infrastructure risk index due to low hazard risk and low exposure to infrastructure relative to the other villages. Bini also has the least vulnerability (Figure 30)		

Projected situation

Spatial representation of current and projected LRI and LHI category for villages of Banjar block for RCP4.5 and RCP 8.5 scenarios are depicted in Figure 31 and Figure 32 respectively.

- The overall infrastructure risk of all the Banjar villages is projected to increase towards mid-century as compared to the baseline for both the IPCC AR5 climate scenarios. Some of the villages risk is likely to be further exaggerated under RCP8.5 as compared to RCP4.5 mid-century scenario.
- The overall infrastructure hazard of the villages is projected to increase towards mid-century as compared to the current conditions for both the emission scenarios.
- Landslides, flood discharge, 1 day and 5-day maximum rainfall are projected to increase towards the mid-century as compared to current conditions thus contributing to increase in the Infrastructure Risk (INR) of the villages.

Figure 30: Current Infrastructure Risk Map for Banjar villages with Hazard, Exposure and Vulnerability Components



Risk Index comprises of the following indicators:
Hazard Indicators : Landslide Hazard, Flood, 1-day and 5-day maximum precipitation**Exposure Indicators** :Road Density, Schools and Health Centres
Vulnerability Indicators : Sex-ratio, Gender gap in literacy rate and work participation rate, Age Dependency Ratio, Disabled Population, Deprived households, Income, BPL, Student Teacher Ratio, Health Indicators, Literacy Rate, Total work participation rate, Households with access to communication/transport, Cooperatives and commercial bank, SHGs, Allotted permanent shelters, Cooking Fuel, sanitation facility, electricity, Permanent houses

Figure 31: Current and Projected Infrastructure Risk Map for Banjar villages, under RCP scenarios 4.5 and 8.5.

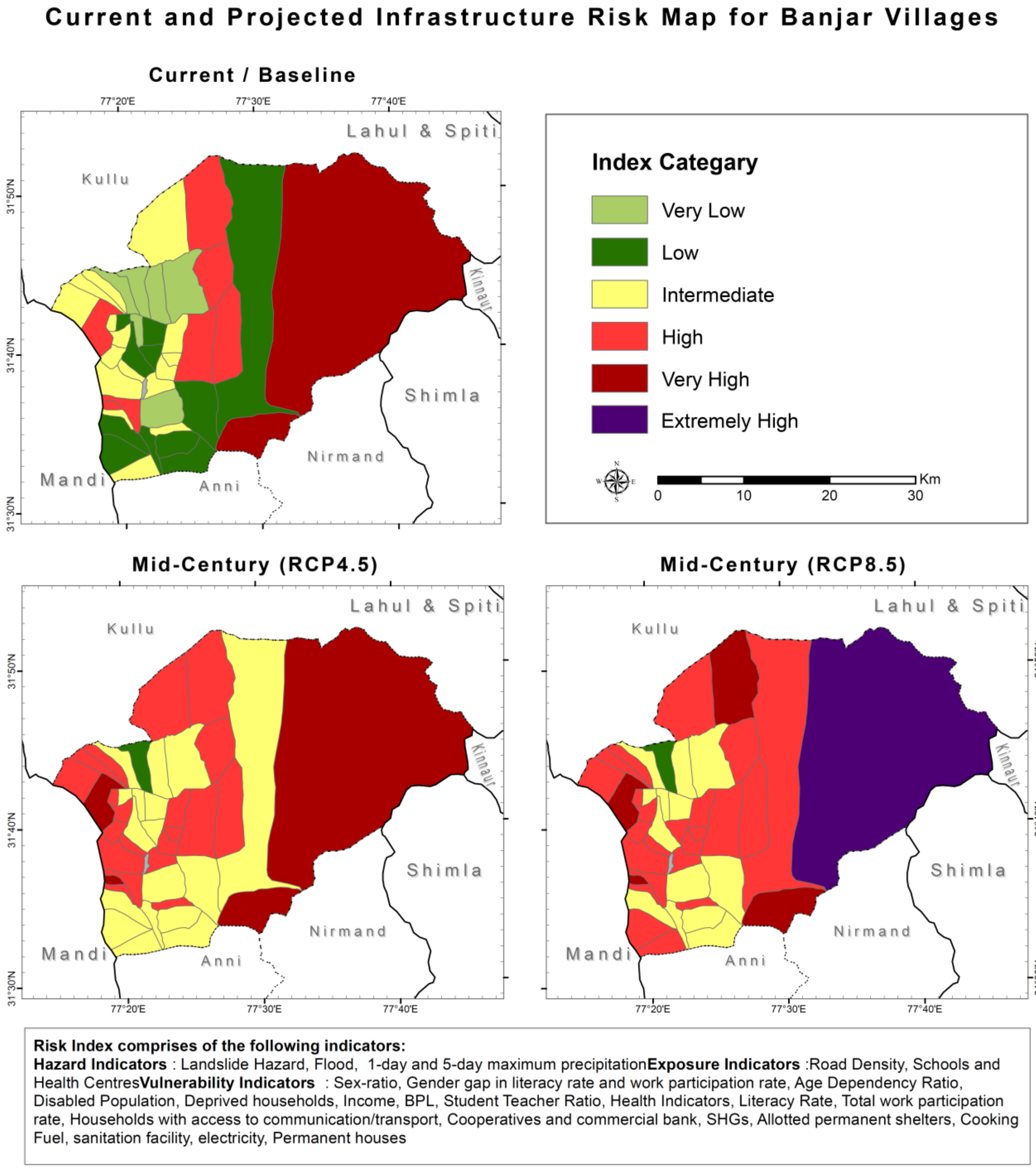
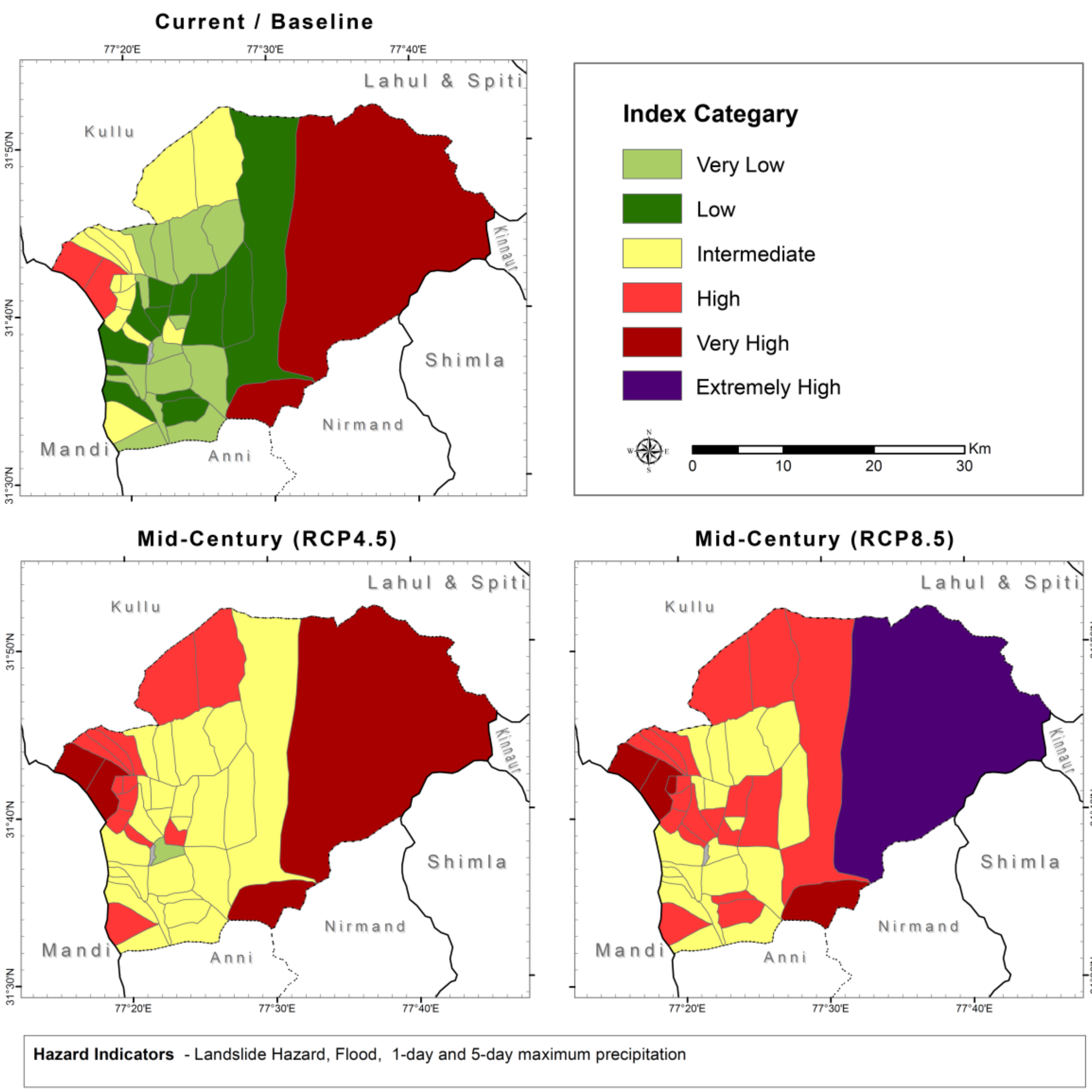


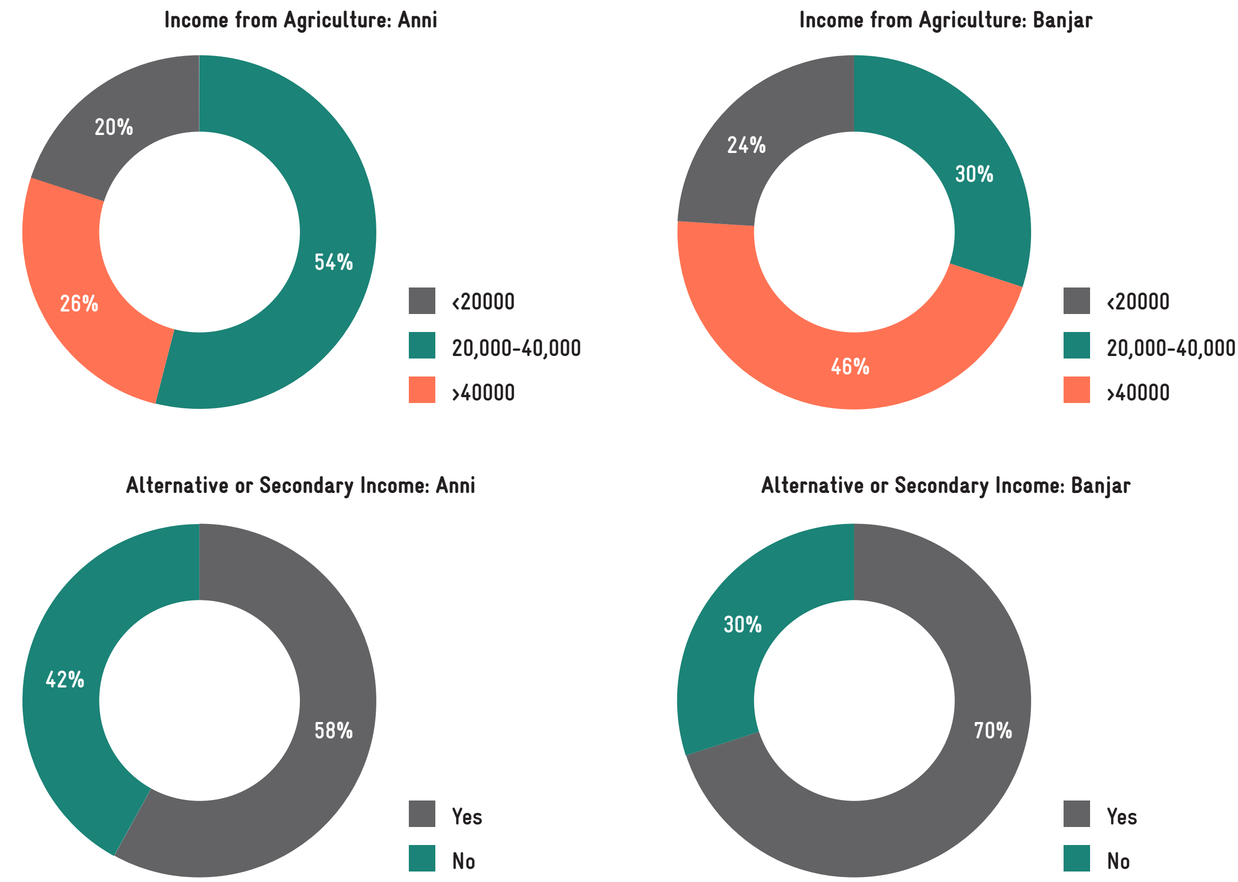
Figure 32: Current and Projected Infrastructure Hazard Map for Banjar villages, under RCP scenarios 4.5 and 8.5.



Field Survey of Vulnerability, Exposure and Risk

The results from the field survey conducted in the blocks of Anni and Banjar show a general high dependency on the agriculture sector, with the 4 main categories of cultivation being vegetables, fruit, wheat and maise. Overall, income from agriculture is typically higher in Banjar, and people appear to have more access to secondary sources of income, particularly from the provision of labour services or retail opportunities (Figure 33). Median farm sizes are 4.7 Bigha in Banjar, and 3 Bigha in Anni. Given the index-based risk assessment suggests significantly higher vulnerability in Banjar than Anni, it is clear that other factors (such as literacy levels, access to education, health etc.) are core drivers of vulnerability in this region. The overall higher dependency (land area under cultivation, and income from agriculture) in Banjar in fact can increase the sensitivity (and also exposure) to extreme climate events, while greater access to secondary sources of income could increase capacities to cope with both rapid and slow onset disasters. It is interesting to note that investment levels in agriculture are higher in Anni than Banjar, with considerably less reliance on bank loans to support this investment (Figure 34). This result is in line with overall lower level of vulnerability in Anni, according to the index based approach.

Figure 33: Information on household income collected during the field survey in the villages of Anni and Banjar. Annual values are in INR.



In Kullu there is a weak correlation between house construction and other indicators of vulnerability, with Anni (low vulnerability) in fact having the far higher proportion

80%

of Kutcha housing (less durable, temporary structures) than in Banjar

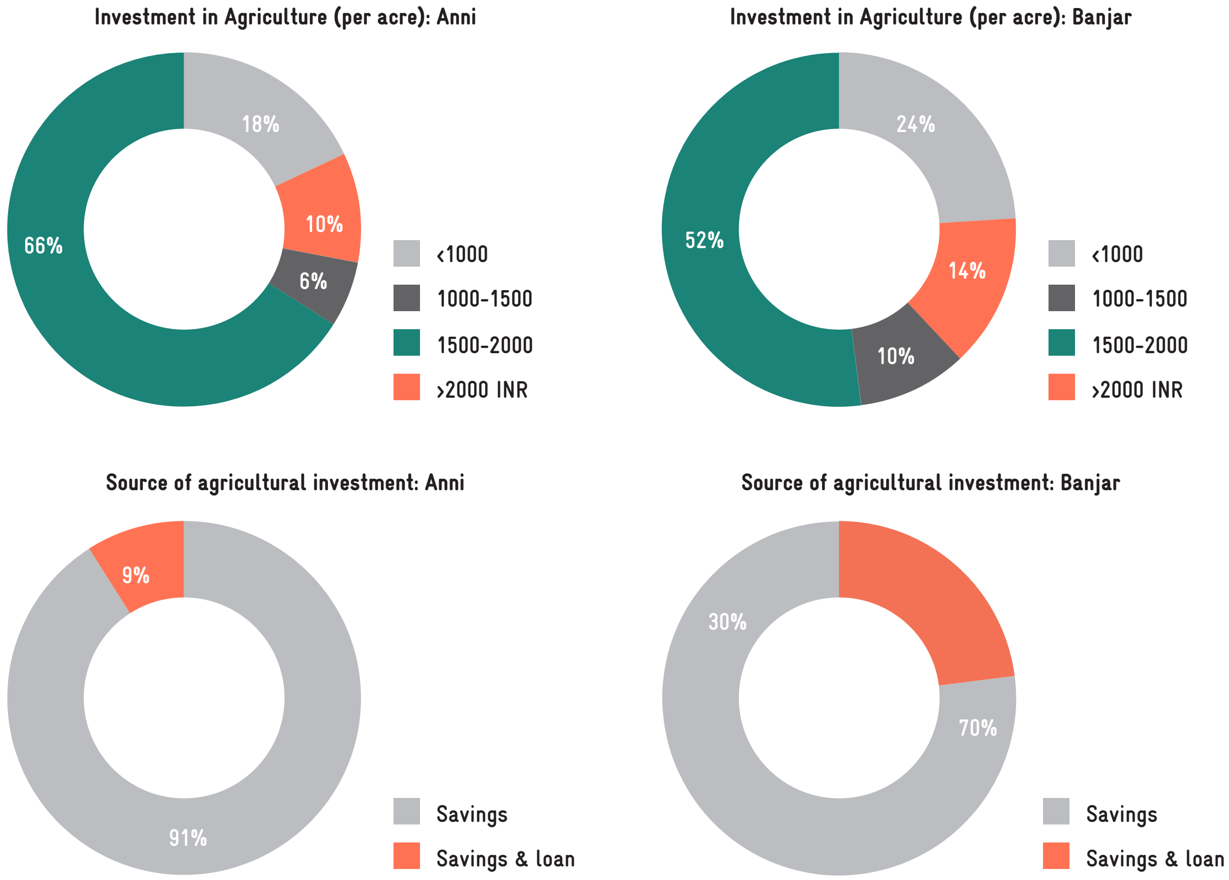
49%

Some vulnerability assessments consider house construction type (Kutcha, Semi-Pucca, Pucca) as a socio-economic indicator of vulnerability. However, results from the field survey suggest in Kullu there is a weak correlation between house construction and other indicators of vulnerability, with Anni (low vulnerability) in fact having the far higher proportion (80%) of Kutcha housing (less durable, temporary structures) than in Banjar (49%). The insufficient supply of electricity reported by 72% of participants in Banjar is indicative of lower levels of infrastructural investment, and hence, in line with higher vulnerability. In contrast, only 2% of participants in Anni reported insufficient supply of electricity.

