



Climate Vulnerability and Risk Assessment: Framework, Methods and Guidelines



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

NMSHE NATIONAL MISSION FOR
SUSTAINING THE HIMALAYAN
ECOSYSTEM



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development
and Cooperation SDC

Climate Vulnerability and Risk Assessment: Framework, Methods and Guidelines

for the Indian Himalayan Region

Jagmohan Sharma**, Indu K Murthy*, T Esteves*, Payal Negi*, Sushma S*,
Shyamasree Dasgupta***, Anamika Barua****, G Bala* and N H Ravindranath*

**Indian Institute of Science, Bengaluru*

***Karnataka Forest Department, Bengaluru*

****Indian Institute of Technology, Mandi*

*****Indian Institute of Technology, Guwahati*

Acknowledgement

This report has been supported by the Indian Himalayas Climate Adaptation Programme (IHCAP), a project of the Swiss Agency for Development and Cooperation (SDC), which is being implemented as a bilateral cooperation programme with the Department of Science and Technology (DST), Government of India. IHCAP has been supporting the implementation of the National Mission for Sustaining the Himalayan Ecosystem (NMSHE) as a knowledge and technical partner.

We would like to express our gratitude to Dr. Akhilesh Gupta, Adviser/Scientist-G & Head, Strategic Programmes, Large Initiatives and Coordinated Action Enabler (SPLICE) and Climate Change Programme, Department of Science and Technology and Dr. Nisha Mendiratta, Scientist-G & Associate Head, Strategic Programmes, Large Initiatives and Coordinated Action Enabler (SPLICE) and Climate Change Programme, Department of Science and Technology for providing invaluable expert insights and guidance for this report. The authors are also privileged to have received a series of contributions from all the Himalayan state governments. We're especially thankful to the state governments of Manipur and Sikkim for being part of the initial trainings when the framework was still being drafted.

We want to thank Dr. Shirish Sinha of SDC, Dr. Mustafa Ali Khan, Ms. Divya Mohan and Ms. Shimpy Khurana at IHCAP for their support and intellectual contribution at various stages of preparation of this report. We also thank climate change experts from various institutions in India, who participated in a workshop to review the draft version of this report at the Indian Institute of Science.

Table of Contents

Part 1 Climate Change Vulnerability and Risk Assessment: Concept and Framework	1
1.1 Climate Variability and Climate Change: Impacts, Vulnerability and Adaptation	4
1.1.1 What is Climate Variability and Climate Change?	5
1.1.2 Impacts of Climate Variability and Climate Change	5
1.1.3 Vulnerability of Natural Ecosystems and Socio-Economic Systems	5
1.1.4 Need for Adaptation to Current Climate Variability and Climate Change	6
1.2 What is Vulnerability? Vulnerability in the Context of Current Climate Variability and Climate Change	6
1.2.1 Definition of Vulnerability and Other Terms	6
1.2.2 Concept of Vulnerability	6
1.2.3 Vulnerability in the Context of Current Climate Variability and Climate Change	8
1.3 Why Assess Vulnerability and Application of Vulnerability Assessment	8
1.3.1 Ranking of Various Blocks, Districts and States According to Vulnerability Index	8
1.3.2 Prioritisation of Regions, Communities, Cropping Systems, etc., for Adaptation Based on Vulnerability Profiles	9
1.3.3 Identification of the Drivers of Vulnerability	9
1.3.4 Vulnerability Assessment for Adaptation Planning	9
1.4 Target Groups and Utility of Vulnerability Assessment	9
1.4.1 Communities	10
1.4.2 Development Agencies (International Agencies, NGOs, Banks, etc.)	10
1.4.3 Policy Makers/Government Departments	10
1.4.4 Researchers and Students	10
1.5 Evolution of Vulnerability Framework	10
1.5.1 Vulnerability Consideration Pre-IPCC 2007	11
1.5.2 Vulnerability Framework of IPCC 2007	11
1.5.3 Vulnerability Framework of IPCC 2014	11
1.5.4 Comparison of IPCC-2007 and IPCC-2014 Vulnerability Frameworks	12
1.6 Vulnerability Assessment at Regional Level: Case Study of the Himalayan Region	14
1.6.1 Physiographic Characteristics and Biological Features of the Himalayan Region with Implications for Vulnerability	14
1.6.2 Current Climatic Features and Implication for Vulnerability	15
1.6.3 Socio-Economic Features of the Himalayan Ecosystem and Implications for Vulnerability	15
1.6.4 Vulnerability Assessment for the Himalayan Region and Communities; Key Features Highlighting the Need for Vulnerability Assessment	16
1.7 Framework for Vulnerability and Risk-Impact Assessment	16
1.7.1 Vulnerability Assessment Framework from IPCC 2014	17
1.7.2 Risk-Impact Framework from IPCC 2014	17

1.7.3	Comparison of Vulnerability Assessment and Risk-Impact Assessment	18
1.7.4	Why Focus on Vulnerability Assessment for Adaptation Planning?	18
1.8	Framework for Vulnerability Assessment (IPCC 2014)	18
1.8.1	Scoping for Vulnerability Assessment	20
1.8.2	Conducting Vulnerability Assessment	20
1.8.3	Current Climate Vulnerability (Inherent) and Climate Change Vulnerability	21
1.8.4	'Hazard' and Vulnerability Assessment under IPCC 2014 Framework	21
1.8.5	Vulnerability Index and Vulnerability Profile	22
1.8.6	Implementation of Vulnerability Assessment for Adaptation Planning	22
1.9	Risk-Impact Assessment Framework	22
1.9.1	Broad Approach and Steps for Risk Assessment	23
1.9.2	Risk Assessment Scenarios	23
1.9.3	The Risk Assessment Approach	23
1.9.4	Framework for Risk Assessment	25
1.9.5	Steps for Assessment of the Risk	25
1.10	Three-Tier Approach to Vulnerability Assessment	26
1.10.1	Need for Multi-Tier Approach (Similar to IPCC Inventory Tier Approach)	26
1.10.2	Three-Tier Approach to Vulnerability Assessment	27
1.10.3	Broad Methods and Steps for Assessment at Different Tiers	28
1.10.4	Comparative Evaluation of Tier 1, Tier 2, Tier 3 and its Applicability for Adaptation Planning	30
	Part 2 Climate Change Vulnerability and Risk Assessment: Methods and Guidelines	33
2.1	Introduction	35
2.1.1	What is Vulnerability and Why Assess Vulnerability?	35
2.1.2	Components of Vulnerability	35
2.2	Vulnerability Assessment Scenarios: Current Climate Vulnerability and Climate Change Vulnerability	37
2.2.1	What is Current Climate Vulnerability Assessment and Why it Should Be Assessed?	38
2.2.2	What is Climate Change Vulnerability Assessment and Why it Should Be Assessed?	39
2.2.3	Comparison of Current Climate and Climate Change Vulnerability Assessment	39
2.3	Summary of Approach and Methods for Vulnerability Assessment	39
2.4	Steps in Vulnerability Assessment	40
2.5	Scoping of Vulnerability Assessment – Step 1	41
2.6	Typology of Vulnerability Assessment – Step 2	44
2.6.1	Assessing 'Hazard Specific Vulnerability'	47
2.7	Selection of Tier Methods – Step 3	47
2.7.1	Tier 1: Top-down Approach	48
2.7.2	Tier2: Combination of Top-down and Bottom-up Approaches	49
2.7.3	Tier 3: Bottom-up and Spatial Approaches	51
2.8	Selection of Sector, Scale, System and Period for Vulnerability Assessment – Step 4	54
2.8.1	Selection of Scale: Why Identify and Select a Scale?	55

2.8.2	Selection of Sectors: Agriculture, Water Resources, Forests and Others	57
2.8.3	Selection of Broad Systems; Socio-Economic and Biophysical Systems	57
2.8.4	Selection of Period: Current, Future and Periodic Assessments	57
2.9	Indicators for Vulnerability Assessment: Identification, Definition, and Selection of Indicators – Step 5	58
2.9.1	Definition of Indicators	58
2.9.2	Indicators for Vulnerability Components: Sensitivity and Adaptive Capacity	59
2.9.3	How to Select an Indicator?	60
2.9.4	Selection of Indicators for Sensitivity and Adaptive Capacity	60
2.9.5	Methods for Indicator Selection: Literature-Based, Stakeholder and Expert Consultation	61
2.10	Quantification and Measurement of Indicators – Step 6	65
2.10.1	List of Indicators and Stratification for Estimation	65
2.10.2	Tier Methodology for Estimation and Quantification of Indicators	66
2.10.3	Matching Methods with Indicators and Tier	68
2.10.4	Methods and Sources of Data for Indicators	70
2.11	Normalisation of Indicators – Step 7	76
2.11.1	Why Normalisation?	76
2.11.2	Method for Normalisation	76
2.12	Assigning Weights to Indicators – Step 8	78
2.12.1	Why Weights?	78
2.12.2	Tier Methodology for Assigning Weights	78
2.12.3	Equal Weights	78
2.12.4	Unequal Weights	79
2.13	Aggregation of Indicators and Development of Vulnerability Index – Step 9	81
2.14	Representation of Vulnerability; Spatial Maps, Charts, and Tables of Vulnerability Profile and Index – Step 10	82
2.15	Vulnerability Ranking of Sectors, Regions, Communities, Cropping Systems, River Basins, Watersheds, Forest Types, etc. –Step 11	83
2.16	Identification of Drivers of Vulnerability for Adaptation Planning – Step 12	86
2.16.1	Why Identify Drivers?	86
2.16.2	Identification of Drivers of Vulnerability	86
	Part 3 Integration of Climate Change Vulnerability and Risk Assessment into Adaptation Planning	89
3.1	Adaptation to Reduce Vulnerability	91
3.2	Vulnerability Assessment for Adaptation Planning	91
3.3	Frameworks and Tool kits for Mainstreaming Vulnerability in Adaptation Planning	91
3.3.1	UNFCCC Framework for Mainstreaming Adaptation	92
3.3.2	Adaptation, Livelihoods, and Ecosystems Planning Tool (ALivE)	94
3.4	Practical Approach and Steps to Incorporate Vulnerability in Adaptation Planning	96
	References	98
	Annexures	101

List of Tables

Part 1

Table 1.1:	Terminologies and their explanation	7
Table 1.2:	Comparison of IPCC Frameworks; 2007 and 2014	13
Table 1.3:	Salient features of Vulnerability Index and Climate Change Risk-Impact Index Frameworks	19
Table 1.4:	Characteristic features of different tiers of assessment	28
Table 1.5:	Methodological steps followed for tiers 1, 2 and 3 assessments	29
Table 1.6:	Important features of Tier 1, Tier 2 and Tier 3 methodological approaches for Vulnerability Index assessment framework and Risk-Impact (R-I) Index assessment framework	31

Part 2

Table 2.1:	Merits and limitations of current climate and climate change vulnerability assessments	40
Table 2.2:	'Goal-Oriented' vulnerability assessment: approach and methods	41
Table 2.3:	Five criteria to assist in scoping for vulnerability assessment	43
Table 2.4:	Stakeholders and the purpose for which they require vulnerability assessment	44
Table 2.5:	Merits and limitations of three tiers for vulnerability assessment	45
Table 2.6:	Rationale for selection of different scales for vulnerability assessment	54
Table 2.7:	Illustration of different types of sector specific vulnerability assessments	56
Table 2.8:	Potential drivers of vulnerability for social and biophysical systems	56
Table 2.9:	Categories of indicators with examples	58
Table 2.10:	Criteria for selection of indicator, features and examples of indicators	59
Table 2.11:	Considerations in selection of a good indicator	60
Table 2.12:	Merits and demerits of having a small vs large number of indicators for assessing vulnerability	63
Table 2.13:	Inventory of indicators for Tier 1 vulnerability assessment relevant to Himalayan states of India (district and village level)	63
Table 2.14:	Examples of different categories of indicators and tier to be adopted for assessment	66
Table 2.15:	Matching of indicators under different tiers and methods	68
Table 2.16:	Case study example of Chikkaballapur district for demonstrating normalisation	76
Table 2.17:	Case study example of functional relationship of indicators with vulnerability	77
Table 2.18:	Case study example of normalised scores of indicators	77
Table 2.19:	Goal-oriented weighting procedure along with tiers	78
Table 2.20:	Case study showing equal weights given to indicators selected for village level vulnerability assessment	79
Table 2.21:	Case study example of unequal weight allocation in two villages of Bagepalli blocks of Karnataka	80
Table 2.22:	Case study example - Number and percentage of villages from different blocks of Chikkaballapur ranked on the socio-economic vulnerability index scale	84
Table 2.23:	Number of households ranked on the socio-economic vulnerability index scale according to their landholdings	85
Table 2.24:	Indicators and drivers of forest vulnerability in Aduvalli forest range, Karnataka	85

List of Figures

Part 1

Figure 1.1:	The risk management and assessment framework	12
Figure 1.2:	Risk arises from interaction of hazard, exposure and vulnerability	13
Figure 1.3:	Conceptual framework showing the scenarios and elements for assessment of risk and vulnerability according to the IPCC 2014 framework for management of risk	14
Figure 1.4:	Common framework for assessment and reduction of vulnerability and risk in the context of climate change	15
Figure 1.5:	Framework showing approach to be followed for vulnerability assessment	20
Figure 1.6:	Conceptual framework for assessment of risk	24
Figure 1.7:	Framework for assessment and reduction of risk under climate change	25
Figure 1.8:	Vulnerability assessment enabling framework for choosing and carrying out assessment as per the capability of stakeholders/agencies	27

Part 2

Figure 2.1:	Framework for assessment of current climate and climate change vulnerability	37
Figure 2.2:	Steps in vulnerability assessment	42
Figure 2.3:	Aggregated Vulnerability Index Value of villages of Chikkaballapur block of Karnataka (Based on equal weights and unequal weights given by the stakeholder)	81
Figure 2.4:	Socio-economic vulnerability profile of districts in Sikkim state (Left Panel) and villages of South Sikkim district (Right Panel)	82
Figure 2.5:	Distribution of villages according to socio-economic vulnerability ranks in six blocks of Chikkaballapur district in Karnataka represented as a bar chart	83
Figure 2.6:	Socio-economic vulnerability profiles of households in the study villages	84
Figure 2.7:	Drivers of socio-economic vulnerability in Chikkaballapur district	86

Part 3

Figure 3.1:	Adaptation planning and implementation process	93
Figure 3.2:	ALivE framework	95
Figure 3.3:	Broad approach and steps to mainstreaming vulnerability in adaptation planning	97

List of Annexures

Annexure 1:	Indicator list by different studies	101
Annexure 2:	Principal Component Analysis	105
Annexure 3:	Indicators and secondary sources of data for vulnerability assessment	106
Annexure 4:	Adaptation Tools and Tool kits	110



Part 1

Climate Change Vulnerability and Risk Assessment: Concept and Framework







Vulnerability and Risk Assessment

Climate change is one of the biggest environmental and developmental challenges that the natural ecosystems and socio-economic systems face. According to the Intergovernmental Panel on Climate Change (IPCC 2014), climate change is already occurring and impacting natural ecosystems and human societies. 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. Among the three factors, vulnerability, which is determined by the sensitivity and adaptive capacity of the systems, can be addressed to overcome the adverse impacts of climate change. Thus, there is a need to assess the vulnerability of natural ecosystems and socio-economic systems and undertake measures to reduce the vulnerability. According to IPCC 2014, the “first step towards adaptation to future climate change is reducing vulnerability and exposure to present climate variability.” According to multiple global climate risk assessments, India is one of the most vulnerable countries in the world. Assessment of vulnerability of a system is one of the critical steps in adaptation planning. Vulnerability could be assessed for the current climate risks and long-term climate change. The focus of this Manual is to provide practical guidance on assessment and estimation of current climate vulnerability of regions, sectors and communities.

Rationale for Vulnerability Assessment

Vulnerability assessment is required for multiple purposes, particularly for adaptation planning. Vulnerability assessment would assist in:

1. Adaptation planning of developmental programmes and projects
2. Prioritisation of adaptation interventions and investment at national, state, district and village levels

3. Developing adaptation proposals for Green Climate Fund, World Bank, Asian Development Bank, Adaptation Fund, bilateral agencies, etc.
4. Meeting the requirements of Paris Agreement, Article 9 that requires assessment of the impact and vulnerability
5. Designing and implementing the ‘Nationally Determined Contributions’ component which aims to better adapt to climate change by enhancing investments in development programmes in sectors vulnerable to climate change
6. Revision of the State Action Plan on Climate Change for assessing the vulnerability and prioritising adaptation programmes and projects

Organisation of the Guidelines

This Manual is aimed at providing vulnerability framework, methodology and guidelines for assessing the vulnerability of biophysical or socio-economic systems. The Guidelines are organised into three parts:

- **Part 1:** Climate Change Vulnerability and Risk Assessment Framework
- **Part 2:** Climate Change Vulnerability and Risk Assessment Methods and Guidelines
- **Part 3:** Integration of Climate Change Vulnerability and Risk Assessment into Adaptation Planning

Target Groups

These Guidelines are aimed at practitioners involved in development, implementation and monitoring of climate change vulnerability reduction and adaptation programmes. This could include departments of agriculture, watershed, forest and health as well as development banks (World Bank and Asian Development Bank), United Nations (UN) agencies, bilateral agencies, non-governmental organisations (NGOs) and research institutions.

1.1 Climate Variability and Climate Change: Impacts, Vulnerability and Adaptation

The growing body of literature which is now available shows that the increasing current climate variability and ongoing climate change are adversely impacting the biophysical systems (mountains, rivers, forests and wetlands) and socio-economic systems (hill communities, coastal communities, agriculture and animal husbandry). Such observed impacts include warming of the atmosphere, melting of glaciers, rising sea level, species range shifts, droughts and flood events, declining crop yields, heat strokes and proliferation of infectious disease vectors to new areas. These observations also indicate the likely trends of impact and persisting vulnerability of biophysical and socio-economic systems in the future under committed warming and climate change.

According to global climate risk assessment (Eckstein et al. 2018), India is one of the most vulnerable countries to climate risks. In India, mountains, coastal and arid zones are considered highly vulnerable. For example, mountains are among the most fragile environments on the Earth. The Indian Himalayan states are characterised by high mountains, slopes, valleys, preponderance of forests and water streams, diverse ecosystems, endemic species, mountain agriculture and horticulture, and diverse ethnic societies. The biophysical richness and socio-cultural uniqueness of the Himalayan states are also characterised by land degradation, deforestation, invasive species, loss of biodiversity, landslides, invasion of commercial crops, low productive agriculture and migration. Further, the Himalayan region experiences diverse weather or climatic conditions (due to varying altitudes), extreme weather events, such as floods and droughts, and high current climate variability. Furthermore, according to preliminary modelling studies, the Himalayan region is projected to experience higher levels of climate change than the Indo-Gangetic plains or the southern region of India.

The available climate change impact assessment studies show adverse impacts of climate change on agriculture, forests and water resources which pose a significant adaptation challenge to the communities. Poor land management, monocropping, inappropriate agriculture practices,

high levels of fertiliser and pesticide application, land fragmentation, over-exploitation of groundwater and loss of biodiversity exacerbate the impacts of climate change. The climatic and non-climatic stresses make the Himalayan ecosystems and communities highly vulnerable to the current climate variability and future climate change.

Thus, there is a need to address the implications of current climate variability and projected climate change by developing adaptation and resilience building strategies in the short and long terms. Assessment of vulnerability and risk is a vital preceding step to develop adaptation policies, strategies and practices.

This Manual presents the framework, methods and guidelines for vulnerability assessment. It is organised into three parts:

Part 1: Climate Change Vulnerability and Risk Assessment Framework

- In this part, the concept of climate variability and climate change, vulnerability, its evolution, IPCC 2014 climate change risk management assessment framework, rationale for vulnerability assessment, its application, the target groups and finally a three-tier approach for vulnerability assessment are presented.

Part 2: Climate Change Vulnerability and Risk Assessment Methods and Guidelines

- This part provides practical guidance on methods for assessment of the current climate change vulnerability of biophysical and socio-economic systems. It also provides detailed steps for assessment of vulnerability, particularly for the selection, quantification and normalisation of indicators, provision of weights and aggregation of indicators to obtain a vulnerability index.

Part 3: Integration of Climate Change Vulnerability and Risk Assessment into Adaptation Planning

- This part provides a framework, approach and methods for mainstreaming vulnerability in adaptation planning, along with a brief introduction to selected adaptation tools.



1.1.1 What is Climate Variability and Climate Change?

The term 'climate variability' is often used to denote deviations over a given period of time (e.g. a month, season or year) when compared to long-term statistics for the same calendar period. Climate variability is measured by these deviations, which are usually termed as anomalies. According to the World Meteorological Organization (WMO), variability may be due to natural internal processes within the climate system (internal variability) or due to variations in natural or anthropogenic external factors (external variability). Climate variability is defined as the variation in the mean state and other statistics of the climate on all temporal and spatial scales, beyond individual weather events.

The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods."

1.1.2 Impacts of Climate Variability and Climate Change

A review of the evidence for response of 94 ecological processes (31 marine, 31 freshwater and 32 terrestrial ecosystems) to anthropogenic climate change published in the journal *Science* reports that 77 of the 94 (82 per cent) processes show changes (Scheffers et al. 2016). With 29 of 32 terrestrial ecological processes showing changes, terrestrial ecosystems are the most impacted. Such changes include the changes pertaining to physiology, morphology, phenology, species distribution changes by range expansion and contraction, and productivity (Net Primary Production or NPP). For example, in the Himalayan region, early greening is reported from the Hindu-Kush-Himalayan region (Panday and Ghimire 2012), habitat contraction up to 30 per cent due to forest loss is projected for snow leopard (Forrest et al. 2012) and rainfall-linked cases of Japanese encephalitis have been reported from the Himalayan region (Bhattachan et al. 2009). Further, the Himalayas experienced an increase in temperature higher than the global mean of about 0.7°C in the last century. In particular, a strong increase in the mean temperature of about 1.7°C was recorded in the

Himalayas potentially inducing strong impacts on the high-altitude ecosystems (Aryal et al. 2014). However, there are limited long-term observed temperature and precipitation records over the Himalayan region, which makes it difficult to accurately characterise the changing climate or its impacts. Furthermore, the Himalayan region has rich biodiversity, often with sharp transitions in vegetation sequences and equally rapid changes from vegetation and soil to snow and ice (Ives and Messerli 2004). According to the International Centre for Integrated Mountain Development (ICIMOD 2009), agriculture in the Himalayan region is expected to be directly affected by climate change through precipitation and temperature changes.

1.1.3 Vulnerability of Natural Ecosystems and Socio-Economic Systems

The ongoing changing temperature and rainfall trends and their variability are already impacting both the natural ecosystems and the socio-economic systems. Further, such impacts are projected to only exacerbate under the future climate change making these systems highly vulnerable. Under anticipation of threat to these systems from the future climate change, effort should be taken to consider system robustness in terms of their health and resilience status, and further, the possibility of reducing exposure to anticipated hazards should be assessed. For example, in case of the communities who dwell in the flood plains of rivers, their poverty levels should be addressed and measures should be taken to shift them away from the flood plains or to change the design of their dwelling houses to elevated areas so as to manage their exposure to flood hazard, and thereby, to reduce their overall vulnerability. Similarly, vulnerability of agriculture to drought could be reduced by providing irrigation facility. In order to reduce the vulnerability of ecosystem services from forest ecosystems under climate change, forest resilience should be built and enhanced by addressing the sources of anthropogenic disturbances, and by adopting measures to assist restoration of degraded forests.

Further, the extent of the impact of current climate variability or future climate change will depend on the vulnerability of a system. For a given level of stress from climate change, two comparable socio-economic systems could experience different levels of impact.

For example, increased drought will impact dry land or rainfed farms much more than groundwater-based irrigated farms in the same village, indicating lower vulnerability of farmers with irrigated facility. Similarly, slum-dwellers are more vulnerable to infectious diseases compared to those living in well-sanitised posh localities within the same area. Such lower vulnerability of the rich people could be because of their better access to physical health status and medical facilities.

1.1.4 Need for Adaptation to Current Climate Variability and Climate Change

Need to assess the vulnerability of natural ecosystems and socio-economic systems to current climate variability

Managing the risks due to current climate variability is necessary to limit the degradation of ecosystems, economic losses, social disruptions and human hardship. Such risk management through adaptation measures can potentially build the capability of natural ecosystems as well as socio-economic systems to resist and respond not only to the current climatic variability but even to the future climatic changes, and thereby to contain the losses. Vulnerability assessment under the current climate variability provides information about the current weaknesses of a natural or a socio-economic system and also the drivers of such weaknesses. It thus enables development of strategies to address the identified system weaknesses and to deal with or adapt to the drivers. The IPCC 2014 has also concluded that by reducing vulnerability to the risks from the current climate variability is the first practical step to curtail losses now and to build resilience to the long-term climate change.

Need to assess the vulnerability of natural ecosystems and socio-economic systems to climate change

Despite the uncertainties associated with the future projections of climatic and non-climatic factors, information about the likely future impact and future vulnerability is useful. Such knowledge deduced from systematically developed information helps by building awareness about the need for initiating affirmative anticipatory action to deal with the risks expected in future. Further, in view of an uncertain future, initiating

and adopting resilience-building measures without avoidable delay is a 'no-regret' strategy, as also, timely action has the benefit of availability of multiple options and costs being more affordable. Delayed action to reduce vulnerability to anticipated risks is sure to limit the options and escalate the costs. Thus, to secure the natural ecosystems and socio-economic systems under future climate, it is important to assess their vulnerability and take measures to reduce it. However, any anticipatory vulnerability reduction or adaptation measures must be considered for their potential to produce unintended adverse outcome(s) (maladaptation). Only such anticipatory measures should be selected that show favourable outcome in case projected scenario realises and remain neutral, and do not cause an adverse outcome in case other than projected scenario realises.

1.2 What is Vulnerability? Vulnerability in the Context of Current Climate Variability and Climate Change

1.2.1 Definition of Vulnerability and Other Terms

The definitions of the important terminologies used in the vulnerability and risk assessments are provided in Table 1.1. These are as defined in the IPCC Working Group II Glossary, 2014.

1.2.2 Concept of Vulnerability

Vulnerability being a non-observable and non-measurable state of a system is a theoretical concept (Hinkel 2011). It indicates predisposition of a natural ecosystem or a socio-economic system to be adversely affected. Predisposition indicates certain lack of capacity of the system to deal with the adverse impact of a hazard. Vulnerability is conceptualised as an internal property of a system that is a function of its current endogenous lack of (adaptive) capacity to overcome the adverse impact (its sensitivity) of a stressor. In anticipation of a climatic hazard or a non-climatic hazard stressor therefore, vulnerability of a natural ecosystem or socio-economic system is assessed as a function of its sensitivity (that determines the first order impact of a hazard/stressor on the system) to such hazard/stressor and its lack of (adaptive) capacity to overcome such sensitivity.



Table 1.1: Terminologies and their explanation

Adaptive Capacity (AC)	The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences.
Exposure (E)	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.
Hazard (H)	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. In this report, the term hazard usually refers to climate-related physical events such as droughts, floods, hurricanes, etc.
Impact (I)	Effects on natural and human systems. It generally refers to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. They are also referred to as consequences and outcomes.
Risk (R)	The potential for consequences where something of value is at stake and where the outcome is uncertain, recognising the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure and hazard.
Sensitivity (S)	Degree to which a system or species is affected, either adversely or beneficially by climate variability or change. The effect may be direct (e.g. change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea level rise).
Vulnerability (V)	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 Index (VI)	A metric characterising the vulnerability of a system. A climate vulnerability index is typically derived by combining, with or without weighting, several indicators assumed to represent vulnerability.

(Source: IPCC AR5 WGII Glossary 2014)

The concept of vulnerability can be operationalised in two ways:

- 1) When vulnerability is considered a pre-existing state of a system (Allen 2003) (referred to as 'starting-point' approach by Kelly and Adger (2000) or 'contextual' approach by O'Brien et al. 2007).
- 2) As overall impact of a disturbance on a system (referred to as 'end-point' approach by Kelly and Adger (2000) or 'outcome' approach by O'Brien et al. 2007). These approaches to understand vulnerability are analogous to considering a system 'before' and 'after' its exposure to a hazard.

The 5th Assessment Report (AR5) of IPCC (2014) focuses on the concept of 'risk' which arises "from the interaction of vulnerability, exposure and hazard." In the risk management framework adopted by the AR5, vulnerability is considered as a 'system property' comprising sensitivity and adaptive capacity and represents the propensity of a system to be adversely affected, independent of exposure.

Unlike 'impact', which can be easily described quantitatively, there exists no generally agreed metric to describe vulnerability quantitatively (Fussler and Klein 2006). Vulnerability is a 'relative measure' (Downing et al. 2001) that is 'place-based' (Hinkel 2011) and 'context-specific' (Cutter et al. 2008; Metzger et al. 2005; O'Brien et al. 2007). According to Hinkel (2011), vulnerability cannot be measured "because it does not denote observable phenomena" and therefore "speaking of measuring vulnerability should be avoided, as this is impossible and raises false expectations". As a number of contextual factors/mechanisms may cause or interact to determine vulnerability, quantifying or reducing it to a single metric is challenging (Adger 2006). Attempts to reduce it to a single metric may hide its complexity (Alwang et al. 2001). However, for easy comprehension and efficient communication with the stakeholders, vulnerability assessed using proxy indicators can be presented as a metric referred to as 'vulnerability index'.

1.2.3 Vulnerability in the Context of Current Climate Variability and Climate Change

All natural ecosystems and socio-economic systems function under the influence of their climatic and non-climatic environments. Often, such influences impose performance constraints on them and result in lower service/productivity outputs. Beyond thresholds, such external influences can impact robustness of a system, rendering the system vulnerable to degradation and loss of sustainability. In the context of climate variability and climate change, the stress from climatic sources is in addition to that from non-climatic sources; and it is suspected that climatic influences would modify the stress from non-climatic influences in an unpredictable and unknown manner.

The complexity of multiple climatic and non-climatic stressors acting concurrently is challenging to deal with. Further, due to lack of necessary knowledge

about the manner in which concurrent interaction of climatic and non-climatic stressors would occur and the impact they would cause on the system, there is, understandably, limited manageability of the system under influence and to deal with the possible adverse impacts. However, between climatic and non-climatic stressors, while climatic stressors are largely outside the realm of management, non-climatic stressors can be managed. So, overall, under the climate variability and climate change context, it is useful to focus on the vulnerable system and the non-climatic sources of stress to deal with the climatic risks. Accordingly, the approach is to reduce the vulnerability of the system of interest and manage the adverse influence of the nonclimatic stressors on it, as reduced adverse influence of non-climatic stresses and system vulnerability would enable the inherent resilience capacity of the system to deal with the climatic change related stresses better.

1.3 Why Assess Vulnerability and Application of Vulnerability Assessment

Awareness about the likely adverse impacts and the perception of threat from an externality, such as climate change creates the demand for vulnerability assessment as the results of vulnerability assessment provide information about the nature and extent of vulnerability and identify its sources. Dealing with the identified sources of vulnerability helps to reduce the current vulnerability, and thereby also improves the preparedness to deal with an unanticipated future. Further, vulnerability assessment helps in identifying vulnerable communities, vulnerable regions or sectors; raising awareness; prioritising the allocation of adaptation funds; identifying mitigation target; monitoring adaptation policy; and scientific research (Hinkel 2011). Utility of the vulnerability assessment results increases if they are acceptable to the stakeholders as the results that are accepted by the stakeholders are likely to be used in decision making by the planners. Involvement of stakeholders in the assessment exercise enhances the quality as well as the utility of the assessment outputs.

