Department of Science and Technology
Ministry of Science & Technology
Government of India

NMSHE NATIONAL MISSION FOR SUSTAINING THE HIMALAYAN ECOSYSTEM

Schweizerische Eidgenossenschaft
Confédération suisse
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Swiss Agency for Development
and Cooperation SDC

CLIMATE VULNERABILITY ASSESSMENT FOR THE INDIAN HIMALAYAN REGION USING A COMMON FRAMEWORK

Indian Institute of Technology Mandi

IHCAP Indian Himalayas Climate Adaptation Programme

Climate Vulnerability Assessment for the Indian Himalayan Region Using a Common Framework

Submitted by
Indian Institute of Technology Guwahati & Indian Institute of Technology Mandi

In collaboration with
Indian Institute of Science Bangalore

Under the project
Capacity Building on Climate Change Vulnerability Assessment in the States of Indian Himalayan Region

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Message

The Himalayas are the largest and tallest mountain range in the world, bordering 8 countries and covering an area of about 43 lakh sq km. Nearly 1.5 billion people depend on Himalaya for Water, Food and Energy. The Himalayan ecosystem is considered as extremely fragile and diverse but vital for India through the provisioning of forest cover, perennial rivers that in turn provide drinking water, irrigation, and hydropower, conserving biodiversity, providing a rich base for high value agriculture, and elegant landscapes for sustainable tourism.

Any impact in the Himalayas would mean an effect on the life of millions of people not only of India but also of entire sub-continent. The Himalayan ecosystem is vulnerable to the impacts and consequences of various climatic and non-climatic factors. These include changes on account of natural causes, climate change resulting from anthropogenic emissions and developmental pathways.

In order to better understand the linkages between climate change and the Himalayan ecosystem for improved management of a fragile ecosystem, the Government of India has launched a National Mission for Sustaining the Himalayan Ecosystem (NMSHE) as part of National Action Plan on Climate Change (NAPCC). The Department of Science & Technology (DST) is coordinating and implementing the mission in collaboration with several other central ministries and the 12 Himalayan States.

I am pleased to learn that the DST in partnership with the 12 Himalayan States has been able to jointly produce a first of its kind vulnerability map and report for the entire Himalayan region. What is even more heartening is to see the concept of cooperative federalism in action wherein a common framework for assessing the climatic vulnerability was used by all the 12 States in partnership with the Central Government. Let me also take this opportunity to thank the Swiss Agency for Development and Cooperation for partnering with India for building resilience in the Himalayas.

I am confident that this document will be of immense value to researchers and policy makers for understanding the climate change vulnerabilities and devising and prioritizing adaptation strategies for the Himalayan region.

I take this opportunity to congratulate and thank all those who contributed to the preparation of the report.

Dr. Harsh Vardhan
Hon'ble Union Minister of Science & Technology,
Earth Sciences, Environment , Forest & Climate Change

Message

Climate change is a growing challenge to humanity and sustainable development through directly and indirectly impacts several socio-economic sectors like agriculture, water and human health. The Himalayan region is likely to be affected much more than plain areas as it is more fragile and sensitive to global and local anthropogenic changes. This puts on risk the livelihoods of the communities of the Himalayan region. In response to the serious threats posed by climate change to the development process and the limitations that Indian Himalayan Region is facing, the Government of India as part of its comprehensive National Action Plan on Climate Change has a dedicated mission for the Himalayan region, namely the National Mission for Sustaining the Himalayan Ecosystem (NMSHE), being coordinated by the Department of Science & Technology.

NMSHE emphasizes on creating knowledge on impacts of climate change and adaptation measures, supporting sub national actions for responding to climate change and strengthening multi-stakeholder platforms for science-policy-practice connect. NMSHE is in its progressive phase, and I am sure in the future, it will develop into a pool of knowledge on which future policy and programmes will rely.

This report presents the initiatives being undertaken under NMSHE to strengthen the capacities of Himalayan States on conducting a vulnerability and risk assessment which is a vital input towards adaptation planning. These initiatives were undertaken with the involvement of the State Climate Change Cells (SCCC) established at sub-national level in the IHR with support under NMSHE.

Bringing out knowledge products on the activities under NMSHE has been a constant effort by DST. In 2017, information booklets on the 'State Climate Change Cells/Centres for Indian Himalayan Region' and on the 'Thematic Task Forces for the Indian Himalayan region' were released during a side event hosted by DST on "Mountain Ecosystem" at 23rd conference of parties (COP-23), at Bonn, Germany.

I wish to compliment the efforts made by the Climate Change Programme, SPLICE Division, DST for bringing out this report on Capacity Building on Vulnerability and Risk Assessment in IHR.

Prof. Ashutosh Sharma
Secretary, Department of Science and Technology

Foreword

The Himalayas are highly vulnerable to climate change impacts. This high vulnerability stems from the peculiar high mountain topography and from the higher than global average warming in the mountains including in the Himalayas. At the same time the Himalayas are the store house of the third highest amount of frozen water on earth and are therefore critical for the water security of the region.

For the purpose of enhanced understanding of the Himalayan ecosystem in context of climate change the NMSHE has taken up several initiates in partnership with various Himalayan States and institutions. Under NMSHE, State Climate Cells/Centers have been established in 11 out of the 12 Himalayan States for building institutional capacity of Himalayan States in the area of climate change adaptation. These centers are working on areas of climate vulnerability assessment, raising public awareness and training and capacity building for climate change adaptation planning.

Task Forces have been established for research on themes such as Natural and Geological Wealth, Water, Ice, Snow including Glaciers, Forest Resources and Plant Diversity, Micro Flora and Fauna and Wildlife and Animal Population, Traditional Knowledge System, Himalayan Agriculture. The Himalayas are important from the cryosphere perspective and in order to better understand this lesser understood component the Inter-University Consortium on Cryosphere and Climate Change was established.

In the past (2013-15), the Indo Swiss Capacity Building Programme on Himalayan Glaciology was also organized to help build capacities of young glaciologists in India. The programme contributed in training 51 researchers from across the country on theoretical and practical aspects of glaciology.

The present report is the result of coordinated efforts which began in 2017 with the development of a Common Framework for Climate Vulnerability and Risk Assessment by the Indian Institute of Science (IISc). Over 2018 the Indian Institutes of Technology at Guwahati and Mandi with technical backing from IISc undertook a series of workshops with the Himalayan States to bring out the results which are captured in this report.

IHCAP a project of SDC has been a consistent partner with the DST providing technical and knowledge support for implementing the NMSHE, including the activities which have resulted in the present report.

I sincerely hope that the report will be useful to researchers and policy makers in developing better understanding of vulnerability in the Indian Himalayan Region.

Dr. Akhilesh Gupta,
Head / Scientist-G
Climate Change Programme (CCP)
Strategic Programmes Large Initiatives and Coordinated Action Enabler- (SPLICE) Division
Department of Science and Technology

Preface

Adaptation to climate change has become imperative in the Indian Himalayan Region (IHR). Concerns about the growing impacts of climate change call for immediate response measures to reduce the vulnerabilities in the region. The Swiss Agency for Development and Cooperation (SDC), through its project, Indian Himalayas Climate Adaptation Programme (IHCAP), has been working towards strengthening the resilience of vulnerable communities in the Himalayas and towards enhancing the knowledge and capacities of research institutions, communities and decision-makers. IHCAP is a bilateral programme between the Government of Switzerland and Government of India to support the implementation of the National Mission for Sustaining the Himalayan Ecosystem (NMSHE). The Department of Science and Technology (DST) of the Government of India is the coordinating agency for implementing the NMSHE.

Climate change is resulting in new threats and uncertainties undermining the socio-economic development in IHR. A comprehensive understanding of the key risks and vulnerabilities based on robust research is a pre-requisite for planning for adaptation. While there have been some vulnerability assessments carried out within Himalayan States there has been a lack of consistency in terms of the framework used for these studies. The multiplicity of challenges in IHR at spatial level calls for the need of a coordinated and integrated approach for adaptation planning.

Under IHCAP, SDC supported the development of a common framework for vulnerability and risk assessment for IHR. This common framework has been applied to understand the vulnerability profile of the entire Himalayan region. Representatives of all 12 State Governments in IHR were brought together through a series of workshops to develop a uniform understanding about vulnerability and risk, availability and requirement of datasets and to map the vulnerability. This initiative contributes towards the objectives of NMSHE for capacity building of Himalayan States to carry out such assessments.

Through IHCAP, it has been our constant endeavor to transfer the knowledge and expertise from Switzerland on climate change adaptation in mountain regions. SDC looks forward to enhance the bilateral cooperation with the Government of India to achieve the common goal of facilitating climate change adaptation in the Himalaya Region.

Ms. Marylaure Crettaz
Head of Cooperation
Swiss Agency for Development and Cooperation (SDC)
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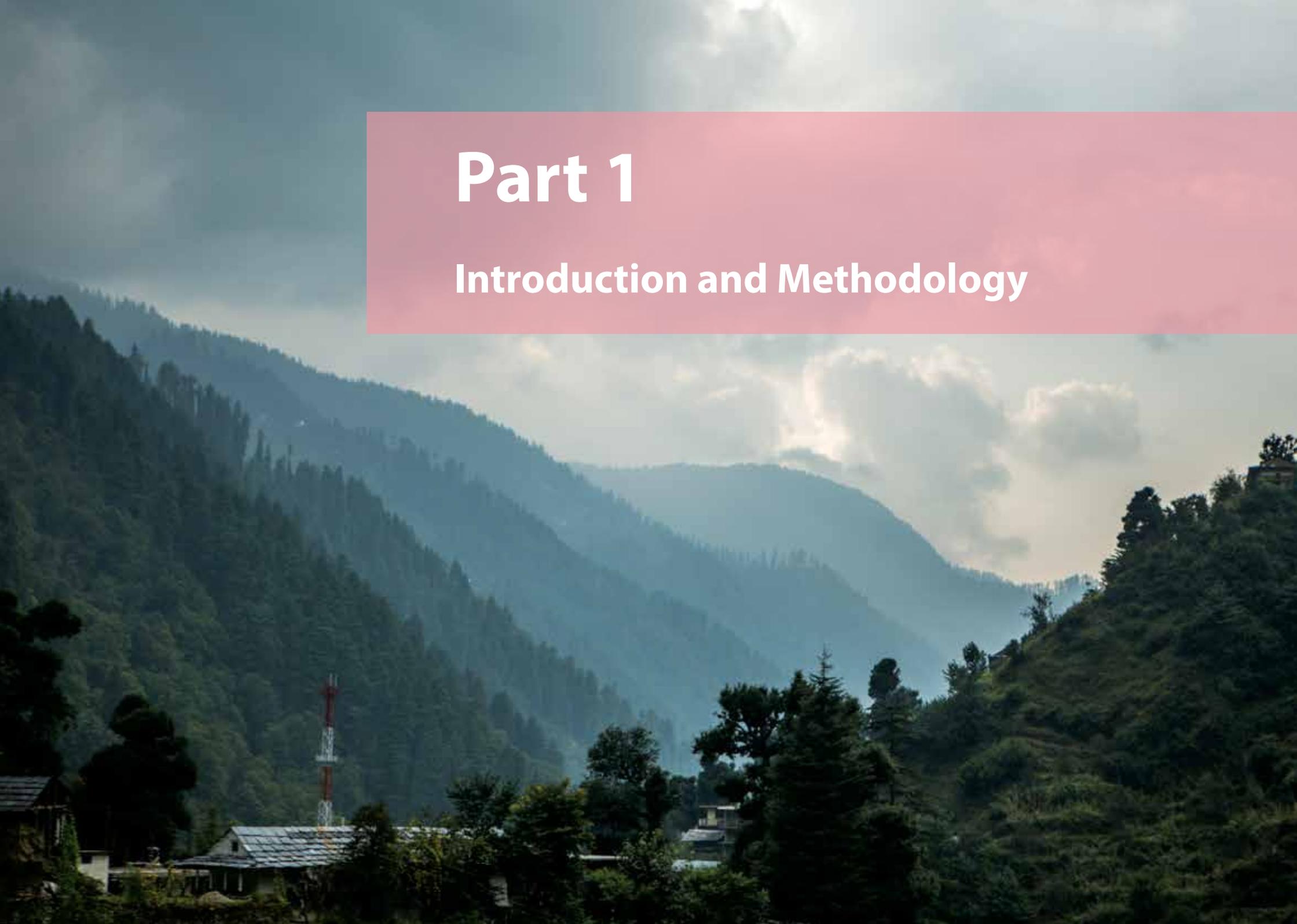Government of Karnataka

Acknowledgement

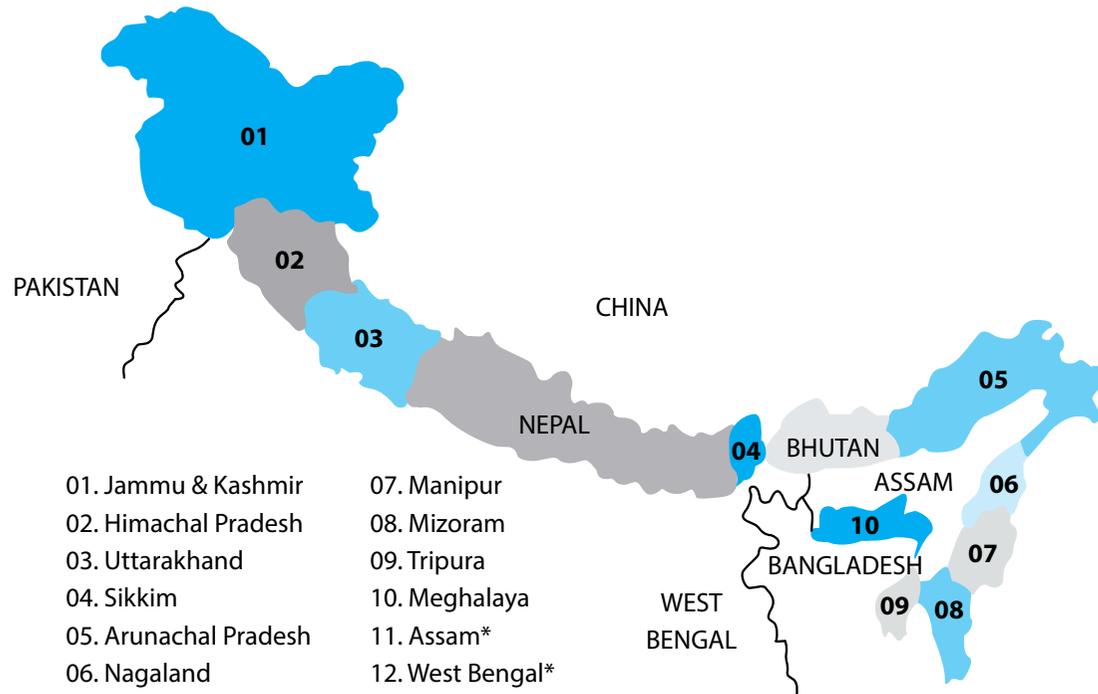# Part 1

Introduction and Methodology

1. Introduction

Climate change is already occurring and impacting natural ecosystems and human societies. By introducing relatively large uncertainties, climate change and climate variability are adversely impacting both biophysical systems (mountains, rivers, forests, wetlands, etc.) and socio-economic systems (hill communities, coastal communities, agriculture, animal husbandry, etc.). Based on this understanding, the Government of India launched the National Mission for Sustaining the Himalayan Ecosystem (NMSHE), which is being implemented by the Department of Science and Technology (DST) through a project of the Swiss Agency for Development and Cooperation (SDC) – the Indian Himalayas Climate Adaptation Programme (IHCAP). As part of this effort, the project titled 'Capacity Building on Climate Change Vulnerability Assessment in the Indian Himalayan Region' aims to bring together various state departments working with the state governments in the Indian Himalayan Region (IHR) through a series of workshops. The objective is to develop a uniform understanding of vulnerability, assess vulnerability based on a common methodological framework and map the same. The focus is not only on building the capacity of individual line departments working with the state governments, but also on fostering the adoption of coordinated and integrated approach among the 12 states in the IHR. Enhanced cooperation among the states of the region will help in improving their understanding and assessment of vulnerability, adaptive capacity and resilience to climate change. Indian Institute of Technology Guwahati (IIT Guwahati) and Indian Institute of Technology Mandi (IIT Mandi) are the nodal

Figure 1: The Indian Himalayan Region (Source: National Mission on Himalayan Studies)

01. Jammu & Kashmir	07. Manipur
02. Himachal Pradesh	08. Mizoram
03. Uttarakhand	09. Tripura
04. Sikkim	10. Meghalaya
05. Arunachal Pradesh	11. Assam*
06. Nagaland	12. West Bengal*

* Only the hill districts

bodies identified for the implementation of the project, with technical support being provided by Indian Institute of Science Bangalore (IISc).