Insufficient supply of electricity reported in Banjar **70%**

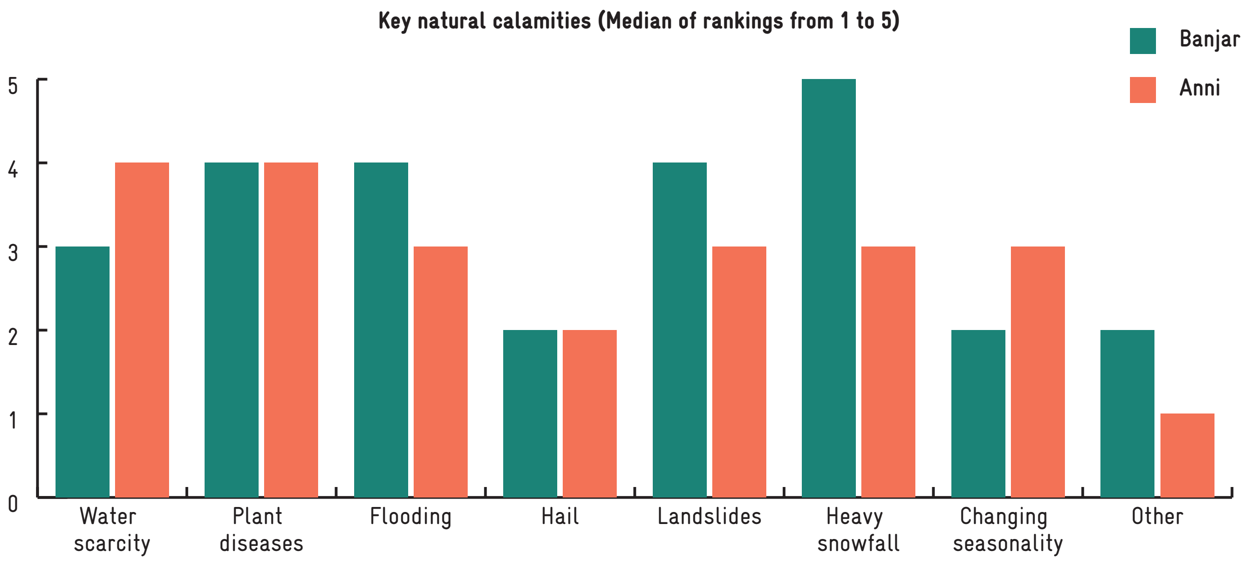
2% Insufficient supply of electricity reported in Anni

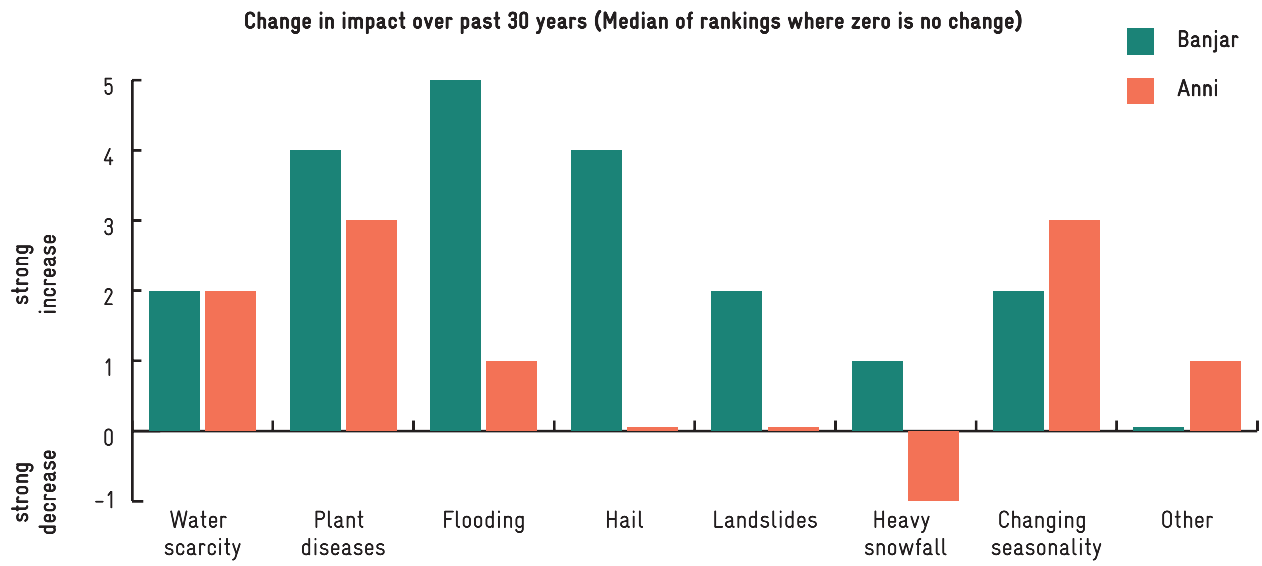
Figure 34: Information on investment collected during the field survey in Anni and Banjar. Annual investment values are in INR.



The field survey also provided information on community perceptions of the hazards and risks impacting upon their livelihoods and village infrastructure (Figure 35). Natural calamities are identified as the main reason for losses in agriculture, and key threats of water scarcity, flooding, and landslides were highlighted, all of which are included under the composite risk index used in this study. Natural calamities are perceived to have been increasing in terms of frequency and/or magnitude most significantly in Banjar over the past 30 years, particularly for flooding.

Figure 35: Community perceptions on natural calamities based on field survey. Calamities were ranked from 1 (least important) to 5 (most important), with median values shown here.





Step 5: Evaluate risk tolerance and limits to adaptation

In order to evaluate risk tolerance levels and possible limits to adaptation, potential losses was calculated in monetary terms for key climate impacts. Based on the impact chain analyses (see Figure 11), the focus is on evaluation of the direct impacts in terms of livelihood impacts (damage to crops and households), and damage to rural infrastructure and public property (roads, schools, and medical facilities). Fatalities, although a key direct impact of natural calamities, were not considered in this analyses owing to difficulties in assigning a monetary value to loss of life. The economic analyses draws upon information coming out of the primary data survey, combined with L&D values reported during recent disasters in Kullu, and in neighboring areas. In this regard, the Uttarakhand flood and landslide disaster from 2013 provides a suitable reference point for Kullu district in Himachal Pradesh, given very similar physiographic characteristics between the two states. All values are scaled according to the results of the composite risk assessment, recognizing likely higher (lower) potential losses in high (low) risk zones respectively. Further methodological details are outlined below.

Losses to rural livelihoods

Quantification of potential losses to rural livelihoods considers potential loss of income as a result of crop damage, and repair costs for damaged households.

Loss of income due to crop damage

Data from the community survey in Kullu (blocks of Anni and Banjar) reports and average annual income from agriculture of INR 40,000, and an average size of land holding of 4 hectares. Average annual income can therefore be expresses as **INR 10,000 per hectare**.

From the community survey, it is also seen that past disasters have caused maximum annual losses of yield in the range of about 20 - 70% (see Table 14). This range is taken as a basis for defining hypothetical high, moderate and low levels of impacts:

- High impact scenario: Potential annual per hectare loss of **INR 7000**
- Moderate impact scenario: Potential annual per hectare loss of **INR 5000**
- Low impact scenario: Potential annual per hectare loss of **INR 2000**

Based on the community survey, the percentage of surveyed households that have suffered High, Moderate, and Low impact scenarios to their crops over the past 30 years is established (Figure 36). These percentages are combined with the potential losses above to establish average household losses at block level:

- Annual potential loss of 6000 per hectare per household in Banjar
- Annual potential loss of 6600 per hectare per household Anni
- Combined across both blocks to give an average household loss of **6300 per hectare.**

Table 9: Development of impact scenarios for loss of income in Banjar and Anni

	Banjar	**Total number of households:**	13952	
Impact scenario	**loss per hectare**	**% of survey households affected**	**potential blockwise number of households affected**	**Total loss**
High	7000	50	6976	48832000
Moderate	5000	50	6976	34880000
Low	2000	0	0	0
None	0	0	0	0
				83712000
			average per household losses	6000
	Anni	**Total number of households:**	12292	
Impact scenario	**loss per hectare**	**% of households affected**	**potential blockwise number of households affected**	**Total lost**
High	7000	76	9341.92	65393440
Moderate	5000	24	2950.08	14750400
Low	2000	4	491.68	983360
None	0	0	0	0
				81127200
			average per household losses	6600
			average of Anni and Banjar	6300

A somewhat arbitrary scaling is applied to the values across the 5 blocks based on current risk levels taking the value of 6300 per hectare as the mid-point (i.e., characteristic of moderate risk). This gives average per household losses of:

Anni (very low risk):
3150 per hectare
(scaling of 0.5)

Naggar (low risk):
4725 per hectare
(scaling of 0.75)

Banjar (moderate risk):
6300 per hectare
(scaling of 1 – midpoint)

Kullu (high risk):
7875 per hectare
(scaling of 1.25)

Nirmand (very high risk):
9450 per hectare
(scaling of 1.5)

This scaling reflects that one would expect actual impacts to be higher in a high risk area, because of the combined effects of other climatic and non-climatic stressors. Note that these values above for Ani and Banjar align very well with the maximum losses reported from the community survey, considering average land holding sizes of around 4 hectares.

To account for future changes in climatic risk, the baseline loss values are scaled for the future (mid-century) according the calculated change in composite risk levels under RCPs 4.5 and 8.5 (considering also changing population dynamics). For example, if risk levels were to rise from an index value of 0.5 to 0.75, then losses would be scaled by a factor of 1.5. Due to lack of information coming out of the community survey, it is not possible to account for the role of existing adaptation strategies in reducing potential losses. In the case of crop insurance, uptake is currently negligible (6% of households have some cover).

Table 10: Current and future potential loss of income across blocks of Kullu

	Current potential losses per household per hectare	Future potential losses per household per hectare (RCP 4.5)	Future potential losses per household per hectare (RCP 8.5)
Ani	3150	3956	4020
Banjar	6300	7439	7573
Kullu	7875	9651	9864
Naggar	4725	6063	6158
Nirmand	9450	10989	11307

Repair costs for damaged houses

Data from the community survey in Kullu (blocks of Anni and Banjar) reports average repair costs relating to high, moderate, and low impact scenarios (Figure 37).

Based on the community survey, the percentage of surveyed households that have suffered High, Moderate, and Low impact damage scenarios to their houses over the past 30 years is known. These percentages were combined with the repair costs to establish average household repair costs at the block level:

- Average household repair costs in Banjar of INR 31,600
- Average household repair costs in Anni of INR 53,200
- Combined across both blocks to give average household repair costs of **INR 42400.**

Table 11: Development of impact scenarios for household damages and repair costs in Banjar and Anni

	Banjar	**Total number of households:**	**13952**	
Impact	**Repair Cost**	**% of survey households affected**	**potential blockwise number of households affected**	**total cost**
High	**50000**	**50**	**6976**	**348800000**
Moderate	**15000**	**42**	**5859.84**	**87897600**
Low	**5000**	**6**	**837.12**	**4185600**
None	**0**	**2**	**279.04**	**0**
				440883200
			average per household cost	**31600**
	Anni	**Total number of households:**	**12292**	
Impact	**Repair Cost**	**% of survey households affected**	**potential blockwise number of households affected**	**total cost**
High	**80000**	**48**	**5900.16**	**472012800**
Moderate	**30000**	**48**	**5900.16**	**177004800**
Low	**10000**	**4**	**491.68**	**4916800**
None	**0**	**0**	**0**	**0**
				653934400
			average per household cost	**53200**
			average of Anni and Banjar	42400

The values were scaled across the 5 blocks based on current risk levels taking the repair value of 42 400 per household (i.e., characteristic of moderate risk). This gives average per household repair costs of:

Anni (very low risk):
21200 (scaling of 0.5)

Naggar (low risk):
31800 (scaling of 0.75)

Banjar (moderate risk):
42400 (scaling of 1 – midpoint)

Kullu (high risk):
53000 (scaling of 1.25)

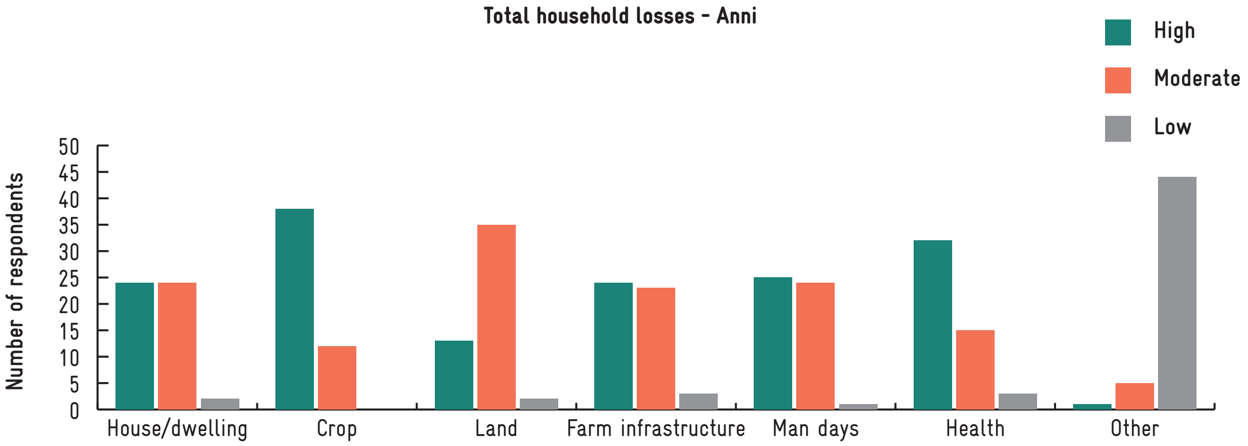
Nirmand (very high risk):
63600 (scaling of 1.5)

To account for future changes in climatic risk, the baseline loss values are scaled for the future (mid-century) according the change in calculated change in composite risk levels under RCPs 4.5 and 8.5 (considering also changing population dynamics). Due to lack of information coming out of the community survey, it was not possible to account for the role of existing adaptation strategies in reducing potential losses. Current or future efforts to improve the quality of houses, or to regulate the construction of housing in highest risk areas, for example, could reduce future losses. Hence the values provided in the analyses here should be considered as a conservative upper limit.