1.3.1 Ranking of Various Blocks, Districts and States According to Vulnerability Index

Blocks, districts and states are administrative units for governance and majority of the regulatory and developmental decision-making happens at these



levels. Results of vulnerability assessment carried out at block, district or state levels can be presented either as numerical vulnerability index (VI) value for different blocks or districts in a state or as a spatial profile of vulnerability at the state level showing blocks and districts under different vulnerability categories such as low, medium, high and very high vulnerability. Using the VI metric, it becomes feasible to rank the blocks and districts in the increasing or decreasing order of vulnerability. Such information helps in the identification of priority blocks/districts for resource allocation and adaptation interventions.

1.3.2 Prioritisation of Regions, Communities, Cropping Systems, etc., for Adaptation Based on Vulnerability Profiles

Vulnerability assessment is a critical pre-requisite to plan adaptation in anticipation of a future stress (Murthy et al. 2011; Ribot 2011). Vulnerability assessment carried out at the local scale informs about the drivers of vulnerability; and that at larger scale, helps in the identification of vulnerable areas, communities, etc., and to prioritise them. Thus, vulnerability profile development for different regions, communities and cropping systems can inform the process of identification of priority area units, communities or assets for taking up local-scale context-specific assessments to evolve adaptation strategies. Prioritisation provides a basis for resource allocation and enhances the resource-use efficiency.

1.3.3 Identification of the Drivers of Vulnerability

In a vulnerability assessment exercise, the current state of a system and the factors affecting it are assessed. Factors that adversely affect a system and thereby its stability, functionality or productivity, are identified as the ones causing vulnerability. Such factors and the system weaknesses are identified as the current drivers of vulnerability so that action could be taken to address them. Managing such drivers can potentially restore a vulnerable system with robust health status, when it has the best chance to respond to an external stressor in the future.

1.3.4 Vulnerability Assessment for Adaptation Planning

According to the Special Report of IPCC on Managing the Risk of Extreme Events and Disasters to Advance

Climate Change Adaptation (IPCC 2012, Summary for Policy Makers), **“Disaster risk management and adaptation to climate change focus on reducing exposure and vulnerability and increasing resilience to the potential adverse impacts of climate extremes, even though risks cannot fully be eliminated.”** Vulnerability reduction is therefore a principal approach to enhance the adaptability of natural ecosystems and socio-economic systems to the impacts of current climate variability and future climate change. In this Manual, we propose to operationalise the concept of vulnerability to:

- Assess the current (internal) state of a system
- Identify the factors/drivers impacting the system
- Address the factors/drivers in order to restore and improve the health of the system

In comparison to a disturbed system, a restored and healthy system is likely to show high autonomous adaptation capability to respond to the adverse impacts from changing climatic conditions and their variability when other non-climatic factors remain well managed. This approach to assess and reduce the vulnerability by taking up appropriate adaptation measures matches well with the approach to address adaptation deficit to deal with the risks in the context of climate change by improving the system status. According to IPCC (2014, AR5, WGII Glossary) ‘adaptation deficit’ is “the gap between the current state of a system and a state that minimises adverse impacts from existing climate conditions and variability.” Vulnerability assessment is thus a useful tool to enable adaptation planning and to minimise adaptation deficit.

1.4 Target Groups and Utility of Vulnerability Assessment

Vulnerability assessment has become a principal tool to generate information about the capacity of natural and human production systems to perform under additional adversity due to anthropogenic climatic variability and climate change. The interest in this regard is immense as climatic impacts are universal in occurrence and everyone including communities, planners, decision makers, development agencies and researchers need such information for adjustments in their own spheres of work. Accordingly, utility of vulnerability assessment for major groups of stakeholders is discussed hereunder.

1.4.1 Communities

Climatic and non-climatic stresses affect the status and availability of natural resources and sustainability of production systems. This has implications for resource accessibility by the communities at local level and thereby for exacerbating their vulnerability. Assessment of vulnerability of communities, and the natural resources they depend on, can help in developing vulnerability reduction and adaptation enhancement strategies. The results of vulnerability assessment can prompt simple adjustments in prevailing practices and the outcome of such adjustments could potentially be enhanced sustainability.

1.4.2 Development Agencies (International Agencies, NGOs, Banks, etc.)

Development agencies aim to promote the capability of socio-economic as well as natural systems to produce benefits for the society. Additional stress from climatic and non-climatic changes has mounted the challenge for securing developmental systems because such changes are impacting their productivity and utility. Use of vulnerability assessment as a tool to understand the current vulnerabilities of developmental systems can help in the identification of active non-climatic sources of vulnerability, dealing with which can potentially enhance the capability of developmental systems to respond under climate change. Vulnerability assessment will help development agencies to prioritise resource allocation to sectors and regions in building resilience to climate change impacts.

1.4.3 Policy Makers/Government Departments

Information grounded in stakeholders' experience and robust science is valuable for policy planning and decision making. It is particularly so because the current decision-making environment has become unusually complex due to overarching global issues such as climate change and strong market forces. Vulnerability assessments can help in dealing with this complexity, as the assessments carried out using robust scientific techniques, and those also involves stakeholders, yield results that are reliable and have high acceptability among stakeholders as well as policy makers. Such results can guide current decision making and inform the future policy direction. Vulnerability assessment

results will help policy makers to prioritise the locations, regions, sectors and communities for adaptation interventions, investment allocation and to formulate climate-resilient policies.

1.4.4 Researchers and Students

The demand for vulnerability assessment has accentuated with increased awareness about climate change. No sector, community or resource is understood to remain unaffected by the impact of climate change. Despite the associated uncertainties, anticipation and prior assessments of the risk from likely adverse impacts of climate change is the standard way to deal with the situation. This can potentially enable coping in the present and prepare for the future. Further, reducing current vulnerabilities is the robust strategy towards such preparedness. Researchers engaged in different sectors require vulnerability assessment results to inform the process of evolving strategies to deal with the intra- and inter-sectorial vulnerabilities for a more adaptable future. Further, researchers well equipped with the tools, techniques and methodologies for vulnerability assessment are likely to advance knowledge on vulnerability and risk assessment.

1.5 Evolution of Vulnerability Framework

The discourse on impacts and risks from changing climate gained importance in 1980s and thereafter when the impacts of industrial pollution and large-scale land use changes started manifesting as a global environmental problem. With increased reporting of the impacts of climate variability and change, and with the development of information about likely future warming scenarios, the global focus shifted from just the assessment and addressing the impacts of such environmental change to overall risk management not only in the current and immediate term but even in the future. Though the concept of vulnerability was part of the discourse, however, the IPCC third assessment report underscored its importance in dealing with the impacts and risks in the context of climate change. With further advancement in the understanding, the applicability of the concept of vulnerability has undergone a transition from a post-hazard (after occurrence of a hazard) to ante-hazard (before occurrence of a hazard) concept. Under the risk management framework presented in SREX



report and then in IPCC AR5, vulnerability is understood as an internal property of a system independent of the exposure. In this section, the framework for understanding the concept of vulnerability, as it evolved, is discussed.

1.5.1 Vulnerability Consideration Pre-IPCC 2007

The pre-IPCC 2007 period witnessed a transition from hazard-based impact assessments to adaptation-driven need for vulnerability assessments (Fussler and Klein 2006). In the discourse that evolved in the context of climate change, vulnerability was understood to indicate the adverse impact of an exposure from a climatic hazard that depended on the rate, magnitude and duration of such exposure, and the sensitivity and adaptive capacity of a system. Vulnerability was thus understood to represent the potential for harmful outcome of the interaction of an external stress (exposure) with the sensitivity and adaptive capacity of a system. Accordingly, the studies attempting vulnerability assessments adopted frameworks that considered vulnerability as a function of exposure (E), sensitivity (S) and adaptive capacity (AC). All the three components were assessed and combined to arrive at the vulnerability. Importantly, the vulnerability assessment discourse prior to 2007 identified sensitivity and adaptive capacity as internal properties of a system, and exposure as external to the system. This approach to assessment, considering vulnerability in terms of an adverse outcome, is referred to as 'end point approach' to vulnerability assessment.

1.5.2 Vulnerability Framework of IPCC 2007

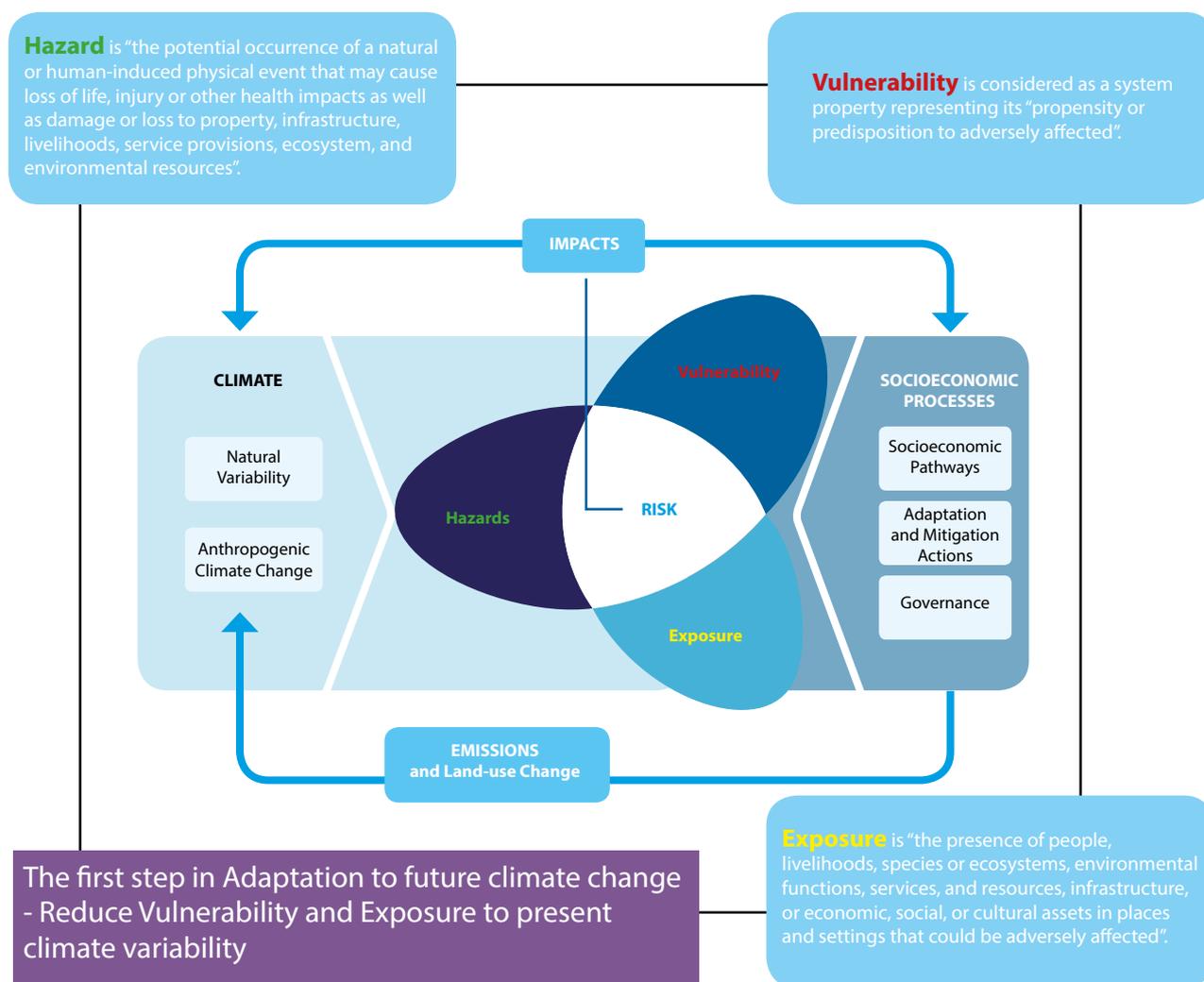
The pre-2007 understanding and articulation of vulnerability and its synthesis as a function of exposure, sensitivity and adaptive capacity were adopted in the IPCC 2007 Working Group II Assessment Report. IPCC 2007 defined vulnerability to climate change as "the degree, to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate

of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity." This definition of vulnerability has remained the same between 2001 and 2007 IPCC reports except that the word 'or' is substituted by 'and' in the first part of the definition in the 2007 report. This is in order to clarify that sensitivity and lack of adaptability should not be taken as alternative definitions of vulnerability but as its co-factors (Fussler and Klein 2006). The vulnerability assessment frameworks continued to consider all the three components – E, S and AC; however, the number of studies and sectors assessed multiplied and novel methodologies, tools and techniques were developed using the IPCC 2007 Framework.

1.5.3 Vulnerability Framework of IPCC 2014

The IPCC Special Report on Managing Risks from Extreme Events and Disasters to Advance Climate Change Adaptation, published in 2012 (SREX 2012), suggested the risk management framework that depicted the risk arising from the interaction of hazard, exposure and vulnerability. This framework separated exposure from vulnerability and considered vulnerability "independent of physical events" (SREX 2012). Vulnerability in this construct is considered a system property composed of its sensitivity and adaptive capacity. The IPCC 2014 report has adopted this construct of vulnerability and defined it as propensity of a system to be adversely affected, which is to be considered independent of the element of exposure. Between 2007 and 2014 IPCC Reports, the perspective regarding exposure has altered from a 'driver perspective' to 'exposure as a spatial concept' (Jurgilevich et al. 2017). Therefore, according to IPCC 2014 report, vulnerability is a characteristic property of a system that indicates its current internal state. The risk management framework adopted by the IPCC in the Fifth Assessment Report (IPCC 2014) depicts that hazard, exposure and vulnerability interact and result in risk within the overall climatic and non-climatic physical and socio-political environments (Figure 1.1). Accordingly, in this Manual, vulnerability assessment framework considers only sensitivity and adaptive capacity as the two cofactors determining vulnerability.

Figure 1.1: The risk management and assessment framework. Risk arises from the interaction of vulnerability, exposure and hazard.



(Source: IPCC 2014)

1.5.4 Comparison of IPCC 2007 and IPCC 2014 Vulnerability Frameworks

The change of approach from IPCC 2007 framework that considered vulnerability as a resultant of exposure, sensitivity and adaptive capacity to ‘a system attribute’ represented by the internal properties of the system (sensitivity and adaptive capacity) in IPCC 2014 framework has brought about a fundamental change in the approach to assess vulnerability. A comparison of the IPCC 2007 and 2014 frameworks is presented in Table 1.2.

The IPCC 2014 framework assesses vulnerability as an endogenous system property independent of exposure. Such treatment of vulnerability eliminates the

complexities related to the assessment of the nature and dosage of exposure to hazard. Further, an assessment of the present internal state of a system, and the treatment of the sources of vulnerability is a robust approach as it is beneficial whether or not climate change occurs. Such treatment of vulnerability also avoids the chances of maladaptation, and in combination with the benefits of restored health of the system, offers a win-win strategy. We, therefore, adopt IPCC 2014 framework to deal with the vulnerability in expectation of an uncertain future. Accordingly, the components of vulnerability and risk are presented in Figure 1.2.

The conceptual framework showing the components and scenarios for assessment of risk and vulnerability is presented in Figure 1.3. Vulnerability under this construct



Table 1.2: Comparison of IPCC Frameworks; 2007 and 2014

IPCC 2007 Framework	IPCC 2014 Framework
Vulnerability Framework: components Exposure (E) Adaptive capacity (AC) Sensitivity (S)	Vulnerability is presented in the overall Risk management framework Vulnerability is presented as one of the three components (other two are Exposure and Hazard) that give rise to risk E component is separated from vulnerability
Vulnerability - the residual impact after the potential impact caused (by E) due to the sensitivity (S) of the system is moderated by its AC; Outcome Vulnerability	Vulnerability (propensity of a system to be harmed), a system property shaped by S and AC of a system; Contextual Vulnerability
Focus of the assessment is on the exposure and the adverse effect that affects a system	Focus of the assessment is on the (internal state of) system
Vulnerability assessed considering E to a hazard (H)	Vulnerability is assessed independent of E
E represents disturbance dosage from a climatic hazard (H); 'driver perspective' of E; so occurrence of H subsumed in E	E represents presence of a vulnerable system at a location where hazard occurs; E as 'spatial concept'; H is a co-factor with E and vulnerability in giving rise to risk

Figure 1.2: Risk arises from the interaction of hazard, exposure and vulnerability. Vulnerability is an endogenous characteristic of a system and is determined by its sensitivity and adaptive capacity.

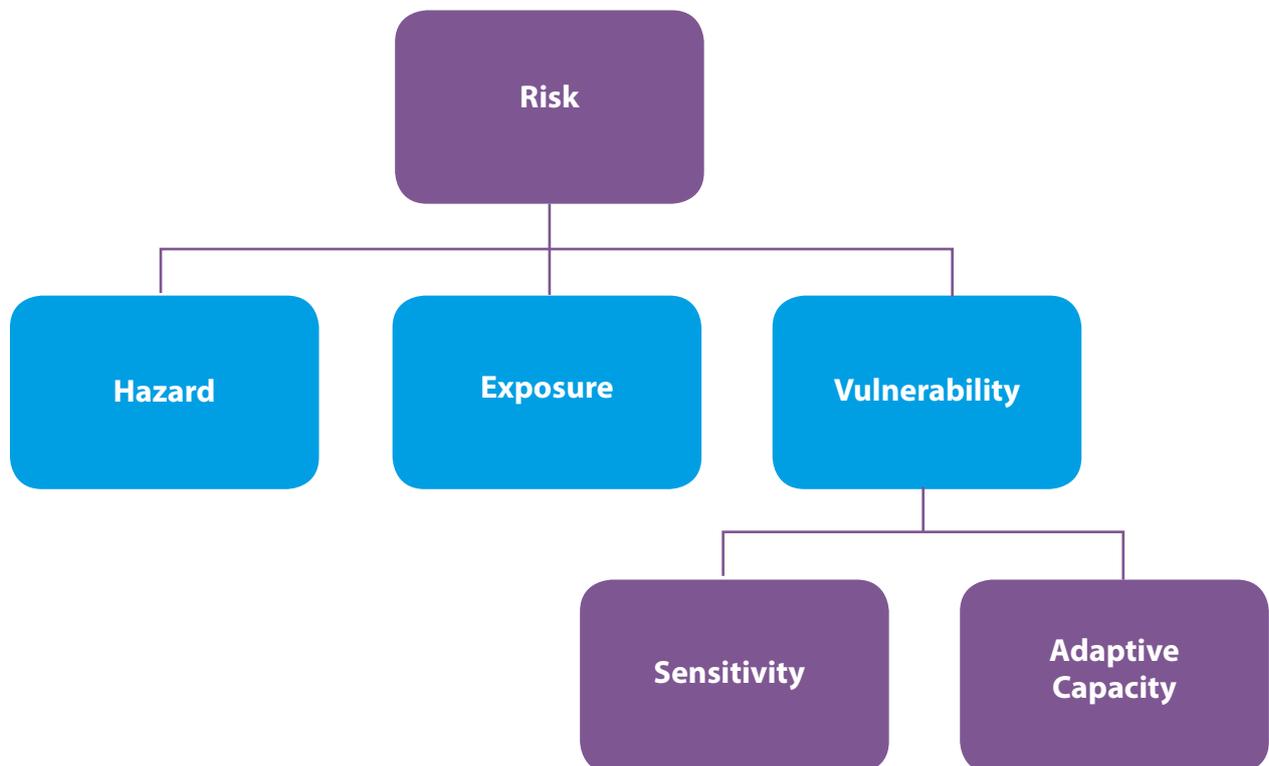
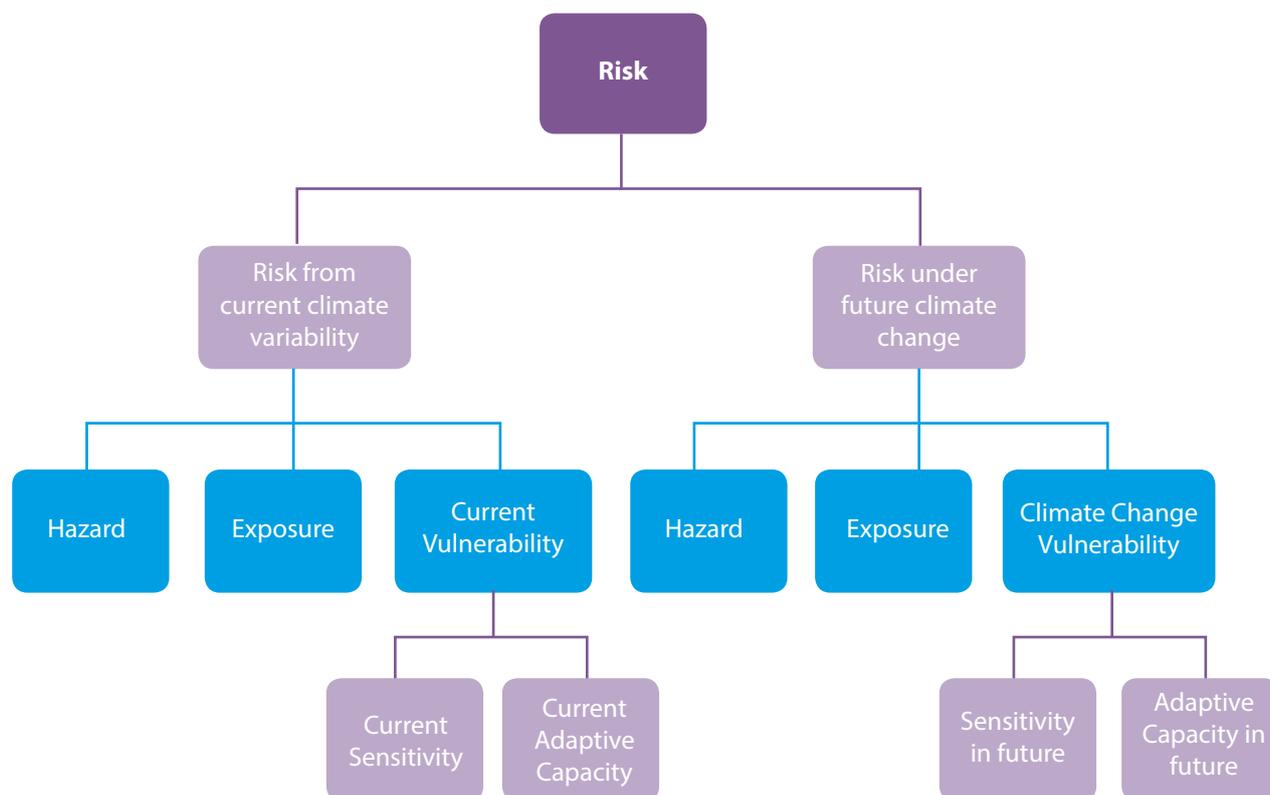


Figure 1.3: Conceptual framework showing the scenarios and elements for the assessment of risk and vulnerability according to the IPCC 2014 framework for management of risk. Risk is assessed under current climate variability and under future climate change. Vulnerability is assessed under the current and the future climate, independent of hazard and exposure. Dealing with the drivers of current vulnerability can potentially reduce the current as well as the future risks



is assessed as a snapshot vulnerability under the current climate (current vulnerability) as well as the future climate (climate change vulnerability). Accordingly, a common framework for assessment and reduction of vulnerability and risk in the context of climate change is presented in Figure 1.4.

1.6 Vulnerability Assessment at Regional Level: Case Study of the Himalayan Region

Vulnerability assessment is required at the regional and local levels for adaptation planning, in particular for ecologically fragile and environmentally degraded regions, subjected to socio-economic pressures. Here the Himalayan region is selected since it is one of the ecologically fragile zones, subjected to multiple socio-economic pressures. Vulnerability assessment in the context of the Himalayan region is challenging due to large diversity including varied terrain, high climatic variability, lack of enabling physical infrastructure,

environmental degradation and incidence of poverty. The distribution of communities in remote locations increases their vulnerability and poses additional constraint for adaptation. Marginalisation due to lack of information flow and resources in general further reduce the capability of the Himalayan communities to deal with the vulnerabilities that climate variability and climate change present. In this section, important features of the Himalayan region that have implications for the vulnerability of the natural ecosystems and the socio-economic systems are presented.

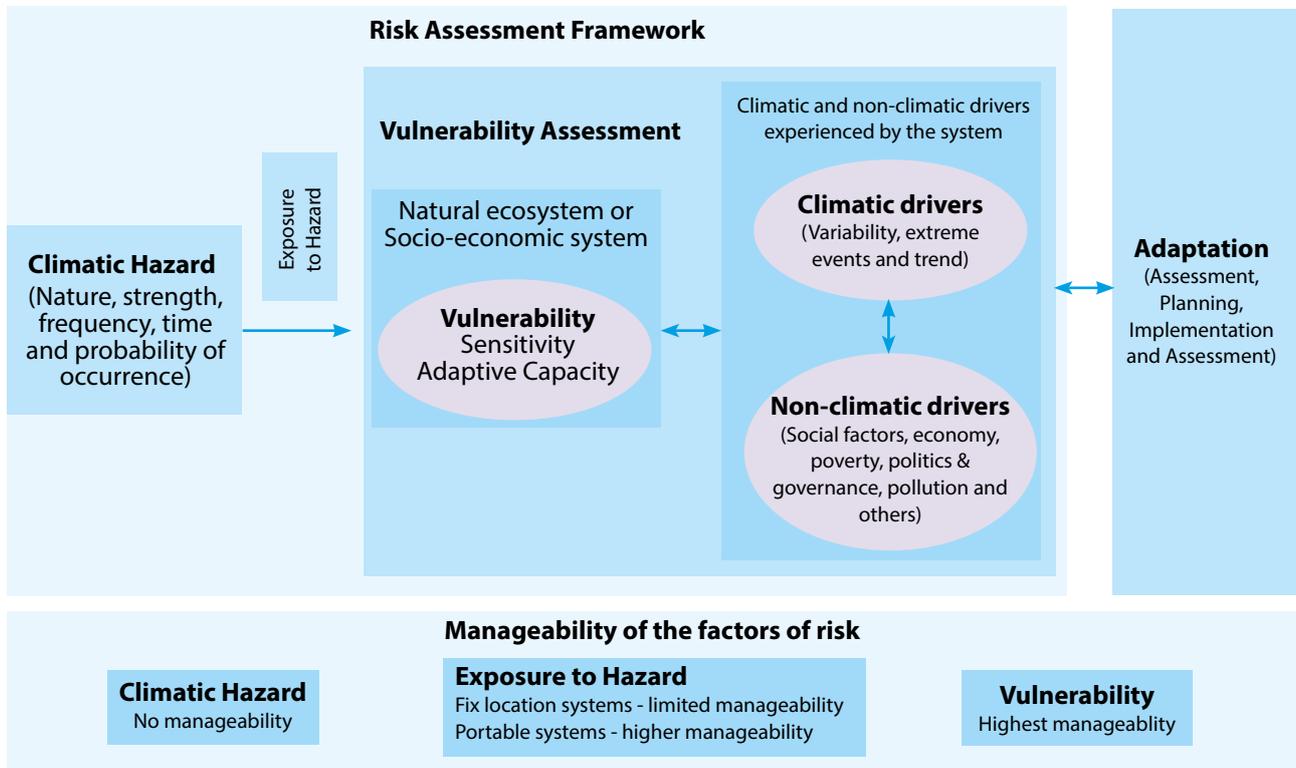
1.6.1 Physiographic Characteristics and Biological Features of the Himalayan Region with Implications for Vulnerability

Geologically, the Himalayan mountains are young and have many fault zones. Hence, the region is susceptible to seismic activity, soil erosion, frequent landslides



Figure 1.4: Common framework for assessment and reduction of vulnerability and risk in the context of climate change. System vulnerability has the highest manageability among the three components of risk

Common framework for management of Vulnerability and Risk



and denudation. The Hindu-Kush-Himalayan ranges are highly heterogeneous in geographical features. Vegetation changes from subtropical semi-desert and thorn steppe formations in the north-west to tropical evergreen rainforests in the south-east (Schickhoff 2005). As a result, these mountains have large biodiversity, often with sharp transitions (ecotones) in vegetation sequences and equally rapid changes from vegetation and soil to snow and ice (Messerli and Ives 2004). The mountains are also important as ‘water towers’. The Himalayan region has very rich biodiversity with high proportions of endemism. Problems associated with modernisation such as urbanisation, land use conversion, and land degradation are also occurring in the Indian Himalayan region.

1.6.2 Current Climatic Features and Implication for Vulnerability

Climatologically and ecologically, the Himalayan region is one of the most sensitive regions. This region has a number of glaciers which give rise to a number of

rivers. With increasing temperature, the area covered by permafrost and glaciers are decreasing in the region. Hence, the Himalayan region is one of the most sensitive regions. Further, the Indian Himalayan region is experiencing increased climate variability, and in particular monsoon rainfall variability, leading to higher frequency of extreme events. This has implications for the vulnerability of natural ecosystems such as mountain streams due to changes in flow and flood regimes, and the agriculture system, which is the primary source of livelihood for the hill communities.

1.6.3 Socio-Economic Features of the Himalayan Ecosystem and Implications for Vulnerability

The communities living in the Himalayan region have large dependency on climate sensitive sectors such as rain-fed agriculture; and have a fragile mountain ecosystem. Agriculture is prone to many extreme climate events. The overall status is the use of ‘not-so-modern’ agricultural options, inputs and technology options, and hence low productivity agriculture.

The growing population is causing ever increasing demand on the ecosystem services and hence is a threat to its sustainability. It not only poses a threat to the livelihood and culture of the local communities but also to the millions living downstream. Migration to the more developed states due to various reasons is also one of the factors causing rapid economic changes. The communities have limited livelihood options and experience higher marginalisation, as physical infrastructure (road and transport, markets, power supply and communication) is limited and there is high dependence on natural resources. Under changing climate, such constraints are likely to add to the vulnerability of the Himalayan communities.

1.6.4 Vulnerability Assessment for the Himalayan Region and Communities; Key Features Highlighting the Need for Vulnerability Assessment

It is clear from the above sections that the Himalayan region has its own peculiarities in terms of difficult terrain, inaccessible areas and extreme and more variable climate compared to non-hilly areas. These peculiarities render it highly sensitive to any climatic and anthropogenic changes. The biophysical and socio-economic constraints exacerbate the vulnerability status in the Himalayan region. It is vital to overcome these constraints by bridging the adaptive capacity of the hill communities to deal with the risks under climate change. Vulnerability assessment can be carried out to identify the drivers of vulnerability to these communities and further to assist in designing adaptation interventions specific to that area. There is an urgent need to conduct vulnerability assessment for the Himalayan region and communities. However, lack of assessment guidelines, lack of resources and institutions that can take up such vulnerability assessments pose a practical challenge.

1.7 Framework for Vulnerability and Risk-Impact Assessment

The conceptual approach for planning adaptation to climate change impacts for the Himalayan communities should have two priorities:

- First, to focus on the restoration of natural ecosystems as well as socio-economic systems to their functionally-robust state under current climate and thereby be better prepared to face an uncertain future.

- Secondly, to assess the risks from the impacts of future climate change to evolve strategies to deal with them.