2. Need for vulnerability assessment in the IHR

IHR is the section of the Himalayas within India, spanning the states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, hilly states of West Bengal, as well as the north-eastern states of Sikkim, Arunachal Pradesh, hilly states of Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura (Figure 1).

The Himalayan ecosystem is vital to the ecological security of the Indian landmass. It plays a crucial role in providing forest cover; feeding perennial rivers that are the source of drinking water, irrigation, and hydropower; conserving

biodiversity; providing a rich base for high-value agriculture, and spectacular landscapes for sustainable tourism. According to the Intergovernmental Panel on Climate Change (IPCC) 2014 report, changes and variability in temperature and rainfall trends are already affecting both the biophysical and socio-economic systems. Under the future climate change scenarios, impacts of climate change are projected to exacerbate, thereby, increasing the vulnerability of biophysical and socio-economic systems. 'Vulnerability,' in this context, is defined as the 'propensity or predisposition of a system to be adversely affected' (IPCC 2014). It is an internal property of a system and includes 'sensitivity,' i.e., susceptibility to harm and 'lack of adaptive capacity,' i.e., 'lack of capacity to cope and adapt'. Mountains are one of the most fragile environments on Earth, and preliminary studies show that the Himalayan region will experience higher levels of climate change and its associated impacts on both the biophysical and socio-economic systems will be severe (Karma et al., 2010). The states in IHR are also characterized by land degradation, deforestation, proliferation of invasive species, loss of biodiversity, landslides, invasion of commercial crops, low productive agriculture, migration, etc. In addition, due to varying altitudes, the region experiences diverse weather or climatic conditions, extreme weather events, floods and droughts, along with high current climate variability. These climatic and non-climatic stresses make IHR ecosystems and communities highly vulnerable to both the current climate variability and the future climate change. For instance, the region has numerous glaciers, which in turn, give rise to a number of rivers. But with an increase in temperature, the area covered by permafrost and glaciers is gradually decreasing (Karma et al., 2010).

The region is also experiencing variability in monsoon rainfall, thereby leading to higher frequency of extreme events. This, in turn, is affecting the flow and flood regimes of the mountain streams along with the agriculture system, which is the primary source of livelihood for the hill communities. Himalayan communities have a large dependency on climate sensitive sectors such as rain-fed agriculture, and have a fragile mountain ecosystem. The communities have limited livelihood options and experience higher marginalization because physical infrastructure (road and transport, markets, power supply and communication) is limited and there is a high dependence on natural resources. Under changing and variable climate, such constraints are likely to add to the vulnerability of Himalayan communities. Therefore, it is vital to conduct vulnerability assessment for IHR and its communities. Vulnerability assessment can help in the identification of the drivers of vulnerability, and assist in designing adaptation interventions specific to the area.

3. Approach to capacity building for vulnerability assessment in the IHR

As climate change poses unprecedented challenges on multiple sectors, it is important to develop strategies taking into consideration the vulnerability of all these sectors. Within the federal structure of India, one of the ways to do so is by building capacity of various concerned state departments to assess vulnerability so that there is an understanding of 'who is vulnerable? What makes them vulnerable and why?' This can be achieved by bringing together representatives from different state departments through a series of workshops to develop a uniform understanding of vulnerability, assess vulnerability based on a common methodological framework and map the same. It will also allow the states to have better visual presentations and understanding of the vulnerabilities and the drivers of vulnerability. This will enable decision-makers to see where resources (e.g. adaptation funds) can

Figure 2: The approach followed under the project towards state-level capacity building

Planning meeting in Bangalore

Inception meeting | Vulnerability assessment manual and the format of the workshops | Need Assessment | Vulnerability assessment - *What, Why and How* | Methodology | Hands-on training with the data analysis and developing maps | Dissemination | Disseminate the outcomes of the project

to be allocated for protection of these vulnerable areas, and how to adapt to any future climate induced disaster (Edwards, et al., 2007).

Figure 2 represents the approach that has been followed under this project in order to bring together representatives from different state departments and capacity building for vulnerability assessment.

3.1 Inception Meeting

The following points were discussed during the inception meeting, which was held on 9 February 2018 at IISc Bangalore.

- Discussion about the methodology manual
  - Common methodology and common framework
  - Approach – Current vs future vulnerability, identifying the tier, combined assessment
- Issues to be addressed during the workshops
  - Selection of the indicators, use of the vulnerability assessment for adaptation, who will be the stakeholders and scale and objective of the vulnerability assessment
- Expected outcome
  - Development of state and district-level vulnerability maps
  - Sectoral and block-level assessments

3.2 Need Assessment Workshop

A series of Need Assessment Workshops were carried out at IIT Guwahati (March 2018) and IIT Mandi (April 2018)

to introduce the common methodological framework for vulnerability assessment to the different state representatives of IHR. It helped in the assessment of the requirements of the states, their current capacities and data availability. During these workshops, participants were provided with an overview of the evolution of vulnerability concept and framework in the context of vulnerability assessment and adaptation to climate change in IHR. An elaborated discussion took place on the goals for assessment of vulnerability, the approach, methods and application to reduce vulnerability citing important examples for the respective participating IHR states. Discussions on sources of data and methods of data collection took place among the participants. After completion of the Need Assessment workshops, a list of twenty indicators was finalized by the resource persons. The participants were given a period of five months to identify and compile data for the selected indicators. This data served as the basis for further proceedings during the methodology workshop.

3.3 Methodology Workshop

The methodology workshop was organized at IIT Guwahati from 10 to 14 September 2018. A total of 88 representatives from the 12 states of IHR had participated. During the workshop, methodological steps were demonstrated to provide hands-on training to the participants with the data that they had shared. Through this workshop, emphasis was laid on the process of analysis using the common methodological framework and visual representation of the key results through maps and other forms. The aim was to help in the identification of drivers of vulnerability in their states, and the most vulnerable areas that need to be prioritized.

The objectives for conducting the methodology workshop were as follows:

- Applying a common methodology for vulnerability assessment and vulnerability maps for the states of IHR
- Hands-on training of the participants in carrying out the vulnerability assessment and developing the vulnerability maps
- Identifying a set of common indicators for a state-level vulnerability assessment and mapping in the pan IHR
- Identifying a set of common indicators for district-level vulnerability assessment and mapping
- Discussion on and finalization of the weights to be given to each of the indicators and finalization of the same
- States carrying out a draft district-level vulnerability assessment and presenting the results in a common format and receiving feedback
- Assisting states to carry out further micro-level vulnerability assessments for vulnerable sectors

The methodology workshop was attended by the representatives from State Climate Cell and the state departments of Agriculture, Horticulture, Soil conservation, Water, Environment, Forestry and biodiversity, Public Health Engineering, Biotechnology, Rural management and development, Disaster Management, Environmental Information System (ENVIS), Department of Science and Technology and Higher Education. It also included representatives from the academic institutions of Tripura and Arunachal Pradesh.

4. Methodology: An indicator-based approach

The project used an indicator-based approach to assess the vulnerability of IHR. The vulnerability assessment includes 12 steps, as shown in Figure 3.

Each of the steps mentioned in Figure 3 have been discussed in detail below:

Step 1: Scoping of vulnerability assessment

The scope and objective is to identify and rank the vulnerable states in the IHR and their respective districts/blocks. The most vulnerable districts need to be identified for prioritisation at the time of policy making for formulating adaptation planning and creating awareness. The stakeholders here are the policymakers and the respective authorities.

Step 2: Selection of type of vulnerability assessment

Vulnerability assessment studies can be of four types:

1. Biophysical vulnerability assessment
2. Socio-economic vulnerability assessment which includes institutional vulnerabilities
3. Integrated vulnerability assessment in which both biophysical and socio-economic/institutional vulnerabilities are considered
4. Hazard-specific vulnerability assessment

For the present assessment, the third type of vulnerability assessment (integrated vulnerability assessment approach) is chosen.

Step 3: Selection of Tier methods

A vulnerability assessment can be carried out simply by utilizing secondary and/or primary data sources, GIS techniques and climate model output. Based on the type of data used, three types of tiers have been identified:

(a) Tier 1 is a top-down approach largely based on secondary data
(b) Tier 2 involves a combination of top-down and bottom-up data
(c) Tier 3 involves largely bottom-up approach, along with spatial remote sensing and GIS information/data

Here, Tier 1 is chosen considering the availability of necessary secondary data.

Step 4: Selection of Spatial scale and period for vulnerability assessment

Vulnerability assessment could be carried out at a different spatial scale, i.e., micro-scale (block-level) or macro-scale (state-level). It can also be carried out for different time periods, i.e., short-term (2030s), mid-term (2050s), or long-term (2100).

The present assessment is done at a macro-scale for short-term, i.e., district-level for 2030s. This was done so that the vulnerability amongst the districts can be compared across the state.

Step 5: Identification, definition and selection of indicators for vulnerability assessment

This is one of the most crucial steps in vulnerability 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 'sensitivity' or 'adaptive capacity'), nature of indicator ('biophysical' or 'socio-economic', etc.). We can select the indicators through an expert consultation. For instance, the following indicators are classified as:

(a) Percentage of area with slope > 30% is a biophysical indicator and captures the sensitivity aspects of vulnerability
(b) Per capita income is the socio-economic indicator and captures adaptive capacity

Step 6: Quantification and measurement of indicators

We need data in quantifiable units to apply mathematical operations over it.

Step 7: Normalization of indicators

Different indicators are measured in different units (e.g., area under forest in terms of sq. km, MGNREGA in terms of days/year, etc.). As the VA is about ranking, the VA indicators have to be brought in common units. In order to make the indicators unit-free, we normalize each indicator. The normalization process varies, depending on the nature of relationship of that particular indicator with

Figure 3: The 12 steps of vulnerability assessment

Step 1: Scoping and objectives of vulnerability assessment

Step 2: Selection of type of vulnerability assessment

Step 3: Selection of tier method

Step 4: Selection of sector, spatial scale, community/system and period of assessment

Step 5: Identification, selection and defining of indicators for vulnerability assessment

Step 6: Quantification and measurement of indicators

Step 7: Normalisation of indicators

Step 8: Assigning weights to the indicators

Step 9: Aggregation of indicators and development of vulnerability index

Step 10: Representation of vulnerability: spatial maps, charts and tables of vulnerability profiles and indices

Step 11: Vulnerability ranking of sectors, regions, communities, cropping systems, river basins, watersheds, forest types, etc.

Step 12: Identification of drivers of vulnerability for adaptation planning

the vulnerability (positive or negative relationship). The following two formulae are explained:

• Case I: Positive relationship with vulnerability

$$\text{Normalized Value} = \frac{\text{Actual Indicator Value - Minimum Indicator Value}}{\text{Maximum Indicator Value - Minimum Indicator Value}}$$

• Case II: Negative relationship with vulnerability

$$\text{Normalized Value} = \frac{\text{Maximum Indicator Value - Actual Indicator Value}}{\text{Maximum Indicator Value - Minimum Indicator Value}}$$

Step 8: Assigning weights to indicators

Weights are assigned to each indicator according to their importance in determining vulnerability of a system. To get reliable result, we need to assign appropriate weight to each indicator. Thorough discussion and consultation with the experts about the nature and importance of each indicator is needed for that. While assigning the weight, it has to be ensured that the weight or proportion assigned to all the indicators add up to 100.

Step 9: Aggregation of indicators and development of vulnerability index

Aggregation of different indicators with weight is necessary to obtain a composite aggregated index or value. For this, the weight were multiplied with the normalised indicator value and aggregated. Normalised and weight values of indicators were aggregated to obtain the overall vulnerability index value for each district in the state.

Step 10: Representation of vulnerability, spatial maps, charts and tables of vulnerability profiles and index

The obtained vulnerability index value can be represented with the help of tables, charts and maps.

- A Vulnerability Index (VI) is a 'metric that characterizes the vulnerability of a system'
- Vulnerability index values lie between 0 and 1, where 0 indicates least vulnerability and 1 indicates most vulnerability

- Arrangement of the assessed VI values in decreasing or increasing order allows for ranking of units of study

The vulnerability index value only provides a sense of quantified status of vulnerability and is largely conceptual in its utility. The value does not have any stand-alone practical significance.

Step 11: Vulnerability ranking of the spatial units

With respect to their respective level/degree of vulnerability, all spatial units are categorized. We here have chosen three categories for distinguishing - low, medium and high vulnerability.

Step 12: Identification of drivers of vulnerability for adaptation planning

Identifying the drivers of vulnerability is crucial for adaptation planning. It enables the authority to chalk out efficient and effective plans to reduce vulnerability.

Part 2

Vulnerability Profiles of the States in the IHR

5. State-level vulnerability assessment in the IHR

Based on a Tier 1 methodology as stated in Section 4, a state-level vulnerability assessment has been carried out for the IHR. It followed an indicator-based approach and used secondary sources of information to quantify the indicators selected. The list of selected indicators along with the rationale for their selection is provided below.

5.1 Selection of indicators and rationale

The indicators for the state-level vulnerability assessment of the IHR were selected through expert consultation. First, four broad indicators were selected: 1) Socio-economic, demographic status and health, 2) sensitivity of agricultural production, 3) forest dependent livelihoods and 4) access to information services and infrastructure. Each of these broad indicators have two to six sub-indicators. The expert consultation led to the selection of indicators that comprehensively represent the inherent social and biophysical systems of the 12 IHR states. The list of indicators, sub-indicators, the rationale for their selection, their functional relationship with vulnerability and the source of data used to quantify them are provided in Table A1.