Table 12: Current and future potential repair costs for household damage across blocks of Kullu

	Current potential repair costs per household	Future potential repair costs per household (RCP 4.5)	Future potential repair costs per household (RCP 8.5)
Ani	21200	26622	27056
Banjar	42400	50068	50970
Kullu	53000	64950	66388
Naggar	31800	40806	41444
Nirmand	63600	73956	76095

Figure 36: Summary of reported losses at household level



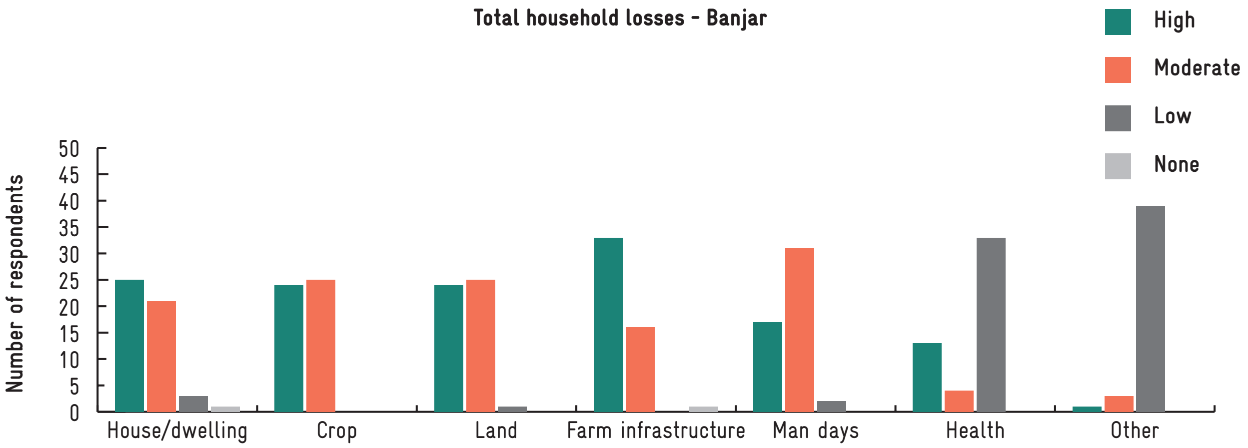
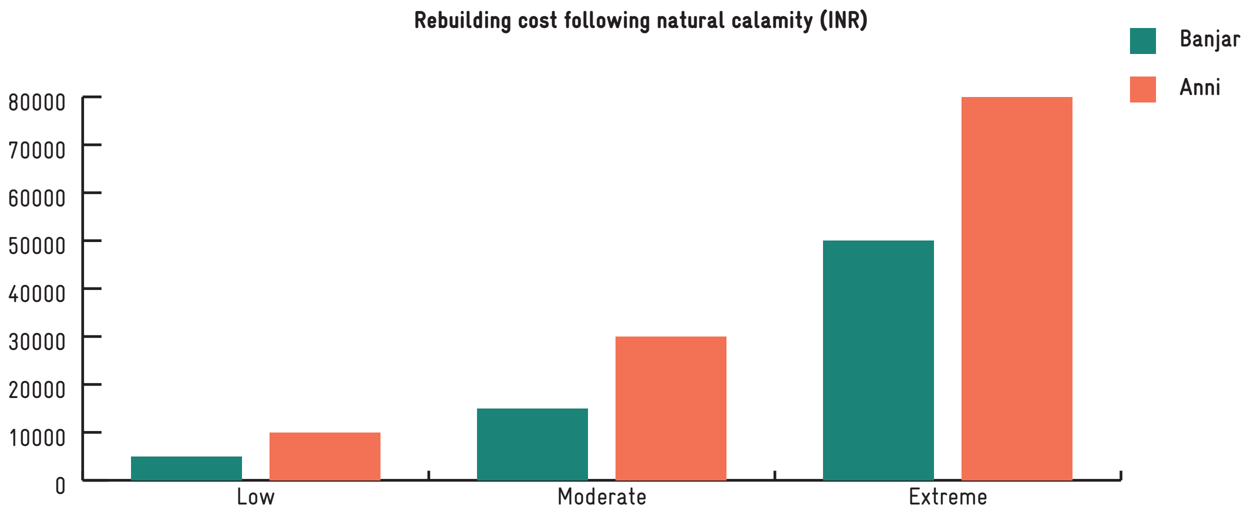


Figure 37: Rebuilding/reparation costs as reported from the community survey (median values)



Synthesis of losses to rural livelihoods

The evidence from the field surveys indicates that past natural calamities have semi-regularly resulted in large losses to rural livelihoods, with a loss in yield from crops of up to 70%, although typically much smaller. Several facts suggest that the losses occurring in the past have remained below intolerable limits:

- 90 % of farmers report that farming remains profitable for them
- Investment in farming remains relatively high
- There has been no reported suicides as a results of losses
- No participants have had to sell land as a result of recent calamities (although it is identified as a potential coping mechanism)
- The majority (64%) of participants are hopeful that their next generation will continue in farming

A key factor in enabling farmers in Kullu to cope with and respond to past disasters is likely their access to personal savings and loans (Figure 32). An absence of broader government or community led support mechanisms has been reported. Based on a lack of broader support mechanisms, and a low uptake of crop insurance, it is assumed that limits to adaptation could be reached in an event where heavy crop losses coincide with high reparation costs for property damage, thus combining to increase the loss in net household beyond a critical threshold. Based on expert judgement, a best estimate is that this threshold could be crossed leading to *intolerable levels of risk* when annual household income is reduced by more than 80 – 90% (Figure 38). This estimate is based on the median income from agriculture of around INR40,000. At the other end of the spectrum, losses in net household income of less than ca. 20% may be considered *acceptable, as* annual investment from saving and loans in agriculture of more than INR2000 (much higher in individual cases) suggest an ability to deal with small-scale, and even regular losses. In between lies the zone of *tolerable risk*, where even relatively large losses in crop yield and/or house reparation costs could be offset by reductions in expenses, earnings from alternative sources of income, and eventually selling of assets or switching from crops to livestock. It is noted that in addition to reparation costs, other factors such as health problems, and loss of man days in the field, can also reduce net annual income, and enhance risk levels.

Considering future climate scenarios and the change in risk across Kullu, house reparation costs and/or loss of income due to crop damages can be expected to increase in the order of 20 – 30% across the different blocks under RCP 8.5, and 16 – 28% under RCP 4.5 by mid 21st century. Hence, in the absence of appropriate adaptation strategies, climate change could result in risk level shifting from the tolerable to intolerable range for many households.

Note that these estimates are based on a reported median recovery time of 1 – 2 years (Figure 39), i.e., it is assumed that after two years crop yields and levels of income have returned to pre-event levels. Obviously more prolonged disasters could result in risk limits being exceeded even if the initial impact on household income may be less. For example, a long-lasting drought leading to an annual reduction in net income of 50%, could become intolerable after 2 or more years.

Figure 38: Estimate of risk tolerance domains for farming households in Kullu district, based on information from community survey and expert judgement. Factors that could increase or reduce losses, and thereby cause a shift from one tolerance domain to another are indicated next to the arrows.

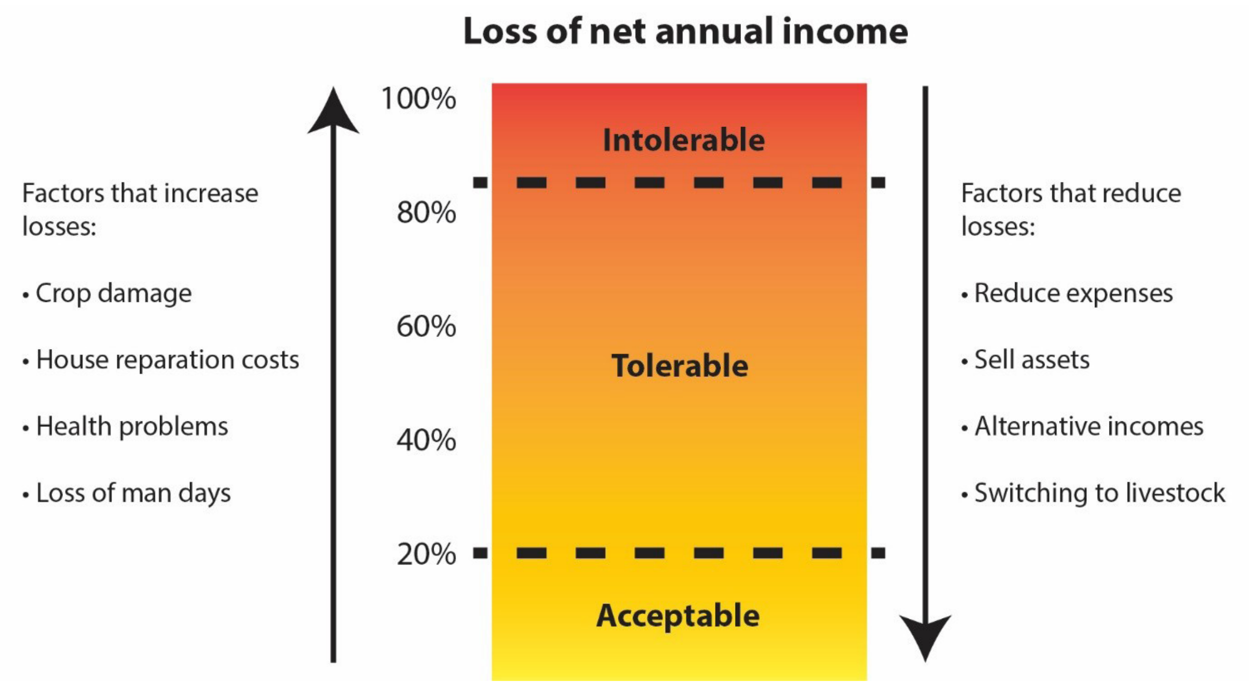
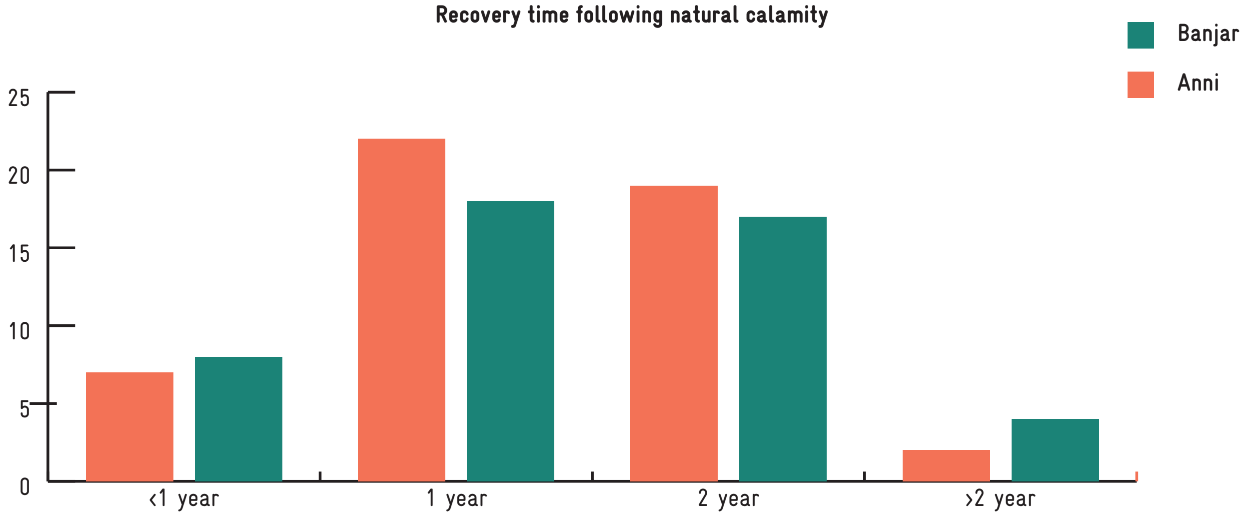


Figure 39: Recovery time following a natural calamity based on responses in community survey



Losses to rural infrastructure

Past disasters can provide a reference point for estimating the potential extent of loss and damage to rural infrastructure (roads, education facilities, and hospitals) that may occur under future scenarios. For this purpose, the Uttarakhand flood and landslide disaster from 2013 provides a suitable reference point, given very similar physiographic characteristics with Kullu district, and the fact that such disasters are expected to become more frequent under a warming climate in monsoon-affected parts of the Himalaya.

A summary of damages to critical infrastructure and estimated repair costs resulting from the 2013 disaster in Uttarakhand are provided in Table 13[8]. The percentage of damaged infrastructure then provides a basis for estimating the damage that could occur under a similar event in Kullu district. This is of course something of a worst-case scenario, given the extreme (estimated at > 100-year return period) nature of the 2013 rainfall generating event. However,

8 Uttarakhand Disaster June 2013: Joint Rapid Damage and Needs Assessment Report. World Bank, Government of India, and Asian Development Bank. August 2013.

in the absence of detailed local landslide and flood modelling it provides a reasonable first-order estimate. For example, the 2013 Uttarakhand disaster destroyed around 28% of the roads across the state – under a similar ratio, around 170 km of road could be destroyed if a similar event were to affect Kullu district, up to 1500 km of road could be damaged, with a repair cost of up to INR 61 crore.

Table 13: Summary of damages to critical infrastructure during the 2013 Uttarakhand flood and landslide disaster.

	Damaged	Total	% damaged	Repair cost (INR)
Schools	873	23093	3.78	600000 per unit
Medical facilities	56	2059	2.72	104000000* per unit
Roads (km)	8908	31929	28	1400000 per km

* Includes cost of replacement medicine and equipment

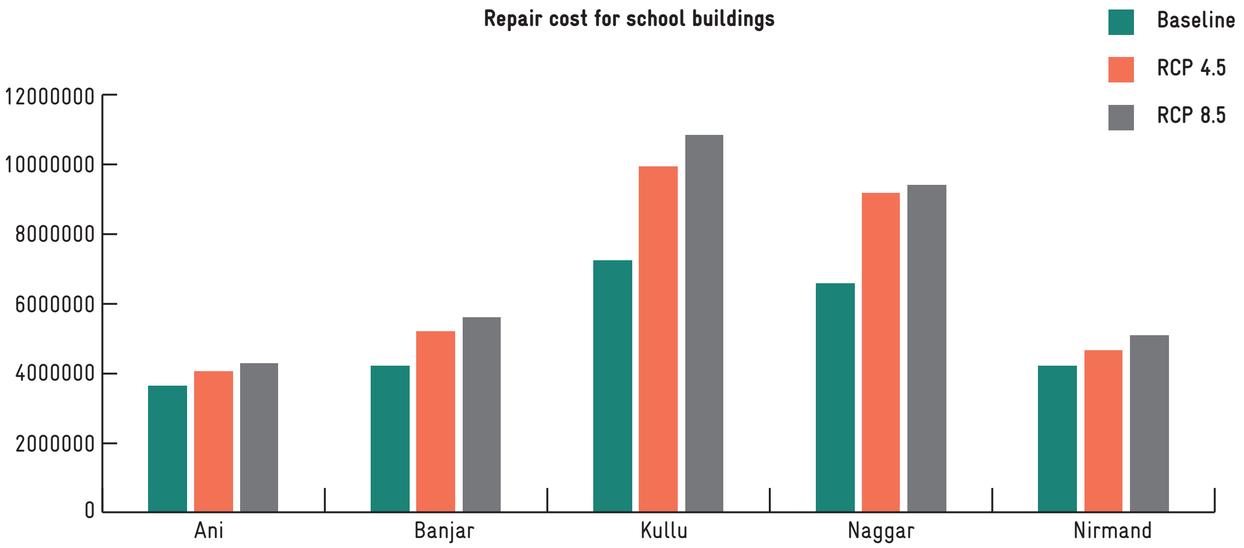
To account for future changes in risk to infrastructure (driven largely by changes in heavy rainfall), the baseline repair costs were scaled according to the change in risk by mid century, for RCP scenarios of 4.5 and 8.5.

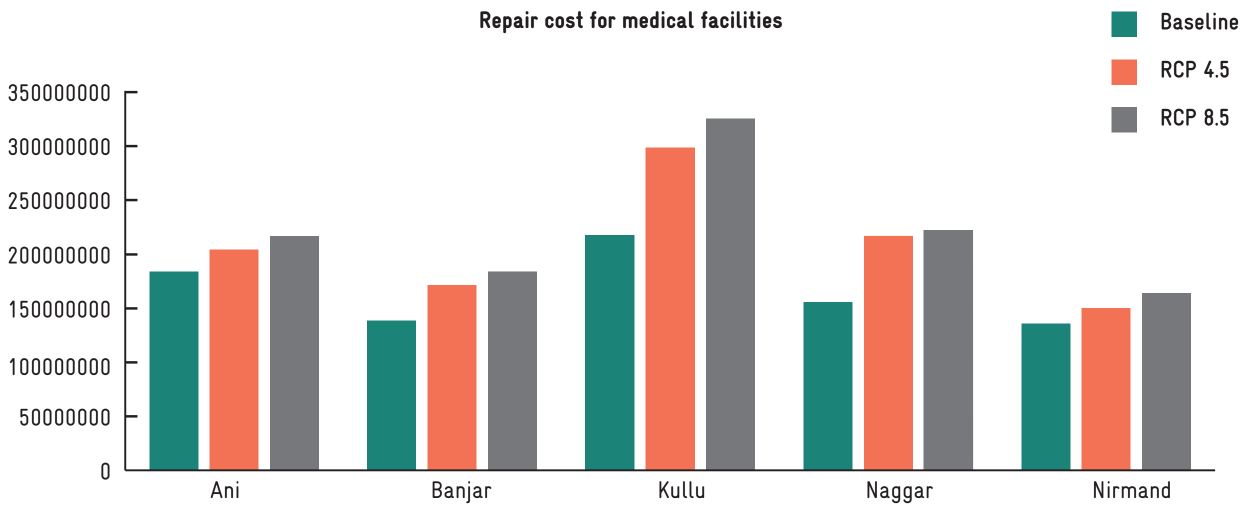
The results show potential damage (and thereby repair costs) to be greatest in Kullu block for school buildings and medical facilities (Figure 40). However, for roads, potential damages could be greatest in Naggar block, where the Rohtang Pass and tunnel represents a major national transportation corridor. In the future, increases will also be most pronounced in Kullu and Naggar blocks. It must be noted that while our assessment considers future changes in population density, changes in road use cannot be reasonably modelled – increasing use of major transportation corridors such as the Leh-Manali highway passing through Kullu and Naggar blocks can nonetheless be anticipated, raising risk levels further in these areas.