System-restoration approach assesses the current vulnerabilities of a system with an objective to treat the drivers of vulnerability and restore its natural (resilience) potential; underlying principle being 'reduction in current vulnerability, potentially reduces the future risks'. This is a 'no-regret' approach, as the system gains health and vitality. It is a robust approach, also because, it avoids the possibility for maladaptation from adaptation measures taken in expectation of a future scenario, when a different scenario realises. Reliable tools and techniques to estimate the probability of occurrence of a future scenario are not available and hence any estimation is associated with high uncertainty. Under system-restoration approach, restoration of a system through assessment and treatment of its current vulnerability is without the consideration of exposure to an anticipated climatic hazard and only depends on the system properties.

Beyond the assessment of current vulnerability and its treatment, it is also useful to assess the impacts of current climatic variability and future climatic change, as it informs about the range of impacts and thereby the risks involved. Such information helps in preparedness to face an uncertain future. Moreover, assessment of future impacts helps in visualising and communicating the future risks. Such communication is essential for building appropriate risk perception among stakeholders. Risk perception helps in building necessary consensus and demand for anticipatory adaptation and risk reduction measures.

Both the vulnerability assessment and risk assessment improve understanding about the likely harm that an anticipated adversity can cause. Both are ante concepts, i.e. they are carried out in anticipation or prior to the actual occurrence of a hazard. Once a hazard has occurred, impact manifests and the considerations move out of the realm of vulnerability or risk assessment to dealing with the impact. Impact is a post-occurrence concept. Once a hazard occurs and interacts with a vulnerable system, vulnerability or risk or impact, all the three merge and result in single outcome - 'harm'. Further, in anticipation of a hazard, while vulnerability is the propensity of a system to be harmed, risk includes the chance that such harm would



actually be realised. And, impact being a post-hazard outcome, becomes known only after the occurrence of a hazard. Vulnerability characterises vulnerable state of a system; risk indicates the chances of a hazard occurring and causing anticipated harm; and, impact is the harm actualised as a result of a hazard.

1.7.1 Vulnerability Assessment Framework from IPCC 2014

Under the IPCC 2014 framework, practically, assessment of vulnerability is largely about identification of the factors that weaken the health and robustness of a system. Therefore, vulnerability assessment of natural ecosystems, or that of socio-economic systems such as a community, involves consideration of the whole range of factors that are predominantly biophysical to those predominantly society-based in origin and impact the system. However, depending on the objectives and the specific context of the assessment, the emphasis (weights) attached to different factors (vulnerability indicators) would vary. For example, while assessing the vulnerability of agriculture to drought, 'availability of irrigation facility' is likely to get higher weight than 'size of a farming family'.

The two components of vulnerability (V) – sensitivity (S) and adaptive capacity (AC) – are non-observable system properties. What is clearly known about S and AC is that they contribute differently to vulnerability - while S adds to vulnerability, AC reduces it. Vulnerability increases as S increases and AC reduces it, and vice versa. It is however not known, as how do S and AC relate one-to-one, i.e. how change in one changes the other? Or, are S and AC independent of each another? It is hard to know the interrelationship between S and AC, as both are practically non-observable, non-measurable and non-quantifiable. Proxy indicators are therefore used to assess them. Due to their non-measurability, the relationship between S and AC or between V and S or V and AC is not possible to quantify. However, recognizing the direct and inverse proportionality of S and AC with vulnerability respectively, the following functional relationship can be stated.

$$\text{Vulnerability (V)} = f[\text{Sensitivity (S), Adaptive Capacity (AC)}]$$

$$\text{As, } V \propto S \text{ and } V \propto 1/AC, \text{ therefore } V = f[S, 1/AC]$$

However, the available literature has largely adopted the IPCC 2007 vulnerability framework and considers exposure (E) as a component of vulnerability, and calculates vulnerability index (VI) by combining the three components in the following ways: generally, $V=S+AC+E$; Hahn et al. 2009, $V=(E-AC)*S$; Ahumada-Cervantes et al. 2017, $V=[E+S+(1-AC)]/3$.

1.7.2 Risk-Impact Framework from IPCC 2014

Risk-Impact assessment refers to the assessment of risk from climatic and/or non-climatic impacts. Location of a system at a place where hazard occurs operationalises its vulnerability and causes impact. The probability that a hazard would occur at the location where a (vulnerable) system of interest is present defines the risk for that system. Therefore, in order to assess the risk therefore, it is vital to know the vulnerability of the system of interest, the nature of hazard, and the chances that such hazard would occur at the place where the system is located. Practically, the risk from a hazard is quantified as a product of (quantified) impact and the probability of the occurrence of a hazard.

$$\text{Risk (R)} = \text{Impact (I)} * \text{Probability of the occurrence of a hazard}$$

Impact is the measurable outcome of a hazard interacting with a vulnerable system. It becomes available for measurement and quantification after hazard has occurred. Impact can be assessed in anticipation of a hazard using models. Further, understanding the manner in which multiple climatic and non-climatic stressors interact among themselves and with the system to produce impact is lacking. The challenge is to know whether the impacts caused by such stressors would finally produce an added or multiplied or neutralised effect for the system.

Conceptually, formulation of risk involves accounting for assessed vulnerability, hazard characterisation and the probability of the occurrence of a hazard. Accordingly, risk can be presented as follows.

$$\text{Risk (R)} = f[\text{Vulnerability (V), Hazard (H), Probability of the occurrence of a hazard}]$$

The main objective is to manage and reduce the risk, and the identification of the factors driving the risk becomes important to us. According to Kaspersen et

al. (2001), **“what is essential is to assess vulnerability as an integral part of the causal chain of risk and to appreciate that altering vulnerability is one effective risk-management strategy.”** This prompts us to probe the vulnerability sources and the ways to reduce exposure from climatic hazards. Therefore, to assess the risk, quantification of system vulnerability and hazard, and deciding the probability of a hazard occurrence become necessary. While indicator-based techniques enable us to quantitatively present vulnerability and hazard, probability of hazard occurrence can be assessed from the past data. Probability from the past data can further be modified either by using future projections for hazard occurrence simulated by climate models, or a range of theoretical probabilities can be used to quantify the risk.

1.7.3 Comparison of Vulnerability Assessment and Risk-Impact Assessment

A quick comparison of the salient features of the vulnerability assessment framework and Risk-Impact (R-I) assessment framework is useful to highlight their important elements including the applicability of the two frameworks (Table 1.3). The comparison is presented for indicator-based assessment methodology and when the results are presented in terms of assessment index values.

1.7.4 Why Focus on Vulnerability Assessment for Adaptation Planning?

The aim of the current Manual is to enable the stakeholders to deal with the risks to natural ecosystems and socio-economic systems in the context of climate change. The approach adopted in the Manual to achieve this involves assessment of vulnerability for the development of appropriate adaptation plans that, as a first step, would help in reducing the current vulnerability. It is useful to mention here that the residual impact from the past exposures to climatic and non-climatic hazards experienced by a system influence the health of the system and contribute to the current system vulnerabilities. Improving the health of a system enhances its capability to respond to the future hazards.

According to the IPCC 2014 framework, this system-health focused and exposure-independent approach to understand, assess and deal with the system

vulnerability (current or inherent vulnerability) offers a ‘win-win’ strategy with or without climate change in the future. This is because reducing the current vulnerability restores and enhances system vitality, and thereby its capability to deal with an uncertain future. Moreover, future is assessed in terms of multiple scenarios and it is hard to reliably assign the probability of actualisation to such scenarios. Given this uncertainty, developing adaptation strategies, providing for one or more identified scenarios, involves the risk of maladaptation and may even lead to differing or conflicting adaptation strategies. According to Eriksen and Kelly (2007) “a methodology that emphasizes the causes of vulnerability is likely to be advantageous.”

This Manual focuses on the assessment of (current) vulnerability adopting the IPCC 2014 risk management framework. Beyond vulnerability assessment, the arena of risk assessment and treatment is again riddled with scenarios, probabilities and uncertainties. It is, however, useful to assess risk as it helps in developing demand for and avoids procrastination of mitigation and adaptation planning.

1.8 Framework for Vulnerability Assessment (IPCC 2014)

Vulnerability lies hidden and dormant within a system, contributing to the overall impact of exposure to a hazard. The concept of vulnerability assessment can be operationalised either through ‘starting-point’ or ‘endpoint’ approach.

- Under ‘starting-point’ approach, vulnerability is assessed as a system-property without considering exposure of the system to a hazard; while under ‘end-point’ approach, vulnerability assessment also considers exposure of the system to a hazard.
- IPCC 2014 framework adopts ‘starting-point’ approach to vulnerability assessment. Accordingly, vulnerability assessment can be understood as an endeavor to assess the propensity of a system to get adversely impacted through identification and quantification of factors and mechanisms (called drivers of vulnerability) that compromise its capacity to resist change and remain resilient and adaptable.



Table 1.3: Salient features of Vulnerability Index and Climate Change Risk-Impact Index Frameworks

	Vulnerability Index Framework	Climate Change Risk-Impact (R-I) Index Framework
Type of framework	- Current Vulnerability - Vulnerability under climate change	Risk under current climate Risk under current climate
Framework Components	Sensitivity (S) and Adaptive capacity (AC)	Hazard (H), Exposure (E) and Vulnerability (V)
Indicators	Required for both, S and AC	Required for AC, S and H
Data requirement	Data on indicator parameters required	-Data on indicator parameters for vulnerability -Data required from climate and sectorial impact modelling
Source of data for indicators	Primary as well as secondary sources depending on the scale and tier of assessment (Local biophysical and household surveys, Agriculture and Water Resource Department data, Census of India, State Planning Department and www.indiastat.com)	Primary as well as secondary sources depending on the scale and tier of assessment (Local biophysical and household surveys, databases such as Agriculture and Water Resource Department data, Census of India, State Planning Department and State Disaster Management Cell data) - Past climate data and CMIP5 and CORDEX model-based climate change projections, climate change impact model outputs
Applicability of the framework	Assessment of vulnerability of natural system or a socio-economic system at multiple scales under current as well as future climate	Risk assessment of a natural system or a socio-economic system at multiple scales to current climate variability as well as future climate change
Merits of the framework	Calculating the Vulnerability Index will assist policy makers to make decisions to reduce current vulnerability Helps in prioritisation and distribution of resources to most vulnerable natural ecosystems or communities Identification of the drivers of vulnerability informs the vulnerability reduction planning process Maladaptation is avoided, as interventions are directed to restore health of a vulnerable system It is a quick method to understand the current sources of weakness of a system Very useful for reducing vulnerability through current, ongoing and soon-to-be implemented plans	Provides an assessment of the overall risk to a vulnerable system which can be efficiently communicated to stakeholders for building consensus for action Can be used as a tool to compare the present and future risks to a natural ecosystem or community under climate change Based on the assessment outcome, well considered risk reduction strategies can be prepared Prompts timely risk-reduction measures
Limitations of the framework	Does not consider future threats and hazards but only focus on the system's current internal state Depending on the purpose of the assessment, data intensity and skill level may become demanding	Intensive data requirement Adaptation measures taken on the basis of risk probabilities may turn out to the disadvantage of the system, i.e. may result in maladaptation Risk assessment is resources and skill demanding (particularly the modelling capabilities) Risk assessment is time consuming

Holman and Nass (2008) summarise the essence of vulnerability assessment as “success for vulnerability assessment can be understood as the ability to facilitate adaptation and justify climate change mitigation efforts. This depends, among other factors, on assessments being scientifically valid, understood and deemed valid by stakeholders at different levels, as well as being relevant to existing decision-making framework at different scales.”

The following broad steps are involved in the vulnerability assessment process (Figure 1.5).

- Scoping the assessment
- Conducting the assessment
- Implementation of the assessment results through adaptation planning

1.8.1 Scoping for Vulnerability Assessment

Scoping is the first and very important step, as it not only decides the focus of the assessment but also guides the assessment process with respect to the resources

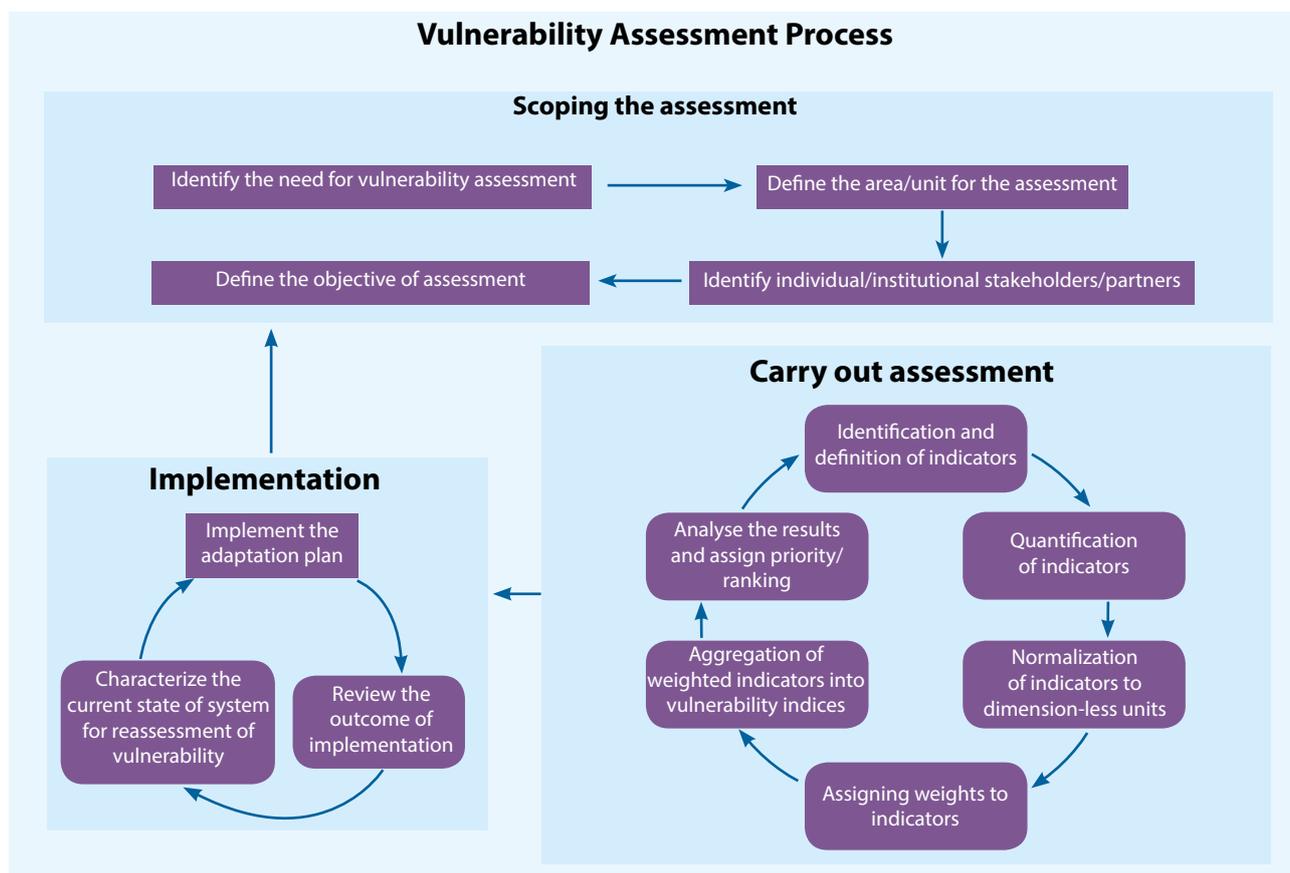
for assessment and role of stakeholders. The overall usefulness and utility of vulnerability assessment results depends on the scoping of the assessment. Scoping of the assessment involves the following four steps.

- Identifying the need for the assessment
- Defining the area/unit of assessment
- Identifying the stakeholders and other participating institutions
- Defining the objective of the assessment

1.8.2 Conducting Vulnerability Assessment

Having decided the scope of the assessment, a six-step methodology can be followed to carry out the assessment. Selection of vulnerability indicators is a vital first step and requires considerations of stakeholders’ perceptions and data availability on indicator parameters. Assigning weights to indicators is fundamental to assessment and can alter the outcome of the assessment. It is useful to assign differential weights to the indicators for which several techniques are now available. Preferably, indicator weights should

Figure 1.5: Framework showing approach to be followed for vulnerability assessment (Adapted from IPCC 2014)





be decided in consultation with the stakeholders, as indicator weights decided by stakeholders enhance the reliability of the assessment results. Analysing the results of the assessment with stakeholders is a good practice that makes the results more acceptable.

1.8.3 Current Climate Vulnerability (Inherent) and Climate Change Vulnerability

In this Manual, vulnerability is assessed as ‘snapshot vulnerability’ defined by the internal state of a system under current climate (inherent or current vulnerability) and future climate (climate change vulnerability). Vulnerability as system property is presented in the IPCC SREX Report (2012) as well as IPCC AR5 (2014, WG II, SPM). The term ‘inherent vulnerability’ was reported by Brooks (2003) in the literature in respect of the systems that cannot be termed as ‘social’ systems. He discussed inherent vulnerability as system property being independent of exposure. Practically, Sharma et al. (2013) have adopted the concept of inherent vulnerability in the context of vulnerability assessment of forests as “a system property that determines the capacity of a system to resist a disturbance and adjust to it.” Inherent vulnerability concept thus follows the IPCC 2014 approach. The concept of inherent vulnerability can be operationalised to assess the vulnerability of natural ecosystems as well as socio-economic systems under current climate and future climate. Therefore, **in the Manual, simply the term vulnerability is used, and it refers to the above mentioned snapshot internal-state dependent vulnerability of a system, assessed now (current) or at any time in the future.**

Climate change vulnerability is the vulnerability of a system assessed in the future after the changed factors of climate have impacted the system’s internal state modifying its sensitivity and adaptive capacity. Assessment of climate change vulnerability is constrained by the lack of techniques to reliably project the vulnerability indicators into the future. Such projections, even when feasible, have limited utility due to the uncertainty associated with the future scenarios. However, it is useful to assess such vulnerability, even considering multiple scenarios, as it informs about its likely temporal trends. This helps to initiate long-term appropriate policy and resource management measures (say anticipatory adaptation measures for forests) that could maintain a system in low vulnerability state.

1.8.4 ‘Hazard’ and Vulnerability Assessment under IPCC 2014 Framework

Vulnerability is defined by its three components – exposure, sensitivity and adaptive capacity – in the IPCC 2007 report. Most of the studies in the recent years reported in the literature consider exposure (to represent a hazard) to assess vulnerability. However, the Risk Management Framework (RMF) reported in the IPCC 2014 Working Group II Report presents exposure and hazard as separate from vulnerability. Thus, the IPCC 2014 RMF delinks vulnerability from hazard – whether current climate hazard or future climate change. Under the IPCC 2014 framework, vulnerability appears in the risk management framework, and is shown as one of the three components – other two being exposure and hazard - that interact and result in risk. Consideration of the definitions for vulnerability, contextual vulnerability (starting-point vulnerability) and outcome vulnerability (end-point vulnerability) provided in the WGII glossary (IPCC 2014) suggests that one of the two approaches, i.e., starting-point or end-point approach, could be used to carry out vulnerability assessment in pursuit of vulnerability reduction.

Generally, the IPCC 2014 RMF diagram indicates that the vulnerability component is independent of hazard, as hazard is shown separately from vulnerability. Experts familiar with vulnerability framework of IPCC 2007 may ask a question - how one can consider vulnerability as independent of climate change or hazard. Given this, let us consider if and how hazard figures in vulnerability assessments. Vulnerability assessment seeks to evaluate the current internal state of the system. Such internal state is the outcome state that has resulted after all the impacts from the past hazards have been experienced by the system. Therefore, vulnerability indicators that represent the characteristic sensitivity and lack of adaptive capacity of the system are selected; the two (sensitivity and adaptive capacity) being the internal properties of any system. For example, while assessing the vulnerability of agriculture (a system), a proxy sensitivity indicator, ‘loss in crop yield’ representing the impact of the exposure of agriculture crop to a hazard (say, drought) is selected. In reality, most often such an indicator could be a composite indicator accounting for the loss in crop yield due to extreme events, drought, non-availability of water in the irrigation dam, untimely rainfall event, crop raiding by wild animals, lack of labour, lack of capital, and so on.

As discussed above, vulnerability is a system property, and it is not linked to hazard. Hazard is an externality to a system. Vulnerability, however, can be assessed independent of or with reference to a hazard. In both the cases, vulnerability assessment improves the understanding of the predisposition of a system to be adversely affected. It improves general understanding when it is not contextualised with respect to a hazard, and hazard-specific understanding when contextualised with respect to a hazard. Accordingly, under the 'starting-point' (contextual vulnerability) approach to assess vulnerability, vulnerability can be assessed as hazard-specific vulnerability by selecting hazard-relevant sensitivity and adaptive capacity indicators. Indicators for hazard are not selected.

Thus, hazard-relevant sensitivity and lack of adaptive capacity indicators of a system are chosen to assess hazard-specific vulnerability. For example, to assess the vulnerability of hill communities to landslides - 'high slope' and 'fragile geology' - which are system properties, can be selected as hazard-relevant sensitivity indicators. These indicators, however, are not relevant to assess their drought vulnerability. Similarly, 'lack of irrigation' is a hazard-specific indicator to assess drought vulnerability of the hill communities; and this indicator is not relevant while assessing their vulnerability to landslides.

1.8.5 Vulnerability Index and Vulnerability Profile

According to IPCC (2014, WGII, Glossary), vulnerability index (VI) is "a metric characterizing the vulnerability of a system. A climate vulnerability index is typically derived by combining, with or without weighting, several indicators assumed to represent vulnerability." It is, therefore, a numerical value that can potentially provide a preliminary sense about the vulnerability status of a system of interest. VI value is obtained as a composite value from the measured values of the proxy indicators of the factors driving vulnerability. VI does not communicate much about a system when considered as a stand-alone metric. However, an analysis of the vulnerability indicators contributing to the index can provide useful insights about the current status of the system. Spatial display of assessed vulnerability under different categories from low to very high vulnerability using VI shows the profile of vulnerability over a geographical area.

The VI metric and vulnerability profile become a powerful empirical tool when it is estimated to compare and rank two or more systems, e.g., two or more regions or community groups. This ranking of regions or communities assists in identifying the more vulnerable regions or communities. Use of VI value or vulnerability profile facilitates efficient communication with the stakeholders including planners and decision makers about the most vulnerable community or region.

1.8.6 Implementation of Vulnerability Assessment for Adaptation Planning

Adaptation planning is preceded by vulnerability assessment at different scales. While large-scale assessments are useful in the identification of most vulnerable areas and in prioritising/ranking them, local scale assessments inform about the specific drivers of vulnerability. After vulnerability assessment, the next step is to use the assessment results in adaptation planning. This is a big challenge since there are very few examples of actual utilisation of the results of vulnerability assessment in designing adaptation strategies and their implementation. The two broad approaches for adaptation planning utilising the vulnerability assessment are as follows:

- First, development of vulnerability profiles, identifying and ranking the extent of vulnerability will help in prioritising adaptation interventions and in allocating investment.
- Secondly, identification of the drivers of vulnerability would assist in developing targeted adaptation interventions to address each of the biophysical or socio-economic drivers.

Adaptation planning is not a one-time process since vulnerability as well as the drivers of vulnerability are dynamic. This requires review of the state of the system and reassessment of vulnerability periodically.

1.9 Risk-Impact Assessment Framework

To reduce the risk of impacts from climate variability and climate change, planners could first target reducing the possibility and extent of impacts, and then plan to deal with the residual impacts. Such risk reduction approach is rooted in the management of exposure of a vulnerable system to a hazard. In anticipation of a climatic hazard, this approach primarily seeks to:



- relocating a community to another location where hazard is not/less likely to occur or by raising the level of dwellings on pillars in a flood-prone area. However, such options depend on the system portability.
- Reduce the vulnerability of the system by building/enhancing its robustness (inherent strengths and health status of the system). This requires information regarding the factors that adversely affect the health of the system and make it vulnerable to impacts. Such information is obtained from vulnerability assessment.

1.9.1 Broad Approach and Steps for Risk assessment

In this Manual, the vulnerability concept, framework and methods are presented in conformity with the understanding provided in the IPCC 2014 WG II report. The IPCC 2014 framework also includes assessment of risk and impact of hazards. The main goal of the framework is to enable development of adaptation strategies with the knowledge about the likely impacts of climatic hazards. The risk/impact according to this framework is a function of hazard, exposure and vulnerability. Vulnerability is only one of the components. Risk according to this framework is assessed as probable harm that can be caused to a biophysical or socio-economic system by an anticipated/expected hazard. Assessing risk has the purpose of taking anticipatory/preparatory action to minimise, or be able to withstand, the harm from impact(s) of a likely future hazard event. Under impending climate change, which is expected to only aggravate under business-as-usual scenario, understanding the risk from current climatic hazards and future climate change trends and hazards is necessary, as it enhances our capability to reduce the risk under an uncertain future.

Risk is assessed for a (vulnerable) system of interest, for hazard(s), when such system is located at a place where such climatic hazard is likely to occur. Risk assessment thus involves assessments of V, H and E that give rise to risk. The conceptual framework to assess risk, adapted from the IPCC (2014), is shown in Figure 1.6.

1.9.2 Risk Assessment Scenarios

It is useful to assess risk arising from the current climatic hazards as well as the climatic hazards expected in future due to climate change, as both provide knowledge that can help in better adaptation to impacts of the likely hazards, at present and in the future. Further, managing current risks by developing system resilience also enhances the capability of the system to autonomously deal with future risks. Accordingly, risk assessments are planned under the following two scenarios:

- Current climate hazard(s) scenario
- Future climate change hazard(s) scenario

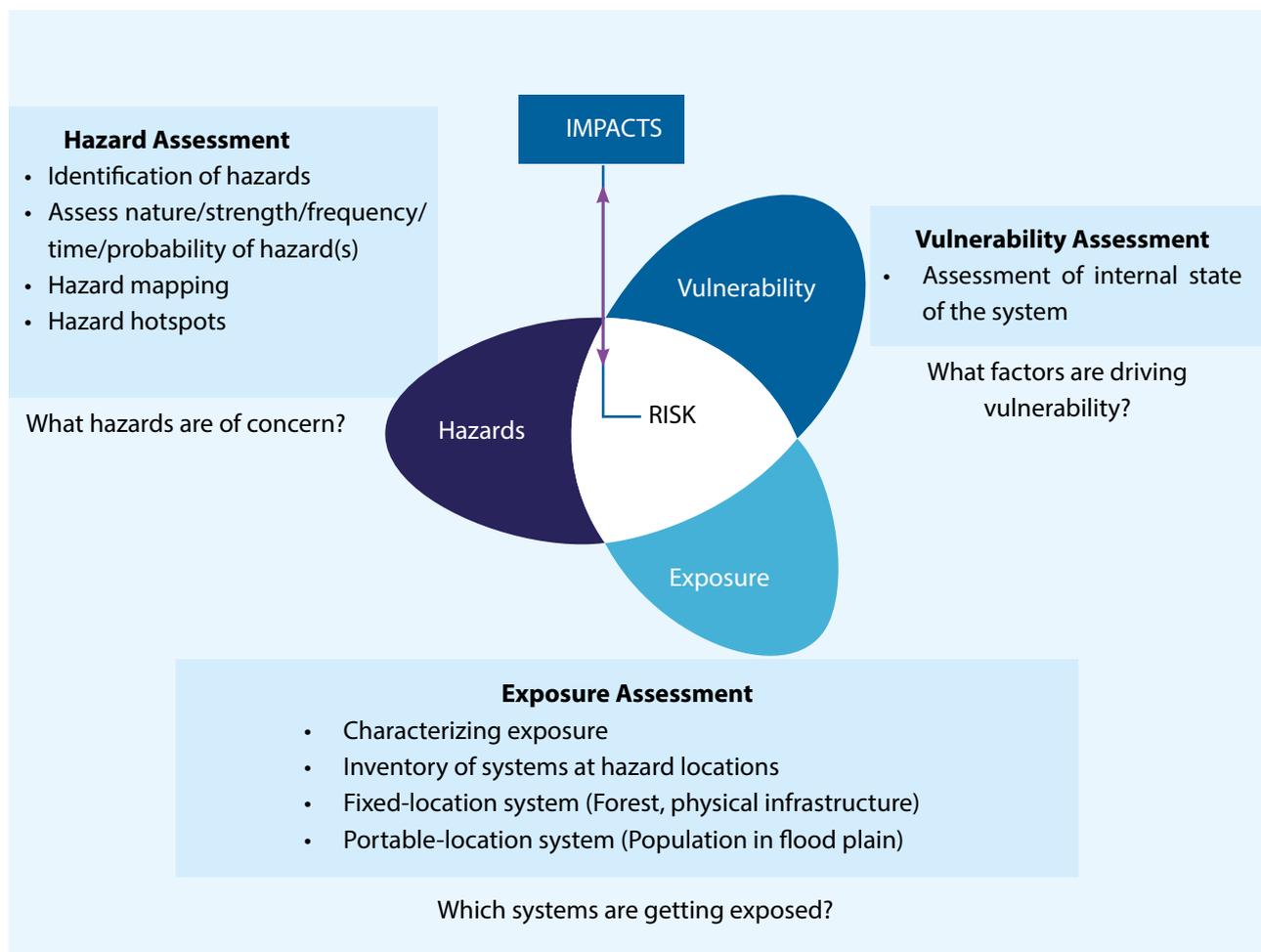
1.9.3 The Risk Assessment Approach

The approach to risk assessment involves collation and analysis of information obtained from the assessments of the three elements that result in risk, namely, vulnerability, hazard and exposure. Assessing these elements for risk involves assessment of the system vulnerability, hazard characterisation, exposure characterisation, and assessing the probability of hazard occurrence at the place where the system is located.

Hazard Assessment

Hazard is defined by IPCC 2014 as “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.” The term hazard in the context of climate change refers to climate-related physical events or trends or their physical impacts. Hazard simply includes the occurrence of climatic events such as extreme high rainfall events (leading to floods), rainfall deficit (leading to droughts), hurricanes and wind gust (leading to soil erosion). The first step in characterisation and assessment of hazard is to identify the hazard(s) that is likely/expected to impact the system. Such identification is followed by characterisation and assessment by developing the information about nature, strength, frequency, time of occurrence, and probability of occurrence of hazard(s).

Figure 1.6: Conceptual framework for assessment of risk (adapted from IPCC 2014)



- For current risk assessment, the above-mentioned information is obtained from the past occurrence of hazard episodes and trends.
- For future risk assessment, such information is obtained from global and regional climate models.

Besides carrying out the risk assessment of a particular system of interest, it is also useful to inventorise and map future hazard(s) in order to identify hazard hotspots at district, state or larger scale. Such knowledge can inform and prompt anticipatory measures in respect of the system(s) located at identified hazard hotspots for reducing vulnerability and managing risk. Followed by the identification of hazard hotspots, it is useful to develop an inventory of systems of interest located at the hotspots. Further, exposure (of a system to identified hazard) needs to be characterised and assessed to assess risk.

Practically, risk assessment is quantified as the probability of actualisation of the assessed outcome vulnerability. Such quantification of risk is obtained as a product of the probability of the occurrence of a hazard and the quantified 'outcome' vulnerability of the system for exposure to such hazard.