5.2 Normalization and Weights assigned

This section presents: a) normalization of quantified indicators; and b) weights assigned to selected indicators. These two steps are essential to arrive at a meaningful vulnerability index value.

a) **Normalization of indicator values:** As the indicators selected are quantified in different units, they need to be normalized to aggregate them. The actual sub-indicator values used and their normalised scores for each of the four indicators for all the 12 study states are presented below. Normalisation is done depending on the sub-indicators' functional relationship with vulnerability (either positive or negative) and corresponding formulae are used as presented in step 7 of Section 4.

i) Socio-economic, demographic status and health: This indicator is composed of six sub-indicators that aim to comprehensively represent the socio-economic, demographic and health status of the 12 IHR states. The six indicators are population density, percentage marginal farmers, livestock to human ratio, per capita income, number of primary healthcare centers per 100,000 households and percentage of women in the overall workforce. Table A2 in the annexure presents the actual value and normalised score for each of the sub-indicators for each of the 12 IHR states.

ii) Sensitivity of agricultural production is captured by considering three sub-indicators - percentage area under irrigation, yield variability and percentage area under horticulture crops. Table A3 presents the actual value of each of the sub-indicators and its corresponding normalised score for each of the 12 IHR states.

iii) Forest-dependent livelihoods are represented by percentage area under open forests and area under forests per 1,000 households. It tries to capture the extent of degradation of forest resources in each state and the competition for this resource. Table A4 presents the actual value of these two sub-indicators and their corresponding normalised scores for each of the 12 IHR states.

iv) Access to information services and infrastructure: This indicator is represented by five sub-indicators, namely, percentage crop area insured under all Insurance Schemes, percentage farmers taking loans, average person days per household under MGNREGA, average percentage area with >30% slope, and road density. Table A5 presents the actual value of these sub-indicators and their corresponding normalised scores for each of the 12 IHR states.

b) **Assigning weights:** As the objective of this vulnerability assessment is to understand the relative ranking of the states in IHR with respect to their vulnerability and to understand the drivers of vulnerability that will help the states to prioritize the adaptation interventions, a Tier 1 method of assigning of weights by stakeholders (employees of State Climate Change Cells) was adopted. The weights were assigned first to the four main indicators and then to the sub-indicators of each indicator. Each state provided weights in this manner and an average of their weights were considered for this state-level assessment.

By multiplying the averaged weights assigned to the sub-indicators with that of the weights assigned to their respective indicator, the weight to be multiplied with the normalized score of each indicator can be

derived. Vulnerability Index is constructed by simply taking a summation of all the normalized scores of the sub-indicators multiplied by their respective weights. Weights assigned to the indicators and sub-indicators are presented in Table A6.

6. State-level vulnerability index

By calculating the sum of normalised scores multiplied with the weights of each of the sub-indicators representing the four indicators, an index value for the four indicators can be derived. This can be used to identify drivers of vulnerability. A composite vulnerability index value can also be derived by taking a simple sum of all the 16 sub-indicators. Based on the composite vulnerability index values, the states have been ranked from highest

vulnerability to lowest vulnerability. Table A7 provides the vulnerability index values for the four main indicators, the composite vulnerability index values for the IHR states and their corresponding vulnerability ranks. Based on this assessment, the vulnerability index is found to be the highest for Assam (0.72) and Mizoram (0.71), followed by Jammu and Kashmir (0.62), Manipur (0.59), Meghalaya and West Bengal (both 0.58), Nagaland (0.57), Himachal Pradesh and Tripura (0.51 both), Arunachal Pradesh (0.47) and Uttarakhand (0.45). Sikkim is the least vulnerable state with the index being 0.42.

It is important to note, however, that vulnerability is a relative measure, which means that this assessment does not portray Sikkim, Uttarakhand or Arunachal Pradesh as having a low vulnerability in an absolute sense. These

states are least vulnerable relative to the other IHR states, and also have several inherent drivers of vulnerability that need to be addressed. These drivers have been discussed in the Section 6.

The composite vulnerability index values may also be multiplied by five, which would distribute the states on a vulnerability scale of very low, low, moderate, high and very high vulnerability. When this was done, Sikkim and Uttarakhand were ranked 2 (low vulnerability); Arunachal Pradesh, Tripura, Himachal Pradesh, Nagaland, West Bengal, Meghalaya, Manipur and Jammu and Kashmir were ranked 3 (moderate vulnerability); and Mizoram and Assam were ranked 4 (high vulnerability) (Figure 4 and 5). None of the states were ranked as very low or very highly vulnerable.

6.1 Sources of vulnerability

This section looks at the major drivers of vulnerability in all the 12 IHR states which are presented in Table 1. It is important to note that the highest weights assigned to sub-indicators are per capita income, percentage area irrigated, area under forests per 1,000 households and percentage area under open forests. Thus, states having low per capita income, low area under irrigation and low area under forests per 1,000 households and high area under open forests will receive a high vulnerability score. For example, Assam has the least area under irrigation, least forest area available per 1,000 rural households and the second lowest per capita income among the other IHR states, and thus scores the highest vulnerability score.
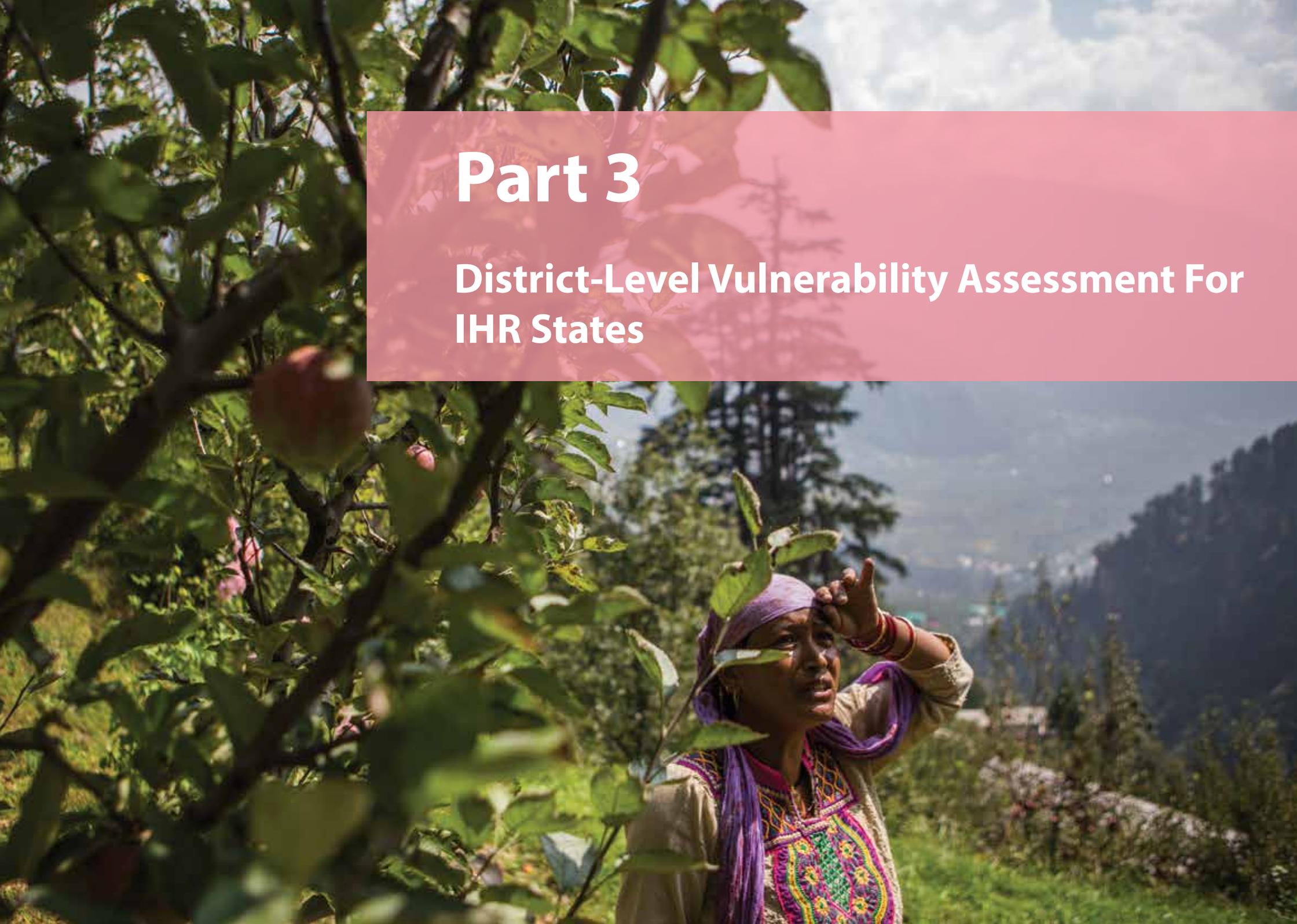
Figure 4: Vulnerability index of IHR States

Figure 5: Vulnerability index of IHR States

Table 1: Drivers of vulnerability in 12 IHR States

Rank	State	Drivers of Vulnerability
1	Assam	The normalized values of all sub-indicators (Table A2-A6) show that Assam, as a state, falls in the higher side of vulnerability index. Other than three sub-indicators, namely, population density, yield variability of food grains and average percentage area with slope greater than 30 degree, the normalized values of all other indicators are above 0.5. Among them, six major drivers of vulnerability are- least area under irrigation, least forest area available per 1,000 rural households, and least number of farmers taking loans as compared to other states. It also has the second lowest per capita income, low percentage area covered under crop insurance and low MGNREGA participation. In fact, other than population density, this state has relatively high vulnerability with respect to all sub-indicators under socio-economic, demographic and health indicator. Similarly, since Assam has more flat lands relative to other states, which suggests lower sensitivity to natural disaster, lack of access to information and infrastructure puts this state into a situation where it would be extremely difficult to cope with any climate variability.
2	Mizoram	The state has very high sensitivity of agriculture sector along with poor connectivity, access to information and infrastructure. The state has seven major drivers of vulnerability - highest yield variability, no area under crop insurance, largest area under open forests, and largest area under slope >30% as compared to other states. It also has the second lowest percentage area under irrigation and the third lowest road density among the 12 states. A glance at the normalized values of the sub-indicators show that agricultural sensitivity and lack of access are two major drivers leading to lack of adaptive capacity of the state.
3	Jammu and Kashmir	Several drivers of vulnerability are evident for the state of J&K. These include, in the order of significance, least road density, no area under crop insurance, low area under forests per 1,000 rural households, high percentage of marginal farmers, low percentage area under horticulture crops, low livestock to human ratio and low percentage of women in the overall workforce. This implies that four out of six sub-indicators under the socio-economic indicator, one out of three under the agricultural sensitivity indicator, one out of two forest-related sub-indicators and all access-related sub-indicators barring the average slope exhibit high degree of sensitivity and lack of adaptive capacity of the state. In fact, this state is in the most difficult situation with respect to two important factors that increase the adaptive capacity - road density and crop insurance. Similar to Assam, one may observe that the states ranking higher in the order with respect to vulnerability are generally lagging in terms of most of the sub-indicators considered. So, similar to Assam, in this state also, the vulnerability is rather composite in nature and not explicitly sector specific.
4	Manipur	Manipur has three major drivers of vulnerability - lowest per capita income, low percentage of farmers taking loans and low area under forests per 1,000 households. Interestingly, other than income, and the availability of healthcare facilities to some extent, the performance of this state with respect to other socio-economic, demographic and health indicators is relatively better than the other states. However, the high vulnerability of the state arises from other indicators as well.
5	Meghalaya	The vulnerability of this state arises from the socio-economic indicators and lack of access to information and infrastructure. The state has four major drivers of vulnerability - very low area under crop insurance, low per capita income, low area under forests per 1,000 households and low percentage of farmers taking loans.
6	West Bengal	West Bengal stands almost at the middle of the ranking. This state has the highest population density, least number of primary healthcare centres per 100,000 households, least percentage of women in the overall workforce, second lowest area under forests, high percentage of marginal farmers and low MGNREGA participation as compared to other states. Given the highest/close to highest normalized values of almost all socio-economic, demographic and health indicators, one would actually expect the state to have higher vulnerability ranking than it has been found to be. However, extremely resilient agricultural sector with maximum irrigation facilities and horticulture, along with access to information services and infrastructure helped the state to have relatively higher adaptive capacity.

7	Nagaland	No area under crop insurance, low percentage of farmers taking loans and low area under forests per 1,000 rural households are the three major drivers of vulnerability in the state. However, this state has high per capita income, low population density, lowest prevalence of marginal farmers and highest women participation in the labour force that make the state relatively resilient.
8	Himachal Pradesh	Himachal Pradesh is an interesting case to observe. This is one of the rare states that is neither the best, nor the worst with respect to any of the sub-indicators in any of the category and the overall vulnerability is at the lower side. Relatively high vulnerability arising out of lack of irrigation and horticulture has been compensated by the fact that the yield variability of foodgrains is much lower in the state, leading to not so high sensitivity of agricultural production. Similarly, while per household availability of forest land is relatively lower in the state, there is no predominance of open forest. While the first lowers the adaptive capacity, the second leads to lower sensitivity, cancelling each other in a way. The state is not doing particularly well in terms of creation of its adaptive capacity through access to information and infrastructure, and it needs to be observed that the weight assigned to this indicator is quite low (19%) to determine the magnitude of the VI alone. Coming to the sub-indicators under the category of socio-economic, demographic and health (weight = 34.5%), the performance of this state is consistently better with very low population density, availability of healthcare centres and very high participation of women in the labour force. Only low livestock to human ratio and the presence of marginal farmers are the two major drivers of vulnerability in the socio-economic sector.
9	Tripura	Although Tripura has the highest percentage under marginal farmers, low per capita income, low percentage area under forests and crop insurance, it has the highest road density, lowest area under slope >30%, highest MGNREGA participation and lowest yield variability in comparison to other states.
10	Arunachal Pradesh	One would expect Arunachal Pradesh to appear more vulnerable when compared to other states in the IHR owing to the fact that it has a large area under slope >30%, low road density, least livestock to human ratio, lowest percentage of area under horticulture crops, least participation in MGNREGA, no crop area under insurance and low percentage of farmers taking loans. However, similar to Himachal Pradesh, most of the high vulnerability sub-indicators in this state fall under the indicator access to information services and infrastructure. This indicator, in itself, carries only 19% of the weights. On the other hand, socio-economic, demographic structure and health, as an indicator, carries a much higher weight (34.5%). And Arunachal Pradesh has been found to be doing relatively well with regard to the sub-indicators under this indicator. For example, this state has the least population density and the highest number of available healthcare facilities among all the 12 states. It also has a relatively low percentage of marginal farmers and high women participation in labour force that reduces the vulnerability of the state. However, the per capita income is not among the best. Besides, the state has the largest area under forests per 1,000 households and moderate area under open forests as compared to other states. Low vulnerability with respect to socio-economic, demographic and health indicators, along with these other sub-indicators highlight the state's adaptive capacity, and offset the many sensitivities giving it a lower vulnerability index value.
11	Uttarakhand	Only one major driver of vulnerability for the state of Uttarakhand - low area under forests per 1,000 households.
12	Sikkim	Although Sikkim has three major drivers of vulnerability - low area under forests per 1,000 households, low percentage area covered by insurance and low percentage of farmers taking loans, it has the highest per capita income and the lowest area under open forests, which relatively lowers vulnerability of the state when compared to other states in the IHR.