An event comparable in magnitude to the 2013 Uttarakhand disaster would clearly overwhelm local financial capacities at the district level in Kullu. For example, the District Disaster Response Fund (DDRF) had a budget of around INR 18 Crore as of 2016 (indicated in Figure 41). However, as outlined in the District Disaster Management Plan of 2017, financial assistance for relief, response, and rehabilitation following natural calamities is available at national, state and district levels, including > INR 150 Crore from the State disaster response fund.

In this context, assigning monetary thresholds at which risks associated with loss of critical infrastructure become intolerable is rather meaningless, as infrastructure such as roads, school building, and medical facilities will be rebuilt with government assistance. Rather risk tolerance levels for communities will relate to the length of time for which critical services are interrupted or unavailable. While quantitative data from the community survey is lacking, it is clear that tolerance levels will be lower during the harvesting season, when damage to critical transportation corridors would prevent crops from reaching economic markets, assuming any spoilt produce is not compensated for (due to currently low uptake of insurance).

Figure 40: Block level repair costs (INR) estimated for a high impact flood and landslide calamity





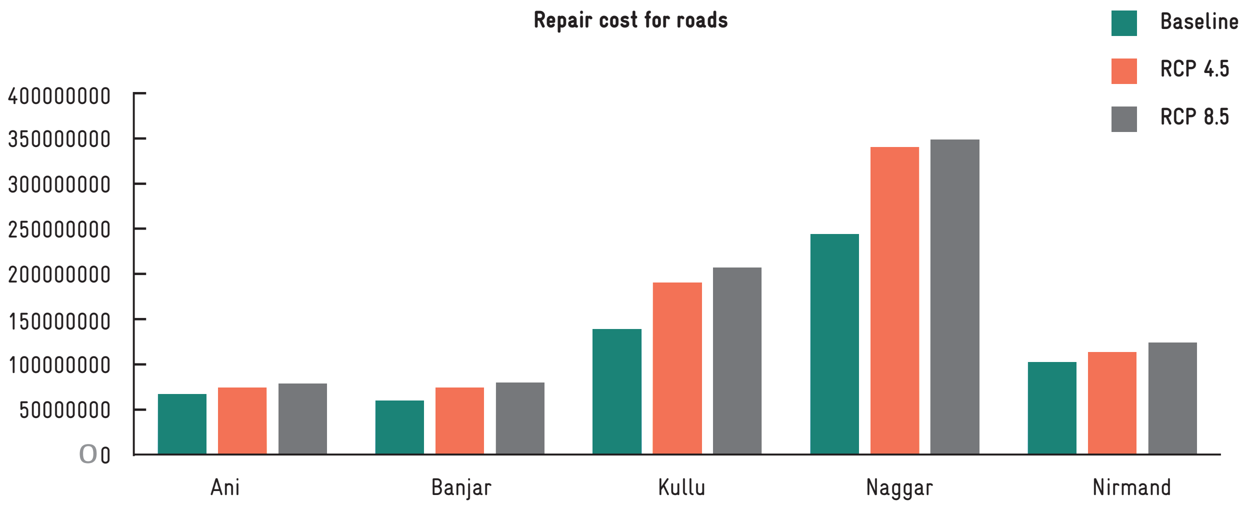


Figure 41: Total reparation costs for a high impact flood and landslide event under RCP 8.5

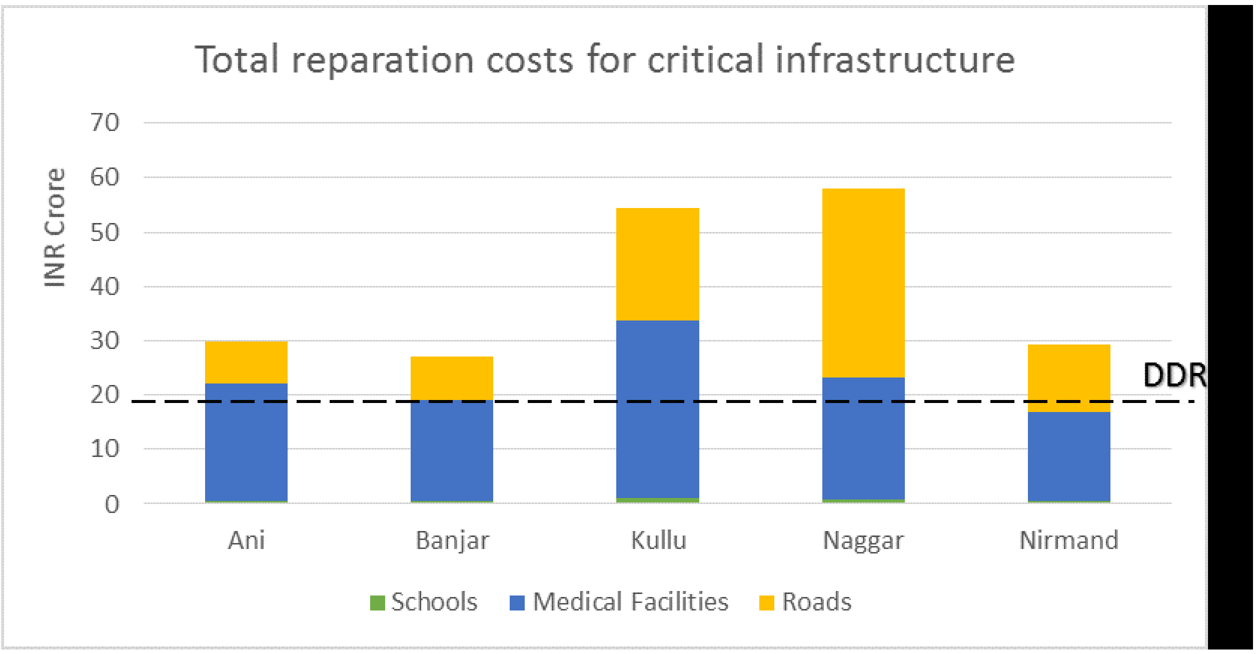


Table 14: Summary of loss and damage resulting from major natural calamities over the past 30 years, based on householder surveys in Banjar and Anni.

Year	Natural Calamity	Impact on community infrastructure	Impact on farm income due to damage to crops, loss of land etc)
1989	disease to livestock and plants	-	death of livestock (60-65%), estimated loss of 7000-8000; yield loss of 30-40%, estimated loss- 10000-12000
1994	Heavy rains	school building, houses, vehicles got damaged, impact on tourist arrival	loss of yield 30-40%, estimated loss-20000-25000
1997	warm weather	several people suffered heat stroke	70% reduced yield of apples, estimated loss-50-55k
1999	water scarcity	impact on daily public routine, loss of tourist	crop yield loss of 30-35%; estimated loss- 10-40k
2000	hail storm	school building, roads and forest got destroyed	halted production of commercial crops, yield reduced 10-15%, estimated loss- 10000-15000
2001	flood	road and houses destroyed, economic loss due to destruction of public property	economic losses of 5000-10000
2002	low monsoon	long queues to get water, water shortage	maize crop got damaged, estimated loss 15000-25000
2002	Cloud burst	heavy sudden rainfall caused destruction to property, there was blackout in the region for 3-4 days	20% loss of yield, estimated loss-5000-8000
2003	heavy rainfall	damage to building, lost regional connectivity	25-30% yield loss, estimated Rs. 15000
2004	Cloud burst	6-7 people died, roads disconnected for weeks	crop production reduced for next season, estimated Rs. 10000-15000
2005	flood	several lost their homes, loss of property and public property loss	sowing of seeds got delayed, estimated loss--5000-7000
2008	heavy rainfall	destruction of property, complete blackout for 1-2 days, mobile signal connectivity lost, impact on business	agricultural produce got destroyed, estimated loss of 20000-25000
2009	hailstorm	damage to buildings and vehicles	crops got destroyed, estimated at 12000-15000
August- Sept 2010	hail storm	several buildings suffered damage	apple production got impacted, estimated loss of Rs 25-55k
June-July 2010	flood	loss of life, several injured; destruction of public property	impact on soil, water logging in fields; estimated loss of 10-15k
November-December 2011	snowfall	impact on regional connectivity, road block for 2-3 weeks	destruction of horticulture, estimated loss of Rs 15-20k
June- July 2012	sudden heavy rainfall	major road block for 3-4 days, impact on business, few incidents of property damage	agricultural produce got destroyed, estimated loss of 10000-25000
July-August 2013	flood	connectivity with regions lost	delay in sowing seeds, loss of agriculture produce, estimated loss-40-45k
Monsoon 2014	flood	road and houses destroyed	crops destroyed in selected regions, estimated loss- 10-15k
December-January 2015	hail storm and snowfall	houses, vehicles, roads destroyed	agricultural produce got destroyed
June-july2016	Cloud burst	destruction of crops and buildings	estimated loss of 10-25k
July-August 2017	heavy rainfall and landslide	loss of life, several injured; destruction of public property, buildings, roadblock due to landslide	estimated loss of 60-80k

May-June 2018	fire	houses and other buildings burned	livestock destroyed, estimated loss- 10-35k
Monsoon of 2018	Flood, Rainfall, Landslide	blocked roads across the state, damage to crops	loss estimated at Rs 30-60k
2019	heavy rainfall	roadblock, complete blackout, destruction of small bridges, roads	loss of agricultural produce, estimated Rs 15-30k

Step 6: Identify feasible options to address potential loss and damage

Experience shows that successful, sustainable adaptation options must be well embedded and supported by local communities, and it is known that the uptake rate of existing technologies (e.g., relating to water management etc.) by the rural sector in India is generally low. Hence the approach used in the current study is therefore to introduce first a broad basket of potential adaptation options, and then focus in more detail on a selection of those options that have been identified by the communities themselves during the focus group discussion. Typically a wide-ranging basket of adaptation options is favored, because it allows for all risk components to be addressed (e.g. reducing vulnerability and/or exposure, and mitigating the hazard potential), and encompasses incremental, fundamental, and transformative response actions (Figure 42). The basket of adaptation options is based on experiences of the project team in the study region, and draws on well-established strategies that have been undertaken to addresses climate related challenges in the Himalaya and elsewhere. As a next step towards selection and implementation of adaptation options it is recommended to undertake an exchange with decision-makers and other stakeholder at district and state levels, whereby the basket of options, and particularly those options favored by the local communities, can be presented and evaluated accordingly.

Disaster risk reduction strategies

Flood and landslides are two of the greatest threats facing Kullu district, with associated risks (and L&D) expected to increase with future warming and increased heavy rainfall in particular. Adaptation options to address L&D associated with flood and landslide fall primarily within the category of DRR strategies and include:

Early warning systems:

- Utilizing the latest scientific understanding, monitoring technology, and local knowledge, to forecast and warn of imminent threats to lives and infrastructure. In addition to the technical requirements, the human component is highly critical (institutional and individual responsibility, and evacuation plans). Hence, the implementation of early warning systems, and in fact, most DRR strategies, must be strongly linked with community-based training and education.

Landuse planning/zoning:

- Integrating science-based hazard and risk mapping into urban planning to reduce the exposure and vulnerability of people and critical infrastructure.
- This requires clarification of the local legal context and regulations, and understanding of community perceptions which influence landuse practices.

Sustainable ecosystem and land management:

- Sustainable agroforestry practices, river management, and agricultural practices can reduce land degradation and erosion, reducing the impacts associated with flooding and landslides.
- Careful planning and construction of roads can reduce adverse effects on slope stability.
- As a low-regret adaptation measure, it is expected that sustainable ecosystems and land management have multiple benefits for a community beyond DRR, relating to recreation and tourism.

Building secure and reliable infrastructure:

- Establishing building standards and maintenance programmes that mean exposed infrastructure is built to withstand potential climate-related threats.

- Regulations and building requirements are commonly linked to hazard zoning.

Community awareness and preparedness:

- Local education and training to ensure that the communities and key organizations are aware of the threats, and to ensure strengthened coping capacities so that locals know what to do and how to respond during an event.

Emergency response strategies:

- To ensure that local authorities and key organizations have well-developed response strategies to safeguard medical aid, key services and lifelines during the emergency phase.

Structural engineering defences:

- Defence structures and engineering solutions that reduce or prevent hazards from occurring in the first place. For example, deflection dams to alleviate flood damage or reinforcement of unstable slopes.

Adaptation to slow onset events

In terms of slow onset events (e.g., issues of water scarcity, changing seasonality) a number of options are available to minimise losses in the agricultural and horticultural sectors.

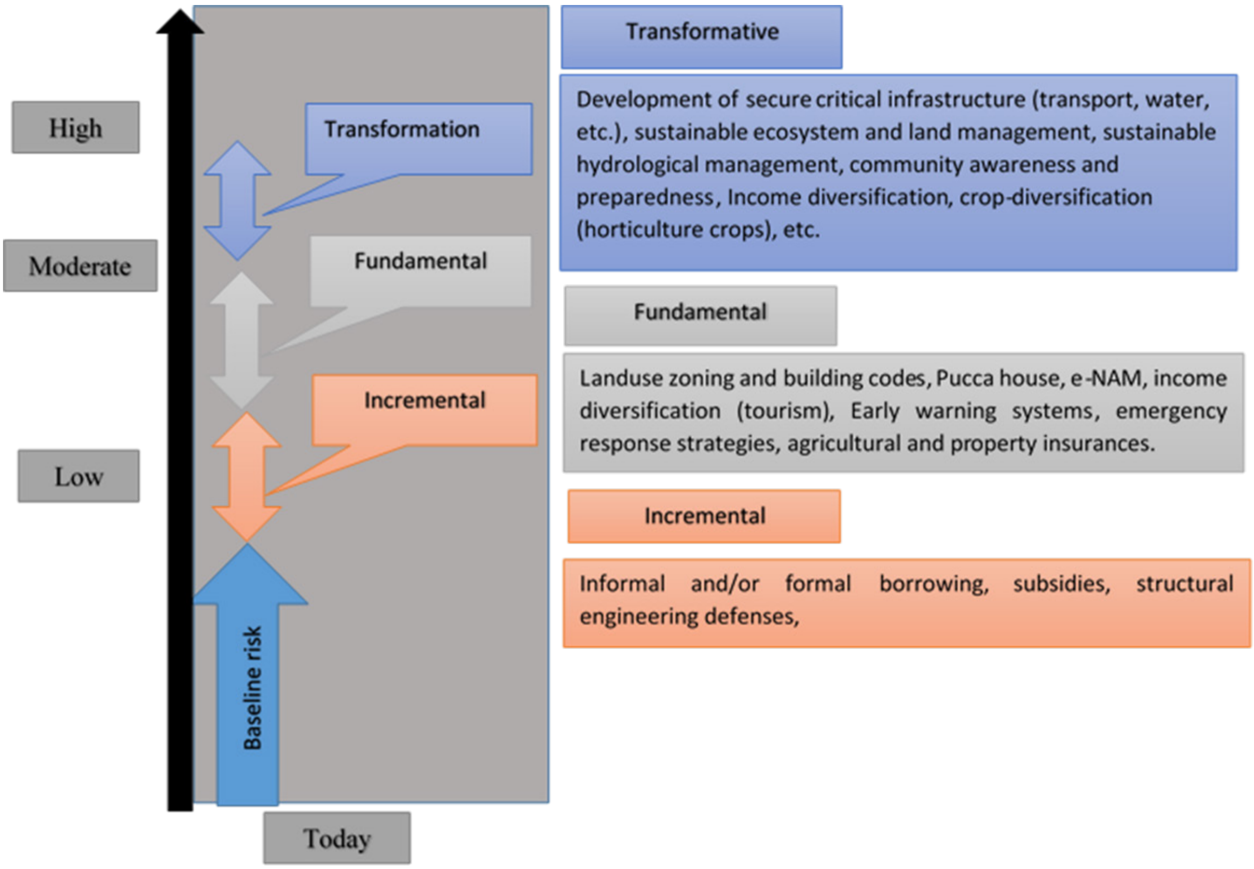
Meteorological based measures:

- Agro meteorological advisories for coping with adverse weather conditions in agronomy.
- Climate-smart insurance, as a special type of weather-parameter-based insurance instruments which reduce financial losses due to extreme weather (see also insurances below).

Improved hydrological management:

- Rain water harvesting through micro-reservoirs to save water to improve water security.
- Water budgeting and efficient irrigation methods, allowing agriculture during drought conditions.
- Artificial spring recharge through permeable ponds to allow recharge of local groundwater reserves.
- Traditional irrigation strategies based on local traditional knowledge to ensure fair water allocation.
- Mulching which reduces evaporation losses and pests and diseases.

Figure 42: **Categorization of basket of potential adaptation options identified for Kullu district**



Food security:

- Agri-Aquaculture, combining small holder agronomy with fish farming and rainwater harvesting to improve food security.
- Family gardens that includes diverse crops and small animal husbandry to improve food security.

Resilient farming and landuse practices:

- Minimum ploughing strategies to reduce the negative side effects of intensive soil cultivation on land erosion.
- Organic and biodiverse agriculture, that is typically more resilient to extreme weather and climate than traditional monocultures.
- Mixed cropping and crop rotation to ensure soil fertility without necessity of a fallow phase (erosion).
- Selection of climate change-resilient varieties, species and genotype to improve resilience against humidity, drought, pests and diseases.