Exposure Assessment

According to IPCC 2014, exposure is "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." Analysis of the nature, frequency and duration of hazard at a location characterises exposure at that location. Such information is useful for the estimation of the probability of occurrence of a hazard at the system



location. Examples could include exposure assessment for communities residing on the mountain slopes or on flood plains, fishing communities or settlements close to oceans and extent of monocrops.

Vulnerability Assessment as a Component of Risk Assessment

The concept, framework and methods for assessing vulnerability are presented in the previous sections. Detailed methods for assessment of vulnerability are provided in Part 2 of this Manual.

1.9.4 Framework for Risk Assessment

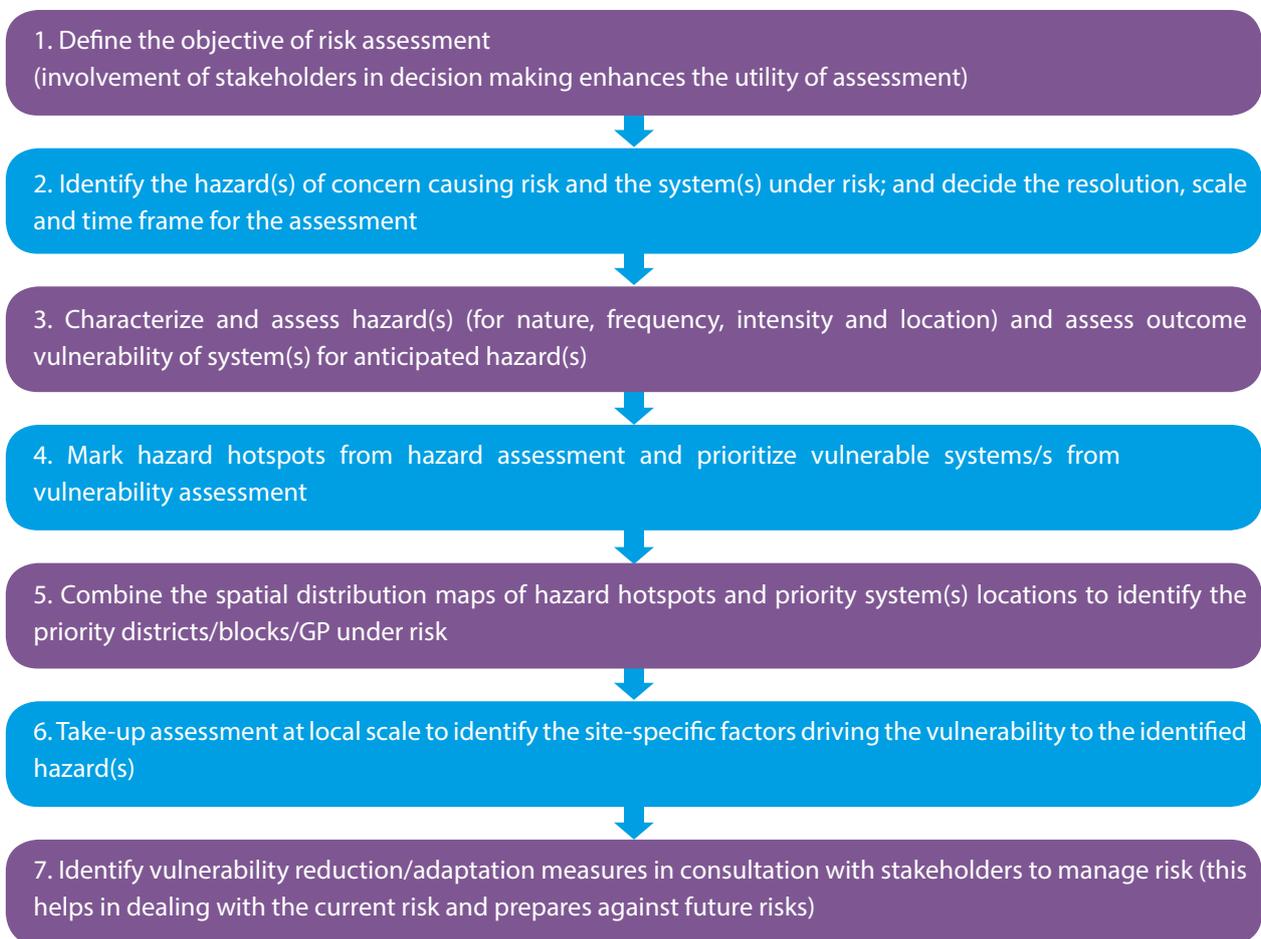
A generic framework for assessing and managing the risk is presented in Figure 1.7. The framework starts with defining the objective(s) of risk assessment and culminates in taking vulnerability-reducing measures to reduce/manage risk. As the elements constituting

risk (Vulnerability, Exposure and Hazard) are dynamic in nature, risk should be periodically assessed and managed. This framework is universal and is applicable to natural ecosystems as well as socio-economic systems.

1.9.5 Steps for Assessment of the Risk

Further, to manage the risk to a system from a hazard, it is essential to undertake risk assessment, as it provides information about the nature and extent of risk. Such information is useful in creating demand for initiating risk-reduction measures in anticipation. Assessment of risk also provides an opportunity for developing appropriate perception among the stakeholders about the possible risks, and it is useful in eliciting individual and collaborative response from them for risk reduction. Accordingly, broad steps to be followed for assessing risk are presented hereunder.

Figure 1.7: Framework for assessment and reduction of risk under climate change



Step 1 Need for and objective(s) of risk assessment: Identifying the need for risk assessment is fundamental to undertaking such an exercise. The identified need for assessment makes it easy to define the assessment objectives in a lucid and precise manner. Stakeholder involvement in the identification of need for risk assessment provides a great value addition in terms of putting the results of the assessment to use.

Step 2 Type and scenario of risk assessment: The purpose of risk assessment is to deal with the current as well as future risks. Accordingly, risk to a system of interest is assessed for scenarios of current climate hazards and extremes, and future climate change trend and hazards. This step requires assessment of scenarios of climatic hazards.

Step 3 Identification of sector, community, region and scale of assessment: Risk could be assessed for a sector (say agriculture, health and water resources) or community or social or socio-economic regions. Assessment could be carried out at local or larger scales such as at household, village, district, state or at country level.

Step 4 Assess vulnerability, exposure and hazard as 'outcome' vulnerability: Once a system of interest and the scale of assessment is decided, the outcome vulnerability of the system from exposure to an identified hazard(s) is assessed. Assessment of exposure and hazard through appropriate indicators is part of the assessment of outcome vulnerability.

Step 5 Assess the probability of occurrence of hazard at the system location: Probability of the occurrence of hazard(s) at the place where system is located can be estimated from the past 30-year climatic data for a hazard. For future hazard(s), such information could be generated using appropriate climate change projection models.

Step 6 Quantify risk: Having quantified the outcome vulnerability in Step 4 and probability in Step 5, risk can be quantified as a product of the two.

Step 7 Representation of risk: The risk quantified in Step 6 can be represented in various formats such as spatial maps, charts, tables and index for effective communication with stakeholders including decision makers.

Challenges in Assessing Risk

Several challenges exist in assessment of risk. Most prominent among them include:

- Lack of data for assessment of vulnerability indicators for future periods, say 2030 or 2050.
- Uncertainty associated with climate change projections on which the future risk assessment scenarios are based.
- Lack of regional climate projections at finer grids based on multiple earth system models and different scenarios.
- Difficulty in selection of climate change projection models.
- Lack of multiple climate change impact assessment models for different sectors, validated for Indian conditions.
- Lack of technical capability of agencies intending to carry out risk assessment.

Due to these challenges, there are no studies as yet, which have developed methods and implemented them for risk assessment. Accordingly, in the Part 2 of this Manual, focus is on assessment of vulnerability, as reducing vulnerability, which can be done more reliably, is a robust approach to reduce risk under climate change.

1.10 Three-Tier Approach to Vulnerability Assessment

1.10.1 Need for Multi-Tier Approach (Similar to IPCC Inventory Tier Approach)

Vulnerability assessment requires resources and skilled manpower. The need for vulnerability assessments is immediate and overwhelming. However, the availability of resources and skills is lacking. At the same time, as the vulnerability reduction measures take time to establish and become effective, their postponement would be detrimental and would require higher investment if delayed. It is, therefore, urgent that such assessments are carried out immediately however preliminary they may



be, as the information generated through assessments would help in initiating certain structural, policy and other adjustments that enable coping with the impacts in the immediate term and to adapt over the long term.

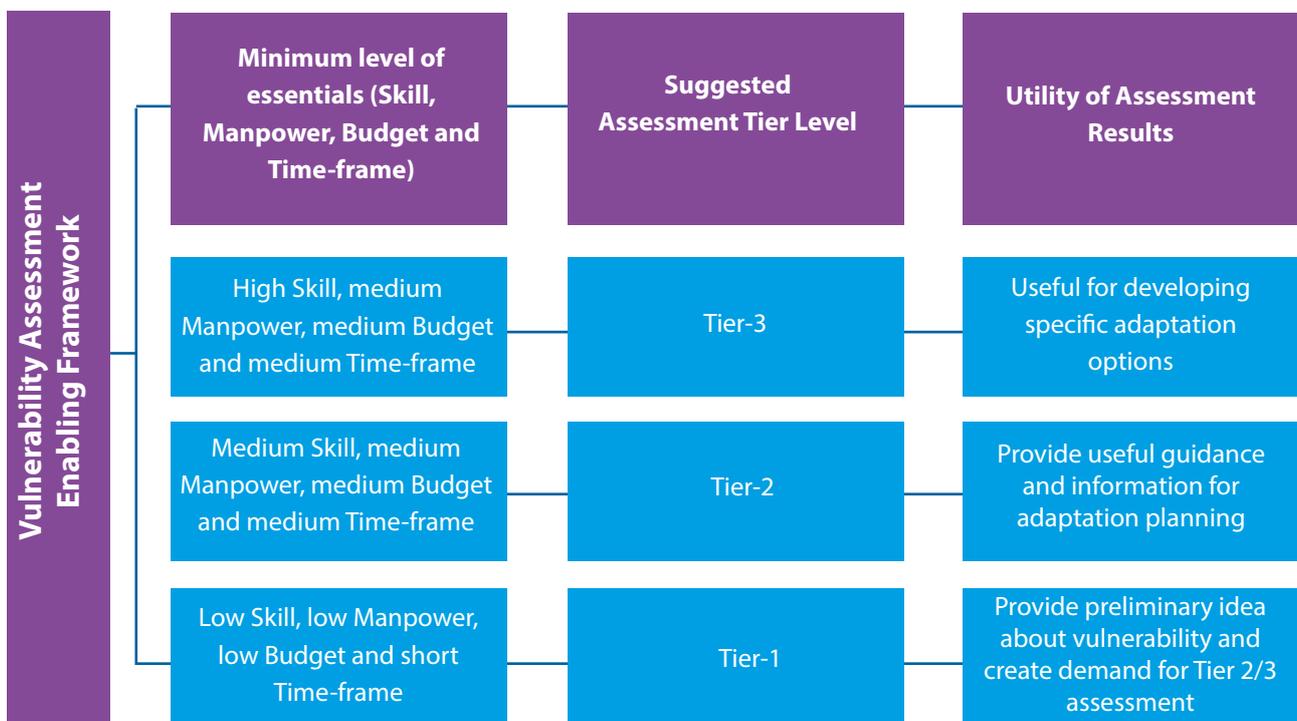
Given the different technical and financial capabilities of different communities, organisations and other stakeholders, it is useful to adopt a multi-tier approach to vulnerability assessment, as such an approach provides opportunity and enables them to carry out the assessment as per their own capabilities. According to De Lange et al. (2010), “implementation of ecological vulnerability assessment may be best accomplished by using a tiered approach, with increasing level of detail at higher tiers.” IPCC also prescribes similar multi-tiered approach for greenhouse gas emission estimations in view of the differentiated capabilities of the (UNFCCC) member nations/parties. Accordingly, the Manual prescribes a three-tier approach based on the four essentials for assessment (skill, manpower, budget and

time period) to enable stakeholders/agencies to carry out vulnerability assessments as per their respective capability. The vulnerability assessment enabling framework is presented in Figure 1.8.

1.10.2 Three-Tier Approach to Vulnerability Assessment

The objective of an assessment and the availability of skills, manpower, budget and time frame available with the agency conducting an assessment determine the appropriate and feasible tier of the assessment. Availability and access to data on indicators can facilitate adoption of higher-tier assessment. The assessment tiers differ with respect to the rigour of methods and data used for assessment. Data on the vulnerability indicators could be from primary and secondary sources including the databases maintained at different levels and scales. The data could be sourced from climate and other models that provide future

Figure 1.8: Vulnerability assessment enabling framework for choosing and carrying out assessment as per the capability of stakeholders/agencies



The essential requirements for carrying out vulnerability assessment are availability of skill, manpower, budgetary resources and time period. Tier 1 assessment can be carried out even when there is low availability of all these essentials.

values for the vulnerability indicators. While Tier 1 offers easy-to-conduct preliminary assessment, Tier 2 is moderately rigorous and Tier 3 is an advanced level of assessment. The characteristic features of different tiers of assessment are presented in Table 1.4.

Accordingly, the choice of tier of assessment under the three-tier approach would be decided based on the capability of the assessment conducting agency to address the essential infrastructural, technical and financial needs of a tier of assessment.

1.10.3 Broad Methods and Steps for Assessment at Different Tiers

Available secondary information about communities or natural ecosystems that has been collected at different points in time and for different purposes can be used to conduct a preliminary vulnerability assessment (Tier 1). Such assessments are constrained in terms of the choice of indicators, and therefore, have limited utility for reducing vulnerability, as site-specific and up-to-date information for the indicators are not collected and stakeholders are not consulted. This is the approach adopted in case of Tier 1 assessments and we refer to it as the ‘top-down’ approach. Under this approach, there is no direct communication with the system or community under assessment. Converse to it, the

‘bottom-up’ approach involves selection of indicators in consultation with the stakeholders, collection of field data on indicators and analysis of the results by involving stakeholders. Tier 3 assessments use ‘bottom-up’ approach and geo-spatial data for vulnerability assessment. Tier 2 assessments use a combination of the two approaches. In this section, we have presented the broad methods and steps that are followed during vulnerability assessments conducted at different tiers. The methodological steps followed for assessment at different tiers are presented in Table 1.5.

Tier 1 methods

Tier 1 assessment methodology involves a top-down approach and does not require primary data collection. It uses readily available secondary databases and relevant averages about the indicators/indicator parameters, and thus, provides the first approximation of vulnerability. Tier 1 approach is simple, cost effective, less time consuming, and requires only basic skills for assessment. Tier 1 methodological steps involve scoping in terms of identification of the need for assessment, unit/community for assessment and objective of the assessment. This is followed by carrying out the assessment using vulnerability indicators and the secondary data sources for such indicators.

Table 1.4: Characteristic features of different tiers of assessment. **Bottom-up** approach indicates contextualised assessment where data on vulnerability indicators is collected from the ground level with the help of stakeholders. Under **top-down** approach, secondary data on vulnerability indicators is used for assessment.

Characteristics	Tier 1	Tier 2	Tier 3
Approach to assessment	Top-down approach	Combination of top-down and bottom-up approaches	Largely bottom-up approach
Skill and expertise availability	Low	Medium	High
Financial resources availability	Low	Moderate	High
Choice of assessment indicators	Constrained; as depends on available secondary data	Less constrained; as primary data is also collected	Unconstrained; as necessary data is collected
Stakeholder consultation	Not consulted	Consulted	Consulted
Rigor of assessment	Preliminary	Moderately rigorous	Highly rigorous and advanced



Table 1.5: Methodological steps followed for tiers 1, 2 and 3 assessments

Tier 1 (Top-down approach)	<p>Step 1: Define objective and assessment unit (village/district/forest/cropping system)</p> <p>Step 2: Select vulnerability indicators (largely secondary data based)</p> <p>Step 3: Indicator weights developed by consulting secondary stakeholders such as officers of government departments or use equal weights</p> <p>Step 4: Calculate indicator values for the assessment units</p> <p>Step 5: Aggregate indicators at the assessment unit level</p> <p>Step 6: Segregate the aggregated value of indicators into different vulnerability classes</p> <p>Step 7: Present the assessed vulnerability as spatial profile or ranking for efficient communication</p>
Tier 2 (Combination of the two tiers)	<p>Step 1: Define objective and unit of assessment (village/block/district, etc.)</p> <p>Step 2: Select vulnerability indicators (from literature/stakeholder consultation/expert consultation)</p> <p>Step 3: Generate indicator values from secondary data, field studies, Participatory Rural Appraisal (PRA), household survey, etc.</p> <p>Step 4: Develop indicator weights (stakeholder consultation/statistical techniques)</p> <p>Step 5: Calculate indicator values for the assessment unit</p> <p>Step 6: Aggregate indicators at the assessment unit level</p> <p>Step 7: Analyse the aggregated value of indicators at the assessment unit level to assess vulnerability</p> <p>Step 8: Present the assessed vulnerability (spatial profile/ranking/vulnerability index/major drivers of vulnerability) for adaptation planning</p>
Tier 3 (Bottom-up approach)	<p>Step 1: Define objective and unit of assessment (village/block/district, etc.)</p> <p>Step 2: Select vulnerability indicators (from literature/stakeholder consultation/remote sensing/spatial database)</p> <p>Step 3: Generate indicator values from biophysical studies, household survey, PRA, remote sensing, spatial datasets, models, etc.</p> <p>Step 4: Develop indicator weights (stakeholder consultation/statistical techniques)</p> <p>Step 5: Calculate indicator values for the assessment unit</p> <p>Step 6: Aggregate indicators at the assessment unit level</p> <p>Step 7: Analyse the aggregated value of indicator (at assessment unit level) using state-of-the-art tools like GIS and interpret the results in consultation with stakeholders</p> <p>Step 8: Present the assessed vulnerability (spatial profile/ranking/vulnerability index/major drivers of vulnerability) for adaptation planning</p>

Tier 2 methods

Tier 2 presents a more rigorous methodological approach that could even involve a combination of bottom-up and top-down approaches. Here, besides the secondary data, primary data collection and community involvement is envisaged. Tier 2 approach, therefore, assumes an assessment team with better skills than that for Tier 1 assessment, and availability of

reasonable amount of resources for carrying out the assessment. Tier 2 methodological approach involves finalisation of objectives and the vulnerability indicators preferably with the help of stakeholders. The results of the assessment are discussed with the stakeholders to draw conclusions and develop actionable vulnerability reduction measures. Most vulnerability assessment studies seem to adopt this approach.

Tier 3 methods

Tier 3 assessment uses state-of-the-art knowledge and techniques, and is thus, a scientifically rigorous exercise. Such assessment generates system-specific information about the drivers of vulnerability that could be applied to evolve vulnerability reduction options. The assessment uses specific information about the system; and in case such specific information is not available, the same is collected. Secondary information is used rarely and only to fill less critical gaps. Advanced technology and techniques such as remote sensing and GIS and computer modelling are made use of. It therefore requires a dedicated team with high level of skills and resources. Tier 3 methodological approach thus enhances the assessment rigor by the use of system-specific information, analysing it by the use of an advanced analytical tool like GIS, developing the results in discussion with the stakeholders, and carrying out the sensitivity analysis of the results.

1.10.4 Comparative Evaluation of Tier 1, Tier 2, Tier 3 and its Applicability for Adaptation Planning

A comparative evaluation of the important features of the three-tier assessment methodological approaches is presented in Table 1.6. Usefulness of an assessment

for adaptation planning depends upon the objectives of assessment.

Tier 1 assessments are introductory in scope. Their usefulness rests in generating awareness about the system vulnerabilities and risks from anticipated impacts. Such information does not feed directly into the adaptation planning process. However, it is useful, and necessary, for creating demand for carrying out the next level of assessment (tiers 2 or 3) for adaptation planning. Tier 2 assessments adopt medium rigor, and thus, are a choice when better resources and skills are available. These assessments provide useful information about the current internal state of a system and the drivers (factors) impacting it. Therefore, tier 2 assessment results can potentially help in initiating adaptation measures for vulnerability reduction. Tier 3 assessments involve highly rigorous process, and thus, are opted when high level of skills and resources are available. Tier 3 assessments are able to generate specific information pertaining to vulnerability and its sources/drivers, which is also vetted by stakeholders. Tier 3 assessments are thus most useful for adaptation planning, as it enables identification of specific adaptation actions at the ground level and initiating long-term policy changes for risk reduction.



Table 1.6: Important features of Tier 1, Tier 2 and Tier 3 methodological approaches for Vulnerability Index assessment framework and Risk-Impact (R-I) Index assessment framework

	Tier 1	Tier 2	Tier 3
Applicability	VI as well as R-I index framework	VI as well as R-I index framework	VI as well as R-I index framework
Indicator data	Secondary data	Primary as well as secondary data	Largely primary data; GIS and remote sensing-based data; climate and other models based data
Data sources	Government sources including reports, maps, past assessments, databases and other than government sources	In addition to Tier 1 data, the data collected from primary sources such as field, biophysical studies, household surveys and PRA. Model output data	In addition to Tier 2 data, data from international organizations and other national government sources; satellite data; remote sensing and GIS maps; internationally coordinated model output data (CMIP5/ CORDEX data)
Application	Provides preliminary assessment of vulnerability to assist in identifying the most vulnerable systems and may lead to carrying out tiers 2 and 3 assessments	More rigorous assessment providing useful system details for initiating measures for vulnerability and risk reduction	Very rigorous assessment informing about the sources of risk/vulnerability and useful for initiating action at the ground level, developing anticipatory strategies and initiating long term policy changes for risk/vulnerability reduction
Merits	Does not require much expertise Quick and easy to implement Requires low level of investment Useful for advocacy purposes and for creating demand for tiers 2/3 assessment	Involvement of stakeholder improves the acceptability and credibility of the assessment results Useful for adaptation planning and for creating demand for adaptation action	Useful for developing site-specific adaptation plans Involvement of stakeholders and use of GIS and other modern techniques increases the accuracy and robustness of the results
Limitations	Tier 1 methodologies are quick but not elaborate Low accuracy of the results Provides only preliminary information about the system vulnerabilities	More elaborate than tier 1 but demands more resources and time It requires medium to high level of expertise	It is time consuming and data intensive More resources are needed It requires very high level of knowledge and skill



Part 2

Climate Change Vulnerability and Risk Assessment: Methods and Guidelines







2.1 Introduction

In Part I, the concept and framework for assessment of vulnerability and risk, according to IPCC (2014), was presented. It was concluded that vulnerability assessment is an activity independent of risk or impact assessment, since vulnerability is one of the three components that determines risk. Among the three components in the risk management framework (Figure 1.1), namely, hazard, exposure and vulnerability, it is the vulnerability component for which adaptation strategies can be developed to reduce the risk of climate hazards. In this Part, we present a detailed methodology and guidelines for the assessment of vulnerability and development of vulnerability profiles.

2.1.1 What is Vulnerability and Why Assess Vulnerability?

Vulnerability is a dynamic and context-specific characteristic, determined by human behaviour and societal organisations. It influences the susceptibility and adaptive capacities of human or social-ecological systems exposed to hazardous climatic or non-climatic events and stresses.

In India, locations such as the Himalayan states, arid zones, coastal areas and mountainous regions are likely to be highly vulnerable to current climate variability and climate change. For example, the Indian Himalayan states have the most fragile biophysical environments and diverse socio-economic, ethnic and indigenous societies. These states are known to experience diverse weather or climatic conditions (due to varying altitudes), extreme weather events (floods, droughts, etc.) and high current rainfall variability. Preliminary modelling studies project higher levels of warming and climate change adversely impacting agriculture,

forests and water resources in these states. The impacts of climate change are further exacerbated by poor land management, land degradation, forest fragmentation, overexploitation of groundwater, loss of biodiversity, monocropping and poor agriculture practices. The nature of interaction of societies with the environment determines the vulnerability of societies and their environment. Vulnerability assessments can provide information regarding the nature and extent to which communities or ecosystems are vulnerable and help to identify the sources of vulnerability.

Vulnerability assessments can help to:

- a) Identify the most vulnerable regions or sectors or communities/systems
- b) Raise awareness regarding the vulnerability of communities/systems
- c) Identify drivers/sources of vulnerability for development of targeted adaptation strategies and allocation of adaptation funds
- d) Assist in developing and implementing adaptation practices and strategies

Addressing the sources of vulnerability enables identification of the drivers, which can be addressed to lower the vulnerability and improve the preparedness to deal with an uncertain future in the context of climate change.

2.1.2 Components of Vulnerability

Vulnerability has two components - Sensitivity (S) and Adaptive Capacity (AC), which are non-observable, non-measurable and non-quantifiable attributes of a system, requiring the use of proxy indicators for the construction of a Vulnerability Index (VI).

Sensitivity

Sensitivity pertains to the change that an external factor brings about in a system. Such change could be adverse or beneficial. For example, reduction in the yield of an agricultural crop as a result of drought indicates the adverse change and sensitivity to drought. However, a timely rain replenishing the soil moisture leading

to a good harvest has beneficial effect on the yield. Further, in case irrigation facility is available to a crop, and despite drought there is no reduction in the yield, such agricultural system is said to be not sensitive to the occurrence of drought. In general, crops with irrigation facility would be less sensitive to drought compared to those without it.

Similarly, while settlements located in the flood zone of a river would be sensitive to flooding, those located away from the flood zone would not be sensitive to it. Within the flooding zone, the settlements that are constructed on raised platforms (stilts) would be less sensitive to flooding than the ones that are not on such raised platforms. Thus, even within the same flooding area, households can be differentially sensitive, depending on the location of the settlements.

Sensitivity is an internal property of a system and is determined by its characteristics. For example, a drought-resistant seed-based crop (system) would be less sensitive to drought compared to that grown using normal seeds. Drought-resistant seeds make a crop inherently less sensitive to the occurrence of drought. Higher sensitivity of a system indicates higher vulnerability.

Adaptive Capacity

Adaptive capacity is the capacity of a system to adjust to the change brought about by an external factor. This means that after an external factor has acted and brought about changes (sensitivity) in a system, it will try to adjust to such changes in order to reduce/avoid the potential damage or take advantage from such change or respond to the consequences of change. Thus,

Vulnerability Index: VI is a metric that characterises the vulnerability of a system. Practically, it is a quantitative representation of vulnerability of a system in comparison to other similar systems (e.g., comparative vulnerability of different districts in a state, villages in a district, coastal communities along a coast and different forests in a landscape) when such systems are assessed using the same set of factors/indicators. VI value provides a quantified perception of the status of vulnerability of a system. However, it does not have any stand-alone significance and largely remains conceptual in utility, unless the VI value is used for ranking/prioritising systems, e.g. to identify the most vulnerable district or community or forest. Thus, VI is a handy tool to prioritise systems for undertaking adaptation planning and rationalising resource allocation. Beyond such

adaptive capacity of a system facilitates it to reduce the losses in case of adverse changes and it helps the system to take advantage of beneficial changes.

For example, provision for crop insurance helps in reducing the adverse impact of crop loss due to drought or unseasonal rain. The availability of crop insurance helps in reducing the potential impact of crop loss on the farming community. Thus, a farmer having crop insurance protection can adapt under climatic variability better than the one without it.

Further, the farming communities that have access to market can take the monetisation benefit of higher yield in a good rainfall year. Comparatively, the farming communities who cannot access market would not be able to take such advantage of the opportunity offered by higher crop yield. Access to market indicates beneficial adjustment to the opportunity offered by higher yield due to good rainfall.

Adaptive capacity too, like sensitivity, is a characteristic internal property of a system. In the above example, availability of access to market is an inherent and characteristic property of the agricultural system of the concerned farming community. Higher adaptive capacity of a system indicates lower vulnerability.

utility, the indicators used to assess vulnerability of a system can be analysed to identify the factors that determine vulnerability and hence are its major drivers. Such analysis is practically useful in developing an understanding about the system and evolving measures to address the sources/drivers of vulnerability for vulnerability reduction.

- VI values lie between 0 and 1, but sometimes they are also expressed as a percentage by multiplying by 100. Arranging the assessed VI values in decreasing or increasing order ranks the systems.
- The VI value provides only a sense of quantified status of vulnerability but largely remains conceptual in its utility, as this value does not have any stand-alone practical significance.

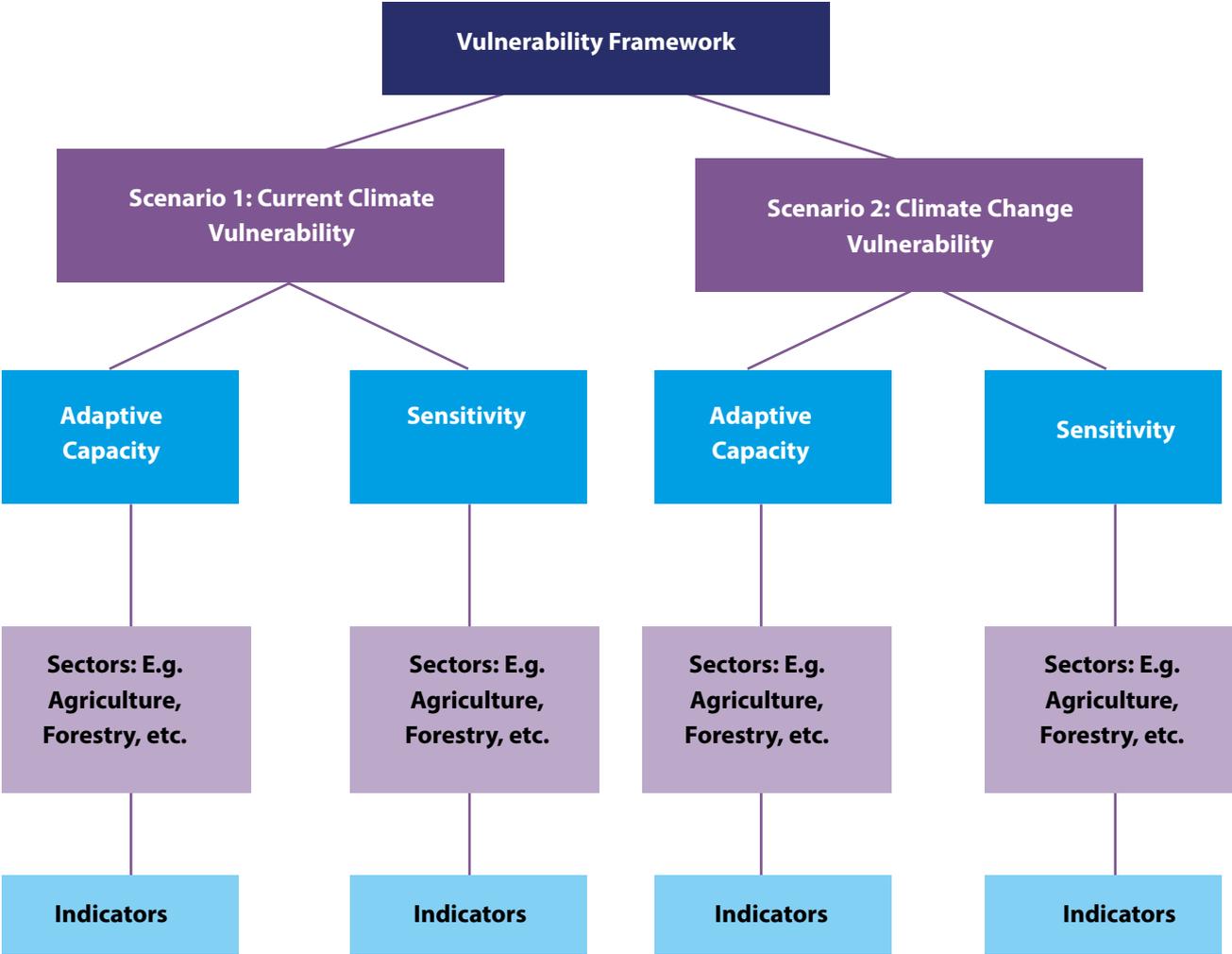


2.2 Vulnerability Assessment Scenarios: Current Climate Vulnerability and Climate Change Vulnerability

Vulnerability assessments under current climate scenario and future climate scenario – namely, current climate and climate change vulnerability are described in Part I. Vulnerability is a characteristic property of a system that represents its current internal state (IPCC

2014). Further, vulnerability can be assessed either as a pre-existing state of a system (contextual/starting-point vulnerability) or as an overall impact of a disturbance on a system (outcome/end-point vulnerability). This Manual presents assessment of ‘contextual’ vulnerability. Accordingly, the framework for assessment of current climate and climate change vulnerability is shown in Figure 2.1.