Part 3

District-Level Vulnerability Assessment For IHR States

7. District-level vulnerability assessment for IHR states

The district-level vulnerability assessment was carried out by the representatives of the respective IHR states. Weights were assigned to the selected indicators in order to carry out the assessments. While detailed state-level reports are being prepared, in this section, a brief summary of the district vulnerability assessment has been provided. During the Methodology Workshop, the

vulnerability indicators were chosen for assessment of all 12 IHR states. They themselves have assigned these weights after significant deliberation. Table 2 provides the weights assigned by each state to the indicators. Table 3 provides rationale (of choosing the particular indicator) and functional relationship of the indicators with vulnerability. Similar to the state-level exercise, a plus sign implies positive relation with vulnerability and negative implies the opposite.

Table 2: Weights assigned by states to the selected indicators

State	% area under slope>30°	% area under forest cover	Yield variability of food grains	Population density	Female literacy rate	Health indicator@	Per capita income/ BPL	Average man-days under MGNREGA
Arunachal Pradesh*	10	30	20	3	15	8	12	2
Assam	8	12	20	5	10	9	25	11
Himachal Pradesh#	16	4	13	14	4	9	4	3
Jammu & Kashmir	15	24	12	8	6	5	20	10
Manipur	6	20	28	7	10	8	18	3
Meghalaya	20	18	30	1	0.5	3.5	17	10
Mizoram	25	25	10	5	5	10	5	15
Nagaland	15	35	22	6	4	3	10	5
Sikkim	23	10	5	13	12	8	14	15
Tripura	7	20	28	16	6	5	14	4
Uttarakhand	24	8	22	5	8	5	20	8
West Bengal**	17	15	15	15	10	10	-	18

@ Infant mortality rate/No of doctors (State marked with *)/No. of Child Deaths (under 5 years of age) (states marked with **)
# Himachal Pradesh has considered 6 other indicators (weights are in parenthesis): % area without irrigation (19); % area under open forest cover (3); Overall literacy rate (41), % agricultural labour (2); Early warning system (2) and % area under fruit crop (3)

Table 3: Selected Indicators for vulnerability assessment

Sl. No.	Indicators	Rationale and functional relationship of indicators with vulnerability	Data Sources
1	% area under slope >30degree (+)	Steep topographical feature implies lack of availability of flat land and difficulty in access; likely to be adversely affected during floods, landslide, cloudburst, etc. and increases sensitivity.	Manipur State Remote Sensing Data (2018), Survey of India, Mizoram Remote Sensing Application Centre (2011-2012), SRTM (NRC), SRTM DEM, Sikkim Land Use Land Cover Data (2011), Tripura Space Application Centre, ASTER GDEM 30m, CARTO DEM 10m NRSC, ASTER DEM (30m)
2	% area under forest cover (-)	Forests provide safeguard ecological processes, provide biophysical stability and alternate livelihood options through extraction of fodder, fuelwood, and NTFPs. It enhances adaptive capacity.	ISFR (2017), FSI Report (2017), FSI Report (2016), Government of Sikkim State Forest Report (2005), Department of Agriculture (Government of Tripura), LISS IV, CARTOSAT PAN 2.5m, Assam State Forest Report (2013)
3	Yield variability of food grains (+)	High variability in yield indicates fluctuations in agro-climatic conditions over time. Agriculture sector has high contribution to the State Domestic Products and employment for the states in IHR. High yield variability reflects lack of adaptive capacity.	Government of India (2015, 2018), Indian Stats Data, Department of Agriculture (Government of Nagaland), District Statistical Handbook (Government of West Bengal), Agriculture Statistics (2007-2017)
4	Population density (+)	Pressure on available natural resources increases sensitivity.	Government of India (2011), Census 2011, Statistical Abstract of Mizoram (2017), Directorate of Economics and Statistics (Government of Tripura)
5	Female Literacy Rate (-)	Educated individuals and societies (especially with high female literacy) have better preparedness and response to disasters, suffer lower negative impacts, and are able to recover faster and hence have higher adaptive capacity.	Government of India (2011), Census 2011, Statistical Abstract of Mizoram (2017), Directorate of Economics and Statistics (Government of Tripura), Primary Census Abstract (2011), Statistical Handbook of Assam (2016)
6	Infant Mortality Rate[1] (+)	Infant Mortality Rate is an indicator of the overall state of the public health, access to improved water, sanitation and medical infrastructure. Higher value implies lack of adaptive capacity.	Census 2011, NHSRC 2011, NHM-HMIS (2015-16), NHM Department of Health and Family Welfare (Government of Nagaland, 2017-18), Jammu and Kashmir State NHM Report, 2014 DESME (2005), Directorate of Family Welfare and Primitive Medicine (Government of Tripura), Department of Health (Himachal Pradesh, 2011), Annual Health Survey (Uttarakhand, 2011-12) **No. of child deaths** (up to 5 years) - GOWB District Statistical Handbook (2010-2011) **No. of doctors**- NRHM (2017)
7	Below Poverty Line (BPL) House- holds (+)	Higher percentage of BPL indicates lesser adaptive capacity.	Government of India (2011), State Economic Survey Report (2017), HDR (Meghalaya, 2008), Economics and Statistical Department (Government of Mizoram, 2015-16), AAY Scheme, Census 2011, Department of Food, Civil Supplies and Consumer Affairs (Government of Tripura)
	Per capita Income[2]	A direct indicator representing the inherent sensitivity of people in a region.	Digest of Statistics, J&K 2014, DES Uttarakhand, Economics and Statistics (Himachal Pradesh)
8	Average man-days under MGNREGA (-)	Provides alternate sources of income and enhances adaptive capacity.	Government of India (2018), MGNREGA- DMU report, MGNREGA website, Ministry of RD, GoI, Rural Development (Uttarakhand, 2015-16)

[1] In case of unavailability of infant mortality rate data, data of no. of child deaths (up to 5 years) (by West Bengal) and no. of doctors (by Arunachal Pradesh) has been considered.
[2] The indicator has been used by all the states.

Two types of district-level vulnerability maps were created by the states: 1) Vulnerability ranking of different districts of the state and 2) Categorising the districts into three different 'vulnerability categories': high, moderate and low.

Figure 6: Vulnerability ranking map of Arunachal Pradesh
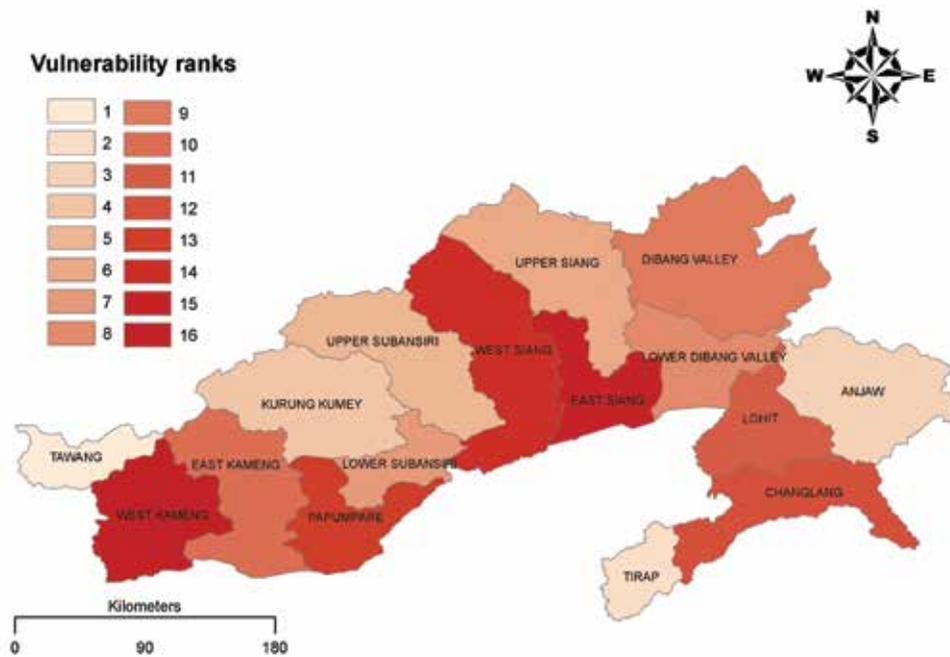
Figure 7: Vulnerability category map of Arunachal Pradesh
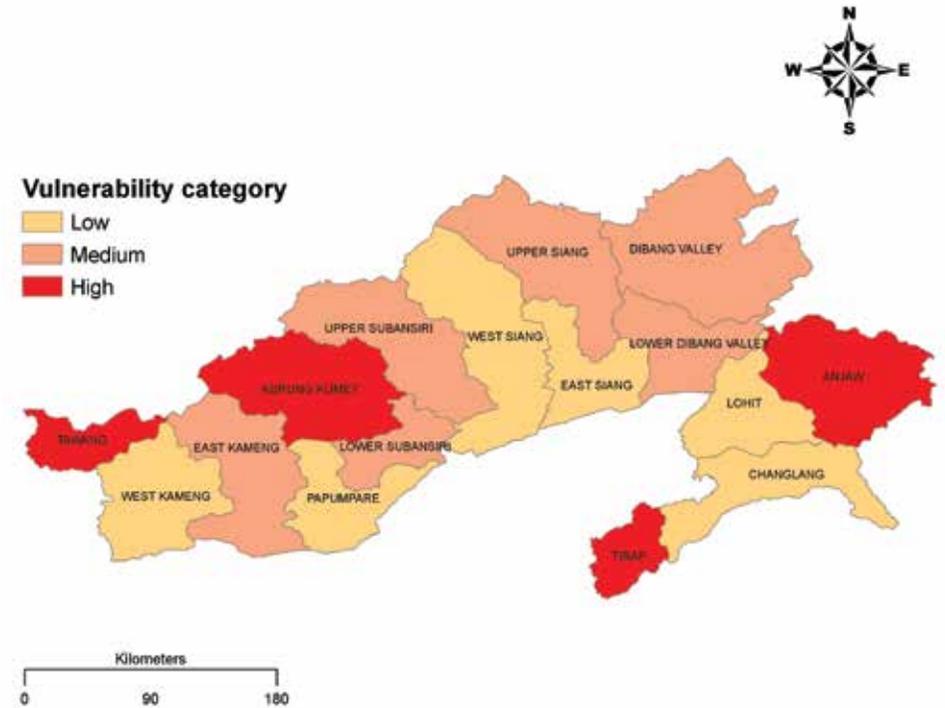
Assam

Figure 8: Vulnerability category map of Assam
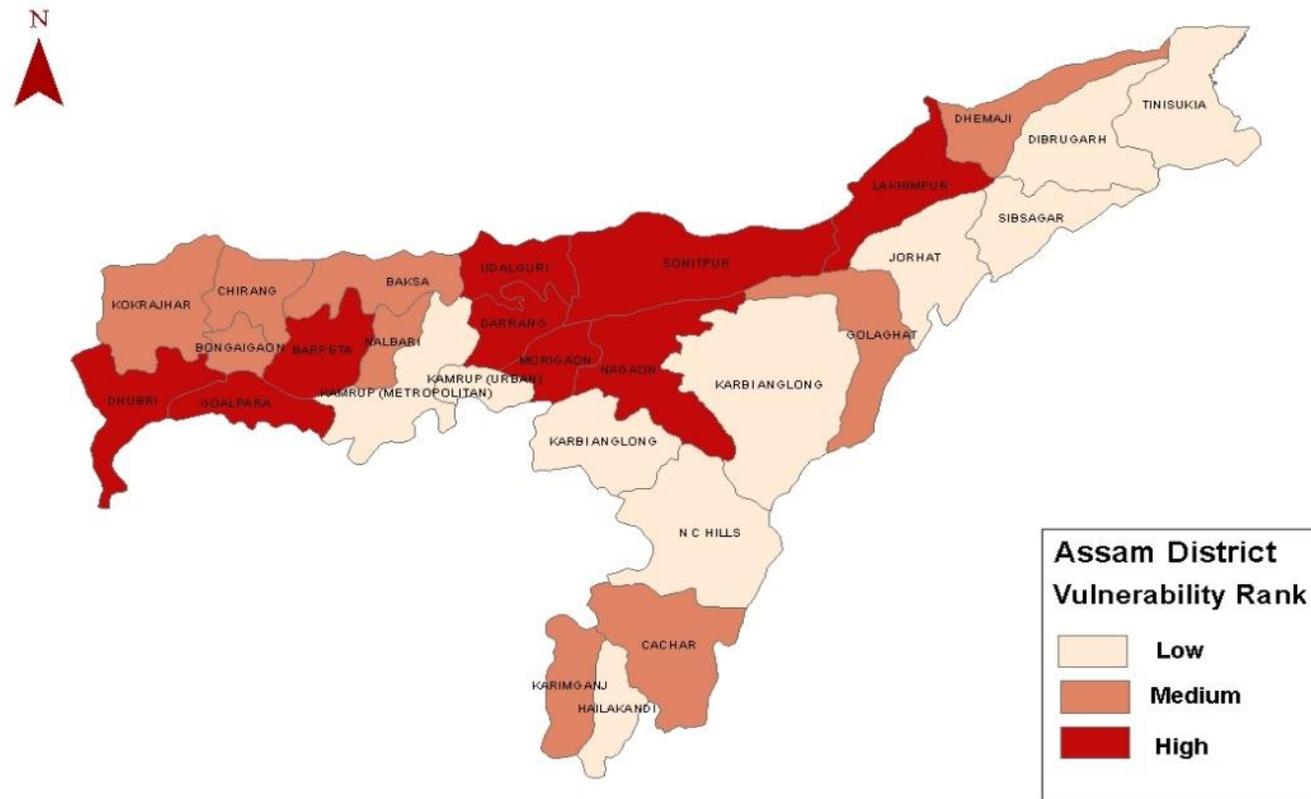
Himachal Pradesh