Priority areas for adaptation identified at the community level

Based on the insights gained through the field survey (Figure 43), rural communities in Kullu district have identified four core areas where support from the government is expected and welcomed:Increasing access to cheap seeds for diversifying crops and recovering from disasters

- Climate-proofing of water infrastructure
- Improving the quality of transport infrastructure, and basic community infrastructure.
- Provision of subsidies to increase farm profitability

These areas of intervention would address livelihood and infrastructural risk associated with both slow onset and sudden onset events. However, there is a clear tendency for the communities to priorities options that would minimize loss of earnings, and damage to critical community infrastructure, rather than options (such as land zone or early warning) that would minimize damage to homes and reduce loss of life. This may reflect the way in which the question was posed, as the survey question focused on identifying areas in which government support is expected. Protection of lives and personal property may rather be perceived as a personal or community-level responsibility and thus less dependent on government support.

Increased access to cheap seeds for diversifying crops and recovering from disasters

The capacity of crops and ecosystems to adapt to a changing climate, resist pests and diseases and tolerate stress requires genetic diversity. Genetically diverse populations and species-rich ecosystems have greater potential to adapt to climate change. Strengthening the diversity of genes, species and ecosystems is crucial to increase resilience to changing environmental conditions and stresses. Some 35% of surveyed farmers in Kullu identified improved access to seed, in order to improve crop diversity, as an area of intervention expected from the government. Measures to foster improved access to seeds include:

- Informal seed networks
- Improve access to credit to allow farmers to acquire improved seed
- Participatory plant breeding and variety selection
- Seed system recovery
- Providing support to genebanks
- Use of indigenous and locally-adapted plants
- Maintain strategic seed stocks locally as a hedge against disaster
- Improve on-farm seed storage technologies and facilities to reduce losses to pests and diseases
- Creation of farmer seed enterprises targeted at local small-scale commercial seed production

Participatory plant breeding and variety selection methods can increase the adoption of improved varieties. They can also reduce the time and costs of developing new varieties (conventional breeding programs typically take 10 or more years to deliver new varieties to farmers for testing, against 3 to 4 years through participatory methods). Selection of crops with tolerance to 'abiotic stresses' (high temperature, drought, flooding, pest and disease resistance etc.) is important to broaden the genetic base of new crop varieties.

Climate-proofing of water infrastructure (reservoirs and irrigation infrastructure)

Improving the access to and adoption of water conserving practices can help irrigated systems to cope with lower water supply. Water conserving technologies are an effective way to maintain cropping intensity, and can provide opportunities to diversify into high-value market crops, reducing reliance on rainfed field crops. Technologies for achieving higher water productivity include:

- Drip irrigation systems: low cost drip irrigation technologies exist in a price range affordable for smallholder farmers.
- Improved water management practices: altering amounts and timing of irrigation, managing water (including drainage) to prevent water logging, erosion, and nutrient leaching where rainfall increases.
- Improving the reliability of the water supply through support for the construction of diversionary structures and holding ponds for rainwater harvesting.

Linked to above, are also methods for improving the harvesting of rainwater. Inter-annual storage of excess rainfall can be an effective way to maintain cropping intensity and smooth volatility in yield caused by climate variability, for example, to cope with weak monsoon seasons. Methods include:

- Capturing runoff through trenches and terraces (common in smallholder rainfed systems).
- Practicing conservation tillage and crop residue retention to increase water storage capacity.
- Diverting rainwater into holding structures for subsequent use.

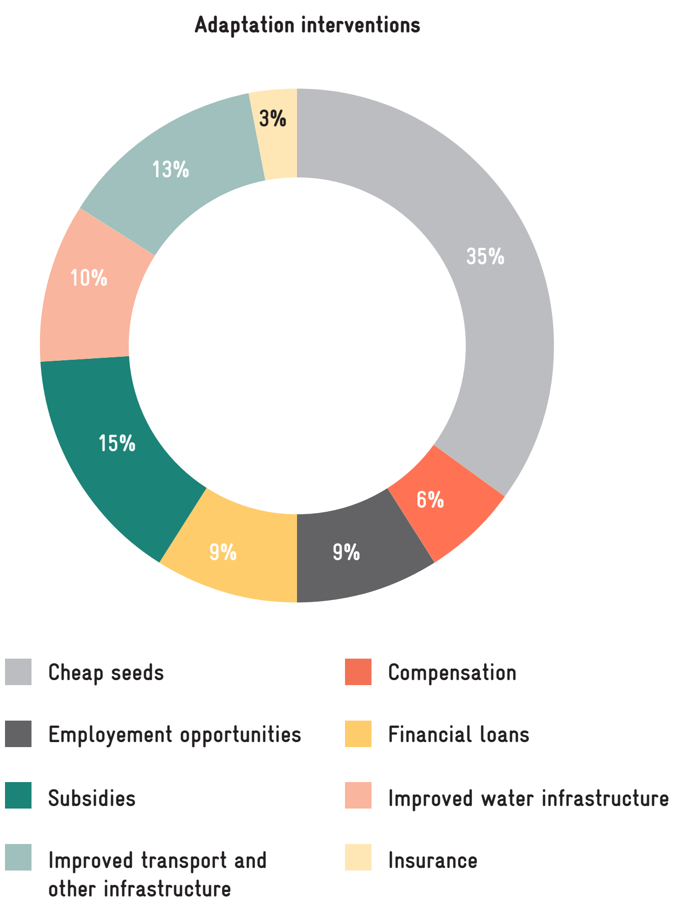
Improving the quality of transport infrastructure, and basic community infrastructure

Climate-smart construction of roads, and ensuring the location and design of critical infrastructure is regulated according to landuse zonation will significantly improve the resilience of critical lifelines and community buildings. Particularly in the aftermath of a disaster, a philosophy of *building back better* should guide the rehabilitation process, recognizing the opportunity to rebuild stronger, safer, and more disaster-resilient infrastructure and systems.

Key activities include:

- Introducing disaster risk reduction measures (including building codes and regulations) to increase the resilience of physical assets being reconstructed, such as raised-floor elevations in flood-prone areas.
- Introducing and enforcing appropriate land-use planning regulations, which curtail reconstruction in high-risk areas.
- Reconstructing improved hazard-control infrastructure, such as flood embankments and slope stabilisation methods.
- Replacing damaged assets with context sensitive, technologically updated alternatives. For example, modernizing damaged telecommunications equipment to keep up with technological advances.
- Using the post-disaster rehabilitation phase as an opportunity to align infrastructure to better meet community needs. For example, reconstructing hospitals with an adequate number of beds.

Figure 43: Community expectations for government support in climate adaptation, Kullu district

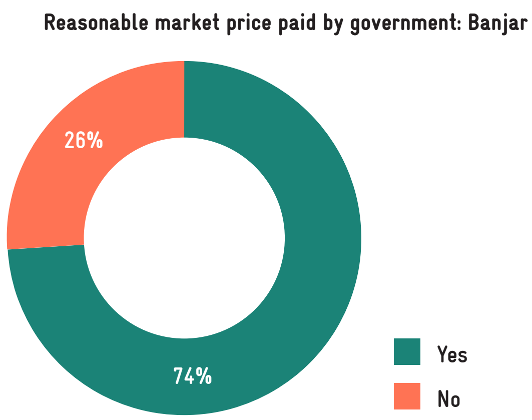


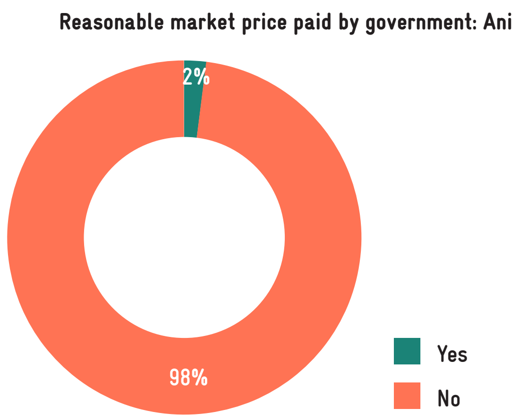
There are differences across Kullu in terms of basic infrastructural needs, for example, in the block of Ani 98% of sampled households reported satisfaction in electricity supply, compared to only 28% in Banjar. Hence, improving electrical supply within the block of Banjar could be seen as an immediate priority, responding directly to the perceived needs of the community.

Provision of subsidies to increase farm profitability

Subsidies encompass a large range of financial support mechanisms that enable farmers to enhance their productivity levels and reduce personal expenses. The need for general subsidies will vary across region, linked to the profitability of the main crop types grown. For example, there is significant differences between the blocks of Ani and Banjar, concerning perceptions around market prices paid by the government (Figure 44). Targeted subsidies could be aimed at the areas outlined above, such as to improve diversification of crops, assist in switching from crops to livestock, or to assist efforts towards efficient water management.

Figure 44: Community perceptions on market prices paid by the government for farm produce





Risk transfer and insurance

Insurance and reinsurance mechanisms and products against natural and human made disasters have rapidly increased over the last decades for spreading the cost of unavoidable losses both over time and over relatively large number of similarly exposed risks. These mechanisms are highlighted under the Disaster Management Plan for Kullu district. However, based on the results of the field survey, it is clear that uptake of crop and other personal insurances are very low in the district. Similarly, insurance mechanisms were not identified by the communities as an area in which they are expecting government support. This tends to suggest a general lack of knowledge and information around insurance options. A low uptake of insurance mechanisms means that the government has to bear a huge cost for compensation and rehabilitation work in post-disaster situations. New financial tools such as catastrophe risk financing, risk insurance, catastrophe bonds, micro-finance, contingent credit facilities and reserve funds, insurance etc., are being promoted with innovative fiscal incentives to cover such losses of individuals, communities, corporate sector and livestock. The Insurance Regulatory and Development Authority (IRDA), India has framed micro insurance regulations, covering insurance for personal accidents, health care for individual and family and assets like houses, livestock, tools and others. Linkages with government insurance schemes like Rashtriya Swathya Bima Yojana, Aam Admi Bima Yojana can be extensively taken up for risk transfer, but requires a strong supporting programme of awareness raising and information.

SUMMARY

Livelihood Risk Index (LRI) and Infrastructure Risk Index (INRI) has been assessed at the block/village level using a composite risk approach. Blocks are ranked based on the calculated index values. Higher index value represents high risk while lower index value represents low risk for the blocks. Kullu block level Risk Index (RI) for Livelihood and Infrastructure has been developed using weighted average of individual components of risk, namely Hazard Index, Exposure Index and Vulnerability Index. The risk analysis has been done for current and projected climate (under RCP4.5 and RCP8.5 climate scenario towards mid-century). A set of 43 indicators for blocks of Kullu have been identified while 50 indicators for villages of Anni and Banjar blocks have been identified for the risk assessment. The indices facilitate the identification of blocks/villages where which have high risk and need special attention towards adaptation.

Key Findings

An overall summary of the risk assessment, including the underlying hazard, exposure and vulnerability indices are provided in Tables 14 – 16. Components which contribute to make a block fall under a specific risk category can be identified from Table 15, for example: Nirmand (rank 5) falls under very high-risk categories for both livelihood (LRI) and infrastructure (INRI) risk owing to high levels of hazard, exposure and vulnerability. In contrast, Banjar has high vulnerability levels, but low hazard levels, leading to low to intermediate levels of risk.

Table 15: Snapshot of blocks risk assessment showing ranks for Livelihood and Infrastructure Risk and its Components for current period: Kullu

	Livelihood			
Blocks	LRI	LHI	LEI	VI
Anni	1	3	1	2
Naggar	2	4	2	1
Banjar	3	1	3	5
Kullu	4	2	4	3
Nirmand	5	5	5	4

LRI: Livelihood Risk Index, LHI: Livelihood Hazard Index, LEI: Livelihood Exposure Index, VI: Vulnerability Index

	Infrastructure			
Blocks	INRI	INHI	INEI	VI
Kullu	1	2	1	3
Banjar	2	1	3	5
Naggar	3	4	2	1
Anni	4	3	4	2
Nirmand	5	5	5	4

INRI: Infrastructure Risk Index, INHI: Infrastructure Hazard Index, INEI: Infrastructure Exposure Index

Table 16: Blocks current and projected Livelihood Risk and its Components: Kullu

		Livelihood Risk Index (LRI)				Livelihood Hazard Index (LHI)			
No	Blocks	BL Rank	BL	MC RCP4.5	MC RCP8.5	BL Rank	BL	MC RCP4.5	MC RCP8.5
1	Anni	1	VL	H	H	3	I	VH	VH
2	Naggar	2	L	H	H	4	H	EH	EH
3	Banjar	3	I	VH	VH	1	VL	I	H
4	Kullu	4	H	VH	VH	2	L	VH	VH
5	Nirmand	5	VH	EH	EH	5	VH	EH	EH

Table 17: Blocks current and projected Infrastructure Risk and its Components: Kullu

		Infrastructure Risk Index (INRI)				Infrastructure Hazard Index (INHI)			
No	Blocks	BL Rank	BL	MC RCP4.5	MC RCP8.5	BL Rank	BL	MC RCP4.5	MC RCP8.5
1	Kullu	1	VL	L	L	2	L	H	H
2	Banjar	2	L	I	H	1	VL	L	I
3	Naggar	3	I	H	H	4	H	VH	VH
4	Anni	4	H	H	H	3	I	I	H
5	Nirmand	5	VH	EH	EH	5	VH	EH	EH

BL: Baseline, MC: Mid-Century

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Summary of the risk assessment is as follows:

Blocks

- Block namely, Nirmand located in South Eastern part of Kullu district with rank 5 is at very high livelihood and infrastructure risk under current climate.
- The block of Anni with rank 1, has very low overall levels of livelihood risk.
- The block of Kullu with rank 1, has very low overall levels of Infrastructure risk.
- The overall livelihood and infrastructure risk of all the Kullu blocks is projected to increase towards mid-century as compared to the baseline for both the IPCC AR5 climate scenarios.
- Blocks livelihood risk is likely to be almost the same under RCP4.5 and RCP8.5 scenario towards mid-century. Blocks infrastructure risk is likely to be almost the same except for Banjar under RCP4.5 and RCP8.5 scenario towards mid-century.
- The overall livelihood hazard, infrastructure hazard and exposure of the blocks are projected to increase towards mid-century as compared to the current conditions for both the emission scenarios.
- Landslides, flood discharge, droughts, extremely wet days, 1 day and 5-day maximum rainfall, warm days and density of population are projected to increase towards the mid-century as compared to current conditions thus contributing to increase in the Livelihood Risk (LR) of the blocks.
- Infrastructure Risk of block Banjar is projected to increase to intermediate under RCP4.5 mid-century and to high under RCP 8.5 mid-century as compared to low under current risk. This is because landslide hazard is expected to increase towards RCP4.5 and RCP8.5 mid-century scenario as compared to the current conditions.

Villages

- Villages namely, Karshaigad and Bishla Dhar located in North Western part of Anni block with ranks 17 and 16 respectively are at very high risk under current climate. The villages of Soidhar, Beongal and Palehi with ranks 1, 2 and 3 respectively have very low overall levels of livelihood risk.
- Village namely, Soidhar of Anni block with rank 17 is at very high infrastructure risk under current climate. The villages of Khani, Buchair, Manjha Desh and Lajheri with ranks 1, 2, 3 and 4 respectively have very low overall levels of infrastructure risk.
- Villages namely, Gara Parli and Karshai Gad-II of Banjar block with ranks 42 and 41 respectively are at very high livelihood risk under current climate. The village of Bini with rank 1 has very low overall levels of livelihood risk.
- Village namely, Mashyar and Shilhi of Banjar block with ranks 42 and 41 respectively is at very high infrastructure risk under current climate. The villages of Manyashi, Chanon, Dusharh, Shangarh, Sachen and Bini with ranks 1, 2, 3, 4, 5 and 6 respectively have very low overall levels of infrastructure risk.
- The overall livelihood risk of most of the Anni and Banjar villages is projected to increase towards mid-century as compared to the baseline for both the IPCC AR5 climate scenarios. Villages risk is likely to be almost the same under RCP4.5 and RCP8.5 scenario towards mid-century except for Soidhar and Beongal. Soidhar and Beongal are projected to move to low risk under RCP4.5 scenario while intermediate risk under RCP8.5 scenario from current very low risk category in the baseline.
- The overall infrastructure risk of all the Anni and Banjar villages is projected to increase towards mid-century as compared to the baseline for both the IPCC AR5 climate scenarios. Villages risk is likely to be further exaggerated under RCP8.5 as compared to RCP4.5 mid-century scenario.
- The overall livelihood and infrastructure hazard of the villages is projected to increase towards mid-century as compared to the current conditions for both the emission scenarios.
- Landslides, flood discharge, drought weeks, extremely wet days, consecutive dry days, 1 day and 5-day maximum rainfall and warm days are projected to increase while cool nights are projected to decrease towards the mid-century as compared to current conditions thus contributing to increase in the Livelihood Risk (LR) of the villages.