Figure 2.1: Framework for assessment of current climate and climate change vulnerability



Vulnerability assessment scenarios

Natural and socio-economic systems are projected to be vulnerable under climate change, and to secure them, there is a need to undertake adaptation and resilience-building measures. However, due to the uncertainty associated with the future climate and impact projections, the decision-makers and other stakeholders will be challenged in formulation of adaptation strategies and their implementation. Moreover, the uncertainty can potentially lead to even maladaptation from adaptive actions undertaken. Nonetheless, and despite such uncertainty, it is necessary to undertake adaptation measures, as delay would limit the options and escalate the costs of adaptation. Further, according to the IPCC 2014 the “first step towards adaptation to future climate change is reducing vulnerability and exposure to present climate variability.” This requires assessing and addressing the current vulnerability, as reducing current vulnerability helps in reducing current risks as well as improves the ability to cope with future risks. Further, uncertainties regarding future can only be reduced but not eliminated. Current vulnerabilities can be assessed reliably and with greater certainty. Thus, a practical and robust option is to assess and deal with the current vulnerability, while the vulnerability under

future climate is kept in view. Accordingly, the following scenarios are considered in this Manual for vulnerability assessment.

- **Assessment Scenario 1:** Vulnerability assessment under current climate (termed as **current climate vulnerability or simply vulnerability**)
- **Assessment Scenario 2:** Vulnerability assessment under future climate (termed as **climate change vulnerability** or simply **future vulnerability**). Future vulnerability informs about the possible future vulnerability and risk scenarios. Such information is useful for creating a demand for initiating policy and other adjustments that can potentially enhance the adaptation capability to anticipated risks.

Current vulnerability (or vulnerability) is assessed using the past and current data on the vulnerability indicators, while future vulnerability assessment requires projected values of the indicators in future. Obtaining projected values for indicators is however challenging and studies reported in literature have combined the current vulnerability with the impact of future climate (projected using models) to assess future vulnerability (Uppgupta et al. 2015; Sharma et al. 2017).

Selection of the type and rigor of vulnerability assessment depends on the objective of the assessment, and the information or data collection and analysis capabilities of the institution conducting the assessment. The merits and limitations of current climate and climate change (future) vulnerability assessments are presented in Table 2.1.

2.2.1 What is Current Climate Vulnerability Assessment and Why it Should Be Assessed?

As the name suggests, current climate vulnerability assesses the current internal state of a system, independent of exposure and hazard. Communities and systems such as agriculture and fishing are exposed to current climate hazards such as droughts and floods, adversely impacting food production and

livelihoods. Thus, it is very important to assess the vulnerability of communities and systems to current climate hazards or risks, even before attempting climate change vulnerability assessments. In this context, an anticipated hazard, hazard-specific vulnerability can also be assessed. Even in such a case, vulnerability and vulnerability assessment remain independent of hazard, as the current ‘characteristic internal properties’ of a system cannot be determined by and thus do not depend on an anticipated hazard. While assessing hazard-specific vulnerability, hazard-relevant sensitivity and adaptive capacity indicators are selected (Refer to Section 1.8.4 of Part 1 of the Manual). Further, vulnerability assessment can be carried out for any scale and sector, ranging from local (household, village, forest, watershed, etc.), regional (block, district, state, river basin, mountain range) to national and global.



Why Assess Current Climate Vulnerability?

- **Identifying current and potential hotspots:** It assists to identify the current and potential vulnerability hotspots by comparing susceptibility to climate change in multiple systems (e.g. mountain communities, cropping, arid zone, forests and water resources). It allows better understanding of the factors driving the vulnerability of a climate change hotspot (e.g., a specific geographical area, which is more likely to be severely affected by climate change than others).
- **Identifying entry points for intervention:** Information on the factors underlying a system's vulnerability can serve as a starting point for identifying suitable adaptation interventions.
- **Prioritising for adaptation:** It enables prioritisation of households, villages, panchayats, blocks, cropping systems, etc., for current adaptation planning and implementation to identify targeted programmes to reduce vulnerability.
- **Tracking changes in vulnerability and monitoring and evaluation (M&E) of adaptation:** A relatively new approach is to use vulnerability assessments to track changes in vulnerability over time. This complements the existing methods for M&E of adaptation measures and generates additional knowledge on the effectiveness of adaptation.

2.2.2 What is Climate Change Vulnerability Assessment and Why it Should Be Assessed?

Climate change vulnerability assesses a system's vulnerability under future climate change scenario by projecting the vulnerability indicators to such time in the future. It is a scientifically rigorous exercise utilising advance techniques such as remote sensing, GIS and climate change and impact modelling. It is useful, as it presents with the possible future vulnerability for awareness raising among the stakeholders and anticipatory planning.

Why Assess Vulnerability to Climate Change?

- To create awareness and demand for resilience-building anticipatory measures in anticipation of an uncertain climate change in the future.
- To identify the most vulnerable mountain systems/communities/regions to projected climate change.
- To assist in developing climate change adaptation practices and programmes.
- To assist in developing programmes to enhance long-term resilience to climate change.

2.2.3 Comparison of Current Climate and Climate Change Vulnerability Assessment

The merits and limitations of conducting current climate and climate change vulnerability assessments are presented in Table 2.1.

In this Manual, the focus is on the current climate vulnerability since policy makers want to mainstream adaptation in ongoing or proposed developmental programmes and projects.

2.3 Summary of Approach and Methods for Vulnerability Assessment

Assessment and addressing of vulnerability and its drivers is one of the critical steps in adaptation to climate variability and climate change. The broad approaches and methods suggested in this Manual are presented in Table 2.2.

In this Manual, it is expected that majority of the vulnerability assessments are characterised by the following three major features:

- i) Assessment of current climate vulnerability*
- ii) Goal of assessment will be to assist in adaptation planning or to reduce vulnerability*
- iii) Assessment largely based on Tier 2 methods*

To reduce the risk on natural ecosystems or social systems from climate change, there is a need to reduce

Table 2.1: Merits and limitations of current climate and climate change vulnerability assessments

	Current Climate Vulnerability Assessment	Climate Change Vulnerability Assessment
Merits	<ol style="list-style-type: none"> 1. Aids policy makers to reduce current vulnerability. 2. Helps in prioritisation and distribution of resources to most vulnerable communities or socio-ecological systems. 3. Identification of the drivers of vulnerability informs the vulnerability reduction planning process. 4. Maladaptation is avoided as interventions are directed to restore the health of a currently vulnerable system. 5. It is a quick method to understand the current sources of weakness of a system. 6. It is useful to reduce vulnerability in current, ongoing and soon-to-be implemented plans and programmes. 	<ol style="list-style-type: none"> 1. Provides an assessment of the future vulnerability of a system under climate change which can be communicated to stakeholders for building consensus for action. 2. Can be used as a tool to compare the present and future drivers of vulnerability by policy makers under a changing climate. 3. Based on the assessment outcome, well considered long-term adaptation plans can be prepared. 4. Prompts timely risk-reduction anticipatory measures.
Limitations	<ol style="list-style-type: none"> 1. Does not consider future threats and hazards and focuses only on the system's current internal state. 2. Depending on the purpose of the assessment, data intensity and skill level may become demanding. 	<ol style="list-style-type: none"> 1. Intensive data requirement 2. Adaptation measures taken on the basis of climate change vulnerability assessment may result in maladaptation due to uncertainties in climate change model projections and impact assessments. 3. It is resources, time and skill demanding, especially with regard to modelling. 4. May not be relevant for adaptation planning for ongoing or proposed projects in the immediate time periods.

vulnerability. This leads to the following questions. Who and what are vulnerable? What action should be undertaken to reduce vulnerability? Converting these questions into goals for further action, i.e. identifying vulnerable systems, their extent of vulnerability and the factors driving such vulnerability, answers them. Accordingly, 'goal-oriented' vulnerability assessment approach is adopted in this Manual to present the methods for vulnerability assessment. The goal of the

vulnerability assessment will determine the tier methods to be adopted, type of indicators to be selected and the procedure for providing weights to the indicators.

2.4 Steps in Vulnerability Assessment

The main steps in current climate vulnerability assessment are presented in Figure 2.2. In the following sections, each step is described in detail along with examples and case studies.



Table 2.2: ‘Goal-oriented’ vulnerability assessment: approach and methods

Goal/Objective	Tier methods for assessment	Indicators for vulnerability assessment	Weighting procedure for indicators
1. Identification and ranking of the most vulnerable regions, sectors and communities - to raise awareness about vulnerability and prioritisation for adaptation interventions	Tier 1 methods, largely top-down	Secondary data-based indicators; <ul style="list-style-type: none"> - Largely demographic and socio-economic indicators - Biophysical indicators – where available 	(i) Equal weights (ii) Weight allocation by secondary stakeholders <ul style="list-style-type: none"> - District administrators, researchers, NGOs
2. Assist in adaptation planning – based on information on vulnerability profiles and drivers/sources of vulnerability	Tier 2 methods, largely bottom-up but incorporating top-down methods as well	<ul style="list-style-type: none"> - Field study derived biophysical indicators - Field survey derived socio-economic indicators - Institutional indicators - Secondary data-based indicators 	Weight allocation by primary stakeholders <ul style="list-style-type: none"> - Village communities/ farmers/mountain communities to provide weights to indicators
3. Spatial adaptation planning – including temporal adaptation planning for current and future climate scenarios	Tier 3 methods; largely bottom-up and spatial methods, including modelling	Spatial indicators <ul style="list-style-type: none"> - Biophysical indicators - Socio-economic indicators Model outputs; climate change projections/ impacts Principal Component Analysis (PCA) for short-listing indicators	Weight allocation by primary stakeholders <ul style="list-style-type: none"> - Village communities / farmers/mountain communities to provide weights to indicators

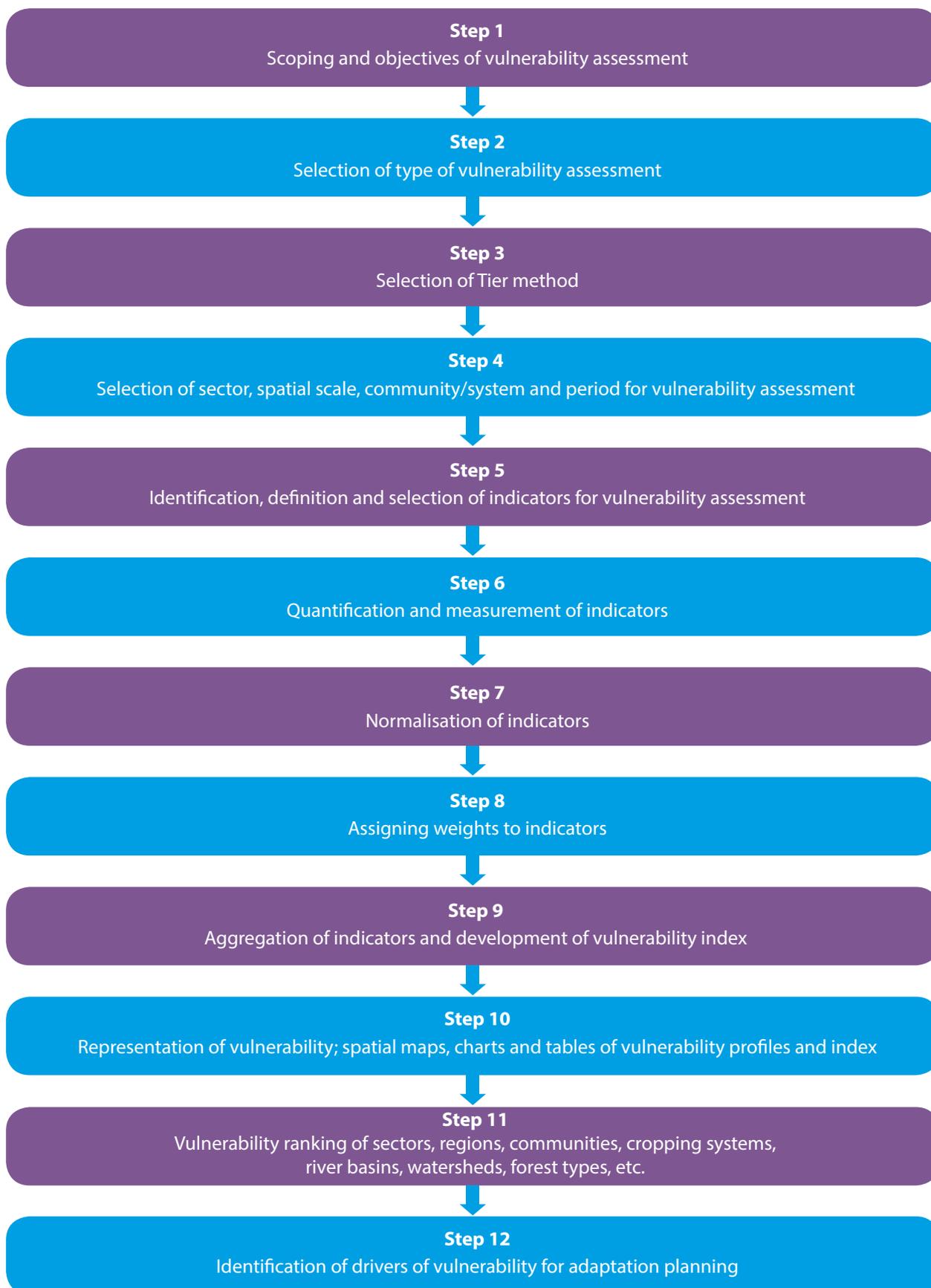
2.5 Scoping of Vulnerability Assessment – Step 1

One of the first steps in vulnerability assessment is scoping, and thereby, to identify the objective or purpose of the assessment and the target audience for whom the vulnerability assessment is being carried out.

Scoping involves the following three steps:

- a) Identification of the need for vulnerability assessment (for example, to rank the most vulnerable districts in a state for adaptation investment allocation)
- b) Defining the specific objective(s) of the assessment (for example, to develop vulnerability profiles of the districts, to rank the districts using vulnerability index and to identify the drivers of vulnerability)
- c) Identification of the stakeholders and target groups for the vulnerability assessment

Figure 2.2: Steps in vulnerability assessment





Five criteria were developed for identifying the need for vulnerability assessment (Oppenheimer et al. 2014) and these criteria can be utilised during the scoping stage of the assessment (Table 2.3). Not all the criteria need to be fulfilled to initiate assessment of vulnerability in study areas/communities/social-ecological systems.

Vulnerability assessment is determined by the following factors, with respect to the scope as well as the unit of assessment:

- a) Region (Himalayan region, arid, semi-arid, Indo-Gangetic plains)
- b) Scale (state, district, block/taluk, village and household)
- c) Sector (mountain cropping system, alpine forests, pasture lands, watersheds, etc.)
- d) Period (current vulnerability, projected future vulnerability)

Table 2.3: Five criteria to assist in scoping for vulnerability assessment (Source: Oppenheimer et al. 2014)

Criteria	Rationale
Exposure of a society, community, or social-ecological system to climatic stressors	While exposure is distinct from vulnerability, exposure is an important precondition to be considered because a system at present or in the future could be exposed to climate hazard. For example, mountain communities are exposed to extreme rainfall-related hazards.
Importance of the vulnerable system(s)	All systems are vulnerable to climate risks. Some communities or social-ecological systems are more vulnerable and more exposed to climatic hazards. Mountain ecological systems are very critical for the social system depending on them.
Limited ability of societies, communities or social-ecological systems to cope with and to build adaptive capacities to reduce or limit the adverse consequences of climate-related hazard	Severe limits of coping and adaptation are core factors that increase vulnerability to climatic hazards. In the mountain regions, for example, communities living on the slopes have limited capability and are not accessible, which makes them highly vulnerable.
Persistence of vulnerable conditions and degree of irreversibility of consequences	A combination of persistent pre-existing conditions that are difficult to alter and climatic hazards push communities or social-ecological systems to critical thresholds that would cause a partial or full collapse of the system. For example, mountain communities living on slopes could be impacted by landslides, the consequences of which are severe and irreversible.
Presence of conditions that make societies highly susceptible to cumulative stressors in complex and multiple-interacting systems	Reduction of a system's capacity to cope or adapt to climate hazards due to conditions such as violent conflict or a critical dependence on highly interdependent infrastructures (e.g. energy/power supply, transport, and healthcare) is yet another criterion for identifying study areas, relevant stakeholders and institutions for vulnerability assessment. Mountain ecosystems are subjected to not only climate-related hazards but also to socio-economic pressures such as forest degradation, land degradation and flooding.

Table 2.4: Stakeholders and the purpose for which they require vulnerability assessment

Stakeholders	Main purpose/utility of vulnerability assessment
National and state level policy/decision makers	Prioritisation of states, districts, villages, cropping systems, forest types and communities for adaptation action and undertaking policy initiatives
Bilateral and multilateral agencies	Prioritisation of resource allocation to sectors/regions for resilience building
Non-government organisations	Creating awareness/demand for vulnerability/risk reduction
Local institutions and communities	Vulnerability reduction and enhancement of adaptive capacity
Researchers	Improved understanding of vulnerable systems and advancing knowledge on vulnerability/risk management

Goals and Objectives of Vulnerability Assessment

The broad goals/objectives of vulnerability assessment in the context of climatic hazards and addressing climate change are as follows:

1. Identification of the most vulnerable regions, sectors and communities – to raise awareness about vulnerability, ranking and prioritization for adaptation interventions
2. Assist in adaptation planning – based on information on vulnerability profiles and drivers/sources of vulnerability
3. Spatial adaptation planning – including temporal adaptation planning for current and future climate scenarios

Stakeholders and Target Audience

Vulnerability assessments are required for multiple stakeholders and for various purposes. The target audience can influence the objectives, type and the rigor of assessments. Some of the potential target audience and purpose of vulnerability assessments are given in Table 2.4.

2.6 Typology of Vulnerability Assessment– Step 2

In the human-dominated landscapes, biophysical and socio-economic systems are intricately linked

to each other and it is no longer practical to consider one without the influence of the other. However, due to certain inherent characteristics of both these types of systems, it is useful to assess them separately as well. Such characteristic in case of natural ecosystems (e.g. rivers, forests) is their ‘capability to autonomously restore’ themselves after disturbance/release of stress, and ‘system portability’ in case of social systems (people can be moved away from the flood zones of rivers to avoid exposure to flood). Accordingly, in this Manual the following three broad typologies for vulnerability assessment are identified.

- Biophysical vulnerability
- Socio-economic, including institutional vulnerability
- Integrated vulnerability, integrating both biophysical and socio-economic/institutional, and
- Hazard-specific vulnerability

Why Do We Assess Biophysical Vulnerability?

Communities depend on natural ecosystems (forests and rivers) and socio-economic systems (food production and fisheries) for their livelihoods. Both these are vulnerable to climate change. Further, both are interlinked, and it is useful to develop a combined vulnerability index that integrates the interactions between the natural resources and socio-economic systems. Natural



forests, freshwater and marine ecosystems maintain a wide range of ecosystem goods and services, including the provisioning and regulation of water flows and quality, timber and fisheries. The poorest of the poor are often, especially dependent on these goods and services. For these groups, biophysical vulnerability means human and/or livelihood vulnerability and thus its importance must be acknowledged.

Why Do We Assess Socio-Economic Vulnerability?

Socio-economic vulnerability assessments can provide vital information useful for policy, project design, strategic planning and project targeting. Socio-economic vulnerability assessment would

help identification of the most vulnerable social groups and also the social factors contributing to vulnerability.

Why Do We Assess Integrated Vulnerability?

Integrated assessments are required where known linkages and interactions and interdependencies exist between biophysical and socio-economic systems. Such assessments are required in most real-life situations for reducing vulnerability of agriculture, water, livestock and forest management systems.

The conditions where the above three types of vulnerability assessments could be adopted, their utility and the target groups are presented in Table 2.5.

Table 2.5: Conditions for adoption of biophysical, socio-economic and integrated vulnerability assessments and their application for different target audience

	Where to adopt?	Application	Who needs this?
Biophysical (natural resources)	<ol style="list-style-type: none"> 1. Scope is dominated by natural resources such as forests, streams and rivers, grasslands and mountains. 2. Natural resources interact with climatic factors such as rainfall and wind and determine the livelihoods and food production. 3. Strong linkages between natural resources and socio-economic status 4. Natural resources are subjected to degradation such as water and wind lead to soil erosion while overgrazing leads to forest degradation 	<ul style="list-style-type: none"> - To identify the biophysical factors contributing to vulnerability - To prioritise natural resources to be considered in adaptation planning - To highlight the impact of natural resource degradation on vulnerability 	<ol style="list-style-type: none"> 1. Watershed managers 2. Forest department 3. Irrigation department 4. World Bank, UN agencies and bilateral funding agencies

	Where to adopt?	Application	Who needs this?
Socio-economic (communities)	<ol style="list-style-type: none"> 1. Social and economic factors impact productivity of water, land and forest resources 2. Social factors (caste, gender) are critical in resource use and management 3. Situations where only socio-economic data is available 	<ul style="list-style-type: none"> - To identify the contribution of social and economic factors to vulnerability - To target adaptation interventions on social and institutional factors 	<ol style="list-style-type: none"> 1. Local communities 2. NGOs 3. Community organisations 4. Government
Integrated (watershed covering both biophysical and socio-economic components)	<ol style="list-style-type: none"> 1. Strong established linkages between biophysical and socio-economic systems (such as agriculture or livestock management) 2. Most assessments involving production systems involving agriculture, fisheries, livestock production, forests 3. Watershed management programmes, Mahatma Gandhi National Rural Employment Guarantee Scheme, livelihood improvement or development programmes, fisheries development 4. Information/Data on both biophysical and socio-economic systems are available 	<ul style="list-style-type: none"> - Required for designing adaptation strategies in most production systems that are vulnerable - In prioritising socio-economic as well as biophysical factors causing vulnerability - For designing technological, institutional, social and economic interventions to reduce vulnerability 	<ol style="list-style-type: none"> 1. Watershed managers 2. Agriculture department 3. Fisheries department 4. Animal husbandry department 5. World Bank, UN agencies and bilateral funding agencies
Hazard-specific	<ol style="list-style-type: none"> 1. Locations/Communities subjected to extreme climatic hazards such as droughts, floods and heat stress events 2. Mountains, coastal areas, flood plains and arid zones which are exposed to climatic hazards regularly 	<ul style="list-style-type: none"> - Enables focusing on the high damage-causing events and regions for vulnerability reduction programmes - Enables identifying the most vulnerable exposure units to climatic hazards - Enables identification of drivers that contribute most to vulnerability to droughts and floods 	<ol style="list-style-type: none"> 1. Disaster management authorities 2. Project Managers dealing with floods and droughts



2.6.1 Assessing Hazard-Specific Vulnerability

Climatic hazards such as droughts leading to crop failure, high rainfall intensity events causing floods and heat stress leading to mortality cause more damage than mean increasing trends in rainfall and temperature. Thus, vulnerability assessment of communities and systems (agriculture or settlements) to climatic hazards is of priority to policy makers and communities. Vulnerability, a characteristic property of a system, indicates its predisposition to be adversely affected. Vulnerable disposition of a system materialises as ‘impact’ once a hazard strikes it. Such impact depends on the nature and type of hazard. Thus, different hazards cause different response and impact on a system. This implies that vulnerable systems show hazard-specific response. Further, we understand that the response of a system is determined by its inherent characteristic properties. However, different properties of a system may be relevant in determining its response to different hazards. For example, for a tree crop raised from drought-resistant seeds lacking in wind firmness property, in case of a cyclone, the relevant property of the tree crop system would be its wind firmness and not its capacity to resist drought. The tree crop not being wind firm would be vulnerable to cyclone. It will however not be vulnerable to drought. Similarly, for dwelling units located in a flood-prone area, in the event of flood, it is the construction of the dwelling units on raised platform and not their plinth area or size of the family that would determine vulnerability.

In anticipation of a hazard, it is therefore useful to understand how a given system would respond (be vulnerable) when such hazard actually strikes. Accordingly, vulnerability of a system can be assessed in the context of a hazard by selecting appropriate hazard-relevant indicators for its sensitivity and adaptive capacity. Examples of hazard-relevant indicators are presented in the box below.

“Further, the hazard-relevant sensitivity and adaptive capacity indicators get higher weights due to their higher relevance in determining vulnerability compared to the other indicators those may also have been chosen. Thus, vulnerability assessment undertaken in the context of a hazard by selecting hazard-relevant indicators and assigning them higher weights enables us to address hazard-specific vulnerability of a system and potentially reduces future risk”.

2.7 Selection of Tier Methods – Step 3

A vulnerability assessment can be carried out simply using secondary data or by utilising secondary and primary data sources, GIS techniques and climate model outputs. It is possible to visualise three tiers for vulnerability assessment (refer to Section 1.10 of Part 1 of the Manual).

- **Tier 1:** It is a top-down approach and is largely based on secondary data.
- **Tier 2:** It involves a combination of top-down and bottom-up data, approaches or studies.
- **Tier 3:** It involves largely a bottom-up approach, along with spatial remote sensing and GIS information/data.

The choice of tier for assessment of vulnerability is dependent on:

- a) Objective of the assessment
- b) Availability of time, skills and resources for the assessment
- c) Availability and access to data
- d) Rigour of methods and information needed for the assessment

System	Hazard	Hazard-relevant indicator		Hazard-irrelevant indicator	
		Sensitivity	Adaptive capacity	Sensitivity	Adaptive capacity
A village in the hills	Cloud burst	Steepness of ground slope	Road connectivity	Sex ratio	Availability of tap water
Agriculture	Drought	Percentage of dryland farms	Use of drought-resistant seeds	Number of elders and children	Large size of land-holdings

2.7.1 Tier 1: Top-down Approach

Tier 1 is a top-down approach, utilizing readily available secondary databases to quantify indicators. As such, it is the ideal method for a rapid assessment of vulnerability. This Manual will focus on providing detailed methods for Tier 1 vulnerability assessments. The following are the characteristics of a Tier 1 approach:

- It does not require primary data collection. However, in cases where secondary data is not available to quantify certain indicators, primary data may need to be collected to fill the gaps.
- Data sources include government reports, maps, past assessments, databases and other secondary sources, as well as sample interviews of stakeholders such as government

officials at district or block level and village representatives

- It is simple, cost effective, less time consuming and requires only basic skills for assessment
- Ideal for a rapid assessment
- Provides a preliminary approximation of vulnerability
- It is an easy-to-apply methodological approach for communities and development agencies, including international funding organisations, NGOs, banks, etc.
- Policy makers and government departments could benefit from this approach for prioritising regions for adaptation planning at a larger scale (block/taluk, district and state levels)

CASE STUDY – TIER 1		
SOCIO-ECONOMIC VULNERABILITY ASSESSMENT USING TIER 1 APPROACH		
	Steps in vulnerability assessment	Details
1.	Scoping of vulnerability assessment	To identify and rank vulnerable districts in Karnataka
2.	Selection of type of vulnerability assessment	Socio-economic vulnerability (SVI) assessment
3.	Selection of tier methods	Tier 1
4.	Selection of sector, Spatial scale, community/ system and period for vulnerability assessment	Spatial scale: District-level assessment Period: For the year 2011 - based on data availability
5.	Identification, definition and selection of indicators for vulnerability assessment	Indicators were selected through expert consultation and literature review. Ten indicators were selected: <ul style="list-style-type: none"> • Population density • Percentage of SC and ST population • Literacy rate (percentage) • Percentage of marginal land holders (< 1 hectare) • Percentage of non-workers • Livestock units/100,000 population • Per capita income (three-year average) • Cropping intensity (percentage) • Percentage irrigated area to total cropped area (three-year average) • Total area under fruit crops (in hectares)
6.	Quantification and measurement of indicators	Indicators were quantified using 2011 Census of India and Statistical Abstract of Karnataka (DES) for the years 2008–09, 2009–10 and 2010–11



CASE STUDY – TIER 1		
SOCIO-ECONOMIC VULNERABILITY ASSESSMENT USING TIER 1 APPROACH		
	Steps in vulnerability assessment	Details
7.	Normalisation of indicators	Principle component analysis (PCA) was conducted to normalize indicators
8.	Assigning weights to indicators	PCA helps generate weights. Varimax rotation performed on results of PCA group indicators into unitless factors. Weights were then computed considering the Eigen values of factors using the formula: $E(X \text{ or } Y \text{ or } Z) / (EX + EY + EZ)$, where EX is the eigen value for the Xth factor (value > 1); EY is the eigen value for the Yth factor (value > 1); EZ is the eigen value for the Zth factor (value > 1)
9.	Aggregation of indicators and development of vulnerability index	The SVI value for each district was calculated using the formula $(W1 * \text{factor-1}) + (W2 * \text{factor-2}) + (W3 * \text{factor-3})$, where W1, W2 and W3 are the weights calculated for factors 1, 2 and 3 and factor-1, factor-2 and factor-3 are the unitless values generated for each factor by running PCA
10.	Representation of vulnerability; spatial maps, charts and tables of vulnerability profiles and index	Maps; district-level SVI was spatially represented in a Karnataka state map
11.	Vulnerability ranking of sectors, regions, communities, cropping systems, river basins, watersheds, forest types, etc.	Unit for Ranking: District. The districts were ranked from 1 to 30, where 1 is the most vulnerable and 30 the least vulnerable. The districts were further categorised into five groups (1 to 5, with each group comprising six districts), where 1 indicates low vulnerability and 5 very high vulnerability
12.	Identification of drivers of vulnerability for adaptation planning	Population density, literacy rate, livestock unit/100,000 population and per capita income are the major drivers of socio-economic vulnerability in the districts of Karnataka

2.7.2 Tier 2: Combination of Top-down and Bottom-up Approaches

Tier 2 assessment involves a combination of top-down and bottom-up approaches, utilising readily available secondary databases and primary data collection, envisaging community/stakeholder involvement to define and quantify indicators. Tier 2 is the most appropriate for adaptation planning. The following are the characteristics of a Tier 2 approach:

- It is a more rigorous methodological approach compared to Tier 1.

- Primary data is also collected through household surveys, PRAs, field measurements, lab experiments, etc.
- It requires advanced skills and resources for carrying out the assessment.
- Policy makers, government departments as well as development agencies could use this approach to guide current decision making by prioritising regions, systems and communities.
- Tier 2 approach is critical for developing targeted adaptation interventions to reduce vulnerability.