Figure 9: Vulnerability ranking map of Himachal Pradesh
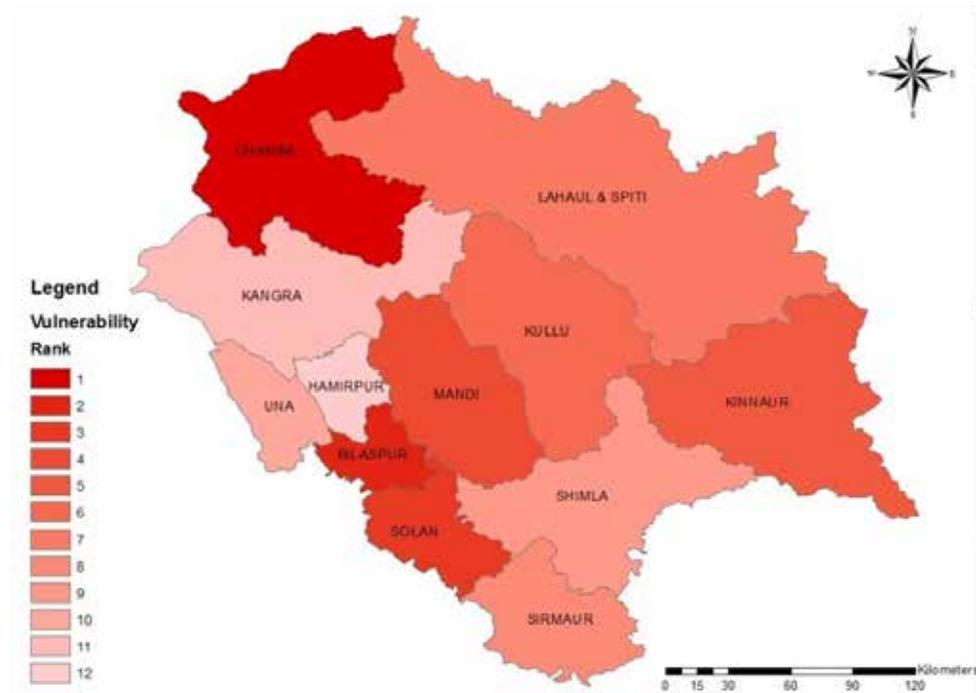
Figure 10: Vulnerability category map of Himachal Pradesh
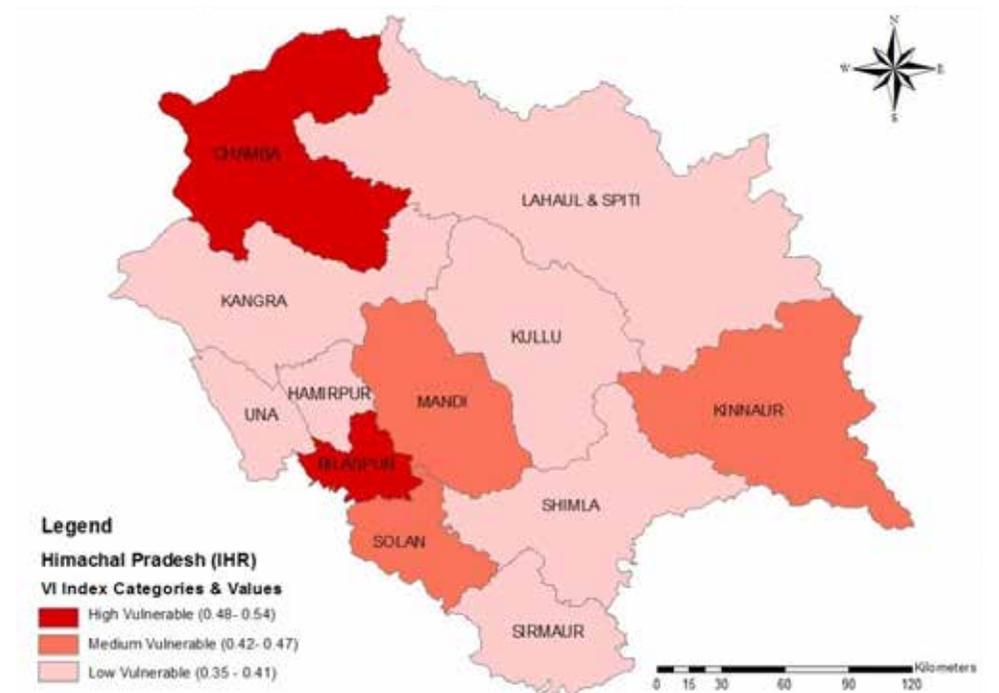
Jammu and Kashmir

Figure 11: Vulnerability ranking map of Jammu and Kashmir
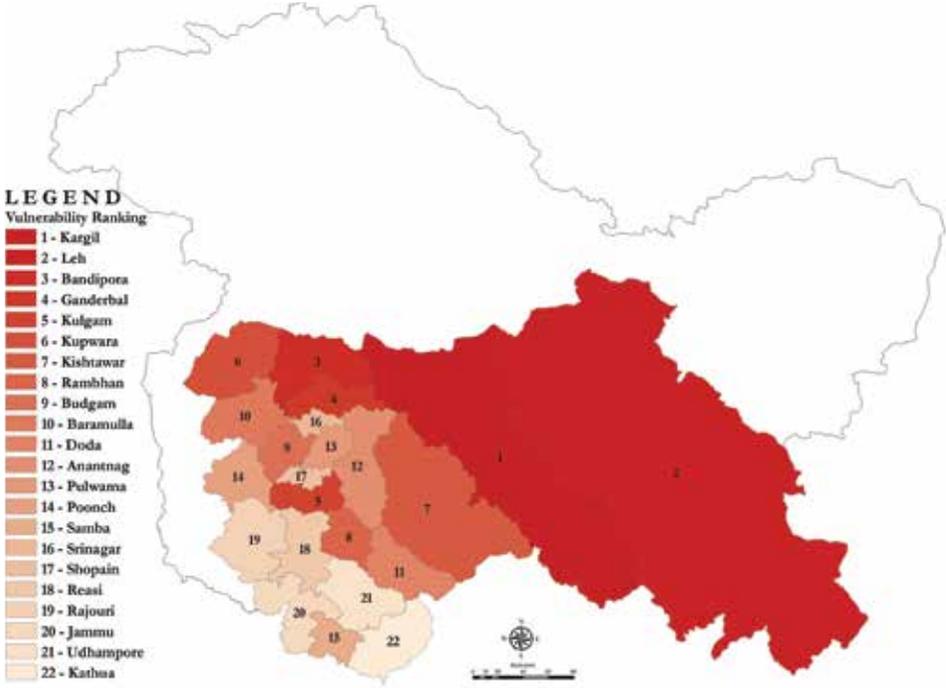
Figure 12: Vulnerability category map of Jammu and Kashmir

LEGEND
Vulnerability Ranking
1 - Kargil
2 - Leh
3 - Bandipora
4 - Ganderbal
5 - Kulgam
6 - Kupwara
7 - Kishtawar
8 - Rambhan
9 - Budgam
10 - Baramulla
11 - Doda
12 - Anantnag
13 - Pulwama
14 - Poonch
15 - Samba
16 - Srinagar
17 - Shopain
18 - Reasi
19 - Rajouri
20 - Jammu
21 - Udhampore
22 - Kathua

LEGEND
Vulnerability Index
0.23 - 0.36 (Low)
0.36 - 0.49 (Medium)
0.49 - 0.62 (High)
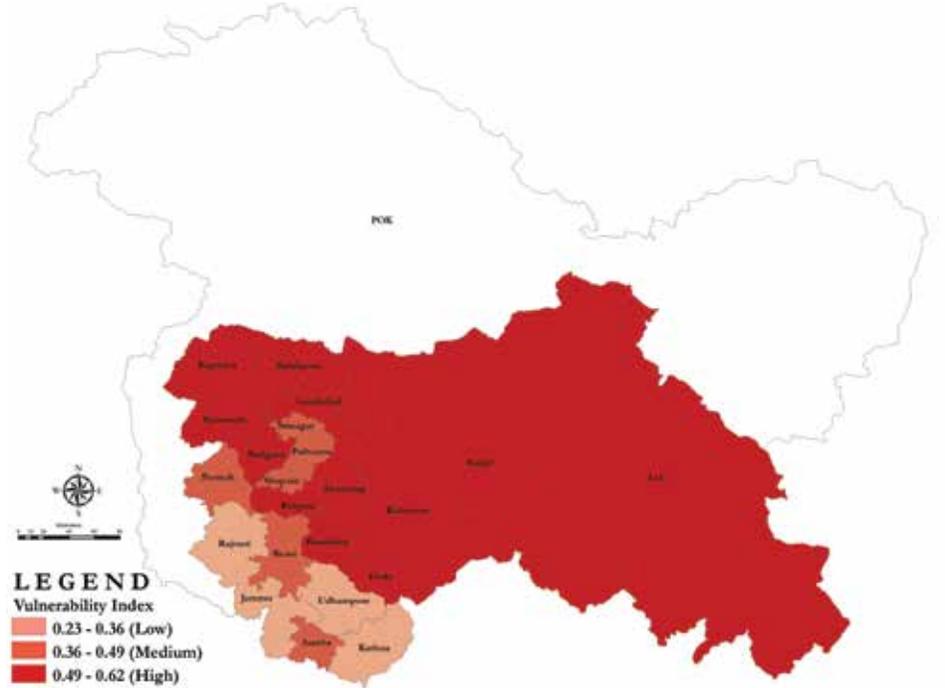
Manipur

Figure 13: Vulnerability ranking map of Manipur
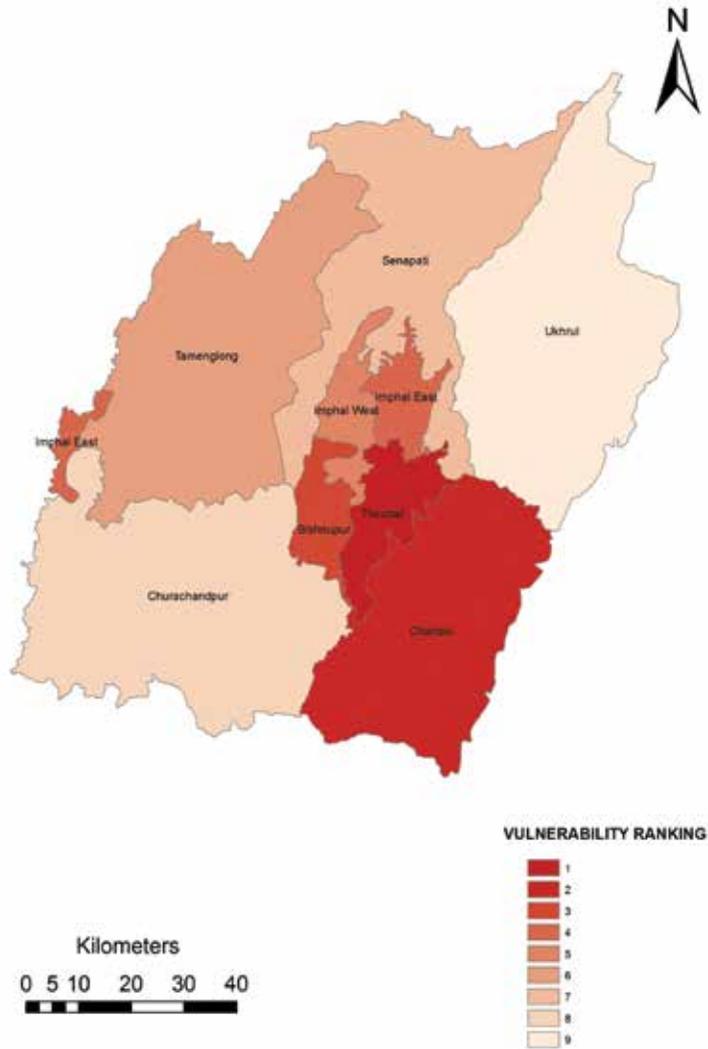
Figure 14: Vulnerability category map of Manipur

VULNERABILITY RANKING

1
2
3
4
5
6
7
8
9

Kilometers
0 5 10   20   30   40

VI CATEGORIES OF DISTRICTS

LOW (0.238 - 0.384)
MODERATE (0.384 - 0.530)
HIGH (0.530 - 0.676)

Kilometers
0 5 10   20   30   40

42
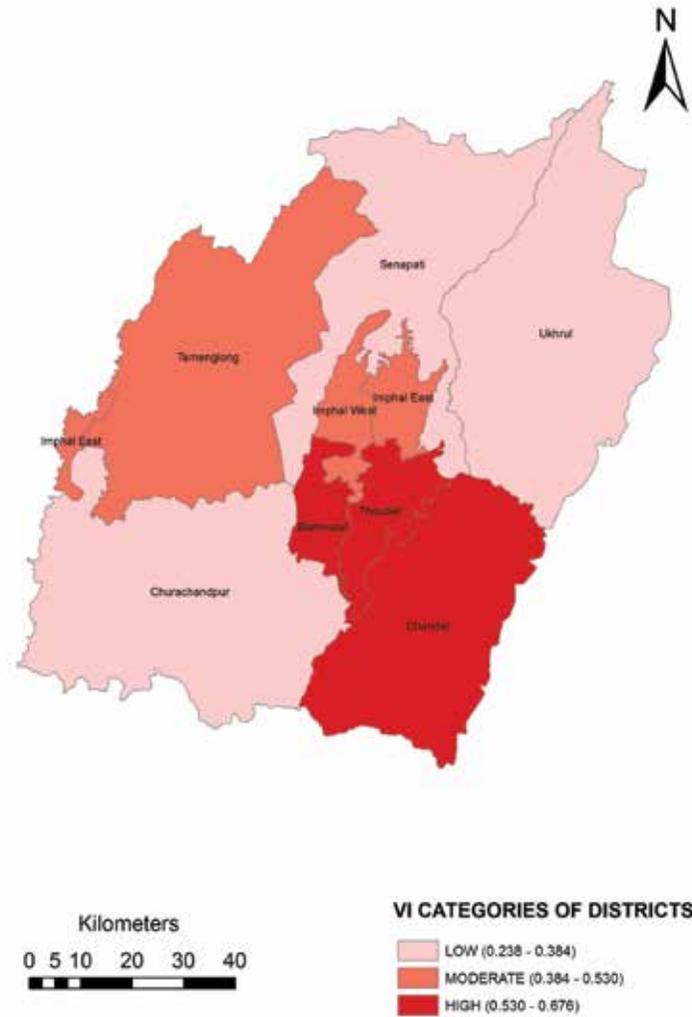
Meghalaya

Figure 15: Vulnerability ranking map of Meghalaya
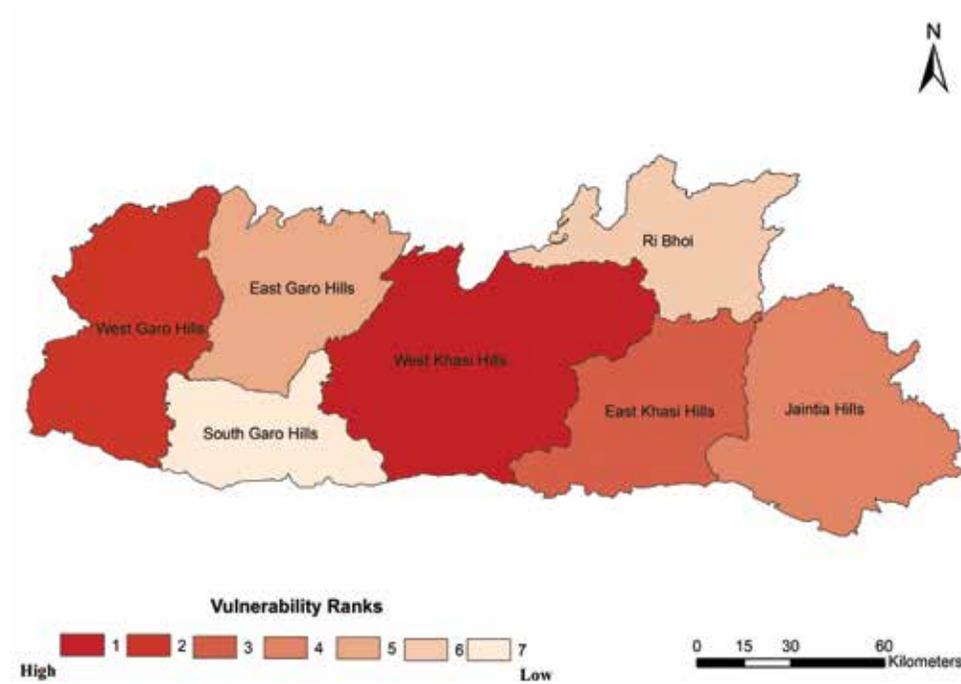
Figure 16: Vulnerability category map of Meghalaya
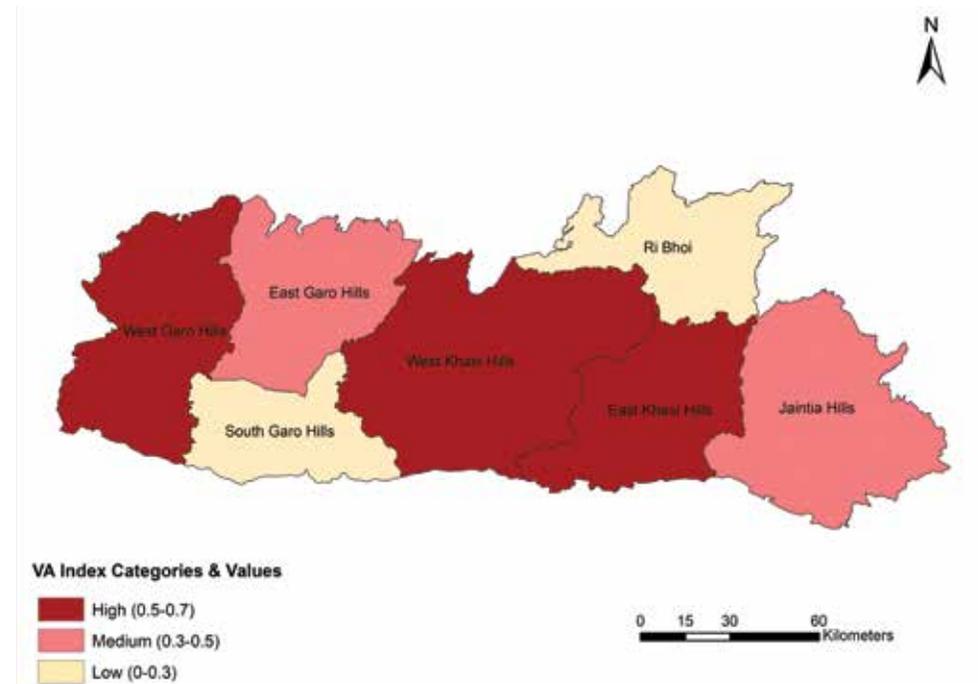
Mizoram