The composite risk assessment was supported with primary data collected in a community survey within the blocks of Anni and Banjar. Importantly, the field survey provided information on community perceptions of the hazards and risks impacting upon their livelihoods and village infrastructure, and their expectations in terms of government supported response strategies. Natural calamities were identified as the main reason for losses in agriculture, and key threats of water scarcity, flooding, and landslides were highlighted, all of which were captured under the composite risk index used in this study. Natural calamities are perceived to have been increasing in terms of frequency and/or magnitude most over the past 30 years, particularly for flooding, while the future risk assessment for Kullu district has shown that heavy rainfall, related flood discharge, and landslides are all projected to increase by the mid-century, increasing the threat to livelihoods and infrastructure.. Significant interannnual variability in water availability will remain in the future, with overall seasonal rainfall amounts expected to decrease, despite an increase in high intensity events.

In order to evaluate risk tolerance levels and possible limits to adaptation, potential losses were calculated in monetary terms for key climate impacts. Based on an impact chain analyses, the evaluation focused on direct impacts in terms of livelihood impacts (damage to crops and households), and damage to rural infrastructure and public property (roads, schools, and medical facilities). The economic analyses drew on information coming out of the community survey to the extent possible, complimented with data on losses during past disasters, including from neighboring states. All values were scaled according to the results of the composite risk assessment, recognizing likely higher (lower) potential losses in high (low) risk zones respectively.

- In terms of losses to rural livelihoods as a result of crop damage, potential losses range from INR3150 – 9450 per hectare under baseline conditions across the 5 blocks of Kullu, increasing to a range of INR4020 – 11307 per hectare by mid 21st century under RCP 8.5.
- In terms of costs for household damage, repair costs are in the range of INR21200 – 63600 per household for baseline conditions (considering the level of impacts they have reported over past 30 years), increasing to INR27056 – 76095 per household by mid 21st century under RCP 8.5.
- Considering critical infrastructure, potential damage (and thereby repair costs) will be greatest in Kullu block for school buildings and medical facilities, while for roads, potential damages will be greatest in Naggar block, where the Rohtang Pass and tunnel represents a major national transportation corridor.
- As a primary result of changing flood and landslide hazard, potential damages will increase for critical infrastructure across all blocks in the future, with largest increases in the blocks of Kullu and Naggar.
- By mid 21st century, combined damages to critical infrastructure caused by a high impact flood and landslide disaster under RCP 8.5 are expected to be in the range of INR Core 30 - 60 across the five blocks.

Considering that there is currently a general lack of support mechanisms, and a low uptake of crop insurance, it is assumed that intolerable levels of risk could be reached in an event where heavy crop losses coincide with high reparation costs for property damage, thus combining to increase the loss in net household beyond a critical threshold. Based on expert judgement, a best estimate is that a threshold could be crossed leading to *intolerable levels of risk* when annual household income is reduced by more than 80 – 90% (based on the median income from agriculture of around INR40,000). Considering future climate scenarios and the change in risk across Kullu, house reparation costs and/or loss of income due to crop damages can be expected to increase in the order of 20 – 30% across the different blocks under RCP 8.5. Hence, in the absence of appropriate adaptation strategies, climate change could result in risk level shifting from the tolerable to intolerable range for many households.

Considering the estimated damages to critical infrastructure, it is clear that an event comparable in magnitude to the 2013 flood and landslide disaster in Uttarakhand would clearly overwhelm local financial capacities at the district level in Kullu. However, significant financial assistance for relief, response, and rehabilitation of critical infrastructure is available at national, state and district levels. Risk tolerance levels for communities will therefore relate to the length of time for which critical services are interrupted or unavailable. For example tolerance levels will be lower during the harvesting season, when damage to critical transportation corridors would prevent crops from reaching economic markets.

Given the increasing climate risk to Kullu, urgent adaptation strategies are needed to minimize potential losses. While a basket of potential options have been presented, the community survey identified four areas in which support from the government is expected:

- Increasing access to cheap seeds for diversifying crops and recovering from disasters: Efforts to increase access to a new and diverse varieties of seeds could strengthen the diversity of genes, species and ecosystems, increasing resilience to changing environmental conditions and stresses, leading to transformative changes in agriculture.
- Climate-proofing of water infrastructure: Water conserving technologies are an effective way to maintain cropping intensity, and can provide opportunities to diversify into high-value market crops, reducing reliance on rainfed field crops, while inter-annual storage of excess rainfall can be an effective way to maintain cropping intensity and smooth volatility in yield caused by climate variability.
- Improving the quality of transport infrastructure, and basic community infrastructure: Climate-smart construction of roads, and ensuring the location and design of critical infrastructure is regulated according to landuse zonation will significantly improve the resilience of critical lifelines and community buildings.
- Provision of subsidies to increase farm profitability: The need for general subsidies will vary across the blocks depending on profitability of the crops grown, but targeted subsidies could assist efforts to diversify crops, switch from crops to livestock, or improve water management.

Insurance, reinsurance mechanisms and other risk transfer mechanisms are highlighted under the Disaster Management Plan for Kullu district. However, it is clear from that uptake of crop and other personal insurances are very low in the district, and there appears to be a general lack of knowledge and information around insurance options, meaning that the government currently has to bear a huge cost for compensation and rehabilitation work in post-disaster situations. Therefore, a strong effort to raise awareness and provide information on the range available risk transfer mechanisms is required, to ensure stronger uptake of the available schemes and reduce the dependence on government support in the post-disaster recovery phase.

Broader Learnings and Perspectives

This study has tested the implementation of a risk-based approach to assess climate change impacts and has identified appropriate response actions to manage current and future risks associated with a spectrum of extreme weather events (rapid-onset) and slow-onset events. Experiences, challenges, and new perspectives arising from the case-study in Kullu district can provide important guidance for other studies and efforts to scale up the activities to other regions.

The benefit of using a risk lens is that it has allowed a more nuanced analyses of the factors that are contributing to climate-related losses in the region, and therefore adaptation strategies can by targeted accordingly. Under typical climate vulnerability assessments (such as those forming the basis of most State action plans in India), it is difficult to disentangle the role of climate and its influence on physical events, from the underlying social, economic, institutional, and cultural factors that determine a communities ability to prepare, respond and recover from a disaster. This leads to broad identification of districts or regions as being "highly vulnerable" but one cannot easily determine what is driving that vulnerability, and therefore, how resources can be best utilized to reduce the potential societal impact. Under the risk approach used in Kullu, separate hazard, exposure, and vulnerability indices have been presented, providing the full spectrum of information needed to inform decision-making. For example, in the block of Banjar, where vulnerability levels are highest, risk reduction efforts could now be targeted towards social programmes that build local capacities, awareness, and enhance resilience, whereas in the block of Nirmand, where both exposure and hazard indices are at their maximum (for both livelihood and infrastructural risk), efforts could rather focus on land zoning/ regulation and early warning systems.

However, a key challenge in the risk approach is that future changes in vulnerability and exposure are characterized by high levels of uncertainty. While general trends in population and economic growth can provide some insight, projecting future economic development at the block or village level, and what this means for levels of exposure and vulnerability in India would be hugely speculative. This is compounded by the fact that one major disaster (such as the 2013 flooding in Northern India), could have a massive and prolonged impact on social development, yet such potential "wild cards" are typically excluding from any future assessment. In Kullu the approach taken has been to consider vulnerability and exposure as baseline conditions only, such that any change in future risk is a function of change in climate only (although trends in population were considered).

How quantified risk levels (e.g. very low to very high) can translate into domains of risk tolerance (acceptable, tolerable, intolerable) remains a second major challenge in the overall assessment framework, for which illustrative examples are largely lacking. In Kullu, a first attempt has been made in which potential losses were scaled according to established risk levels, under the assumption that losses will be greater in high risk zones, and then combined with qualitative information from the community survey to establish domains at which these losses could exceed the coping capacities of farmers. Several key indicators emerged that could be further exploited in future studies or upscaling efforts to characterize whether or not risk levels remain tolerable. These included:

- Profitability (it is assumed if farmers continue to report a profit, then risks have remained at a tolerable level)
- Investment (continued investment indicating that risks remain tolerable)
- Suicides (absence of suicides suggest farmers are coping and risks remain tolerable)
- Selling of land (seen as an adaptation strategy, not needing to sell land suggests risks remain tolerable)
- Next generation farming (a reported expectation that next generations will continue farming indicates that risks remain tolerable).

One of the novel characteristics of this study has been the consideration of both slow onset and rapid onset events, made possible through the use of a compound hazard index. This recognises that a farming community may face highest levels of risk if they are, e.g., exposed to both prolonged effects of rising temperature causing related crop disease, and regular catastrophic flooding, and further reinforces the need for combined response strategies that draw across the boundaries of climate change adaptation and disaster risk management. The strong focus on climate change within the state disaster management plan for Himachal Pradesh is promising, but decision-making needs to be supported with further interdisciplinary assessments of wide-ranging climate risks at the ground level, across all districts.

APPENDIX

Appendix I

Indicators

Table A- 1: Indicators for hazard assessment at village/block level for Kullu (Himachal Pradesh)

No	Indicators	Abb	Unit	Scale*	Impacts#	Data Source	Time Period
1	Landslide Hazard	LH	Probability	B/V	IN/L	Google Earth	2000 - 2017
2	Flood Discharge (1-2% probable flow)	FL	cumecs-day	B/V	IN/L	SWAT Hydrological model outputs, CORDEX climate data-RCP4.5, RCP8.5 (IITM, Pune)	1981-2010 (BL), 2021-2050 (MC), 2071-2100 (EC)
3	1-day maximum precipitation	RX1	mm	B	IN/L		
4	5-day maximum precipitation	RX5	mm	B	IN/L		
5	Crop water Stress(ET/PET) in South West Monsoon season	CWSSWM	Ratio	B/V	L	SWAT Hydrological model outputs, CORDEX climate data-RCP4.5, RCP8.5 (IITM, Pune)	1981-2010 (BL), 2021-2050 (MC), 2071-2100 (EC)
6	Crop water Stress(ET/PET) in North East Monsoon season	CWSNEM	Ratio	B/V	L		
7	Frequency of Drought in South West Monsoon season	DRSWM	Number of weeks	B/V	L		
8	Surface Water stress in South West Monsoon season	SWSWM	mm/ten thousand population	B/V	L		
9	Surface Water stress in North East Monsoon season	SWNEM	mm/ten thousand population	B/V	L		
10	Ground Water stress in South West Monsoon season	GWSWM	mm/ten thousand population	B/V	L		
11	Ground Water stress in North East Monsoon season	GWNEM	mm/ten thousand population	B/V	L		
12	Extremely Wet Days-Annual total rainfall when rainfall>99th percentile	EWD	mm	B/V	L		
13	Consecutive Dry Days-maximum number of Consecutive Days With Rainfall Less Than 1 mm	CDD	Number of Days	B/V	L		
14	Consecutive Wet Days-maximum number of Consecutive Days With Rainfall >= 1 mm	CWD	Number of Days	B/V	L		
15	Cool nights- days when minimum temperature < 10th Percentile	CN	% of days	B/V	L		
16	Warm Days - days when maximum temperature > 90th Percentile	WD	% of days	B/V	L		
17	Heat Index	HI	Severity of days	B	L		
18	Temperature Humidity Index	THI	Severity of days	B	L		

**B*: Block, *V*: Village, *B/V*: Block/Village*

*#: **IN/L:** IN: Infrastructure, L: Livelihood*

All hazard indicators have positive (+) dependency means that an increase in the measured variable indicates an increase in vulnerability.

Table A- 2: **Indicators for exposure assessment at village/block level for Kullu (Himachal Pradesh)**

No	Indicators	Abb	Unit	Scale*	Impacts#	Data Source	Time Period
1	Road Density	RDEN	Km/Sq. Km	B/V	IN	Open Street Map updated with mapping from Google EAarth.	2000 - 2017
2	Schools (Primary/Pre-Primary, Middle, Secondary and Senior Secondary School)	EI	Number/ Thousand population	B/V	IN	Census of India: Village Amenities - Himachal Pradesh	2014-15
3	Community, Primary and Primary Health Sub Centres-If within 2 kms from village considered as available	CPSHC	Numbers	B/V	IN	Census of India: Village Amenities - Himachal Pradesh	2011
4	Density of Population	DP	Persons/Sq. Km	B/V	L	Census of India: Primary Census Abstract - Himachal Pradesh	2011
5	Share of Marginal Workers	MGW	Percentage	B/V	L		
6	Agricultural and Cultivators to Main Workers	ACMW	Percentage	B/V	L		
7	Net Area Sown	NSA	Percentage of the district geographical area	B/V	L	Census of India: Village Amenities - Himachal Pradesh	2011
8	Forest Area	FA	Percentage of the district geographical area	B/V	L		2011
9	Net Irrigated Area	IA	Percentage to Net Sown Area	B/V	L		2011

B**: *Block,* ***V*: Village,* ***B/V****: Block/Village*

#: ***IN/L:*** *IN: Infrastructure, L: Livelihood*

All hazard indicators have positive (+) dependency means that an increase in the measured variable indicates an increase in vulnerability.

Table A- 3: **Indicators for vulnerability assessment at village/block level for Kullu (Himachal Pradesh)**

No	Indicators	Abb	Unit	Scale*	Impacts#	Data Source	Time Period
Sensitivity							
1	Sex-ratio	SR	No of females/ 1000 males	B/V	IN/L	Census of India: Primary Census Abstract - Himachal Pradesh	2011
2	Gender gap in literacy rate	GGLR	Percentage	B/V	IN/L		
3	Gender gap in work participation rate	GWPR	Percentage	B/V	IN/L		
4	Age Dependency Ratio	ADR	Percentage	B/V	IN/L	Socio Economic and Caste Census 2011	2011
5	Disabled Population	DIP	Percentage	B/V	IN/L		
6	Deprived households	DH	Percentage	B/V	IN/L		
7	Households still dependent on biomass as fuel for cooking	BM	Percentage	B/V	IN/L	Census of India: House listing and Housing Census - Himachal Pradesh	2011
8	Households with highest earning member Income as less than Rs. 5,000	IN	Percentage	B/V	IN/L	Socio Economic and Caste Census 2011	2011
Adaptive Capacity							

No	Indicators	Abb	Unit	Scale*	Impacts#	Data Source	Time Period
9	Literacy Rate	LR	Percentage	B/V	IN/L	Census of India: Primary Census Abstract – Himachal Pradesh	2011
10	Total work participation rate	TWPR	Percentage	B/V	IN/L		
11	Households with access to communication/transport	COMTR	Percentage	B/V	IN/L	Census of India: House listing and Housing Census – Himachal Pradesh	2011
12	Households availing banking services	BNKS	Percentage	V	IN/L		
13	Population with access to Cooperatives and commercial bank	CCB	Percentage	B	IN/L	District Census handbook: Kullu: Census of India	2011
14	Black Topped (pucca) Road	PR	(Available (1)/Not Available (0))	V	IN/L	Census of India: Village Amenities – Himachal Pradesh	2011
15	All Weather Road	AWR	(Available (1)/Not Available (0))	V	IN/L		
16	Commercial Bank	CB	(Available (1)/Not Available (0))	V	IN/L		
17	Cooperative Bank	COB	(Available (1)/Not Available (0))	V	IN/L		
18	Agricultural Credit Societies	ACS	(Available (1)/Not Available (0))	V	IN/L		
19	Self – Help Group	SHG	(Available (1)/Not Available (0))	V	IN/L		
20	Public Distribution System Shop	PDS	(Available (1)/Not Available (0))	V	IN/L		
21	Nutritional Centres-ICDS (Integrated Child Development Scheme)-If within 2 kms from village considered as available	NCICDS	(Available (1)/Not Available (0))	V	IN/L		
22	Nutritional Centres-Anganwadi Centre-If within 2 kms from village considered as available	NCAC	(Available (1)/Not Available (0))	V	IN/L		
23	Households with access to drinking water source within premises	DW	Percentage	B/V	IN/L	Census of India: House listing and Housing Census – Himachal Pradesh	2011
24	Households having access to sanitation facility within the premises	SF	Percentage	B/V	IN/L		
25	Households having electricity as main source of lighting	EL	Percentage	B/V	IN/L		
26	Households living in Permanent houses	PH	Percentage	B/V	IN/L		

*****B**: *Block,* **V**: *Village,* **B/V**: *Block/Village*

#: **IN/L:** *IN: Infrastructure, L: Livelihood*

All sensitivity indicators have positive (+) dependency means that an increase in the measured variable indicates an increase in vulnerability while the adaptive capacity indicators have negative (-) dependency means that an increase in the measured variable indicates a decrease in vulnerability.