CASE STUDY – TIER 2		
AGRICULTURE VULNERABILITY ASSESSMENT USING TIER 2 APPROACH		
	Steps in vulnerability assessment	Details
1.	Scoping and objectives of vulnerability assessment	To identify the extent to which MGNREGS work implementation lowered vulnerability of villages in the study districts
2.	Selection of type of vulnerability assessment	Sectoral Vulnerability Assessment: Agricultural Vulnerability (AVI) Assessment
3.	Selection of tier methods	Tier 2
4.	Selection of sector, spatial scale, community/system and period for vulnerability assessment	Sector: Agriculture sector; Spatial scale: Village level – 40 villages from 4 districts across 4 states of India, involving over 2,000 stakeholders; Period: pre- and post MGNREGS implementation - 2006 and 2011
5.	Identification, definition and selection of indicators for vulnerability assessment	Ten biophysical indicators were selected based on expert judgement and literature: <ul style="list-style-type: none"> • Groundwater depth (meters below ground level) • Irrigation intensity (percentage) • Net area irrigated (in hectares) • Number of days of irrigation water availability • Area under food grains (in hectares) • Cropping intensity (percentage) • Crop yield (ton/hectare) • Soil organic carbon (percentage) • Soil erosion (ton/hectare/year) • Livestock population (Number)
6.	Quantification and measurement of indicators	TA combination of methods was adopted for quantifying the indicators. <ul style="list-style-type: none"> • Field measurements; groundwater depth – conductivity method • Household surveys; irrigation intensity, net area irrigated, number of days the irrigation water is available, area under food grains, cropping intensity, crop yield and livestock population • PRA; Irrigation intensity and cropping intensity • Laboratory estimation; Soil organic carbon – Walkley Black rapid titration method and Soil erosion - Universal Soil Loss Equation
7.	Normalisation of indicators	Normalisation was done based on the functional relationship of an indicator to climate variability. If an indicator has negative functional relationship, then vulnerability increases with decrease in the value of the indicator. Similarly, if an indicator has a positive functional relationship, then vulnerability increases with increase in the value of the indicator. Normalisation of indicators having negative as well as positive relationship with vulnerability was achieved using equations and methods described in Section 2.11.



CASE STUDY – TIER 2		
AGRICULTURE VULNERABILITY ASSESSMENT USING TIER 2 APPROACH		
	Steps in vulnerability assessment	Details
8.	Assigning weights to indicators	Weights were assigned to all indicators based on MGNREGS beneficiary perceptions on a scale of 0 to 1, where the aggregated value of all indicators adds to 1. The perceptions of beneficiaries were based on the significance of a particular indicator and its relevance in helping them cope against climate risks. The exercise was carried out as part of a participatory rural appraisal (PRA) conducted in each of the study villages.
10.	Representation of vulnerability; spatial maps, charts and tables of vulnerability profiles and index	Charts representing agricultural vulnerability were prepared for the sample villages of the study districts.
11.	Vulnerability ranking of sectors, regions, communities, cropping systems, river basins, watersheds and forest types	Unit for ranking: Village The 10 villages of each district were ranked by multiplying the index values of each village with 5, arriving at a vulnerability scale of 1 to 5, where 1 is very low vulnerability and 5 is very high vulnerability.
12.	Identification of drivers of vulnerability for adaptation planning	Drivers not identified.

Note: The normalisation, weighting and aggregation steps were adapted from Esteves et al. 2016

2.7.3 Tier 3: Bottom-up and Spatial Approaches

Tier 3 approach is dominated by spatial analysis of biophysical and socio-economic indicators. This approach involves primary data collection supported by secondary data where required, community/stakeholder involvement and uses advance techniques such as remote sensing, GIS, climate and other models to quantify indicators and assess vulnerability. The following are the characteristics of this approach:

- It is a scientifically rigorous exercise
- Generation of primary data using bottom-up approaches and methods

- Use of satellite data, remote sensing and GIS maps of biophysical and socio-economic indicators
- Data can be sourced from national government, international organisations and other sources
- Requires a dedicated team with the necessary advanced skills and corresponding resources
- Policy makers, government departments as well as development agencies could use this approach to guide current decision making and inform the future policy direction by prioritising regions, systems and communities for anticipatory adaptation planning and interventions for risk reduction

CASE STUDY – TIER 3		
VULNERABILITY ASSESSMENT FOR FORESTS IN WESTERN GHATS REGION OF KARNATAKA USING TIER 3 APPROACH		
	Steps in vulnerability assessment	Details
1.	Scoping and objectives of vulnerability assessment	To develop vulnerability profile for forests in the Western Ghats Karnataka (WGK) landscape.
2.	Selection of type of vulnerability assessment	Integrated assessment considering both biophysical and socio-economic indicators.
3.	Selection of tier methods	Tier 3
4.	Selection of sector, spatial scale, community/system and period for vulnerability assessment	Sector: Forest Spatial Scale: grid cells of 2.5' x 2.5' size (approx. 18.66 Km ²) Period of assessment: Data for different indicators pertained to 1998-2011 period.
5.	Identification, definition and selection of indicators for vulnerability assessment	Indicators were selected through expert consultation and literature review. Further, based on the availability of data on indicators, the following indicators were selected. 1. Biological richness (BR) 2. Disturbance index (DI) 3. Canopy cover (CC) 4. Slope (S) BR and DI are composite indicators consisting of biophysical and socio-economic sub-indicators. CC and S are single parameter biophysical indicators.
6.	Quantification and measurement of indicators or source of indicators	Method for estimating indicators: Secondary data procurement Source of Data: For BR and DI, data was obtained from the Indian Institute of Remote Sensing (IIRS), Dehradun. For CC, data from Forest Survey of India (FSI), Dehradun was used. For S, data was provided by the Karnataka Forest Department.
7.	Normalisation of indicators	To develop unitless values for indicators through normalisation, indicator values were divided into three range-groups indicating low, medium and high vulnerability, which were assigned 1, 2 and 3 vulnerability class values, respectively.
8.	Assigning weights to indicators	Method: Weights to indicators were assigned using pairwise comparison method (PCM).



CASE STUDY – TIER 3		
VULNERABILITY ASSESSMENT FOR FORESTS IN WESTERN GHATS REGION OF KARNATAKA USING TIER 3 APPROACH		
	Steps in vulnerability assessment	Details
9.	Aggregation of indicators and development of vulnerability index	<p>a) The range (maximum and minimum values of an indicator) of measured value of an indicator is split into appropriate vulnerability classes, i.e. low, medium and high vulnerability. For example, the values for BR indicator obtained from the database of IIRS ranged between 2 and 91 with biological richness increasing from 2 to 91. This range of values was split into three sub-ranges: 2–33, 34–49 and 50–91 indicating high (vulnerability class value 3), medium (2) and low (1) vulnerability classes respectively, as vulnerability of a forest ecosystem vary inversely with the BR. Similarly, ‘vulnerability class value’ of 1, 2 or 3 was assigned to each indicator at grid cell level.</p> <p>b) Multiply the ‘vulnerability class value’ (1, 2 or 3) of an indicator with its weight to obtain ‘vulnerability value’ contribution by it for a grid cell.</p> <p>c) Add the ‘vulnerability value’ (VI) for all the indicators for a grid cell to obtain the VI value at grid cell level.</p>
10.	Representation of vulnerability; spatial maps, charts and tables of vulnerability profiles and index	<p>Maps: The range of VI values obtained at grid cells level for the WGK landscape were subjected to classification using ‘cluster analysis’ technique into four vulnerability classes from ‘low’ to ‘very high’. Accordingly, each grid cell was classified under low, medium, high or very high vulnerability classes. This was spatially represented in the WGK landscape map.</p>
11.	Vulnerability ranking of sectors, regions, communities, cropping systems, river basins, watersheds and forest types	<p>Unit for ranking: Grid cell Forests in a grid cell were ranked under one of the vulnerability classes from ‘low’ to ‘very high’ vulnerability.</p>
12.	Identification of drivers of vulnerability for adaptation planning	<p>The study presents BR as the most important indicator determining vulnerability of forests in the WGK landscape. BR indicator is assigned 55.6% weight. DI, CC and S indicators with 26.6%, 12.3% and 5.9% weights respectively, contribute to vulnerability in that order.</p>

Source: Sharma et al. 2015

Tiers 2 and 3 methodological approaches would involve stakeholders’ engagement to finalise indicator selection, and to discuss results of the vulnerability assessments to draw conclusions and develop actionable vulnerability reduction measures. They also generate system-specific

information about the sources of vulnerability for the development of current and anticipatory adaptation strategies and initiation of long-term policy changes for risk reduction. The merits and limitations of each tier are presented in Table 2.6.

Table 2.6: Merits and limitations of the three tiers of vulnerability assessment

	Tier 1	Tier 2	Tier 3
Merits	<ol style="list-style-type: none"> 1. Does not require much expertise. 2. Quick and easy to implement. 3. Requires low level of resources and skills. 4. Adequate largely for ranking of vulnerability at a macro level such as districts and blocks. 	<ol style="list-style-type: none"> 1. Involvement of stakeholders improves the acceptability and credibility of the assessment results. 2. Useful for advocacy purposes and for creating demand for assessments. 3. Useful for developing adaptation strategies at micro level, such as watersheds, panchayats and forest types. 	<ol style="list-style-type: none"> 1. Useful for developing site-specific adaptation plans. 2. Involvement of stakeholders and use of GIS and other modern techniques increase the accuracy and robustness of the results. 3. Could be used for developing climate change vulnerability profiles. 4. Useful for developing adaptation strategies to climate change by addressing the climate change related vulnerability drivers.
Limitations	<ol style="list-style-type: none"> 1. Tier 1 methodologies are quick but not elaborate. 2. Low accuracy of the results. 3. Provides only preliminary information about a system's vulnerabilities. 	<ol style="list-style-type: none"> 1. Requires more resources and time. 2. Requires medium to high level of expertise. 3. Requires access to primary and secondary data at a micro-scale. 	<ol style="list-style-type: none"> 1. It is time consuming and data intensive. 2. It requires very high levels of knowledge and skill. 3. Requires climate change and impact model outputs.

2.8 Selection of Sector, Scale, System and Period for Vulnerability Assessment – Step 4

The purpose and utility of a vulnerability assessment is to identify the sectors, regions and communities/systems which are most likely to be adversely impacted by climate hazards and to enable mainstreaming of adaptation strategies through development programmes and projects. Selection of scale or sector is critical for focusing vulnerability assessment. Depending on the objective of assessment, it is possible to select the scale of the assessment first, followed by the selection of critical sectors for a given scale. Conversely, a sector could be selected and then the scale could be determined for vulnerability assessment.

- Scale:** Vulnerability assessment could be carried out at a micro-scale such as at a village level where households or farmers can be assessed for vulnerability. Similarly, vulnerability assessment could be carried out at a macro-scale such as at a district, watershed and state levels. One can rank the most vulnerable regions on a spatial scale and further select the sectors within the region for vulnerability assessment.
- Sector:** Vulnerability assessment could start from the sector and the appropriate scale could be identified. For example, if agricultural sector is the focus of vulnerability assessment, then the assessment will have to be made separately for sub-sectors such as irrigated agriculture, semi-arid agriculture, rainfed



agriculture or mountain agriculture. Here, one could further select the scale for each of the sub-sectors such as:

- Selecting higher elevation, mid-elevation or low-elevation mountain agriculture
- Arid zone agriculture at state, district, block or village scale

iii. **System – Biophysical/Socio-economic:** Vulnerability assessment could also be conducted for different biophysical systems/socio-economic communities such as:

- Landless households, small farmers, large farmers
- Social groups such as different social castes
- Indigenous and agricultural communities
- Farmers living in the mountains and plains of the same region
- Natural sources of water including mountain springs
- Forest ecosystems

iv. **Period:** Vulnerability could be assessed for the current climate or for the future climate under climate change scenario. Future climate change scenario vulnerability could be assessed for:

- Short-term period of 2030s
- Mid-term period of 2050s
- Long-term period of 2100

Selection of the above categories is determined by the objective of the assessment and resources available. Developing targeted adaptation strategies and practices would require finer levels of region, scale, sub-sectors and short and long term vulnerability assessments. In the following sections, details of scale, sector, social communities and period of vulnerability assessment are presented in detail.

2.8.1 Selection of Scale: Why Do We Identify and Select a Scale?

The first step is to select the region for assessment of vulnerability, which could be the Himalayan mountain

region or the plains in the Himalayan states or in North-East India. Vulnerability could also be compared across the regions such as the Himalayan regions vs. arid zones vs. The Western Ghats vs. North-Eastern region. Once the region is identified, the next step is to determine the spatial scale of assessment. The rationale for selection of a scale for vulnerability assessment is given in Table 2.7.

The scale of assessment is determined by the objective and availability of resources and data. The scale should be determined right at the beginning of designing of a vulnerability assessment to enable appropriate selection of indicators and methods. The main factor that determines the scale of assessment is the purpose of the assessment such as ranking of districts or blocks at the macro-level for prioritising adaptation interventions or development of location-specific adaptation practices and strategies for implementation at the micro-level. Selection of scale would influence the following:

- Determine resources necessary for conducting the assessment as well as selection of tiers [Tier 1/Tier 2/Tier 3]
- Selection of larger scales like national, state or district for the current climate vulnerability assessments would mean the use of Tier 1 approach (refer to Section 2.7 for details), requiring fewer resources and skills
- Climate change vulnerability assessments even at a larger scale, however, would need the use of advanced technology and techniques such as remote sensing, GIS and computer modelling, requiring a dedicated team with high level of skills and necessary resources
- As the scale gets finer, i.e. community, agricultural system, forest land, watershed, etc., the skill and rigor required to carry out the assessment increases as it envisages stakeholder involvement and/or field measurements (explained in Section 2.7 – Case Study – Agriculture vulnerability assessment using Tier 2 approach)

Table 2.7: Rationale for selection of different scales for vulnerability assessment

Scale	Utility
National	To identify and prioritise the most vulnerable regions in a country for mainstreaming adaptation strategies in central government schemes and programmes. For example, identifying the most vulnerable forest types across the country to manage by developing adaptation practices to lower their vulnerability. Another example could be the selection of mountain agriculture at different altitudes, semi-arid, coastal and arid agriculture. National level studies are necessary for comparison across countries for vulnerability ranking.
State	To identify and prioritise the most vulnerable states in the region for adaptation planning and implementation. For example, identifying the most vulnerable Himalayan states to current climate variability and future climate change or the most vulnerable states for flood or cyclone events.
District	To prioritise and rank the most vulnerable districts in a state for targeted adaptation planning and implementation. This is one of the most commonly used scales for vulnerability assessment which aids the state government to prioritise and allocate limited adaptation investment funds.
Village	To identify and prioritise the most vulnerable villages in a district for targeting adaptation finance to build resilience and lower vulnerability. This scale is most critical for developing location-specific adaptation strategies.
Household	To identify and prioritise the most vulnerable communities or social groups for a targeted adaptation action. The households within a village could be ranked based on the vulnerability. For example, ranking of irrigated farmers, rainfed farmers, plantation owners and landless households.
Watershed	To identify and prioritise the most vulnerable watersheds and to further understand the drivers and mainstream adaptation measures. The Government of India has Integrated Watershed Management Programme (IWMP) across the country. IWMP may want to prioritise watersheds for adaptation investments.

Table 2.8: Illustration of different types of sector-specific vulnerability assessments

Sector	Utility
Agricultural vulnerability	To identify and prioritise agricultural vulnerabilities and their drivers and for mainstreaming adaptation measures for the same. Vulnerability can be assessed for different agricultural systems, for example: <ul style="list-style-type: none"> - Mountain agriculture at different altitudes, semi-arid and arid agriculture - Irrigated, rainfed and coastal agriculture - Rice production system, millet systems, mixed cropping systems, horticultural system
Forest vulnerability	To identify and prioritise forest vulnerabilities and their drivers and for mainstreaming adaptation measures for the same. Vulnerability could be assessed based on: <ul style="list-style-type: none"> - Forest types: Evergreen, moist deciduous, deciduous and scrub forest - Based on levels of degradation: High crown density (> 70%), moderate crown density (40-70%), low crown density (10-40%) and scrub forests (< 10%)
Water resource vulnerability	To identify and prioritise water resource vulnerabilities and their drivers and for mainstreaming adaptation measures for the same. Vulnerability could be assessed for the following: <ul style="list-style-type: none"> - River basins - Watersheds: macro or micro - Lake catchment



2.8.2 Selection of Sectors: Agriculture, Water Resources, Forests and Others

Vulnerability assessment can be conducted at a spatial scale such as village, district or state and also at sectoral level. As different government departments have jurisdiction over different sectors, generation of sector-specific vulnerability indices (Table 2.8) would be targeted towards specific policymakers and land/resource managers to assist in the management of their respective sectors. Further, selection of a sector for vulnerability assessment will also determine the scale, selection of indicators and methods required for quantification. Table 2.5 provides where to adopt, application of vulnerability profiles and target groups for broad categories of vulnerability assessments, i.e. biophysical, socio-economic and integrated. In Table 2.8, the utility of agriculture, forest and water resource sector-specific vulnerability is presented.

2.8.3 Selection of Broad Systems: Socio-Economic and Biophysical Systems

Vulnerability could be broadly assessed with focus on biophysical or socio-economic systems, based on the objective of identifying the dominant biophysical or socio-economic drivers of vulnerability. It is possible to conduct vulnerability assessment completely based on biophysical or socio-economic indicators. Further, vulnerability can be assessed for different social groups (caste) or economic categories (small and large farmers), since social and economic status can determine vulnerability. Thus, vulnerability could be assessed at three levels.

- Biophysical system vulnerability
- Socio-economic system vulnerability
- Integrated system vulnerability

Table 2.5 provides explanation for where to adopt these categories of vulnerability assessment, its application and the target group.

Socio-economic vulnerability could be assessed for the following categories:

- Landless households, small farmers, large farmers
- Social groups such as different social castes

- Indigenous and agricultural communities
- Farmers living in the mountains and in the plains of the same region
- Irrigated vs. rainfed landholding farmers

For example, an assessment of farmers with rainfed landholdings vs. those having irrigated lands from two neighbouring villages in a semi-arid district of Karnataka revealed that farmers having irrigation facility were relatively more vulnerable to drought. This was because they solely depended on agriculture for their livelihoods and depleted groundwater sources could not provide the water required to maintain crop production. Rainfed farmers, however, had diversified their income sources, allowing them to cope with crop failure due to drought (Esteves et al. 2016).

Biophysical vulnerability could be conducted for different scales (Table 2.7) or at a sectoral level (Table 2.8). The spatial scale could be at village, district, state and watershed levels. Similarly, biophysical vulnerability could also be assessed at sectoral level such as agriculture, water and forest.

2.8.4 Selection of Period: Current, Future and Periodic Assessments

Vulnerability can be assessed for the current climate variability and long-term climate change. Further, vulnerability can be assessed for short term, mid-term or long-term periods. Thus, vulnerability is dynamic requiring assessments to be repeated over time to understand how communities move along the scale of vulnerability, or how adaptation interventions could have reduced the vulnerability. The rationale for multi-period assessments is provided below.

- Assessments maybe repeated periodically to compare changes in vulnerability over time since households could shift on the scale of vulnerability.
- Information pertaining to different years can be collected to assess changes over defined time periods.
- Periodic vulnerability assessment can be a useful tool to assess the efficacy of adaptation strategies implemented.

- Periodic assessment of vulnerability in project areas can determine to what extent resilience is enhanced or if adaptation strategies implemented are leading to maladaptation.
- In the example provided in Section 2.7 (Case Study – Agriculture vulnerability assessment using Tier 2 approach) vulnerability of agricultural production systems and livelihoods of beneficiaries of MGNREGS was assessed for pre- and post- implementation of the scheme (2006-07 and 2011-12 were compared). The assessment revealed that MGNREGS works lowered the vulnerability of beneficiaries and agricultural production systems.

2.9 Indicators for Vulnerability Assessment: Identification, Definition and Selection of Indicators – Step 5

Indicators constitute the main component of vulnerability analysis. Selection of correct and

appropriate number of indicators is a major challenge for vulnerability experts. This section presents the types of indicators, procedures for selection of indicators and the rationale for selection.

2.9.1 Definition of Indicators

Vulnerability cannot be observed or measured or quantified directly. Thus, vulnerability assessment requires proxies to characterise and assess vulnerability. Indicators are such quantifiable proxies that can represent a characteristic or a parameter of a system of interest. Indicators could be selected to reflect vulnerability or its components and drivers. Indicators can be observed, measured or estimated. Most vulnerability assessments use indicators. Selection of indicators is one of the most critical steps of vulnerability assessment. In this section, the indicators for the components of vulnerability, the types of indicators, methods for selecting indicators, factors determining the selection of indicators and methods for estimation or quantification of indicators are presented.

Table 2.9: Categories of indicators with examples

Category of indicator	Examples
Biological	<ul style="list-style-type: none"> - Crop varieties (short or long duration) - Irrigated crops (rice, sugarcane) - Forest types (evergreen or deciduous or montane) - Invasive species
Physical	<ul style="list-style-type: none"> - Slope - Altitude - Soil fertility
Social	<ul style="list-style-type: none"> - Gender - Caste - Marginality - Inaccessibility
Economic	<ul style="list-style-type: none"> - Landholding size - Occupation - Income sources diversification
Institutional	<ul style="list-style-type: none"> - Presence of community-based organisation(s) at grassroots level - Presence of banks - Access to credit - Opportunity for insurance - Social security programmes such as MGNREGS - Presence of watershed programmes



2.9.2 Indicators for Vulnerability Components: Sensitivity and Adaptive Capacity

Vulnerability is a function of sensitivity and adaptive capacity components of a system. Thus, there is a need to select indicators to represent both these components. For construction of vulnerability index, several sets of proxy indicators could be identified for the two components of vulnerability – sensitivity and adaptive

capacity. Indicators can reflect biological, physical, social, economic and institutional characteristics of a system. The types and examples of indicators are listed in Table 2.9. Indicators could also be categorised as primary and secondary indicators. Examples of primary indicators include crop yields on farms, availability of irrigation water and number of crops grown. Secondary indicators include literacy, presence of banks, household size and size of landholding.

Table 2.10: Criteria for the selection of indicator, features and examples of indicators

Criteria	Features or types	Examples of indicators
Objective of vulnerability assessment	1. Vulnerability ranking of states, districts and villages	Population density, size of landholding, literacy level, livestock population density and presence of bank or credit society
	2. Development of location-specific adaptation interventions to reduce vulnerability	Area under irrigation per farm, extent of multiple cropping, access to social security programmes such as MGNREGS, sources of income, extent of agro-forestry
Scale of vulnerability assessment	1. Macro-scale: State, district, river basin, landscape level	Population density, literacy levels, occupation pattern, distance from the health centre, access to motorable road, percentage of households having electricity, percentage of area under forests
	2. Micro-scale	Area irrigated per farm, springshed density/village, livestock holding per household, cropping intensity, fertiliser application per hectare
Resources availability – financial and technical	1. Limited financial resources and technical capacity	Per capita income, households availing banking facilities
	2. Adequate resource and technical capacity	Tree crown density, groundwater depth, soil fertility, participation in MGNREGS, extent of use of banks and credit societies
Tier approach adopted	1. Tier 1	SC/ST population, road density, literacy rate
	2. Tier 2	Extent of irrigation, education/skill level, livelihood support institutions, land available for grazing and collection of fuelwood and Non Timber Forest Produce, diversification of income sources
	3. Tier 3	Slope map, soil fertility map, forest vegetation crown density, forest degradation map, distribution of water bodies, marginalised households, sources of livelihood

Table 2.11: Considerations in selection of a good indicator

Critical considerations	Answers (examples only)
1. What is being measured?	Area owned by small and marginal farmers (percentage)
2. Why is it being measured?	Small and marginal farmers are more sensitive to extreme climate events
3. How is this indicator defined?	As percentage of the total land owned by small and marginal farmers
4. Whose vulnerability does it measure?	All small and marginal farmers
5. When is it measured or the timeline?	Normally for a given year
6. Will it measure absolute numbers or proportions?	Proportion (or even numbers)
7. Where does the data come from?	Public records, census data, local statistics office
8. How accurate and complete will the data be?	Depends on the system's reporting capabilities
9. Are there any warnings or problems?	Potential for errors in collection, collation and interpretation, e.g. definition of small farmer
10. Are tests such as standardisation, significance tests, or statistical process control needed to interpret data and the variation they show?	The size and distribution of small and marginal farmers in a village or a block or district could be compared to regional or state level data to check the validity of distribution. For example, if the distribution in the project area is too divergent from the regional trends, further validation may be required.

2.9.3 How to Select an Indicator?

Selection of indicators is an iterative process, and depends on the objectives of vulnerability assessment, scale, tier method to be adopted, and availability and access to data. Vulnerability assessment undertaken with the objective of identifying districts and ranking them on a scale of vulnerability normally depends on the broader scale indicators and secondary data. However, for developing location-specific adaptation, mainly primary indicators, which are derived from the ground are required. Details and examples for indicator selection are presented in Table 2.10.

Asking certain probing questions about the system facilitates identification and selection of appropriate indicators. Answers to such questions also enhance the information and understanding about the system. Some of the critical questions that could guide the selection of indicators are listed in Table 2.11.

2.9.4 Selection of Indicators for Sensitivity and Adaptive Capacity

Indicators have to be selected to represent 'sensitivity' and 'adaptive capacity' – the two components of vulnerability. Selection of indicators is determined by the goal of the vulnerability assessment and the choice of tier. In practice, the choice of indicators is limited by data availability or resource constraints (time and budget). The number of indicators required to represent a factor varies from case to case and should be guided by integrating local expertise and by evolving a consensus among the involved experts and stakeholders.

Selecting Indicators Representing Sensitivity

Indicators for sensitivity should reflect to what extent a system is sensitive or responding to the exposure from an external stress or hazard such as drought or landslide. Sensitivity indicators are usually biophysical or physical;



e.g. high altitude and gradient of slopes, poor soil type, deficient crop inputs, unreliable irrigation systems in use, high water demand for crops and low density of vegetation cover. Unlike socio-economic characteristics, these indicators – particularly topography parameters – tend to be less dynamic or remain constant. The following steps could be adopted for selecting the sensitivity indicators:

- I. Prepare a list of system weaknesses and peculiarities that make it prone to suffer losses. For example, high proportion of people living in flood zone of a river makes a community sensitive to flood hazard, or a village situated on a steep mountain slope is sensitive to landslide hazard.
- II. Shortlist the factors identified above by deleting the overlapping factors in consultation with the stakeholders and experts. While shortlisting the factors, consider the context of assessment. Vulnerability assessment can be conducted in the context of a specific hazard such as the vulnerability of hill communities to landslides. In such a case, hazard-specific factors like terrain and steepness of slopes become prominent which may not be the case when vulnerability of hill communities is assessed in the context of drought. Retain the important factors accordingly.
- III. Define the shortlisted factors in terms of 'definite and well-defined' indicators. For example, the 'steepness of slope' factor is defined as 'per cent or degree of slope' and listed as a sensitivity indicator. In case of sensitivity of agricultural crop to drought, 'crop yield variability' could be the well-defined indicator.
- IV. Check the availability of data on the shortlisted indicators. Drop the indicators for which data is not available or adopt another measurable parameter, which can represent this indicator and for which data is available or otherwise collect the data afresh.

Selecting Indicators Representing Adaptive Capacity

Adaptive capacity indicators should reflect the ability or capacity of systems, institutions and infrastructure to adjust to potential damage or change due to external stresses or hazards, including climate. To identify and select adaptive capacity indicators, the following steps could be observed:

- I. Prepare a comprehensive list of system strengths. For example, road accessibility for a community or proximity to market or presence of village-level institutions or accessibility to primary health centre or availability of multiple sources of water.
- II. Shortlist the factors from the identified list above by deleting the overlapping factors in consultation with the stakeholders and experts. In case vulnerability is being assessed in the context of a specific hazard (e.g. cloud burst or landslide) then factors such as remoteness and accessibility of the location decide the capacity to seek or provide outside help. In such a case, factors like road and communication network become prominent which may not be the case when vulnerability of hill communities is assessed in the context of drought. Accordingly, the important factors should be retained.
- III. Define the shortlisted factors in terms of 'definite and well-defined' indicators. For example, the factor 'connectivity of the community to outside world' can be defined in terms of 'time required to reach the village with help'. In case of vulnerability of agricultural crop to drought, the indicator could be 'per cent area under irrigation'.
- IV. Check the availability of data on the shortlisted indicators. Drop the indicators for which data is not available or adopt another measurable parameter which can represent this indicator and for which data is available or otherwise collect the data afresh.
- V. The adaptive capacity indicators may represent the strengths of a system. However, to quantify their contribution to vulnerability it is the lack of such capacity that needs to be assessed, as capacity to adapt reduces vulnerability. Accordingly, inverse of the adaptive capacity parameter value should be calculated and added to quantified sensitivity to arrive at the vulnerability.

2.9.5 Methods for Indicator Selection: Literature-Based, Stakeholder and Expert Consultation

Selection of indicators for vulnerability assessment is a challenging task. The vital questions are: which indicators and how many indicators to be selected? If too many indicators are selected, it will be a challenge to give weights for the indicators and further, there could be autocorrelation among the indicators. Selection of

too few indicators may lead to missing critical drivers of vulnerability. There is also a challenge with respect to collecting data for the indicators; some secondary data may be available at the district level but may be too coarse or average. Further, some indicators may be difficult or too expensive to measure (e.g. soil fertility). In this section, we present the criteria and methods for selecting indicators. The indicator selection process very often involves a combination of methods including literature review, reconnaissance survey, and expert and stakeholder consultations. The three methods are described hereunder:

Literature-Based: The literature-based method involves listing and identification of the indicators from the published studies conducted in the same region or similar contexts.

- If available, focus on past vulnerability assessments conducted for your study region/ community/system and the indicators selected in these assessments
- In the absence of past assessments, review studies reporting existing social and environmental issues for the study region/ community/system
- Indicators may be selected from vulnerability assessments conducted in other regions, if the social and environmental issues are similar. The source of literature could include published journal articles and reports, library, internet, other developmental programme project evaluation or completion reports
- Based on the literature, select indicators which are likely to be potential drivers of vulnerability in the proposed study area. This should be based on the cause-effect relationship between the indicator and vulnerability

Stakeholder Consultations: Stakeholders vary from project to project, depending on the objective of the assessment and the scale of assessment. Consultation of stakeholders increases the legitimacy and hence the quality and credibility of indicators selected. Some of the factors determining the stakeholders and the approach for consultations are as follows:

- Select the location (village/watershed/block, etc.) and conduct a reconnaissance survey of the biophysical systems, institutions and the socio-economic structure
- Selection of stakeholders depending on the objective and scale:
 - Village-level vulnerability assessment for identifying adaptation options: farmers, local leaders (panchayat), key informants, agriculture extension officers, animal husbandry officers, local NGOs
 - District or state level vulnerability assessment: district administrators, domain experts, NGOs
 - Watershed level vulnerability assessment: farmers' representatives, watershed experts, finance experts, social scientists, NGOs
- Identification and selection of indicators are based on the knowledge and expertise of local citizens and stakeholders
- Indicators may be identified and selected by visiting the area under consideration for the vulnerability assessment and interviewing or conducting consultative meetings with stakeholders

Expert Judgement: Expert judgement involves consultations with experts, working in the area or sector relevant to the objective of the proposed vulnerability assessment. Some of the features of expert judgement are as follows:

- Experts include agriculture scientists, social scientists, anthropologists, biologists or domain experts in forestry, water resources, health, etc., and NGOs. Preferably, the experts should be from the same region, who have a good understanding of the sector
- Indicator selection based on expert judgement is subjective, as it relies on the experience and perception of experts or NGOs
- Expert judgement might be captured through participatory workshops or in interviews with selected experts



Iterative Approach to Selection of Indicators

Selection of indicators is an iterative process involving multiple steps for all the three methods described above.