Figure 17: Vulnerability ranking map of Mizoram
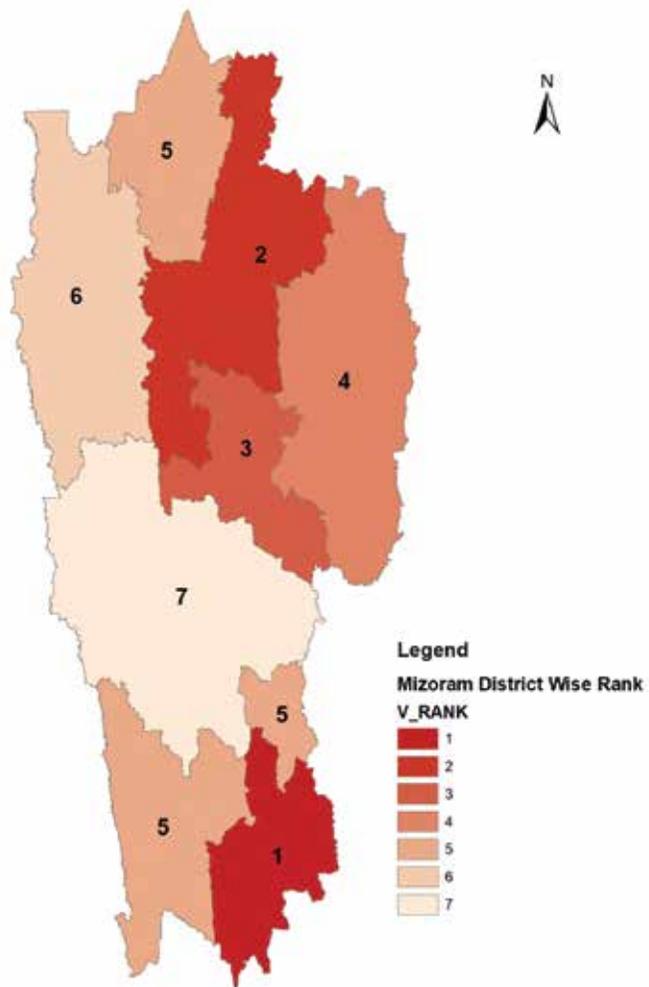
Figure 18: Vulnerability category map of Mizoram
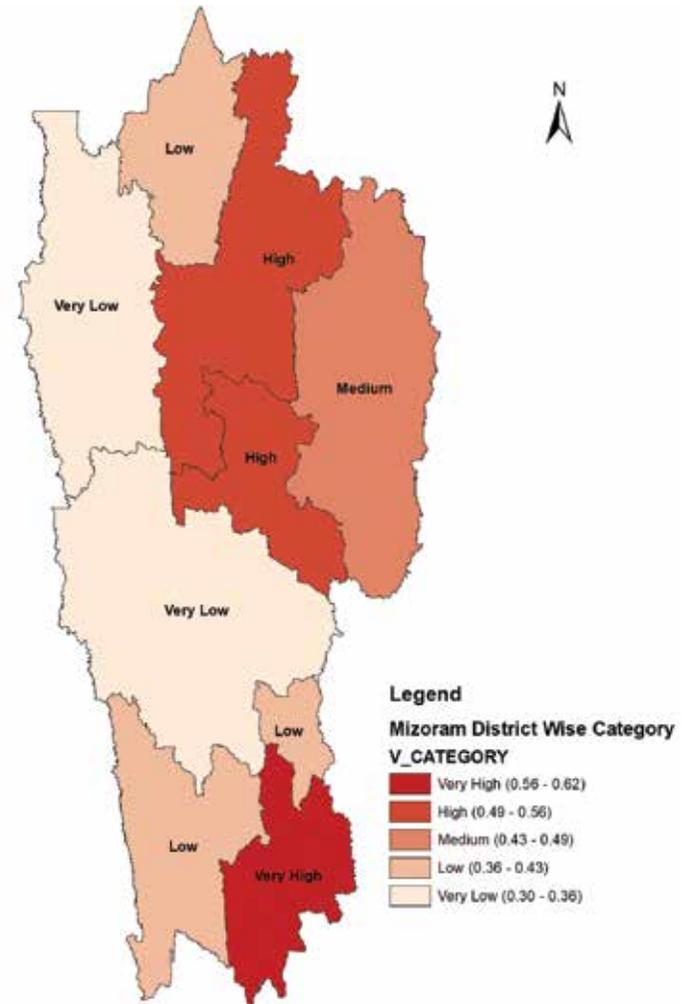
Nagaland

Figure 19: Vulnerability ranking map of Nagaland
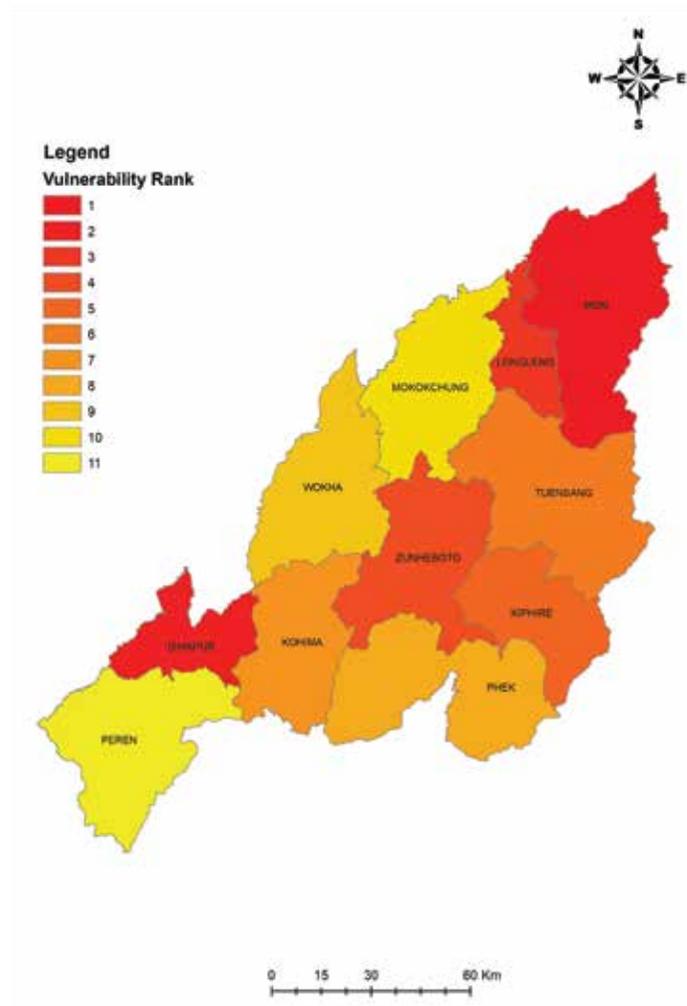
Figure 20: Vulnerability category map of Nagaland
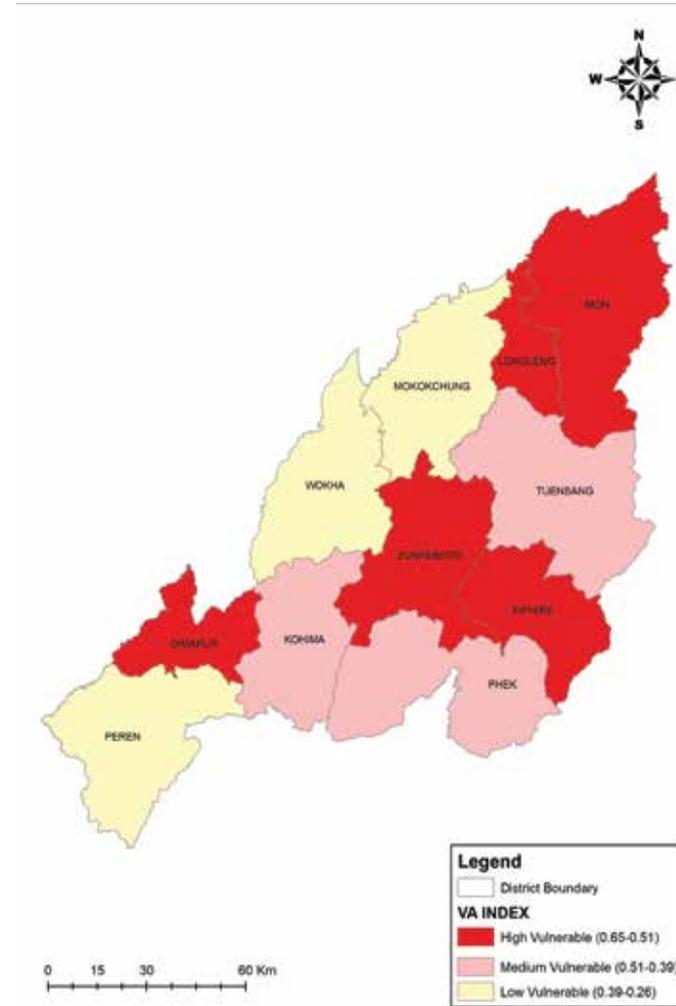
Sikkim

Figure 21: Vulnerability ranking map of Sikkim
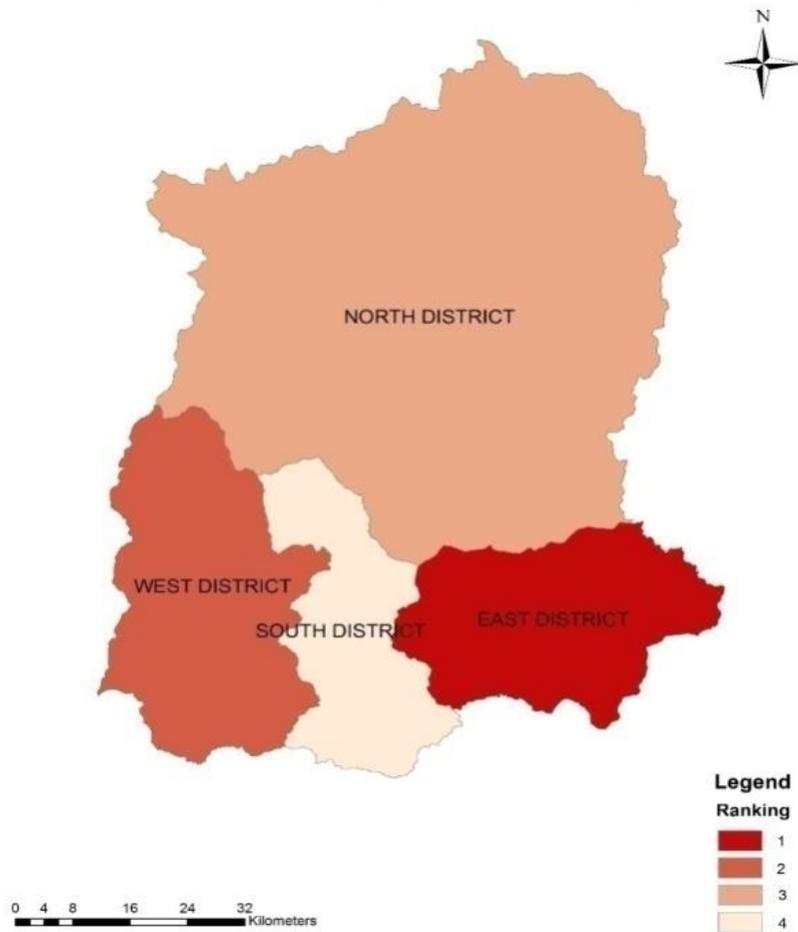
Figure 22: Vulnerability category map of Sikkim
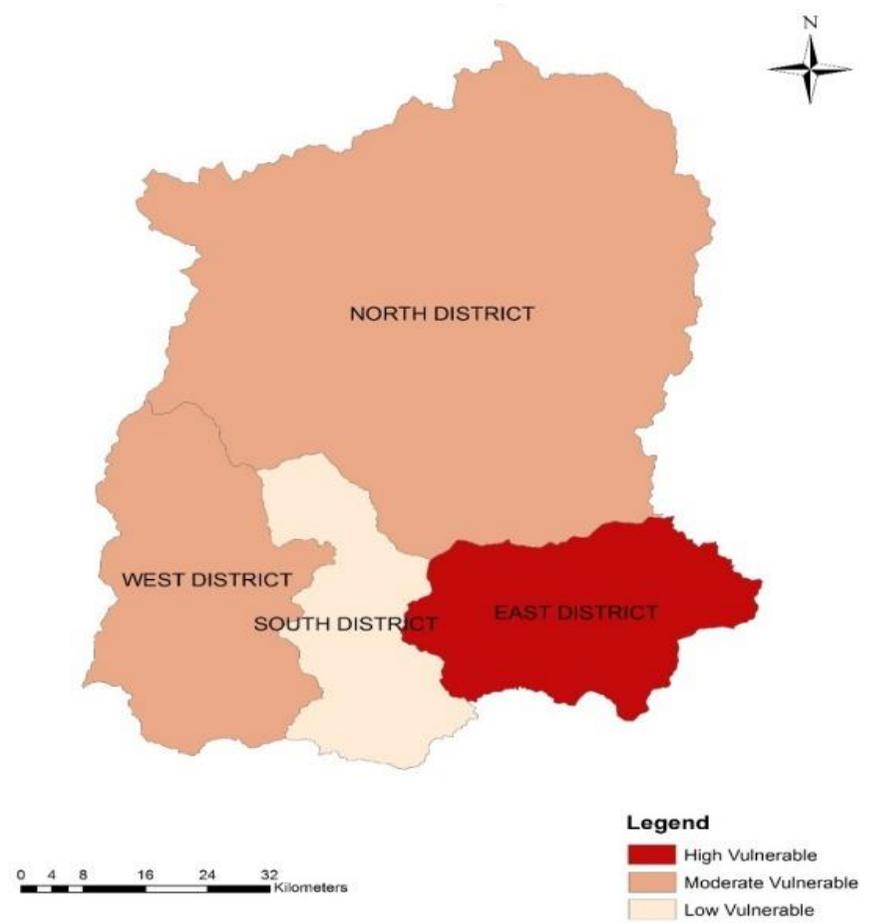
Tripura