Kullu Blocks Results

Table A- 4: Kullu Block wise Livelihood Risk Index values, ranks and category under current and projected scenario - RCP4.5 and RCP8.5

		Index value			Category		
Blocks	Rank_BL	Baseline	MC RCP4.5	MC RCP8.5	Baseline	MC RCP4.5	MC RCP8.5
Anni	1	0.391	0.491	0.499	VL	H	H
Naggar	2	0.399	0.512	0.520	L	H	H
Banjar	3	0.470	0.555	0.565	I	VH	VH
Kullu	4	0.479	0.587	0.600	H	VH	VH
Nirmand	5	0.565	0.657	0.676	VH	EH	EH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Table A- 5: Kullu Block wise Livelihood Hazard Index values, ranks and category under current and projected scenario - RCP4.5 and RCP8.5

		Index value			Category		
Blocks	Rank_BL	Baseline	MC RCP4.5	MC RCP8.5	Baseline	MC RCP4.5	MC RCP8.5
Banjar	1	0.314	0.468	0.498	VL	I	H
Kullu	2	0.455	0.651	0.691	L	VH	VH
Anni	3	0.479	0.668	0.694	I	VH	VH
Naggar	4	0.499	0.761	0.786	H	EH	EH
Nirmand	5	0.599	0.774	0.830	VH	EH	EH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Table A- 6: Kullu Block wise Livelihood Exposure Index values, ranks and category under current and projected scenario - RCP4.5 and RCP8.5

		Index value			Category		
Blocks	Rank_BL	Baseline	MC RCP4.5	MC RCP8.5	Baseline	MC RCP4.5	MC RCP8.5
Anni	1	0.403	0.513	0.513	VL	I	I
Naggar	2	0.446	0.521	0.521	L	H	H
Banjar	3	0.502	0.603	0.603	I	EH	EH
Kullu	4	0.523	0.651	0.651	H	EH	EH
Nirmand	5	0.531	0.633	0.633	VH	EH	EH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Table A- 7: Kullu Block wise Vulnerability Index values, ranks and category under current scenario - RCP4.5 and RCP8.5

	Baseline		
Blocks	Rank	Index value	Category
Naggar	1	0.253	VL
Anni	2	0.291	L
Kullu	3	0.459	I
Nirmand	4	0.565	H
Banjar	5	0.595	VH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Table A- 8: Kullu Block wise Infrastructure Risk Index values, ranks and category under current and projected scenario - RCP4.5 and RCP8.5

		Index value			Category		
Blocks	Rank_BL	Baseline	MC RCP4.5	MC RCP8.5	Baseline	MC RCP4.5	MC RCP8.5
Kullu	1	0.240	0.329	0.359	VL	L	L
Banjar	2	0.336	0.416	0.447	L	I	H
Naggar	3	0.415	0.579	0.593	I	H	H
Anni	4	0.448	0.498	0.528	H	H	H
Nirmand	5	0.784	0.868	0.947	VH	EH	EH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Table A- 9: Kullu Block wise Infrastructure Hazard Index values, ranks and category under current and projected scenario - RCP4.5 and RCP8.5

		Index value			Category		
Blocks	Rank_BL	Baseline	MC RCP4.5	MC RCP8.5	Baseline	MC RCP4.5	MC RCP8.5
Banjar	1	0.027	0.266	0.360	VL	L	I
Kullu	2	0.229	0.495	0.587	L	H	H
Anni	3	0.322	0.474	0.564	I	I	H
Naggar	4	0.626	1.117	1.159	H	VH	VH
Nirmand	5	0.920	1.174	1.410	VH	EH	EH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Table A- 10: Kullu Block wise Infrastructure Exposure Index values, ranks and category under current scenario - RCP4.5 and RCP8.5

	Baseline		
Blocks	Rank	Index value	Category
Kullu	1	0.032	VL
Naggar	2	0.367	L
Banjar	3	0.387	I
Anni	4	0.730	H
Nirmand	5	0.866	VH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Anni Block-Villages Results

Table A- 11: Anni Village wise Livelihood Risk Index values, ranks and category under current and projected scenario - RCP4.5 and RCP8.5

		Index value			Category		
Blocks	Rank_BL	Baseline	MC RCP4.5	MC RCP8.5	Baseline	MC RCP4.5	MC RCP8.5
Soidhar	1	0.367	0.420	0.440	VL	L	I
Beongal	2	0.391	0.431	0.444	VL	L	I
Palehi	3	0.399	0.457	0.477	VL	H	H
Jaban	4	0.416	0.454	0.461	L	H	H
Khani	5	0.420	0.478	0.475	L	H	H
Karana	6	0.441	0.477	0.482	I	H	H
Buchair	7	0.444	0.504	0.498	I	H	H
Dingi Dhar	7	0.444	0.496	0.507	I	H	H

Kungash	9	0.461	0.498	0.503	H	H	H
Kohila	10	0.463	0.500	0.506	H	H	H
Shilhi	11	0.469	0.506	0.512	H	H	H
Franali	12	0.472	0.512	0.517	H	H	H
Lajheri	13	0.474	0.536	0.535	H	VH	VH
Manjha Desh	14	0.479	0.523	0.530	H	VH	VH
Karad	15	0.483	0.545	0.545	H	VH	VH
Bishla Dhar	16	0.556	0.598	0.605	VH	VH	VH
Karshaigad	17	0.582	0.650	0.652	VH	EH	EH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Table A- 12: Anni Village wise Livelihood Hazard Index values, ranks and category under current and projected scenario - RCP4.5 and RCP8.5

		Index value			Category		
Blocks	Rank_BL	Baseline	MC RCP4.5	MC RCP8.5	Baseline	MC RCP4.5	MC RCP8.5
Buchair	1	0.387	0.568	0.551	VL	I	I
Soidhar	2	0.417	0.576	0.634	VL	I	H
Khani	3	0.452	0.627	0.618	L	H	H
Beongal	4	0.467	0.587	0.625	L	I	H
Lajheri	5	0.476	0.660	0.657	L	VH	VH
Palehi	5	0.476	0.650	0.711	L	H	VH
Karad	7	0.507	0.693	0.693	L	VH	VH
Dingi Dhar	8	0.565	0.719	0.754	I	VH	VH
Karshaigad	9	0.582	0.785	0.793	I	EH	EH
Karana	10	0.587	0.696	0.710	I	VH	VH
Kungash	11	0.608	0.720	0.736	H	VH	VH
Kohila	12	0.611	0.723	0.739	H	VH	VH
Manjha Desh	13	0.617	0.749	0.769	H	VH	EH
Shilhi	14	0.618	0.729	0.746	H	VH	VH
Jaban	15	0.622	0.736	0.755	H	VH	VH
Franali	16	0.626	0.746	0.763	H	VH	EH
Bishla Dhar	17	0.685	0.811	0.833	VH	EH	EH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Table A- 13: Anni Village wise Livelihood Exposure Index values, ranks and category under current scenario - RCP4.5 and RCP8.5

	Baseline		
Blocks	Rank	Index value	Category
Jaban	1	0.307	VL
Kohila	2	0.310	VL
Bishla Dhar	3	0.325	VL
Beongal	4	0.347	L
Lajheri	5	0.353	L
Palehi	5	0.353	L
Manjha Desh	7	0.359	L
Soidhar	8	0.368	L
Kungash	9	0.377	L

	Baseline		
Blocks	Rank	Index value	Category
Khani	10	0.400	I
Buchair	11	0.405	I
Shilhi	12	0.408	I
Karana	13	0.434	H
Karad	14	0.444	H
Karshaigad	15	0.458	VH
Dingi Dhar	16	0.471	VH
Franali	17	0.472	VH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Table A- 14: Anni Village wise Vulnerability Index values, ranks and category under current scenario - RCP4.5 and RCP8.5

	Baseline		
Blocks	**Rank**	**Index value**	**Category**
Dingi Dhar	1	0.297	VL
Karana	2	0.302	VL
Franali	3	0.317	VL
Soidhar	3	0.317	VL
Jaban	5	0.320	VL
Beongal	6	0.360	L
Palehi	7	0.368	L
Shilhi	8	0.381	L
Kungash	9	0.397	L
Khani	10	0.407	L
Manjha Desh	11	0.461	I
Kohila	12	0.468	I
Karad	13	0.498	I
Buchair	14	0.539	H
Lajheri	15	0.594	H
Bishla Dhar	16	0.658	VH
Karshaigad	17	0.706	VH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Table A- 15: Anni Village wise Infrastructure Risk Index values, ranks and category under current and projected scenario - RCP4.5 and RCP8.5

		Index value			Category		
Blocks	**Rank_BL**	**Baseline**	**MC RCP4.5**	**MC RCP8.5**	**Baseline**	**MC RCP4.5**	**MC RCP8.5**
Khani	1	0.282	0.421	0.439	VL	I	I
Buchair	2	0.322	0.460	0.477	VL	I	I
Manjha Desh	3	0.329	0.360	0.407	VL	L	L
Lajheri	4	0.340	0.484	0.505	VL	I	H
Karshaigad	5	0.376	0.530	0.562	L	H	H
Franali	6	0.388	0.420	0.468	L	I	I
Karad	7	0.395	0.544	0.571	L	H	H
Karana	8	0.429	0.461	0.509	I	I	H
Dingi Dhar	9	0.435	0.472	0.519	I	I	H
Jaban	10	0.441	0.478	0.529	I	I	H
Beongal	11	0.442	0.482	0.530	I	I	H
Kohila	12	0.461	0.496	0.546	I	H	H
Kungash	13	0.507	0.540	0.590	H	H	VH
Shilhi	14	0.527	0.563	0.615	H	H	VH
Bishla Dhar	15	0.538	0.576	0.629	H	H	VH
Palehi	16	0.545	0.587	0.629	H	VH	VH
Soidhar	17	0.618	0.663	0.710	VH	VH	EH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Table A- 16: Anni Village wise Infrastructure Hazard Index values, ranks and category under current and projected scenario - RCP4.5 and RCP8.5

		Index value			Category		
Blocks	Rank_BL	Baseline	MC RCP4.5	MC RCP8.5	Baseline	MC RCP4.5	MC RCP8.5
Buchair	1	0.077	0.492	0.542	VL	I	H
Khani	2	0.098	0.517	0.571	VL	I	H
Lajheri	3	0.162	0.593	0.658	VL	H	H
Karad	4	0.254	0.700	0.782	L	H	VH
Karshaigad	5	0.339	0.799	0.897	I	VH	VH
Manjha Desh	6	0.390	0.482	0.625	I	I	H
Franali	7	0.404	0.498	0.642	I	I	H
Karana	8	0.429	0.525	0.671	I	I	H
Kungash	9	0.474	0.573	0.723	I	H	H
Kohila	10	0.507	0.610	0.762	I	H	VH
Jaban	11	0.569	0.679	0.832	H	H	VH
Shilhi	12	0.576	0.685	0.842	H	H	VH
Dingi Dhar	13	0.582	0.695	0.835	H	H	VH
Bishla Dhar	14	0.617	0.730	0.890	H	H	VH
Beongal	15	0.665	0.786	0.931	H	VH	VH
Palehi	16	0.681	0.807	0.935	H	VH	VH
Soidhar	17	0.799	0.935	1.074	VH	VH	EH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Table A- 17: Anni Village wise Infrastructure Exposure Index values, ranks and category under current scenario - RCP4.5 and RCP8.5

	Baseline		
Blocks	Rank	Index value	Category
Karshaigad	1	0.084	VL
Manjha Desh	2	0.136	VL
Lajheri	3	0.264	L
Beongal	4	0.300	L
Bishla Dhar	5	0.339	L
Khani	6	0.340	L
Buchair	7	0.350	L
Kohila	8	0.409	I
Dingi Dhar	9	0.425	I
Karad	10	0.433	I
Jaban	11	0.434	I
Franali	12	0.444	I
Karana	13	0.555	H
Palehi	14	0.585	H
Shilhi	15	0.623	H
Kungash	16	0.650	H
Soidhar	17	0.738	VH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Banjar Block-Villages Results

Table A- 18: Banjar Village wise Livelihood Risk Index values, ranks and category under current and projected scenario-RCP4.5 and RCP8.5

		Index value			Category		
Blocks	Rank_BL	Baseline	MC RCP4.5	MC RCP8.5	Baseline	MC RCP4.5	MC RCP8.5
Bini	1	0.376	0.412	0.411	VL	L	L
Kanon	2	0.428	0.468	0.468	L	I	I
Dhaugi	3	0.431	0.472	0.473	L	I	I
Kotla	3	0.431	0.474	0.477	L	I	I
Tarangali	3	0.431	0.469	0.471	L	I	I
Bihar	6	0.434	0.470	0.470	L	I	I
Bahu	7	0.442	0.479	0.479	L	I	I
Kalwari	8	0.444	0.482	0.485	L	I	I
Sehuli	9	0.445	0.483	0.483	L	I	I
Ratwah	10	0.446	0.485	0.487	L	I	I
Palach	11	0.449	0.488	0.490	L	I	I
Tandi	12	0.461	0.497	0.497	I	I	I
Bala Gad	13	0.462	0.501	0.502	I	H	H
Chanon	14	0.467	0.504	0.506	I	H	H
Deotha	14	0.467	0.504	0.506	I	H	H
Ghiaghi	16	0.468	0.504	0.505	I	H	H
Jauri	16	0.468	0.509	0.508	I	H	H
Tinder	18	0.470	0.507	0.508	I	H	H
Thati Bir	19	0.471	0.510	0.513	I	H	H
Sajwar	20	0.472	0.508	0.508	I	H	H
Lapah	21	0.477	0.529	0.508	I	H	H
Rashala	22	0.481	0.519	0.520	I	H	H
Chethar	23	0.483	0.520	0.518	I	H	H
Sharchi	24	0.484	0.521	0.522	I	H	H
Chakurtha	25	0.486	0.530	0.532	I	H	H
Seraj	25	0.486	0.526	0.526	I	H	H
Shanshar	27	0.488	0.540	0.537	I	H	H
Mohni	28	0.489	0.527	0.527	I	H	H
Thani Char	28	0.489	0.526	0.526	I	H	H
Shapnil	30	0.490	0.526	0.526	I	H	H
Khabal	31	0.504	0.541	0.541	H	H	H
Shilhi	32	0.505	0.537	0.560	H	H	VH
Siri Kot	33	0.508	0.543	0.544	H	H	H
Shangarh	34	0.509	0.557	0.552	H	VH	VH
Pakhari	35	0.515	0.553	0.555	H	VH	VH
Mashyar	36	0.520	0.564	0.588	H	VH	VH
Manyashi	37	0.527	0.574	0.569	H	VH	VH
Chippni	38	0.530	0.575	0.574	H	VH	VH
Sachen	39	0.531	0.577	0.573	H	VH	VH

Blocks	Rank_BL	Index value			Category		
		Baseline	MC RCP4.5	MC RCP8.5	Baseline	MC RCP4.5	MC RCP8.5
Dusharh	40	0.532	0.575	0.574	H	VH	VH
Karshai Gad-II	41	0.555	0.587	0.582	VH	VH	VH
Gara Parli	42	0.566	0.616	0.612	VH	EH	EH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Table A- 19: Banjar Village wise Livelihood Hazard Index values, ranks and category under current and projected scenario - RCP4.5 and RCP8.5

Blocks	Rank_BL	Index value			Category		
		Baseline	MC RCP4.5	MC RCP8.5	Baseline	MC RCP4.5	MC RCP8.5
Shilhi	1	0.447	0.544	0.614	VL	I	VH
Karshai Gad-II	2	0.450	0.548	0.531	VL	I	I
Chethar	3	0.492	0.604	0.596	L	H	H
Lapah	4	0.502	0.657	0.594	L	VH	H
Bini	5	0.503	0.610	0.609	L	VH	VH
Bihar	6	0.507	0.615	0.614	L	VH	VH
Siri Kot	6	0.507	0.614	0.615	L	VH	VH
Tandi	6	0.507	0.615	0.615	L	VH	VH
Shapnil	9	0.508	0.615	0.616	L	VH	VH
Khabal	10	0.510	0.623	0.621	L	VH	VH
Sajwar	10	0.510	0.618	0.616	L	VH	VH
Bahu	12	0.512	0.622	0.622	L	VH	VH
Sehuli	12	0.512	0.625	0.624	L	VH	VH
Ghiaghi	14	0.513	0.622	0.624	L	VH	VH
Mohni	14	0.513	0.627	0.626	L	VH	VH
Thani Char	16	0.514	0.624	0.625	L	VH	VH
Kanon	17	0.519	0.639	0.638	I	VH	VH
Sharchi	17	0.519	0.630	0.633	I	VH	VH
Jauri	19	0.521	0.642	0.641	I	VH	VH
Seraj	20	0.522	0.642	0.643	I	VH	VH
Deotha	21	0.523	0.634	0.638	I	VH	VH
Rashala	21	0.523	0.635	0.639	I	VH	VH
Tinder	23	0.524	0.636	0.639	I	VH	VH
Chanon	24	0.526	0.638	0.643	I	VH	VH
Bala Gad	25	0.527	0.643	0.647	I	VH	VH
Dhaugi	26	0.529	0.652	0.654	I	VH	VH
Pakhari	27	0.531	0.644	0.650	I	VH	VH
Ratwah	28	0.536	0.652	0.658	I	VH	VH
Tarangali	28	0.536	0.651	0.658	I	VH	VH
Palach	30	0.539	0.655	0.662	I	VH	VH
Thati Bir	30	0.539	0.657	0.664	I	VH	VH
Kalwari	32	0.541	0.657	0.665	I	VH	VH
Kotla	33	0.557	0.686	0.695	H	VH	VH
Dusharh	34	0.558	0.688	0.686	H	VH	VH
Chakurtha	35	0.559	0.690	0.698	H	VH	VH