- **First iteration:** This involves obtaining the list of indicators from literature or expert consultation or stakeholder consultation.
- **Second iteration:** If selection of indicators is by adoption of one of the three methods, it is preferable to validate the indicators selected by adopting another method. For example, indicators selected using literature review could be validated by consulting experts from the region. Very often, the tendency is to identify a large number of indicators – some with a direct bearing on vulnerability and others with limited impact on vulnerability. It is always a challenge to select appropriate number of

indicators to avoid; too many or too few. The merits and demerits of having too many or too few indicators are presented in Table 2.12

- **Final iteration:** It will be ideal for experts to consult stakeholders to shortlist the indicators which may have a direct bearing on sensitivity or adaptive capacity components of vulnerability

Indicators and Rationale

Table 2.13 provides an illustrative list of indicators that may be applicable for the Himalayan region. This list may undergo change depending on the state selected, perceptions of stakeholders, resource availability and community/system selected for vulnerability assessment. Additional examples of indicators used by various vulnerability studies are given in the Annexure 1.

Table 2.12: Merits and demerits of having a small vs. large number of indicators for assessing vulnerability

	Too few indicators	Too many indicators
Merits	Quick assessment	In-depth information
	Data gathering is easy	Drivers recognised easily
Demerits	Drivers not easily recognised	Time consuming
	Indicators will be general	Data collection is difficult
	All the drivers might not be covered	Dependence on stakeholder consultation

Table 2.13: Illustrative list of indicators for Tier 1 vulnerability assessment relevant to the Himalayan states of India (district and village levels)

Biophysical Indicators: District level – for ranking districts		
Sensitivity/Adaptive Capacity	Indicators (units)	Rationale
Sensitivity	Percentage of sown area under rainfed agriculture (without irrigation facility)	Higher percentage of such areas indicates higher sensitivity of crop yields to drought
Adaptive capacity	Biological richness (IIRS data)	Current biological richness and potential to host richness
Sensitivity	Degraded land as percentage of total land	Lands with diminished capacity to be resilient and produce environmental benefits

Biophysical Indicators: District level – for ranking districts		
Sensitivity/Adaptive Capacity	Indicators (units)	Rationale
Adaptive capacity	Livestock population density (percentage units per sq. km)	Potential source of income diversity or pressure on grassland
Adaptive capacity	Water spring density (number/sq. km)	Status of surface water availability
Sensitivity	Area owned by marginal farmers (percentage)	Marginal farmers are more vulnerable
Adaptive capacity	Cropping intensity	Cropping intensity is defined as a ratio between net sown area (NSA) and gross cropped area (GCA). Higher the index, greater is the efficiency of land use
Adaptive capacity	Area under perennial fruit crops	Higher area under perennial tree crops indicates higher adaptive capacity
Adaptive capacity	Percentage area under forests (in hectares)	Higher the area, higher the adaptive capacity
Sensitivity	NPK fertiliser consumption (in tonnes)	Higher levels of use indicate higher vulnerability
Socio-economic and Institutional Indicators: District level		
Sensitivity	Human population density (number of people/sq. km)	Higher population density translates to higher exposure
Sensitivity	SC/ST population (percentage)	Higher percentage of marginalised population increases the sensitivity to adversity
Adaptive capacity	Literacy (percentage)	Lower literacy rate translates to lower capacity to adapt
Sensitivity	Rural population density	Higher proportion of rural population indicates higher dependence on natural resources-based livelihoods
Adaptive capacity	Electrification (percentage of villages electrified in a district)	Indicates adaptive capacity
Adaptive capacity	Percentage of villages having banking or cooperative credit institutions in a district	Lack of access to credit and institutions is an indicator of lack of adaptive capacity
Sensitivity	Percentage of <i>kaccha</i> households in rural areas	Indication of sensitivity
Adaptive capacity	Number of households engaged in Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS)	Lack of access to MGNREGS support is an indicator of low adaptive capacity
Socio-Economic and Institutional Indicators: Village level		
Adaptive capacity	Percentage annual household income from Broom grass plantation (percentage)	It provides additional and alternate source of income and reduced vulnerability



Biophysical Indicators: District level – for ranking districts		
Sensitivity/Adaptive Capacity	Indicators (units)	Rationale
Sensitivity	Percentage of <i>kaccha</i> houses	Higher percentage indicates higher vulnerability
Sensitivity	Per cent of households with agriculture as primary occupation	Single source of income results in lower adaptive capacity
Adaptive capacity	Per cent of households with other occupation sources (non-agriculture)	Indicates additional source of income in case of crop failure
Sensitivity	Number of adults (men + women) involved in agriculture or other allied activities	Number of family members dependent on the earning member. Higher ratio indicates higher vulnerability
Adaptive capacity	Distance from the market place	Indicates lack of opportunities to adapt
Adaptive capacity	Literacy rate	Lack of education reduces the capacity to access resources to deal with the adverse impact
Adaptive capacity	Presence of village level institutions such as banks, credit societies, Joint Forest Management societies, etc.	Such institutions enhance adaptation response. Their absence indicates lower adaptive capacity
Sensitivity	Households below poverty line (percentage)	Higher poverty indicates higher vulnerability due to low adaptive capacity
Adaptive capacity	Villages with pucca (motorised) road	Presence indicates higher adaptive capacity
Adaptive capacity	Distance from the nearest health centre (in km)	More the distance lower the adaptive capacity
Adaptive capacity	Per cent households in a village with access to safe drinking water	Lower percentage indicates lower adaptive capacity

2.10 Quantification and Measurement of Indicators – Step 6

This section deals with approach and methods for estimating the indicators for vulnerability assessment. The methods could vary from sourcing the data from published secondary sources to field observation, measurements, surveys and modelling. The methods depend on the tier selected and technical and financial resources available to the team making the assessment.

2.10.1 List of Indicators and Stratification for Estimation

The iterative process described in the previous section will help arrive at the final list of indicators for which data

will have to be generated to conduct the vulnerability assessment. But prior to data collection on the indicators, there is a need to stratify the indicators to take decisions on which method to adopt for different indicators. Regarding the tier to be selected, an assessment could use different tiers for different indicators, though there are many studies which largely or wholly adopt only Tier 1 method and source all the indicators from secondary sources.

To facilitate selection of methods for estimating or quantification, the indicators could be stratified into biological, physical, social, economic and institutional (Table 2.14). For example, all the social indicators could be collected through PRA and household surveys and physical indicators may require field measurements. Further, stratification also helps in decisions on the

Table 2.14: Examples of different categories of indicators and tier to be adopted for assessment

Category of indicator	Examples of indicators	Which tier to adopt?	Sensitivity/Adaptive Capacity
Biological	- Crop varieties (short or long duration)	- Tier 1	Adaptive capacity
	- Irrigated crops (rice, sugarcane)	- Tier 1	Adaptive capacity
	- Forest canopy density	- Tier 1 or Tier 3 (spatial)	Adaptive capacity
	- Invasive species	- Tier 1 or Tier 3 (spatial)	Sensitivity Adaptive capacity
Physical	- Slope	- Tier 3	Sensitivity
	- Altitude	- Tier 3	Sensitivity
	- Soil fertility	- Tier 3	Adaptive capacity
Social	- Gender	- Tier 1	Sensitivity
	- Caste	- Tier 1	Sensitivity
	- Marginality	- Tier 1	Sensitivity
	- Inaccessibility	- Tier 1	Sensitivity
Economic	- Landholding	- Tier 1 or Tier 2 – depending on scale, for example, state level assessment will be Tier 1 while assessment at village level could adopt Tier 2	Adaptive capacity
	- Occupation		Adaptive capacity
	- Income sources		Adaptive capacity
Institutional	- Presence of banks	- Tier 1 or Tier 2	Adaptive capacity
	- Access to credit	- Tier 2	Adaptive capacity
	- Access to insurance	- Tier 2	Adaptive capacity
	- Social security programmes such as MGNREGS	- Tier 1 or Tier 2	Adaptive capacity
	- Presence of watershed programmes	- Tier 1 or Tier 2	Adaptive capacity
			Adaptive capacity

methods and technical capacity needed. If a large number of biological indicators are needed, then a biologist or agricultural expert may have to be involved. If the indicators are largely socio-economic then a social scientist may have to be involved.

2.10.2 Tier Methodology for Estimation and Quantification of Indicators

The broad methods to be adopted for estimation and quantification of indicators will be determined by the objective of the assessment, technical capability of the institutions and resource availability. Vulnerability

assessment could adopt a multi-tier approach involving tiers 1, 2 and 3 depending on the intensity of the effort involved in generating the indicators (refer to Section 1.10 in Part 1 of this Manual for details). Most studies are likely to adopt Tier 1 or Tier 2 for estimation of the indicators, which are described below.

Tier 1: Tier 1 methods use a top-down approach to vulnerability assessment to obtain the first sense about vulnerability of a system as skills and resources to carry out assessment are lacking. Assessment involves selection of vulnerability indicators based on the indicators identified in a comparable context in the



literature. The assessment team may adopt the following sequential steps to identify vulnerability indicators for Tier 1 assessment:

- 1) Collect as much information as possible about the system of interest from literature and other sources including, whenever feasible, from the primary stakeholders, e.g. local community (for example, a village having agriculture-dependent households and low levels of literacy) or experts.
- 2) Consider such information for identification of factors that are adversely impacting the system, and develop a complete list of all such factors (in the above mentioned example the factors determining vulnerability could be; lack of irrigation facility, lack of electricity for irrigation pump sets, lack of other sources of income, poverty, lack of pucca dwellings, dwellings with kachha roof, lack of education facilities, small size of landholdings, lack of micro-finance opportunities, and large proportion of aged persons and children).
- 3) Consider the listed factors for overlap and shortlist them by reducing from among the ones that show overlap (for example, poverty, lack of pucca dwellings, lack of water supply, lack of electricity and lack of toilet facility, all of these factors that enhance vulnerability of a household have overlap underpinning poverty. However, depending on the context and objective of the assessment, one or more of these may be retained so that overlap is minimum but no factor that is significant in determining vulnerability is ignored, i.e. while assessing health vulnerability of a community, which has direct connect with poverty, lack of water supply and lack of toilet facility may be selected as additional indicators).
- 4) For each of the shortlisted factors (vulnerability indicators), identify and decide a measurable parameter. These parameters provide a quantification of these factors (indicators), which determine the vulnerability of the system (for example, for lack of water supply and lack of toilet facility, measurable parameter could be number of households without municipal water connection and number of households without a toilet, respectively). These are vulnerability indicators, however only such of the indicators could be finally selected for which data is also available.
- 5) Consider the availability of data for the shortlisted parameters to reconsider the indicators selected.
- 6) Finalise the indicators considering the constraint of lack of data (for example, ideally one may want to select both of the indicators from the above example (lack of water supply and lack of toilet facility), however, if data is available for neither or one of them, the indicator choice gets constrained and limited to the indicator for which data is available.

Tier 2: Tier 2 methods use a combination of bottom-up and top-down approaches to vulnerability assessment taking advantage of the skills and resources available with the assessment team. It is useful to focus on and define the system as narrowly as possible, as it helps in the identification of indicators that can closely represent the system and its characteristics. Effort is made to systematically involve stakeholder community, particularly primary stakeholders in the selection of indicators. The assessment team can adopt the following sequential steps to identify vulnerability indicators for Tier 2 assessment:

- 1) Gather information about the system of interest from literature and other sources including that from the primary stakeholders.
- 2) Depending on the specific objective(s) of the assessment, organise and analyse the information to identify the factors and mechanisms that are impacting the system.
- 3) Develop a complete or exhaustive list of the factors and mechanisms that are adversely impacting the system in consultation with the stakeholders.
- 4) Check the factors and mechanisms for overlap and avoid overlap by deleting by involving domain area experts and stakeholders, and using techniques like Principle Component Analysis (PCA) (refer to Annexure 2 for details).
- 5) Mechanisms are dynamic processes, which may be complex to parameterize and quantify. Therefore, identify static parameter that can represent them as proxy. For example, the disadvantageous position of women candidates compared to men candidates in an election process (vulnerability mechanism) can be represented by the proportion of women candidates that are elected (proxy parameter that is quantifiable).

- 6) For each of the shortlisted factors and mechanisms, identify and decide a measurable parameter. These parameters represent and measure the factors/mechanisms that adversely impact the system and determine its vulnerability.
- 7) Reconsider the measurable proxy indicators selected for the shortlisted factors and mechanisms for feasibility of gathering/obtaining data on them and accordingly finalise the list of indicators.

Tier 3: Tier 3 approach to select vulnerability indicators is a rigorous bottom-up approach where indicators are systematically developed from the study site/community. So, selected indicators have high capability to represent the relevant system attributes in a precise manner. This approach is resource intensive and requires highly skilled assessment team. While, as in case of Tier 2 selection process, other factors such as involvement of stakeholders and use of modern tools and techniques to inventorise and select optimum number of indicators is a requirement under Tier 3 methodology also, it further makes use of state-of-the-art information gathering

techniques like remote sensing and computer-based models for selection of particularly the spatially profiled biophysical and socio-economic indicators. The steps followed to select vulnerability indicators under the Tier 3 approach remain the same as in the case of Tier 2 approach with a difference that all data felt necessary to decide the optimal indicators is actually generated.

2.10.3 Matching Methods with Indicators and Tier

Tier selection is dependent on the scale and objective of the study, resources available – both financial and technical, and data availability. The features of the tiers, conditions under which different tiers could be adopted, merits and demerits are presented in Section 2.7 of Part 2 of this Manual. Once indicators are identified and the tier to be adopted is decided, the next important step is to choose the method for quantification or estimation of the indicator. This is particularly crucial when tiers 2 and 3 approaches are to be adopted. An illustration of the matching of indicators, tier and methods to be adopted is presented in Table 2.15.

Table 2.15: Matching of indicators under different tiers and methods

Sensitivity/Adaptive Capacity	Indicators (units)	Methods
Biophysical Indicators: District level – for Ranking Districts		
Sensitivity	Percentage of sown area under rainfed agriculture (without irrigation facility)	Household survey
Adaptive capacity	Biological richness (Indian Institute of Remote Sensing (IIRS) data)	Ecological plot method
Sensitivity	Degraded land as percentage (wasteland)	Secondary data
Adaptive capacity	Livestock population density (adult cattle (percentage) units per sq. km)	Secondary sources/PRA
Adaptive capacity	Water spring density (number/sq. km)	PRA/Field study
Sensitivity	Area owned by marginal farmers (percentage)	Secondary data/PRA
Adaptive capacity	Cropping intensity (percentage)	Household survey
Adaptive capacity	Area under perennial fruit crops (percentage of total crop area)	Household survey/PRA
Adaptive capacity	Percentage area under forests (in hectares)	Secondary data/PRA



Sensitivity/Adaptive Capacity	Indicators (units)	Methods
Adaptive capacity	NPK fertiliser consumption (in tonnes)	Secondary sources
Socio-economic and Institutional Indicators: District Level		
Sensitivity	Human population density (number of people per sq. km)	Secondary source
Sensitivity	SC/ST population (percentage)	Secondary source/PRA
Adaptive capacity	Literacy (percentage)	Secondary source/PRA
Sensitivity	Rural population density	Secondary source
Adaptive capacity	Electrification (percentage of villages electrified in a district)	Secondary source/household survey
Adaptive capacity	Percentage of villages having banking or cooperative credit institutions in a district	Secondary sources/survey of banks
Sensitivity	Percentage of kaccha households in rural areas	Secondary sources
Adaptive capacity	Number of households engaged in MGN-REGS	Secondary sources/PRA
Socio-economic and Institutional Indicators: Village Level		
Adaptive capacity	Percentage annual household income from Broom grass plantation (percentage)	Household survey/PRA Household survey Household survey
Sensitivity	Percentage of kaccha houses	Household survey
Sensitivity	Per cent of households with agriculture as primary occupation	Household survey
Adaptive capacity	Per cent of households with other occupation sources (non-agriculture)	Household survey
Sensitivity	Number of adults (men + women) involved in agriculture or other allied activities	
Adaptive capacity	Distance from the market place	PRA/mapping
Adaptive capacity	Literacy rate	Secondary sources/ household survey
Adaptive capacity	Presence of village level institutions such as banks, credit societies, JFM societies, etc.	PRA
Sensitivity	Households below poverty line (percentage)	Secondary sources
Adaptive capacity	Villages with pucca (motorised) road	Secondary source/PRA
Adaptive capacity	Distance from the nearest health centre (in km)	PRA
Adaptive capacity	Percentage of households in a village with access to safe drinking water	PRA/household survey

2.10.4 Methods and Sources of Data for Indicators

Vulnerability assessment normally requires diverse category of indicators namely, biological, physical, social, economic and institutional. The method to be adopted to obtain an indicator data depends on the category of indicator and the tier selected – based on the objectives and resource availability. In this section, a description of the broad methods is provided along with the examples of methods to be adopted for an illustrative set of indicators. Generic methods are briefly explained below. Appropriate methods need to be selected for each indicator and some indicator assessments may require the use of one or multiple methods. For example, decline in groundwater could be measured as well as obtained through household survey or PRA. Many of the methods are standard textbook methods in ecology, agriculture science, economics, and social sciences, and thus not explained in detail.

1. Collection of Secondary Data: This is one of the most commonly deployed method in vulnerability analysis. This method is usually recommended for Tier 1 vulnerability assessment. This method is normally adopted under the following conditions:

- Top-down method where vulnerability assessment is done at macro-scale such as national, state and district levels
- Data availability is at macro-scale
- Limited time, technical and institutional resources. This method is usually for rapid assessment of vulnerability.
- Normally useful for ranking of the units (such as states and districts), with respect to vulnerability scale (highly vulnerable to least vulnerable)
- The main sources of data are as follows (refer to Annexure 3 for details):
 - Census data at state and district levels
 - Statistical abstracts
 - Government department websites
 - GIS maps from publicly accessible websites

2. Participatory Rural Appraisal: This method is adopted normally at a panchayat or village

level to obtain data or information regarding indicators. This method could involve the following:

- Discussions with panchayat and village leaders
- Discussions with government officers or NGOs or farmer groups or women or expert groups
- Key informants or knowledgeable elders
- Normally this method is adopted when secondary data may not be readily available and indicator values are required at an aggregated level such as a village, panchayat or a block
- Firstly, this involves collection of information from a group of individuals belonging to a stakeholder group. Secondly, explaining the objective and context of the study. Thirdly, asking questions on the qualitative or quantitative aspects of the indicator. Fourthly, recording the data based on the responses of the stakeholders – both qualitative and quantitative.
- Normally social scientists or NGOs or social workers who are familiar with the local language and the context of the region and study are expected to conduct PRAs.

3. Household Survey: This method is adopted for collecting data and information from a farmer, individual family or household level. This method involves the following steps:

- Identifying a set of indicators and data relevant to the indicators
- Preparing a structured format or questionnaire and pre-testing in a few households
- Sampling of the households, based on stratification of the households of a village or a location; such as based on landholding (small, medium and large farmers, and landless)
- Interview of the household (head of the family or a member of the family)



- Recording the data, data compilation using excel and data analysis
- Household survey is done normally by NGOs or trained volunteers or researchers

4. Field Measurements: This method is adopted for Tier 2 and Tier 3 approaches. This method could be adopted under the following conditions:

- Quantitative estimates of biological or physical indicators such as estimating tree density and diversity, tree biomass, crop yields, water runoff, soil erosion, soil organic carbon, depth of water in a borewell, etc.
- Select the indicator and identify the field method, procure tools or instruments
- Select sample locations for measurements such as borewells, forest area, crop fields, etc.
- Conduct measurements of depth of water or density of trees or soil sample for estimating soil organic carbon
- Refer to standard textbooks of agronomy, soil science, ecology, water resources, etc., for detailed methods
- Adoption of measurement technique requires technical skills relevant to the indicator and access to instruments or even laboratory, for example, soil organic carbon estimation
- Adequate time and resource availability

5. Expert Judgement: In cases where data is not available in the required scale or quality, or if time is a limiting factor, local experts may be consulted to quantify certain indicators. Consultation could include questions like, has there been a reduction in production of rice due to delayed rainfall or high intensity rainfall? Has the biodiversity declined? Has the groundwater level declined? Expert judgement should be used only as a last resort to obtain the data for the indicators since experts may provide biased information or may lack knowledge of the field situation.

6. Modelling: Modelling or equations can be used to determine the value of indicators when direct estimations are not possible. For example, estimation of the tree biomass stock, soil erosion, water runoff, or soil organic carbon content. Here, often, simple equations (for example, universal soil equation for estimating soil erosion) or simple regression models (biomass estimation using diameter and height data) are adopted. This method is largely adopted for Tier 2 or Tier 3 approaches.

Example of methods: In this section, methods for quantification and estimation of a select set of indicators belonging to different categories – biological, physical, social and economic – are provided for the sake of illustration.

Physical Indicator: Groundwater Level

Description	Groundwater level in the village
Significance of indicator	Groundwater levels are generally declining, contributing to increased vulnerability in rural areas. Availability of groundwater is a critical indicator for adaptive capacity.
Unit	Water level from the ground surface (feet or meters)
Method and source of data	<ol style="list-style-type: none"> Secondary data: Past and present records from the Central Groundwater Board (CGWB) should be collected, if available. They maintain observation wells and have secondary data to analyse changes, if any. Household survey: Using the questionnaire method the following data can be collected. <ol style="list-style-type: none"> The approximate depth of wells/borewells at the time of drilling Current depth The number of abandoned borewells that have recently been recharged due to increase in groundwater levels Field measurements: <ol style="list-style-type: none"> Current groundwater levels can be estimated using simple devices such as a multimeter attached to a wire.
Instrumentation or materials	Survey questionnaire and chalked steel tape, multimeter and wire
When to measure	- Annually, but pre- and post-monsoon measurements are ideal to assess the changes in groundwater levels
Number or samples	<ul style="list-style-type: none"> Household survey: All households owning private wells/borewells. If the number of households is more than 30, then randomly select 10 households, if the number of households is less than 10, then select all. Field measurements: All the wells/borewells in the village <ul style="list-style-type: none"> All wells and borewells within the village If the number of wells/borewells is large (more than 50), conduct a random sample survey of 25 per cent of households having well/borewells
Measurement steps or procedure	<p>Household survey:</p> <ol style="list-style-type: none"> Collect information on depth of borewells at the time of drilling, current depth, the number of abandoned borewells that have been recharged in the region Questionnaires can be used to determine if there has been any change in water yield from borewells over time. Data on change in area irrigated over the years can also be calculated. <p>Field measurements:</p> <ol style="list-style-type: none"> The conductivity method comprises a pair of wires coupled to a multimeter on one end and at the suspended end the insulation is shaven off to expose the metal core of the wires. A weight is attached at the suspended end to avoid any unwanted wind ups. The bolts holding the borewell cap are loosened to incorporate the wires into the borewell shaft. The set up is gradually lowered into the borewell shaft until the uninsulated end of the suspended wires touches the water surface. This completes the circuit and thus a deflection is seen in the multimeter. The depth of groundwater with reference to the ground level is the difference between the length of the wire immersed keeping the borewell cap as reference and the length of the shaft above ground level. <p>Note: If the well cap is not vented, wait for 15-30 minutes before measurement to allow water levels to equilibrate to atmospheric pressure. Also, if the well is in use, measurements are taken before pumping or 4 to 5 hours after pumping, to ensure water levels are static.</p>



Description	Groundwater level in the village
Data recording formats	Conductivity Method
	Location of well/borewell (GPS)
	Total length of wire lowered Feet or meters
	Length of the shaft above ground level Feet or meters
Calculation of steps or procedure	Groundwater depth = Total length of wire lowered – Length of the shaft above ground level (feet or meters)
Limitations	<ol style="list-style-type: none"> 1. Condensed water on the inner periphery of the borewell shaft might set off a false deflection in the multimeter. 2. There are chances of the suspended wire getting stuck in the shaft, which might be non-recoverable and resulting in the loss of wire. 3. Presence of some objects in the borewell shaft might result in accidental disfiguring of the wires which in turn results in an erroneous reading.

Biological Indicator: Crop Diversity and Crop Yield

Definition/Description	Assessment of the crops cultivated and the crop yields per unit area during the main season or different growing seasons in a year
Significance of indicator	Crop diversification is an indicator of adaptive capacity. Shifting from monocropping to diversified multi-crop cultivation decreases the risk of crop failure, increases food security, improves land-soil quality and thereby reduces vulnerability. Similarly, increase in crop yields increases annual incomes of households, thereby directly improving their standard of living and contributes to adaptive capacity of the farmer.
Unit	<ol style="list-style-type: none"> 1. Crop diversity – Number of different crops planted in a single cropping season 2. Crop yields – in kg, tonnes or in local units
Method and source of data	<p>Field observation: Reconnaissance survey of area cultivated to verify changes in crop diversification during the cropping season.</p> <p>Household survey: Questions covering landholding, crops cultivated, irrigation practices, seasonality, crop yields and percentage increase in the household’s annual income due to changes in crop yields, if any.</p>
When to measure	Field observations during the cropping season and household surveys at the end of the cropping season
Sample selection	Households can be stratified based on landholding and select a sample
Location of sampling	Settlements and croplands
Number or samples	<p>Field observation: Complete enumeration or sampling</p> <p>Household survey:</p> <ol style="list-style-type: none"> 1. If the number of households is less than 30, then select all the households for survey. 2. If the total number of households is large, then select at least 30 households per strata (such as small farmers and large farmers)
Measurement steps or procedure	<p>Field observation: Reconnaissance survey and demarcation of croplands and cropping pattern – all seasons or main cropping season</p> <p>Household survey:</p> <ol style="list-style-type: none"> 1. Collect the demographic and household data of the most recent year 2. Identify households for sampling 3. Conduct the questionnaire survey in the selected households involving the men and women of the family

Economic Indicator: Diversity of Sources of Income

Description	Number of income sources – Diversification of income sources
Significance of indicator	Higher diversification of sources of income or livelihoods contributes to reduction in vulnerability. Even if one source, for example, crops fail, income from an alternate source such as livestock or sheep or trees can compensate for the loss.
Unit	Number of sources and percentage contribution of different sources
Method and source of data	Household survey: Questions covering the main and subsidiary occupations, number of days employed in different occupations, and the proportion of income from the different sources.
When to measure	Household surveys at the end of the cropping season
Sample selection	Households can be stratified based on landholding
Sampling location	Settlements
Number or samples	Household survey: 1. If the number of households is less than 30, then select all the households for survey. 2. If the total number of households is large, then select at least 30 households per strata (such as small farmers and large farmers)
Measurement steps or procedure	Household survey: 1. Collect the demographic and household data of the most recent year 2. Identify households for sampling 3. Conduct the questionnaire survey in the selected households involving the men and women of the family 4. Ask relevant questions with respect to main and subsidiary occupation, number of days employed in different occupations, and proportion of income from the different sources.



Institutional Indicator: Access to Market

Description	Assessing people's accessibility to markets and processing infrastructure
Significance of indicator	<p>Access of households to markets for fruits and vegetables, storage facilities and transportation reduces the vulnerability of the farmers.</p> <ul style="list-style-type: none"> • Markets are of fundamental importance in the livelihood strategy of most rural households, rich and poor alike. Improved accessibility to markets enhances adaptive capacity. • Low population density in rural areas, remote locations and minimal transportation are physical barriers that increase the vulnerability
Unit	<ul style="list-style-type: none"> - Distance to markets – in km or miles - Time taken to reach markets and other processing infrastructure – in hours
Method	Household survey: Questions related to distance to nearest markets, mode of transportation, frequency of visits, usage of markets, changes in accessibility to markets and other infrastructure
When to measure	Preferably post-harvest season or summer season
Sample selection	Households can be stratified based on their location in a village
Number or samples	Household survey: <ol style="list-style-type: none"> 1. If the number of households is less than 30, then select all the households for survey. 2. If the total number of households is large, then select at least 30 households per strata (such as small farmers and large farmers)
Measurement steps or procedure	Household survey: <ol style="list-style-type: none"> 1. Collect demographic and household data of the most recent year 2. Identify the households and conduct the questionnaire interview in the selected households involving the men and women of the family 3. Roads, distance and infrastructure can be observed for verification.

2.11 Normalisation of Indicators – Step 7

2.11.1 Why Normalisation?

Indicators selected for a vulnerability assessment have different units of measurement. For example, the area is measured in hectares, population in numbers and crop yield in kg or tonnes. These indicators with different units cannot be added or aggregated without normalisation. The normalisation procedure enables aggregation of indicators with different units, by removing the units and converting all the values into dimensionless units. The normalised values of indicators lie between 0 and 1 and thus could be aggregated.

Case study of Vulnerability Ranking of Six Blocks of Chikkaballapur district in Karnataka

Objective: The case study aims at assessing the vulnerability of different blocks of Chikkaballapur district and ranking of the blocks based on the vulnerability index.

Scale: Block level vulnerability assessment in Chikkaballapur district.

Indicators: (i) Cultivated area per household (ha), (ii) Percentage area irrigated, (iii) Percentage of marginal farmers, (iv) Percentage of agricultural labourers in total work force. All indicators are at block level

Source of data for indicators: Census (2011) and Agricultural Census.

Demonstration of vulnerability estimation steps and methods: In the following sections, methods of normalisation of indicators, utilisation of equal and unequal weights, aggregation of the normalised values, estimation of the Vulnerability Index at block level and ranking of the blocks based on vulnerability index is demonstrated.

2.11.2 Method for Normalisation

Before normalising the indicators, it is important to identify the functional relationship between the indicators and vulnerability. Two types of functional relationship are possible:

1. Positive relationship; vulnerability increases with increase in the value of the indicator
2. Negative relationship; vulnerability increases with decrease in the value of the indicator

The functional relationship of the indicators considered for Chikkaballapur case study with vulnerability is presented in Table 2.16.

Normalisation Method for Indicators with Positive Relationship with Vulnerability

In positive relationship cases, higher the value of the indicator, higher will be the vulnerability. For example, suppose we have collected information on the average distance to nearest health centre or average time taken to reach the nearest drinking water source. As the values of these indicators increase, greater will be the vulnerability of the community. In this case, we say that the variables have direct and positive functional relationship with vulnerability and the normalisation is done using the formula:

$$x_{ij}^p = \frac{X_{ij} - \text{Min } i \{X_{ij}\}}{(\text{Max } i \{X_{ij}\} - \text{Min } i \{X_{ij}\})}$$

In the above formula, X_{ij} is the variable that is being normalised i.e. in this case X_{ij} is the value of j^{th} indicator for i^{th} region and x_{ij}^p is the normalised value. Normalised value of x_{ij}^p scores will lie between 0 and 1. The value 1 will correspond to that household with maximum value and 0 will correspond to the household with minimum value. Table 2.17 presents data for the indicators selected for block level assessment of vulnerability of Chikkaballapur district.