Figure 23: Vulnerability ranking map of Tripura
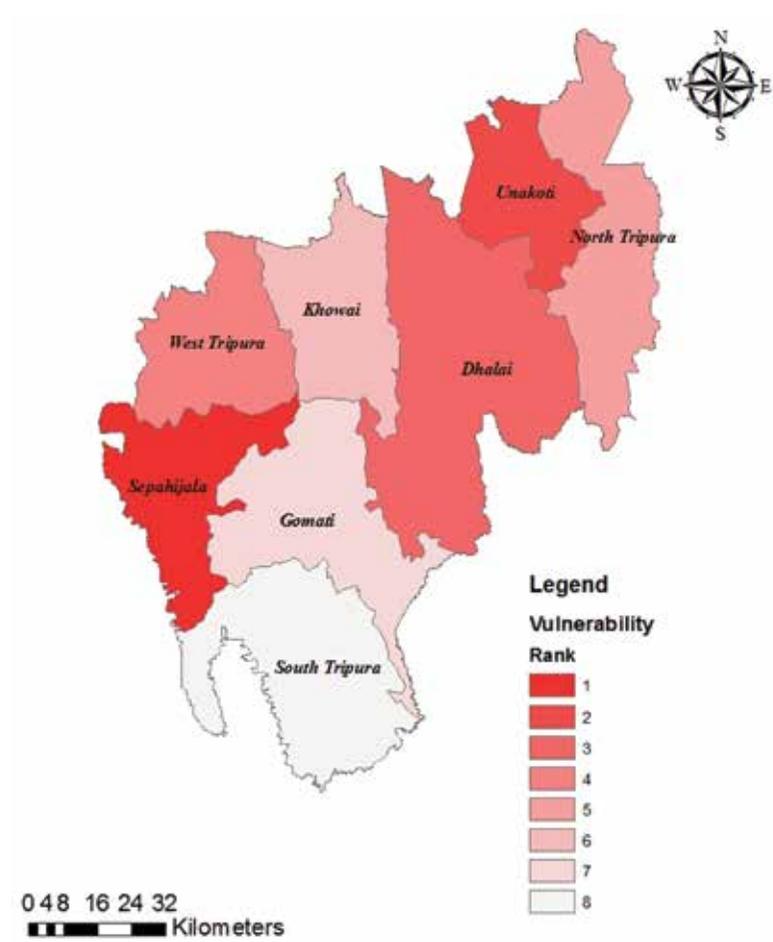
Figure 24: Vulnerability category map of Tripura
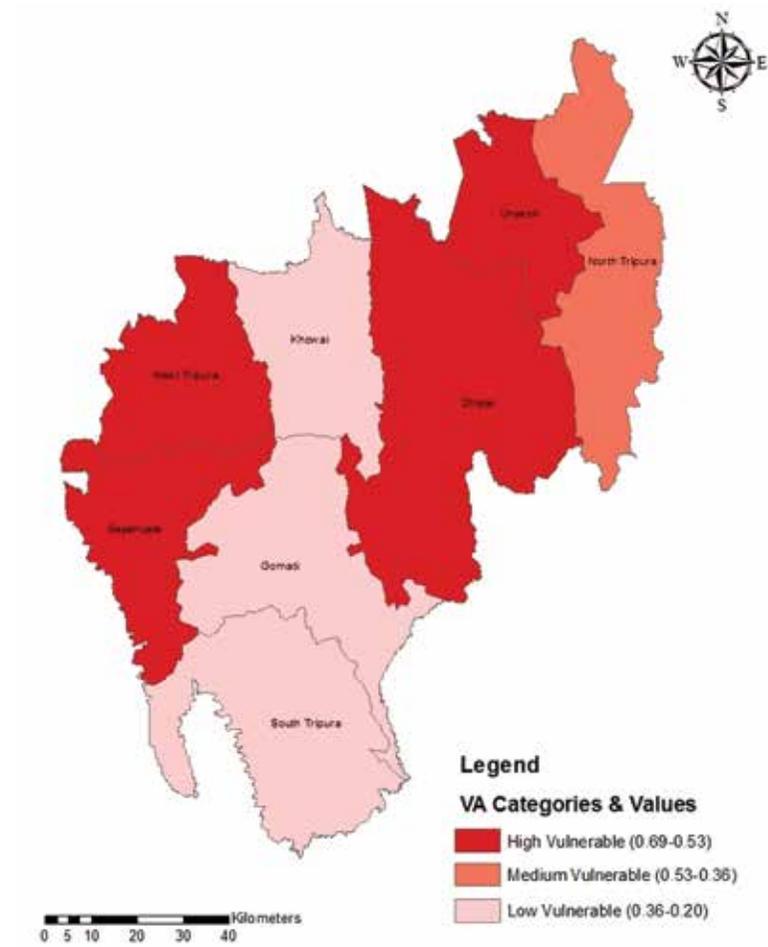
Uttarakhand

Figure 25: Vulnerability ranking map of Uttarakhand
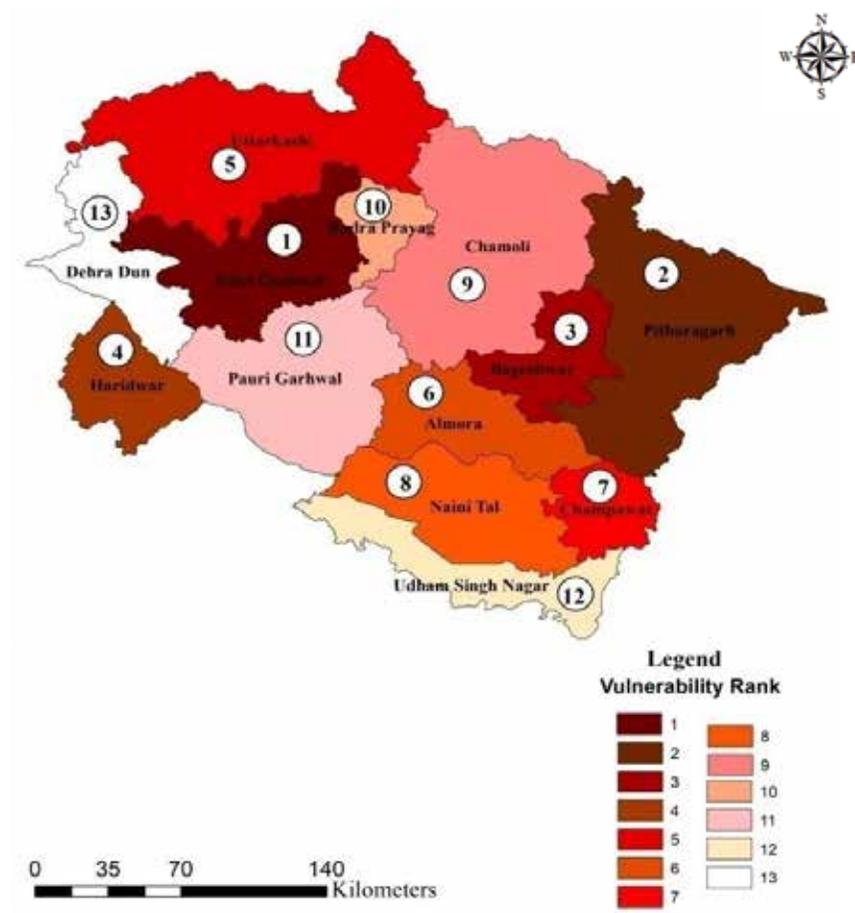
Figure 26: Vulnerability category map of Uttarakhand
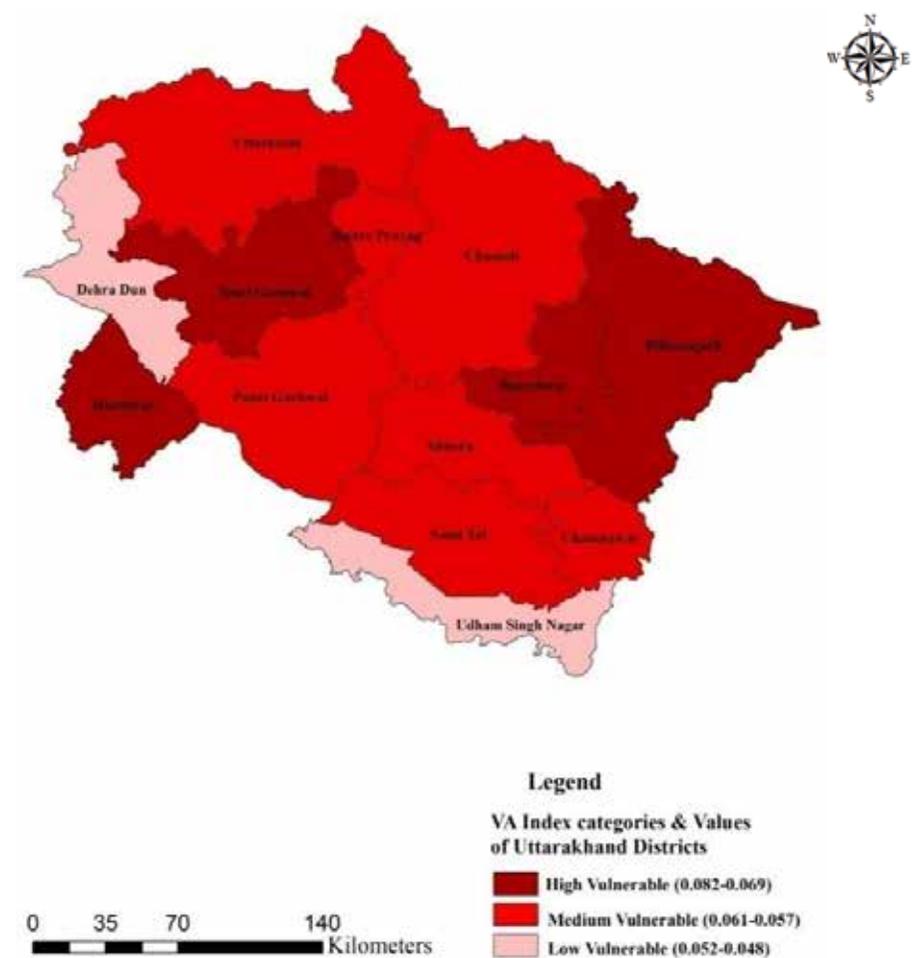
West Bengal (Block-level assessment for two IHR districts)

Figure 27: Vulnerability ranking map of West Bengal

Figure 28: Vulnerability category map of West Bengal
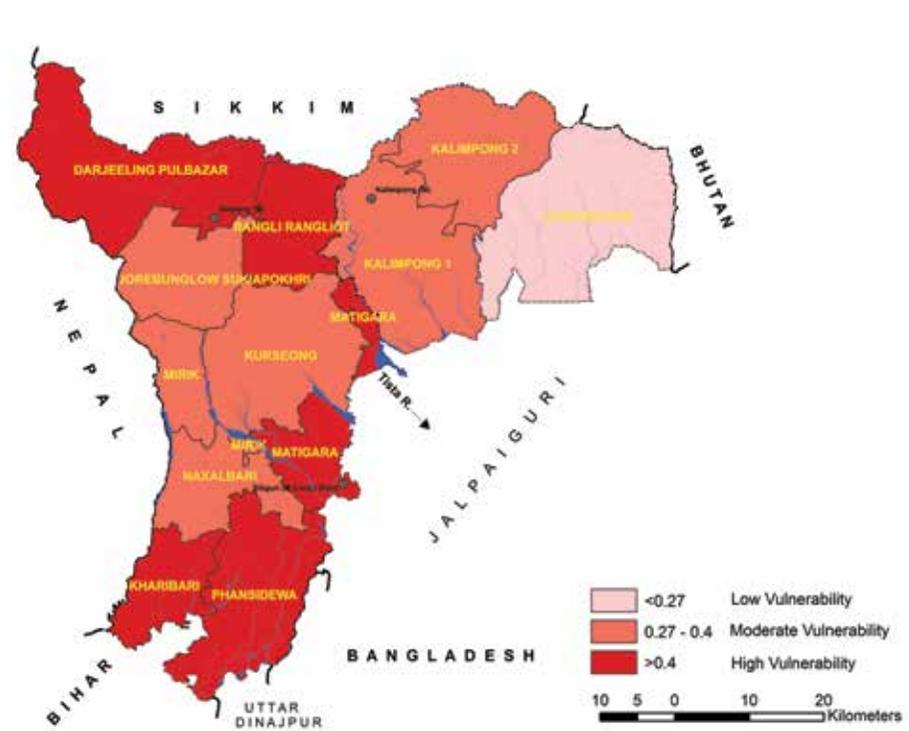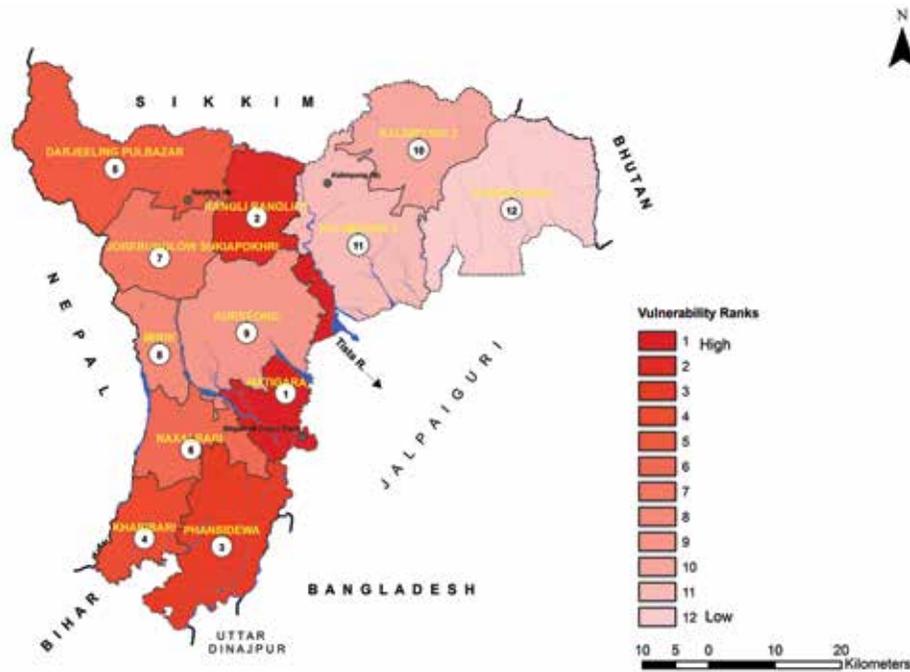
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3.   Karma, T., Sharma, E., Chettri, N., & Shrestha, A. (2010). Climate change vulnerability of mountain ecosystems in the Eastern Himalayas. ICIMOD, Kathmandu.