		Index value			Category		
Blocks	Rank_BL	Baseline	MC RCP4.5	MC RCP8.5	Baseline	MC RCP4.5	MC RCP8.5
Mashyar	36	0.565	0.697	0.767	H	VH	EH
Chippni	37	0.585	0.720	0.718	H	VH	VH
Manyashi	38	0.591	0.732	0.718	H	EH	VH
Sachen	39	0.592	0.729	0.719	H	EH	VH
Shangarh	40	0.593	0.737	0.722	H	EH	VH
Gara Parli	41	0.616	0.767	0.754	VH	EH	EH
Shanshar	42	0.645	0.799	0.792	VH	EH	EH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Table A- 20: Banjar Village wise Livelihood Exposure Index values, ranks and category under current scenario - RCP4.5 and RCP8.5

	Baseline		
Blocks	Rank	Index value	Category
Shanshar	1	0.263	VL
Tinder	2	0.306	VL
Bini	3	0.327	VL
Sehuli	4	0.348	L
Lapah	5	0.352	L
Pakhari	6	0.357	L
Gara Parli	7	0.358	L
Kalwari	8	0.365	L
Palach	9	0.374	L
Dhaugi	10	0.381	L
Kotla	11	0.385	L
Sajwar	12	0.386	L
Tarangali	12	0.386	L
Chakurtha	14	0.387	L
Ghiaghi	15	0.388	L
Tandi	16	0.396	L
Bahu	17	0.397	L
Deotha	18	0.398	L
Jauri	18	0.398	L
Ratwah	20	0.409	I
Siri Kot	21	0.411	I
Kanon	22	0.415	I

	Baseline		
Blocks	Rank	Index value	Category
Shapnil	22	0.415	I
Chanon	24	0.416	I
Bihar	25	0.420	I
Mashyar	26	0.422	I
Shangarh	27	0.425	I
Seraj	28	0.427	I
Thati Bir	29	0.429	I
Chippni	30	0.432	I
Thani Char	31	0.436	I
Sharchi	32	0.439	I
Mohni	33	0.440	I
Chethar	34	0.442	I
Shilhi	35	0.450	H
Khabal	36	0.451	H
Rashala	37	0.465	H
Bala Gad	38	0.478	H
Sachen	39	0.488	H
Manyashi	40	0.567	VH
Dusharh	41	0.580	VH
Karshai Gad-II	42	0.608	VH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Table A- 21: Banjar Village wise Vulnerability Index values, ranks and category under current scenario - RCP4.5 and RCP8.5

	Baseline		
Blocks	Rank	Index value	Category
Bini	1	0.298	VL
Kanon	2	0.350	VL
Kotla	3	0.352	VL
Tarangali	4	0.370	VL
Bihar	5	0.376	VL
Bala Gad	6	0.381	VL
Dhaugi	7	0.383	VL
Ratwah	8	0.394	VL
Bahu	9	0.418	L
Manyashi	10	0.423	L
Kalwari	11	0.425	L
Palach	12	0.435	L
Thati Bir	13	0.445	L
Rashala	14	0.456	L
Dusharh	15	0.457	L
Chanon	16	0.458	L
Sehuli	17	0.476	I
Tandi	18	0.480	I
Deotha	19	0.481	I
Jauri	20	0.486	I
Sharchi	21	0.493	I
Ghiaghi	22	0.502	I
Seraj	23	0.509	I
Shangarh	24	0.510	I
Chakurtha	25	0.512	I
Sachen	26	0.513	I
Chethar	27	0.515	I
Mohni	27	0.515	I
Thani Char	29	0.518	I
Sajwar	30	0.521	I
Shapnil	31	0.547	H
Khabal	32	0.550	H
Shanshar	33	0.557	H
Chippni	34	0.572	H
Mashyar	35	0.574	H
Lapah	36	0.577	H
Tinder	37	0.579	H
Siri Kot	38	0.605	H
Karshai Gad-II	39	0.606	H
Shilhi	40	0.617	H
Pakhari	41	0.657	H
Gara Parli	42	0.724	VH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Table A- 22: Banjar Village wise Infrastructure Risk Index values, ranks and category under current and projected scenario - RCP4.5 and RCP8.5

		Index value			Category		
Blocks	Rank_BL	Baseline	MC RCP4.5	MC RCP8.5	Baseline	MC RCP4.5	MC RCP8.5
Manyashi	1	0.195	0.245	0.254	VL	L	L
Chanon	2	0.217	0.272	0.284	VL	I	I
Dusharh	3	0.219	0.276	0.290	VL	I	I
Shangarh	4	0.223	0.273	0.283	VL	I	I
Sachen	5	0.225	0.276	0.286	VL	I	I
Bini	6	0.226	0.280	0.290	VL	I	I
Tandi	7	0.236	0.286	0.293	L	I	I
Thani Char	8	0.243	0.300	0.313	L	I	I
Palach	9	0.244	0.303	0.318	L	I	I
Sajwar	10	0.249	0.302	0.310	L	I	I
Ghiaghi	11	0.251	0.309	0.323	L	I	I
Sharchi	12	0.252	0.305	0.314	L	I	I
Sehuli	13	0.254	0.312	0.327	L	I	I
Mohni	14	0.256	0.310	0.318	L	I	I
Deotha	15	0.258	0.317	0.332	L	I	H

		Index value			Category		
Blocks	Rank_BL	Baseline	MC RCP4.5	MC RCP8.5	Baseline	MC RCP4.5	MC RCP8.5
Chippni	16	0.261	0.319	0.333	L	I	H
Seraj	17	0.262	0.319	0.329	L	I	H
Karshai Gad-II	18	0.271	0.323	0.331	I	I	H
Shapnil	19	0.280	0.338	0.353	I	H	H
Kanon	20	0.290	0.348	0.359	I	H	H
Tarangali	21	0.294	0.354	0.372	I	H	H
Khabal	22	0.296	0.348	0.354	I	H	H
Kotla	23	0.302	0.370	0.392	I	H	H
Bala Gad	24	0.307	0.363	0.374	I	H	H
Dhaugi	25	0.309	0.368	0.381	I	H	H
Jauri	25	0.309	0.371	0.387	I	H	H
Rashala	25	0.309	0.367	0.382	I	H	H
Kalwari	28	0.311	0.372	0.390	I	H	H
Ratwah	29	0.312	0.374	0.392	I	H	H
Siri Kot	29	0.312	0.367	0.379	I	H	H
Bihar	31	0.313	0.363	0.368	I	H	H
Shanshar	31	0.313	0.371	0.389	I	H	H
Thati Bir	33	0.320	0.381	0.398	I	H	H
Bahu	34	0.334	0.388	0.398	H	H	H
Pakhari	35	0.346	0.404	0.419	H	H	H
Tinder	36	0.357	0.413	0.426	H	H	H
Lapah	37	0.364	0.415	0.425	H	H	H
Gara Parli	38	0.371	0.430	0.448	H	H	VH
Chakurtha	39	0.375	0.446	0.472	H	VH	VH
Chethar	40	0.380	0.432	0.440	H	VH	VH
Shilhi	41	0.480	0.531	0.585	VH	VH	VH
Mashyar	42	0.553	0.613	0.683	VH	VH	EH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Table A- 23: Banjar Village wise Infrastructure Hazard Index values, ranks and category under current and projected scenario - RCP4.5 and RCP8.5

		Index value			Category		
Blocks	Rank_BL	Baseline	MC RCP4.5	MC RCP8.5	Baseline	MC RCP4.5	MC RCP8.5
Bihar	1	0.013	0.161	0.178	VL	L	I
Tandi	2	0.027	0.179	0.199	VL	I	I
Sajwar	3	0.056	0.213	0.239	VL	I	I
Shangarh	4	0.062	0.213	0.241	VL	I	I
Sharchi	4	0.062	0.221	0.248	VL	I	I
Manyashi	6	0.064	0.216	0.243	VL	I	I
Sachen	7	0.065	0.219	0.247	VL	I	I
Lapah	8	0.076	0.229	0.259	VL	I	I
Bini	9	0.078	0.240	0.271	VL	I	I
Khabal	10	0.085	0.240	0.260	VL	I	I
Bahu	11	0.090	0.252	0.282	VL	I	I

		Index value			Category		
Blocks	**Rank_BL**	**Baseline**	**MC RCP4.5**	**MC RCP8.5**	**Baseline**	**MC RCP4.5**	**MC RCP8.5**
Chanon	12	0.096	0.261	0.296	VL	I	I
Siri Kot	13	0.099	0.266	0.301	VL	I	I
Karshai Gad-II	14	0.100	0.258	0.281	VL	I	I
Mohni	15	0.114	0.274	0.299	L	I	I
Thani Char	16	0.115	0.284	0.323	L	I	I
Tinder	17	0.116	0.286	0.325	L	I	I
Chethar	18	0.128	0.286	0.308	L	I	I
Bala Gad	19	0.133	0.300	0.334	L	I	I
Ghiaghi	19	0.133	0.306	0.348	L	I	H
Pakhari	21	0.139	0.314	0.358	L	I	H
Rashala	22	0.143	0.318	0.362	L	I	H
Shapnil	23	0.146	0.322	0.367	L	I	H
Deotha	24	0.147	0.323	0.369	L	I	H
Palach	25	0.153	0.330	0.377	L	I	H
Chippni	26	0.157	0.329	0.373	L	I	H
Tarangali	27	0.173	0.353	0.405	I	H	H
Kalwari	28	0.182	0.365	0.418	I	H	H
Sehuli	29	0.188	0.364	0.408	I	H	H
Shanshar	29	0.188	0.362	0.414	I	H	H
Seraj	31	0.196	0.366	0.397	I	H	H
Thati Bir	32	0.197	0.380	0.431	I	H	H
Dusharh	33	0.199	0.372	0.412	I	H	H
Ratwah	34	0.201	0.386	0.439	I	H	H
Gara Parli	35	0.209	0.386	0.439	I	H	H
Kanon	36	0.224	0.397	0.431	I	H	H
Dhaugi	37	0.246	0.424	0.462	I	H	H
Jauri	38	0.294	0.481	0.530	I	H	VH
Kotla	39	0.375	0.579	0.645	H	VH	VH
Chakurtha	40	0.425	0.639	0.716	H	VH	VH
Shilhi	41	0.629	0.782	0.943	VH	VH	VH
Mashyar	42	0.823	1.003	1.213	VH	VH	EH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Table A- 24: Banjar Village wise Infrastructure Exposure Index values, ranks and category under current scenario - RCP4.5 and RCP8.5

	Baseline		
Blocks	**Rank**	**Index value**	**Category**
Dusharh	1	0.000	VL
Chippni	2	0.055	VL
Seraj	3	0.082	VL
Chanon	4	0.097	VL
Manyashi	4	0.097	VL
Sachen	4	0.097	VL
Sehuli	4	0.097	VL

	Baseline		
Blocks	Rank	Index value	Category
Shangarh	4	0.097	VL
Thani Char	4	0.097	VL
Karshai Gad-II	10	0.106	VL
Ghiaghi	11	0.119	VL
Mohni	12	0.140	L
Palach	13	0.143	L
Deotha	14	0.146	L
Jauri	14	0.146	L
Shapnil	14	0.146	L
Sajwar	17	0.171	L
Gara Parli	18	0.180	L
Kotla	18	0.180	L
Chakurtha	20	0.188	L
Shanshar	21	0.195	L
Shilhi	21	0.195	L
Sharchi	23	0.200	L
Tandi	23	0.200	L
Siri Kot	25	0.231	I
Pakhari	26	0.242	I
Khabal	27	0.253	I
Mashyar	28	0.263	I
Dhaugi	29	0.297	I
Kanon	29	0.297	I
Bini	31	0.301	I
Thati Bir	32	0.318	I
Kalwari	33	0.327	I
Rashala	33	0.327	I
Tarangali	35	0.340	I
Ratwah	36	0.342	I
Tinder	37	0.375	H
Bala Gad	38	0.407	H
Lapah	39	0.439	H
Bahu	40	0.493	VH
Chethar	41	0.496	VH
Bihar	42	0.551	VH

VL: Very Low, L: Low, I: Intermediate, H: High, VH: Very High, EH: Extremely High

Appendix II

Normalization of Data

Normalization is done to convert raw data into a normalized form. Normalized values always lie between 0 and 1. The normalization process varies, depending on the nature of relationship of that particular indicator with the risk (positive or negative relationship). The following two formulae are explained:

Whenever an indicator has positive relationship normalized value for each of the indicator is computed as:

$$NV = \frac{[X - \text{minimum}(X)]}{[\text{maximum}(X) - \text{minimum}(X)]}$$

Whenever an indicator has negative relationship with vulnerability then the normalized value is computed as:

$$NV = \frac{[\text{minimum}(X) - X]}{[\text{maximum}(X) - \text{minimum}(X)]}$$

This is possible when, for example, higher literacy leads to lower vulnerability. Where,

NV = Normalized value of X, X is an observed value for the blocks for a given variable, Max X is the highest value of the variable across the blocks, Min X is the lowest value of the variable across the blocks.

Calculation of Weights

Iyengar and Sudarshan (1982) developed a method to work-out a composite index from multivariate data and linked the weight to variance across the indicators. This methodology is statistically sound and well suited for the development of risk index to climate change also.

Method: It is assumed that there are M regions / villages, K indicators of vulnerability and x_{ij}, i= 1, 2 ...M; j= 1, 2...K are the normalized scores. Let x_{ij} be the normalized value of the indicator j corresponding to region i. The level or stage of development of i^{th} zone, y_i, is assumed to be a linear sum of x_{ij} as,

$$\bar{y}_i = \sum_{j=1}^{K} w_j x_{ij} \qquad \left(0 < w < 1 \text{ and } \sum_{j=1}^{K} w_j = 1\right)$$

where w's are the weights. In Iyengar and Sudarshan's method the weights are assumed to vary inversely as the variance over the regions in the respective indicators of vulnerability. That is, the weight w_j is determined by,

$$w_j = {}^{c}/\sqrt{var_i(x_{ij})}$$

where c is a normalizing constant such that

$$c = \left[\sum_{j=1}^{j=K} {}^{1}/\sqrt{var_i(x_{ij})}\right]^{-1}$$

The choice of the weights in this manner would ensure that large variation in any one of the indicators would not unduly dominate the contribution of the rest of the indicators and distort the overall ranking of the blocks/villages. The vulnerability index so computed lies between 0 and 1, with 1 indicating maximum vulnerability and 0 indicating no vulnerability at all.

Calculation of Indices

$$Hazard\ Index = \left[\sum_{i=1}^{n} (w_i * NV_i)\right]$$

Where, i = 1 ....n is the number of indicators, w= weights, NV = Normalized value

Similarly Exposure and Vulnerability Indices have been calculated. Higher index value represents high risk while lower index value represents low risk.

Cluster Analysis

Cluster analysis or clustering is the task of assigning a set of objects into groups (called clusters) Cluster analysis is a class of statistical techniques that can be applied to data that exhibit "natural" groupings. Cluster analysis sorts through the raw data and groups them into clusters. A cluster is a group of relatively homogeneous cases or observations. Objects in the same cluster are more similar (in some sense or another) to each other than to those in other clusters.

Statistics associated with cluster analysis include:

- Agglomeration schedule: An agglomeration schedule gives information on the objects or cases being combined at each stage of a hierarchical clustering process.
- Cluster centroid: The cluster centroid is the mean values of the variables for all the cases or objects in a particular cluster.
- Cluster centers: The cluster centers are the initial starting points in non-hierarchical clustering. Clusters are built around these centers, or seeds.
- Cluster membership: Cluster membership indicates the cluster to which each object or case belongs.
- Distances between cluster centers: indicate how separated the individual pairs of clusters are. Clusters that are widely separated are distinct, and therefore desirable.

Inception Meeting on Integrated Climate Vulnerability and Risk Assessment in Himachal Pradesh

Date: 25th OCTOBER, 2018

Venue: Jaypee Greens Resort, Greater Noida

Programme: Inception Meeting

Time	Agenda Activity	Lead by
	Inaugural	
10:30-10:35	Welcome Address	GIZ
10:35-10:50	Opening Remarks Climate Change Adaptation in Rural Areas-India	GIZ
10:50-11:15	Introduction to the Integrated Climate Risk and VA study	Mario Rohrer, University of Geneva
	State of Knowledge	
11:15-11:40	Climate Vulnerability and Risk in Himachal Pradesh (presentation on study sites in broader context of state assessment)	INRM
11:40-12:05	Does Farm-level Adaptation to Climate Change enhance agricultural income? evidence from drought-prone households in rural India	Chandra Sekhar Bahinipati, Indian Institute of Technology, Tirupati
12:05-12:30	Experiences from Europe	Mario Rohrer, University of Geneva
12:30-13:00	**Q&A (30 minutes)**	
13:00-14:00	**Lunch**	
	Establishing Local Priorities – Round Table Discussions	
14:00-15:30	**Round Table Discussions:** Tables grouped according to states. Tasked with discussing a series of focus questions.	Facilitator: INRM and GIZ
15:30-16:30	**Plenary discussion:** Each table to have assigned rapporteur who reports back to plenary (10 mins each)	
	Closing remarks	
16:30-16:45	Key learning's from the discussions	INRM, MSE, Geneva
16:45-16:55	Next steps in the project	INRM
16:55-17:00	Vote of Thanks	GIZ

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