Annexures

Table A1: List of indicators and sub-indicators for Tier 1 vulnerability assessment relevant to IHR states of India, rationale for selection, functional relationship with vulnerability and sources of data

Indicators	Sub-indicators	Rationale for selection	Functional relation with Vulnerability	Source of data
Socio-economic, demographic status and health	Population Density (Total population of a state divided by the total geographical area)	Population density determines the extent of dependency and per capita availability of finite resources. High density could lead to degradation of resources, further increasing sensitivity. Further, higher the population density, higher the exposure of community to climatic hazards.	Positive	Calculated using Geographic Area and population data from Census of India (2011)
	Percentage of Marginal farmers	Marginal farmers (land holding <1 ha) are known to have low social and economic capital and thus are inherently more sensitive and have lower adaptive capacities.	Positive	Agriculture Census - State Tables (2010-11) accessed at, http://agcensus.dacnet.nic.in/DatabaseHome.aspx
	Livestock to human ratio (Total livestock population in a state divided by the total population of that state)	Livestock provides an alternate source of income and assists in crop production. Sale of livestock during distress also provides households with a coping strategy in the context of climatic hazards.	Negative	Estimated using Census of India (2011) and 19th Livestock Census (2012)
	Per Capita Income (2014-15) at current prices as on 31.03.2017	A direct indicator representing the inherent sensitivity of people in a region. Higher per capita income provides higher capacity to cope with any damage or loss arising out of climatic hazard.	Negative	Press Information Bureau, GoI, Ministry of Statistics & Programme Implementation[3]
	Number of Primary Health Centres per 100,000 Households (2017)	Access to primary health care centres is pivotal for the wellbeing of households. An indication of adaptive capacity.	Negative	NITI Aayog ,http://niti.gov.in
	Percentage of women in the overall workforce	Women are known to be more sensitive to climate risks. Regions with a greater number of women in gainful employment would signify gender equality, enhanced purchasing power and independency, thus lower vulnerability due to reduced sensitivity of women in these regions.	Negative	Census of India (2011)

[3] Estimates for the State of West Bengal are at base year 2004-05, the remaining states are for 2014-15 at current prices, as on 31.03.2017. Data for the same can be accessed at http://pib.nic.in/newsite/PrintRelease.aspx?relid=169546

Indicators	Sub-indicators	Rationale for selection	Functional relation with Vulnerability	Source of data
Sensitivity of agricultural production	Percentage area irrigated (2010-11)	Crop production with irrigation is less sensitive to delayed rainfall or droughts.	Negative	Table 6.7: Percentage of net irrigated area to net sown area of All Social Groups, 2005-06 and 2010-11, All India Report on Agriculture Census 2010-11
	Yield variability of food grains (2005-2015) - Coefficient of variation calculated for 10 year food grain yield data	A stable food production system with little to no variation in yield is inherently resilient to climate shocks and thus has high adaptive capacity.	Positive	Calculated using Table 4.1.4: Total Food grains - State-wise yield, Agricultural Statistics at a Glance 2016
	Percentage area under Horticulture Crops (2016)	Fruit trees are harder than field crops when sensitivity to climate shocks is considered. A larger area under horticulture tree crops providing an alternative source of farm-based income reduces sensitivity to climate variability and increases adaptive capacity.	Negative	Computed using Horticultural Statistics at a Glance 2017 and geographical area of states.
Forest Dependent Livelihoods	Percentage area under open forest	Large tracts of open forests indicate a higher level of forest disturbance and degradation. Forest is a major source of livelihood in the Himalayan states. Forests provide vital environmental services and thus degradation of forests indicate higher sensitivity.	Positive	State of Forest Report 2017 – Forest Cover
	Percentage area under forests per thousand rural household (2017)	Availability of alternate livelihood options through extraction of fodder, fuelwood, and NTFPs from forests.	Negative	State of Forest Report 2017 – Forest Cover
Access to information services and infrastructure	Percentage crop area insured under all Insurance Schemes (2015-16)	Crop insurance helps farming households mitigate losses due to climate risks, thereby enhancing their adaptive capacity.	Negative	Table 14.16(a): State-wise crop area insured under all Insurance Schemes, Agricultural statistics at a Glance 2016
	Percentage farmers taking crop loans (2015-16)	Farmers with access to crop loans can invest in essential agronomic practices to lower yield variability, thus enhancing resilience of cropping systems.	Negative	Table 14.9(b): State-wise Agriculture Loan disbursed during 2015-16, Agricultural Statistics at a Glance 2016

Indicators	Sub-indicators	Rationale for selection	Functional relation with Vulnerability	Source of data
	Average person days per Household under MGNREGA (2006-2016)	Non-climate sensitive wage labour under MGNREGA provides households with income security, especially during the years of droughts and floods.	Negative	Calculated using DMU report – MGNREGA Website
	Percentage area with >30% slope	Areas with high slope can be inaccessible, highly unstable and prone to landslides. This sub-indicator is a hazard specific indicator that determines the sensitivity of a region, hampering access to information services and infrastructure.	Positive	Computed using GIS tools and NRSC Data at a district level and averaged for states.
	Road Density (surfaced roads in km divided by total geographic area in Sq km)	Direct indicator representing accessibility, which is essential in regions that are exposed to climate and disaster risks.	Negative	Total and Surfaced Road Length - State-wise Table- 21.1(B), accessed at, http://www.mospi. gov.in/statistical-year-book-india/2017/190

Table A2: Sub-indicator values for the indicator Socio-economic, demographic status and health

State	Socio-economic, demographic status and health											
	Population density (2011) Person/sq. km		Percentage of marginal farmers (2011-12)		Livestock to human ratio (2017-18)		Per Capita Income (2014-15)		Number of Primary Health Centres per 100,000 Households (2017-18)		Percentage of women in the overall workforce (2011)	
	AV	NV	AV	NV	AV	NV	AV	NV	AV	NV	AV	NV
Arunachal Pradesh	17	0.00	18	0.175	1	1.000	103633	0.676	53	0.000	40	0.165
Assam	398	0.67	67	0.772	2	0.790	54618	0.986	16	0.765	29	0.734
Himachal Pradesh	123	0.19	70	0.801	1	0.860	124500	0.544	36	0.343	43	0.059
Jammu & Kashmir	56	0.07	83	0.964	1	0.877	62857	0.934	30	0.471	26	0.857
Manipur	128	0.19	51	0.573	4	0.000	52436	1.000	15	0.778	43	0.024
Meghalaya	132	0.20	49	0.549	2	0.828	68202	0.900	20	0.682	41	0.153
Mizoram	52	0.06	55	0.617	4	0.188	85659	0.790	26	0.564	40	0.172
Nagaland	119	0.18	4	0.000	2	0.619	78526	0.835	32	0.435	44	0.000
Sikkim	86	0.12	54	0.607	2	0.643	210394	0.000	19	0.708	37	0.333
Tripura	350	0.58	86	1.000	2	0.706	71666	0.878	11	0.868	29	0.723
Uttarakhand	189	0.30	74	0.847	2	0.640	134784	0.479	12	0.834	34	0.470
West Bengal*	589	1.00	82	0.950	3	0.351	78903	0.832	4	1.000	23	1.000

* The population density was considered only for Darjeeling and Kalimpong districts of West Bengal

Table A3: Sub-indicator values and normalized scores for the indicator sensitivity of agricultural production

State	Agri-based livelihoods					
	% Area Irrigated (2010-11)		Yield Variability of Food Grains (2005-2015)		% Area Under Horticulture Crops (2016)	
	AV	NV	AV	NV	AV	NV
Arunachal Pradesh	26.8	0.65	18	0.37	1	1.00
Assam	5.5	1.00	15	0.29	9	0.60
Himachal Pradesh	19.9	0.77	11	0.14	6	0.76
Jammu and Kashmir	45.8	0.35	13	0.20	2	0.96
Manipur	18.8	0.79	14	0.26	5	0.81
Meghalaya	23.4	0.71	16	0.32	6	0.75
Mizoram	10.0	0.93	38	1.00	6	0.73
Nagaland	22.6	0.72	16	0.30	6	0.74
Sikkim	22.3	0.73	13	0.20	11	0.52
Tripura	24.0	0.70	6	0.00	14	0.36
Uttarakhand	47.5	0.32	8	0.06	5	0.79
West Bengal	67.1	0.00	11	0.15	21	0.00

AV = Actual value and NV = Normalized value

Table A4: Sub-indicator values and normalized scores for the indicator forest dependent livelihoods

State	Forest dependent livelihoods			
	Percentage area under open forest		Area under forest/1,000 rural households	
	AV	NV	AV	NV
Arunachal Pradesh	23	0.049	334	0.000
Assam	54	0.715	5	1.000
Himachal Pradesh	35	0.310	12	0.981
Jammu and Kashmir	46	0.537	15	0.970
Manipur	57	0.789	45	0.879
Meghalaya	43	0.474	40	0.895
Mizoram	67	1.000	172	0.494
Nagaland	53	0.698	45	0.879
Sikkim	21	0.000	36	0.907
Tripura	24	0.065	13	0.978
Uttarakhand	27	0.128	17	0.964
West Bengal	58	0.797	7	0.995

Table A5: Sub-indicator values and normalized scores for the indicator Access to information services and infrastructure

State	Access to information services and infrastructure									
	Percentage crop area insured under all Insurance Schemes (2013-15)		Percentage farmers taking loans (2015-16)		Average person days per household under MGNREGA (2006-2016)		Average Percentage area with >30% slope		Road Density	
	AV	NV	AV	NV	AV	NV	AV	NV	AV	NV
Arunachal Pradesh	0	1.00	1	0.98	25	1.00	70.5	0.99	0.18	0.95
Assam	1	0.97	0	1.00	30	0.87	3.7	0.02	0.76	0.61
Himachal Pradesh	6	0.77	6	0.77	43	0.57	26.4	0.35	0.72	0.64
Jammu and Kashmir	0	1.00	6	0.79	34	0.78	24.6	0.32	0.10	1.00
Manipur	4	0.83	1	0.96	45	0.53	3.9	0.02	0.60	0.71
Meghalaya	0	0.99	3	0.89	41	0.63	9.5	0.10	0.40	0.82
Mizoram	0	1.00	2	0.94	52	0.36	71.4	1.00	0.35	0.86
Nagaland	0	1.00	1	0.96	45	0.52	52.7	0.73	1.08	0.43
Sikkim	0	1.00	3	0.91	55	0.30	21.1	0.27	0.82	0.58
Tripura	0	0.99	14	0.47	68	0.00	2.5	0.00	1.82	0.00
Uttarakhand	26	0.00	18	0.34	35	0.76	23.3	0.30	0.63	0.69
West Bengal	9	0.64	27	0.00	29	0.89	17.9	0.22	1.24	0.33

AV = Actual value and NV = Normalized value

Table A6: Weights assigned to the four main indicators and their respective sub-indicators and the final weights to be multiplied with the normalized scores

Indicator	Indicator Weights (WI)	Sub-indicators	Sub- indicator Weights (Wi)	Weights to be multiplied with normalizes scores (WI*Wi)
Socio-economic, demographic status and health	0.345	Population Density	0.17	(0.35*0.17) = 0.06
		Percentage marginal farmers	0.15	(0.35*0.15) = 0.05
		Livestock to human ratio	0.09	(0.35*0.09) = 0.03
		Per Capita Income	0.26	(0.35*0.26) = 0.09
		Number of Primary Health Centre per 100,000 HH	0.18	(0.35*0.18) = 0.06
		Percentage of women in overall workforce	0.15	(0.35*0.15) = 0.05
		Total	**1.00**	
Sensitivity of agricultural production	0.271	Percentage area irrigated	0.38	(0.27*0.38) = 0.10
		Yield variability of food grains	0.42	(0.27*0.42) = 0.11
		Percentage area under horticulture crops	0.20	(0.27*0.20) = 0.05
		Total	**1.00**	
Forest Dependent Livelihoods	0.194	Percentage area under open forests	0.58	(0.19*0.58) = 0.11
		Area under forests/1,000 rural households	0.42	(0.19*0.42) = 0.08
		Total	**1.00**	
Access to information services and infrastructure	0.19	Percentage crop area insured under all Insurance Schemes	0.20	(0.19*0.20) = 0.04
		Percentage farmers taking loans	0.14	(0.19*0.14) = 0.03
		Average person days per household under MGNREGA	0.24	(0.19*0.24) = 0.05
		Average Percentage area with >30% slope	0.34	(0.19*0.34) = 0.06
		Road density	0.08	(0.19*0.08) = 0.02
Total	**1.00**	**Total**	**1.00**	**1.00**

Table A7: Vulnerability index values of the four indicators, composite vulnerability index values
and corresponding ranks of IHR states

State	Vulnerability Index Values of the four main Indicators				Composite Vulnerability Index	Ranking of the States
	Social - economic, demographics status and health	Sensitivity of agricultural production	Forest dependent livelihoods	Access to Information Services and Infrastructure		
Assam	0.80	0.62	0.83	0.60	0.721	1
Mizoram	0.45	0.92	0.79	0.82	0.715	2
Jammu and Kashmir	0.69	0.41	0.72	0.69	0.619	3
Manipur	0.52	0.57	0.83	0.49	0.588	4
Meghalaya	0.57	0.56	0.65	0.58	0.583	5
West Bengal	0.89	0.07	0.88	0.45	0.581	6
Nagaland	0.38	0.55	0.77	0.74	0.570	7
Himachal Pradesh	0.44	0.50	0.59	0.57	0.510	8
Tripura	0.81	0.34	0.45	0.27	0.507	9
Arunachal Pradesh	0.32	0.61	0.03	0.99	0.466	10
Uttarakhand	0.58	0.30	0.48	0.39	0.449	11
Sikkim	0.35	0.46	0.38	0.54	0.422	12

About DST NMSHE

The Department of Science and Technology (DST) was established in May 1971, with the objective of promoting new areas of Science & Technology and to play the role of a nodal department for organising, coordinating and promoting S&T activities in the country.

The National Mission for Sustaining the Himalayan Ecosystem (NMSHE) coordinated by the Department of Science and Technology, is one of the eight missions under India's National Action Plan on Climate Change. The broad objectives of NMSHE include - understanding of the complex processes affecting the Himalayan Ecosystem and evolve suitable management and policy measures for sustaining and safeguarding the Himalayan ecosystem, creating and building capacities in different domains, networking of knowledge institutions engaged in research and development of a coherent data base on Himalayan ecosystem, detecting and decoupling natural and anthropogenic induced signals of global environmental changes in mountain ecosystems, studying traditional knowledge systems for community participation in adaptation, mitigation and coping mechanisms inclusive of farming and traditional health care systems and developing regional cooperation with neighbouring countries, to generate a strong data base through monitoring and analysis, to eventually create a knowledge base for policy interventions.

About SDC IHCAP

The Swiss Agency for Development and Cooperation (SDC) has been a partner of India for more than sixty years. Since 2011, SDC's programme focuses specifically on the issue of climate change and environment.

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