Table 2.16: Case study example of functional relationship of indicators with vulnerability

Indicator	Functional Relationship
Cultivated area per household (ha)	Negative
Percentage area irrigated	Negative
Percentage of marginal farmers	Positive
Percentage of agricultural labourers in total work force	Positive



Table 2.17: Indicator values at the block level for demonstrating normalisation (adapted from Esteves et al., 2016)

Block	Cultivated area per household (ha)	Percentage area irrigated	Percentage of marginal farmers	Percentage of agricultural labourers in total work force
Bagepalli	1.15	13.31	60.06	48.68
Chikkaballapur	0.83	17.31	73.05	45.14
Chintamani	1.12	16.45	64.16	41.19
Gauribidanur	0.99	14.68	68.61	56.97
Gudibanda	0.88	16.04	70.22	52.68
Sidlaghatta	1.26	16.35	58.82	40.28

Here, increased percentage of marginal farmers will increase the vulnerability of a village. Percentage of marginal farmers is maximum in Chikkaballapur block (73.05% are marginal farmers) and minimum in Sidlaghatta (58.82% are marginal farmers). Hence the normalisation of this indicator for Bagepalli block is calculated using the formula:

$$x_{ij}^p = \frac{X_{ij} - 58.82}{73.05 - 58.82} = \frac{X_{ij} - 58.82}{14.23} = \frac{60.06 - 58.82}{14.23} = 0.09 \text{ (Table 2.18)}$$

Normalisation method for indicators with negative relationship with vulnerability

For indicators where the vulnerability increases with decrease in the value of the indicator the following normalisation method is to be adopted. For example, for percentage area irrigated indicator, a higher value of the variable implies higher resilience of cropping systems to rainfall variability leading to reduced

vulnerability. Thus, this indicator has a negative or inverse functional relationship with vulnerability. In this case, the normalised score of the indicator ‘percentage area irrigated’ for Chintamani block is computed using the formula:

$$x_{ij}^n = \frac{Max\ i\{X_{ij}\} - X_{ij}}{Max\ i\{X_{ij}\} - Min\{X_{ij}\}} = \frac{17.31 - X_{ij}}{17.31 - 13.13} = \frac{17.31 - 16.45}{17.31 - 13.13} = 0.22 \text{ (Table 2.18)}$$

In the above formula, X_{ij} is the variable that is being normalised i.e. in this case X_{ij} is the value of j^{th} indicator for i^{th} region and x_{ij}^n is the normalised value. Normalised value of x_{ij}^n scores will lie between 0 and 1. The value 1 will correspond to that block with maximum value and 0 will correspond to the block with minimum value.

The normalised scores for the dataset using the functional relationship formulae are as given in Table 2.18.

Table 2.18: Case study example of normalised scores of indicators (Esteves et al., 2016)

Block	Cultivated area per household (ha)	Percentage area irrigated	Percentage of marginal farmers	Percentage of agricultural labourers in total work force
Bagepalli	0.26	1.00	0.09	0.09
Chikkaballapur	1.00	0.00	1.00	0.29
Chintamani	0.33	0.22	0.38	0.05
Gauribidanur	0.63	0.66	0.69	1.00
Gudibanda	0.88	0.32	0.80	0.74
Sidlaghatta	0.00	0.24	0.00	0.00

2.12 Assigning Weights to Indicators – Step 8

2.12.1. Why Weights?

Vulnerability is a function of sensitivity and adaptive capacity components. Each of these components will have many indicators and vulnerability value will be an aggregate value of these normalised indicator values. Different indicators have different levels of impact on vulnerability. For example, percentage area irrigated may have a higher impact on agriculture vulnerability than say, land area per household. Thus, there is a need to provide weights to the indicators to reflect the comparative importance or contribution of each indicator to the total vulnerability of the system or communities.

All the indicators quantified may or may not be given equal weight according to the type of the assessment done. Weights indicate as to which indicators get higher importance. Equal weights are given when the indicators are of equal importance.

After computing the normalised scores, vulnerability indices are constructed by giving either equal weights or differing weights to the indicators/components.

2.12.2. Tier Methodology for Assigning Weights

The tier and the methodology for assigning weights to the indicators is determined by the objective of the vulnerability assessment (Table 2.19).

It can be observed that Tier 1 method involves providing equal weights to the indicators or weight allocation by secondary stakeholders such as district administrators, experts and NGOs. However, for adaptation planning, involving Tier 2 methods, would require weight allocation for the indicators by the primary stakeholders such as mountain communities, farmers, fishermen, etc.

2.12.3. Equal Weights

Often, equal weights are given if there are a large number of indicators or if there are difficulties in obtaining weights for the different indicators from stakeholders. The method for equal weighing techniques is described below.

Simple average of the scores

When equal weights are assigned, Vulnerability Index is constructed by taking a simple average of all the normalised scores. The formula is:

Table 2.19: Goal-oriented weighting procedure along with tiers

Goal/Objective	Tier methods for vulnerability assessment	Weighting procedure for indicators
1. Identification of the most vulnerable regions, sectors and communities - to raise awareness about vulnerability and prioritization for adaptation interventions	Tier 1 methods, largely top-down	(i) Equal weights (ii) Weight allocation by secondary stakeholders - District administrators, researchers, NGOs
2. Assist in adaptation planning – based on information on vulnerability profiles and drivers/sources of vulnerability	Tier 2 methods, largely bottom-up but incorporating top-down methods as well	Weight allocation by primary stakeholders - Village communities/ farmers/mountain communities to provide weights to indicators
3. Spatial adaptation planning – including temporal adaptation planning for current and future climate scenarios	Tier 3 methods; largely bottom-up and spatial methods	Weight allocation by primary stakeholders - Village communities/ farmers/mountain communities to provide weights to indicators



$$VI = \frac{\sum_j x_{ij}^p + \sum_j x_{ij}^n}{K}$$

Where, VI_i is the vulnerability index of region i , x_{ij}^p and x_{ij}^n are normalised values of j^{th} indicators [with positive and negative relationship with vulnerability respectively] in i^{th} region and K is the number of indicators.

Table 2.20 provides an example of estimating vulnerability index and ranking of blocks based on equal weights. Vulnerability index values are used to rank different regions/sectors/communities/systems. A region with highest index value is said to be most vulnerable and it is given the Rank 1, the region with next highest index value is assigned Rank 2 and so on. It can be observed that Gauribidanur with an aggregated Vulnerability Index of 0.74 is ranked as most vulnerable (Rank 1) and Sidlaghatta as least vulnerable with Vulnerability Index of 0.06 (Rank 6).

To elaborate further, the aggregated vulnerability index value of Bagepalli block for example was arrived at using the formula given above:

$$VI = \frac{\sum_j x_{ij}^p + \sum_j x_{ij}^n}{K} = \frac{(0.26 + 1.00 + 0.09 + 0.50)}{4} = \frac{1.85}{4} = 0.46 \text{ (Table 2.20)}$$

2.12.4. Unequal Weights

The method of simple averages gives equal importance for all the indicators which is not necessarily correct.

Hence many vulnerability experts prefer to give weights to the indicators, based on their contribution to vulnerability. There are several methods for assigning unequal weights to the indicators. In this section, only expert judgment and stakeholder consultation methods are briefly presented since these are simple practical methods which are widely used.

i. Expert judgment: In this method, the weights are assigned based on expert opinion. This method is subjective, and opinion based. The experts who are knowledgeable about the region and sector of vulnerability assessment should be consulted for obtaining weights. The expert consultation is taken as final. The steps for obtaining weights for the indicators through expert judgment will require the same steps given for 'stakeholder consultation'. The weights here will be provided by the experts.

ii. Stakeholder consultation: Stakeholders such as farmers, local community members or local knowledgeable individuals are more likely to be familiar with the region, sector and context. Based on their real-life observation and experience, the local stakeholders are likely to be knowledgeable about the relationship between the indicators and the vulnerability of the system or community. Thus, it is desirable to adopt the stakeholder consultation method for assigning weights. The following steps could be adopted for obtaining weights through stakeholder consultation.

Table 2.20: Case study example of aggregated vulnerability index and ranking of blocks based on equal weights (adapted from Esteves et al., 2016)

Blocks	Indicators								Aggregated Vulnerability Index (NV1+ NV2+ NV3+ NV4/4)	Vulnerability rank of the blocks
	Cultivated area per household (ha)		Percentage area irrigated		Percentage of marginal farmers		Percentage of agricultural labourers in total work force			
	AV	NV1	AV	NV2	AV	NV3	AV	NV4		
Bagepalli	1.15	0.26	13.31	1.00	60.06	0.09	48.68	0.50	0.46	4
Chikkaballapur	0.83	1.00	17.31	0.00	73.05	1.00	45.14	0.29	0.57	3
Chintamani	1.12	0.33	16.45	0.22	64.16	0.38	41.19	0.05	0.24	5
Gauribidanur	0.99	0.63	14.68	0.66	68.61	0.69	56.97	1.00	0.74	1
Gudibanda	0.88	0.88	16.04	0.32	70.22	0.80	52.68	0.74	0.69	2
Sidlaghatta	1.26	0.00	16.35	0.24	58.82	0.00	40.28	0.00	0.06	6

AV = Actual value of Indicator and NV is normalised value of indicator

Step 1: Select a group or a team of knowledgeable stakeholders (e.g., farmers, women, panchayat leaders, agriculture extension workers).

Step 2: Describe the objective of the vulnerability assessment and its context (e.g., to rank the villages for adaptation interventions).

Step 3: Describe the purpose of assigning weights (e.g., to identify the indicators which have higher or lower impact on the vulnerability, in a quantitative manner).

Step 4: Present the list of indicators to the stakeholders. It is always desirable to have fewer indicators so that the stakeholders can comprehend and compare and provide proportional weights.

Step 5: "Budget allocation method" – Select a unit of 100, taking the total value as 100, ask the stakeholders what proportion or weightage they would assign to indicator 1 in influencing vulnerability. Repeat the process for the second and subsequent indicators. Alternatively, ask the stakeholders

which among the indicators has the most impact on vulnerability and what proportion they would assign to that indicator out of 100. Next, ask the stakeholder to identify the second most important indicator and assign its proportion. Continue the same procedure for all the identified indicators.

Step 6: Ensure the weight or proportion assigned to all the indicators, add up to 100.

$$W_{\text{Total}} = W_1 + W_2 + W_3 + \dots + W_n = 100$$

Where $W_1, W_2, W_3, \dots, W_n$ are the individual weights assigned corresponding to the indicators 1, 2, 3, 4... to n.

In Table 2.21 and Table 2.22, the index values range from 0 to 1, unlike in the procedure described for procuring weight through stakeholder consultation, where the values were taken to be in the range of 0 to 100. This is mainly to enable better understanding of the weights especially for the local community stakeholders who are likely to be more familiar with percentages, adding up to 100.

Table 2.21: Aggregated vulnerability index and ranking of blocks based on weights provided by stakeholders unequal weights (adapted from Esteves et al., 2016)

Blocks	Indicators								Aggregated Vulnerability Index ($NV1*W1 + NV2*W2 + NV3*W3 + NV4*W4/4$)	Rank
	Cultivated area per household (ha)		Percentage area irrigated		Percentage of marginal farmers		Percentage of agricultural labourers in total work force			
	NV1	W1	NV2	W2	NV3	W3	NV4	W4		
Bagepalli	0.26	0.05	1.00	0.8	0.09	0.05	0.50	0.1	0.217	1
Chikkaballapur	1.00		0.00		1.00		0.29		0.032	6
Chintamani	0.33		0.22		0.38		0.05		0.053	4
Gauribidanur	0.63		0.66		0.69		1.00		0.173	2
Gudibanda	0.88		0.32		0.80		0.74		0.103	3
Sidlaghatta	0.00		0.24		0.00		0.00		0.048	5

NV = normalised value and W = weight



Table 2.21 presents an example of estimating Vulnerability Index and ranking of blocks based on weights provided by the stakeholders in the study area. Based on the weights provided by the stakeholders, the most vulnerable and least vulnerable blocks are Bagepalli and Chikkaballapur respectively, instead of Gauribidanur (most vulnerable) and Sidlaghatta (least vulnerable) as given in Table 2.20 (based on equal weights). As observed, the ranking of the blocks has drastically changed by providing unequal weights obtained from stakeholders.

The aggregated vulnerability index value of Bagepalli block was arrived at by using the following formulae:

$$VI = \frac{\sum_j (x_{ij} \times w_j)}{K} = \frac{((0.26 \times 0.05) + (1.00 \times 0.80) + (0.09 \times 0.05) + (0.5 \times 0.10))}{4} = \frac{0.867}{4} = 0.217$$

Where, VI_i is the vulnerability index of region i , in this case Bagepalli Block, x_{ij} are normalised values of j^{th} indicators in i^{th} region, w_j are the weights assigned to j^{th} indicators and K is the number of indicators.

2.13 Aggregation of Indicators and Development of Vulnerability Index – Step 9

Aggregation of different indicators with appropriate weights is necessary to obtain a composite aggregated

index or value. The weights are multiplied with the normalised indicator value and aggregated. The indicators values can be calculated for each sector or for the whole system. Normalised and weighted values of indicators can be aggregated to obtain the Vulnerability Index or the ranking of the systems.

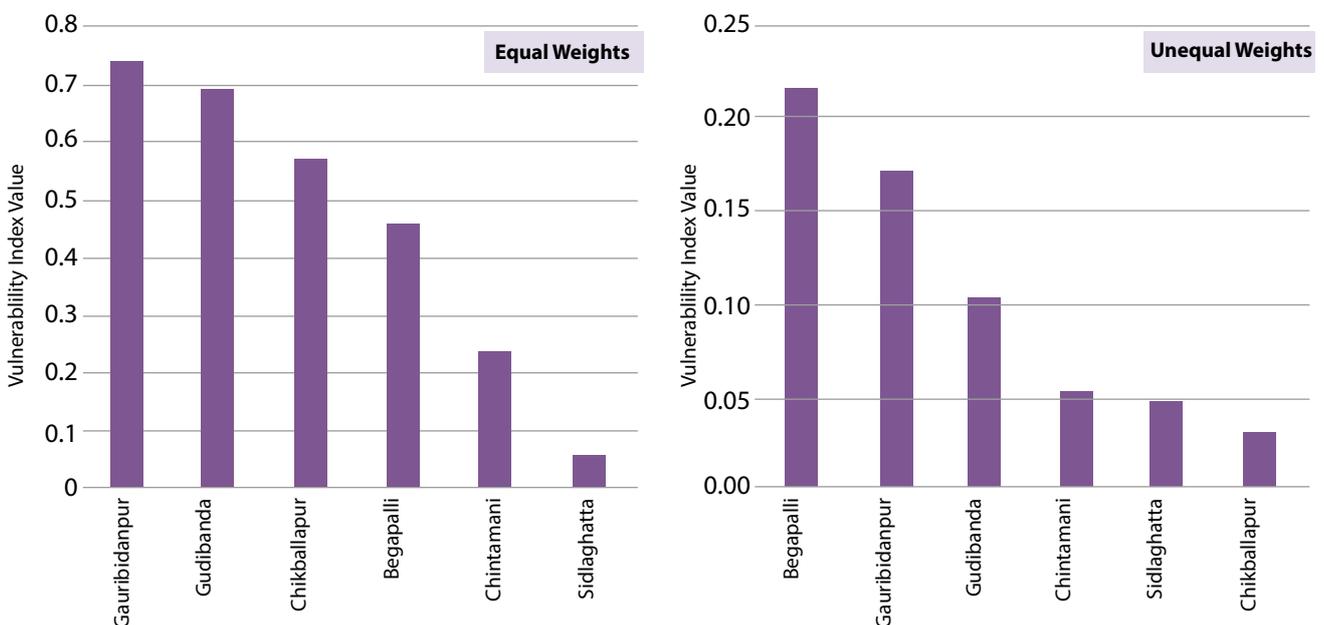
Steps for aggregating indicator values to obtain ‘Vulnerability Index’

Step 1: Estimate the normalised value of the selected indicators as described in Section 2.11, Table 2.20 and Table 2.21.

Step 2: Multiply the normalised indicator value with the weight allocated for the indicator to obtain Vulnerability Index value of the selected indicator (Table 2.20 and Table 2.21).

Step 3: Aggregate the normalised weighted indicator values for a selected block or region to obtain the overall Vulnerability Index value for that block or district or region.

Figure 2.3: Aggregated vulnerability index values of blocks of Chikkaballapur district of Karnataka (Based on equal weights – Table 2.20 and unequal weights – Table 2.21, given by stakeholders)



2.14 Representation of Vulnerability; Spatial Maps, Charts, and Tables of Vulnerability Profile and Index – Step 10

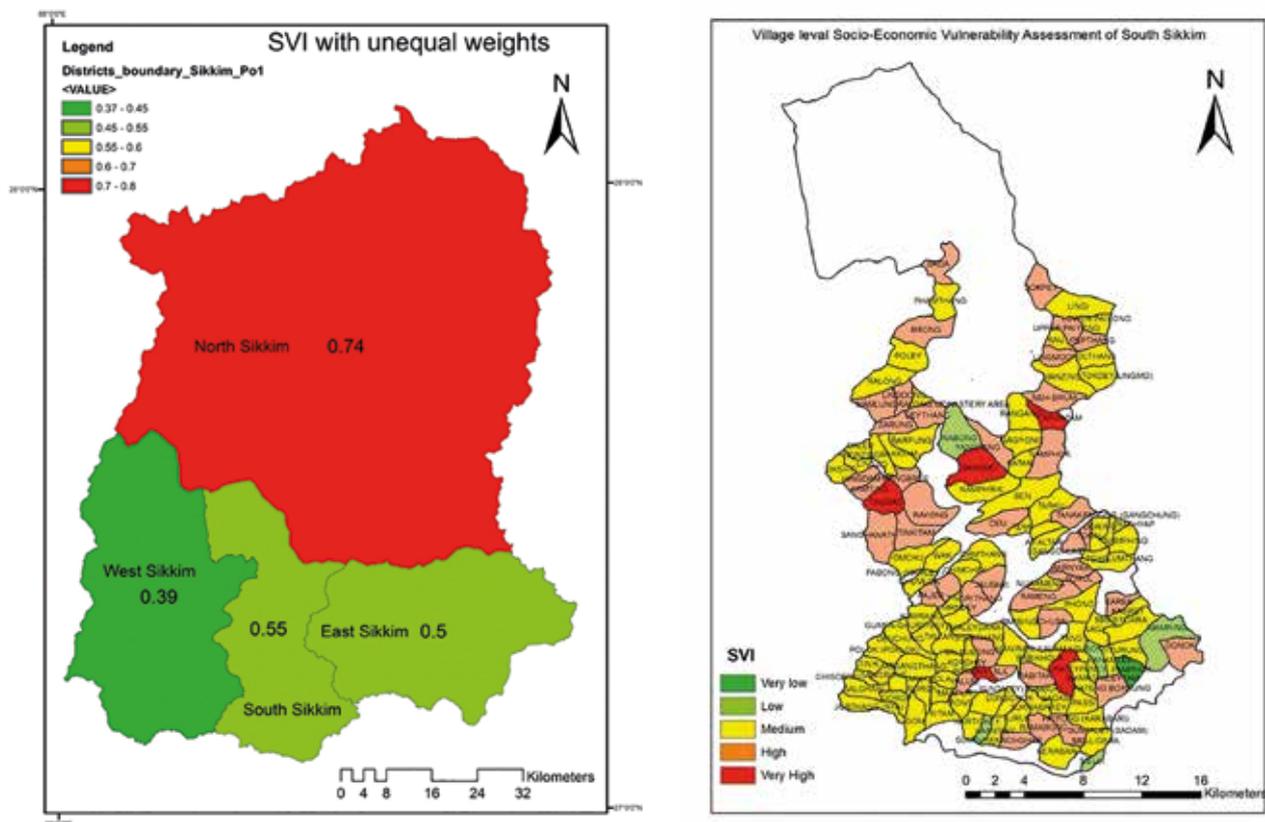
Vulnerability index is normally developed to assist the policy makers, development administrators, NGOs and banks in prioritizing the districts, blocks, watersheds, sectors or cropping systems. Such agencies would be interested in three outputs – (i) A comparative index value of different districts or cropping systems or communities, (ii) The spatial distribution of the high or low vulnerability units, and (iii) To identify the drivers of vulnerability, so that adaptation investments can be focused on dominant drivers. It is always preferable to present vulnerability profiles or indices as spatial maps with a gradient of colours indicating the level of

vulnerability. This requires the physical magnitudes of index values to be converted into colourful illustrations of maps and graphs.

Spatial maps of ranking of classes of vulnerability (very high to very low)

Result of vulnerability assessment can be classified on a scale of very high to very low vulnerability and represented spatially through profile maps. Figure 2.4 presents vulnerability at two scales – district (Left Panel) and village (Right Panel). The results indicate the vulnerability ranking of districts, on the basis of vulnerability index in Sikkim, as most vulnerable (districts in red) to least vulnerable (districts in dark green). On the Right Panel of Figure 2.4, vulnerability ranking of villages in South Sikkim district is presented on a scale of very high (most vulnerable - Red) to very low (least vulnerable–dark Green).

Figure 2.4: Socio-economic vulnerability profile of districts in Sikkim state (left panel) and villages of South Sikkim district (right panel)





- Maps may be created using computer programmes such as geographic information systems (GIS) – specialist software for managing, analysing, and presenting geographical data.
- Simple hand-drawn maps are another alternative.
- Maps are particularly useful for presenting geographical comparisons, such as variation of

vulnerabilities across regions.

Vulnerability index values of different villages/blocks/districts could also be presented in the form of bar charts, where each bar provides the number of villages/blocks/districts under different vulnerability ranks. Figure 2.5 shows the distribution of villages under different vulnerability classes such as low to very high in the six blocks of Chikkaballapur district of Karnataka. It can be observed that most of the villages belong to high vulnerability rank in all the blocks and in four of the six blocks, there are no villages belonging to low and very high vulnerability rank classes.

2.15 Vulnerability Ranking of Sectors, Regions, Communities, Cropping Systems, River Basins, Watersheds, Forest Types, etc. – Step 11

Vulnerability ranking, or comparative vulnerability index values could be presented in a tabular form. This is particularly applicable for ranking of villages and households where spatial vulnerability profile representation is not feasible. For example, a village level and households level assessment as part of a multi-scale vulnerability approach for adaptation planning for the state of Karnataka, assessed current climate vulnerability of 1,220 villages in Chikkaballapur district, and all the households from two villages (Gundlapalli and Saddapalli) from Bagepalli taluk.

Distribution of villages in the six blocks of Chikkaballapur district across different vulnerability classes is presented in Table 2.22. None of the villages were ranked 1 (very low vulnerability) and majority of the villages were ranked under high vulnerability class.

Figure 2.5: Distribution of villages according to socio-economic vulnerability ranks in six blocks of Chikkaballapur district in Karnataka represented as a bar chart (Esteves et al., 2016)

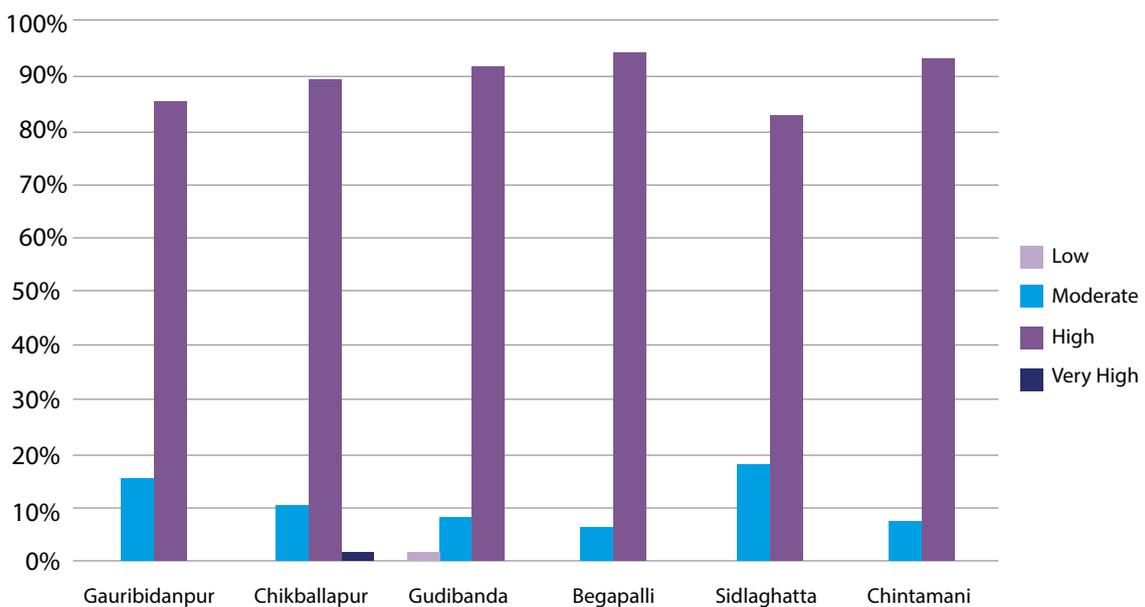
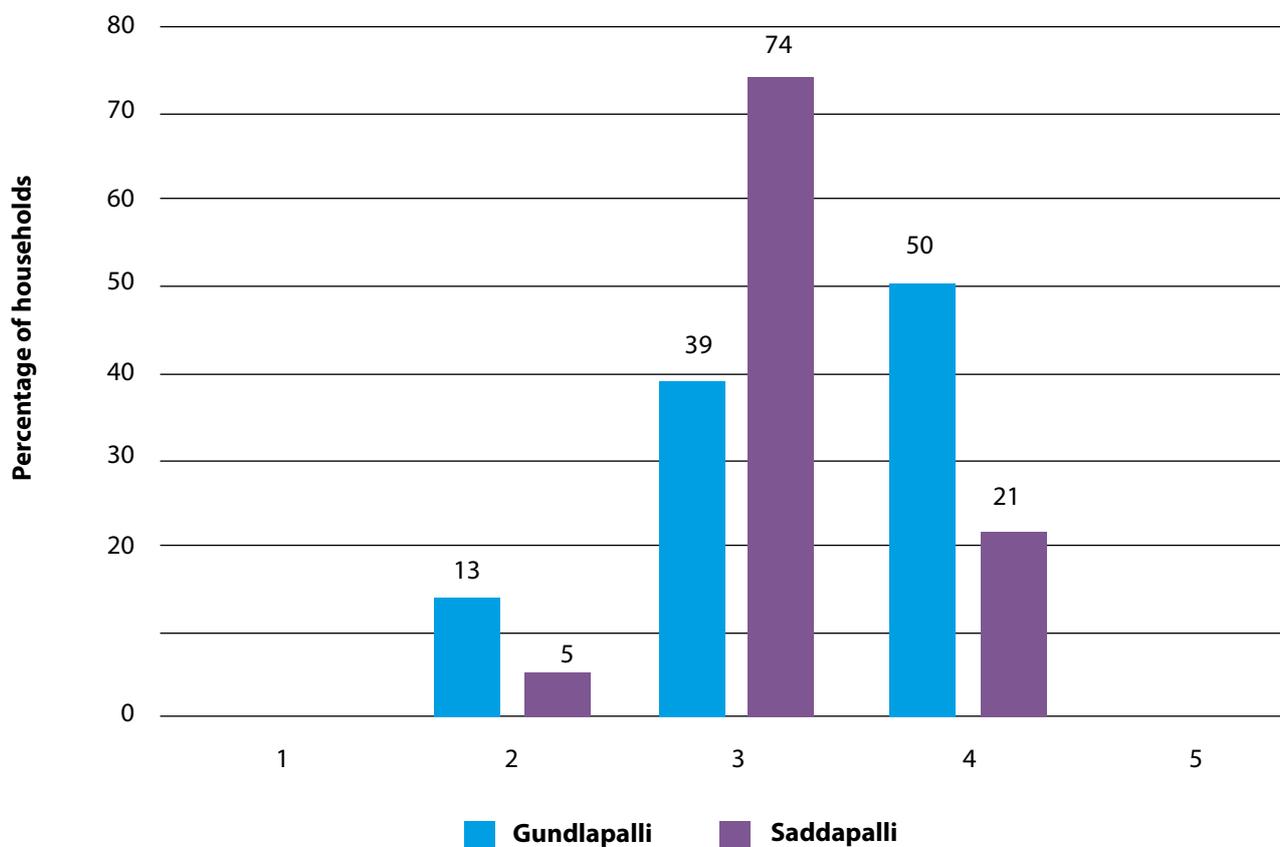


Table 2.22: Case study example - Number and percentage of villages from different blocks of Chikkaballapur district ranked on the socio-economic vulnerability index scale

Blocks	Socio-economic vulnerability index scale								Total	
	2 (Low)		3 (Moderate)		4 (High)		5 (Very High)		Number	Percentage
Gauribidanur	0	0%	20	15%	112	85%	0	0%	132	100
Chikkaballapur	0	0%	23	10%	197	89%	2	1%	222	100
Gudibanda	1	1%	7	8%	77	91%	0	0%	85	100
Bagepalli	0	0%	12	6%	200	94%	0	0%	212	100
Sidlaghatta	0	0%	43	18%	199	82%	0	0%	242	100
Chintamani	0	0%	23	7%	304	93%	0	0%	327	100
Overall	1	1%	128	10.5%	1089	89.3%	2	0.16%	1220	100

Source: (Esteves et al., 2016). No village showed very low vulnerability

Figure 2.6: Socio-economic vulnerability profiles of households in the study villages (Esteves et al., 2016). The households show low (2) to high (4) vulnerability





Based on this assessment, the block with the highest percentage of villages showing high vulnerability, i.e., Bagepalli (94%) was selected to conduct a household level vulnerability assessment. A census survey of two neighbouring villages was conducted and the result of that vulnerability assessment at household level as a graphical representation in Figure 2.6. The bar graph (Figure 2.6) presents the percentage of households from both the study villages ranked on a vulnerability scale of 1 (very low) to 5 (very high).

The households were also classified based on their landholding size and then ranked on the same

vulnerability scale. The results are presented in Table 2.23.

Further, Sharma et al. (2013) have assessed the current vulnerability of forests at local scale and presented the results of assessment in terms of vulnerability index (VI) and the contribution of different indicators to the VI (Table 2.24).

Thus, vulnerability profiles or index values can be presented in different formats keeping in mind the target audience and the end use.

Table 2.23: Number of households ranked on the socio-economic vulnerability index scale according to their landholdings (Esteves et al., 2016)

Vulnerability rank	Village	Landholding			
		Landless	Marginal	Small	Large
Rank 2 (Low)	Gundlapalli	0	3	4	0
	Saddapalli	0	1	1	1
Rank 3 (Moderate)	Gundlapalli	3	13	9	1
	Saddapalli	0	35	10	4
Rank 4 (High)	Gundlapalli	0	6	15	2
	Saddapalli	0	12	2	0

Table 2.24: Indicators and drivers of forest vulnerability in Aduvalli forest range, Karnataka (Sharma et al., 2013)

Indicator	Indicator parameter measured	Indicator weight	Measured value of indicator	Indicator contribution to VI
Invasive species	Area-proportion of forest floor covered by invasive species	0.469	0.278	0.130 (52.7%)
Forest dependence of community	Forest dependence Index	0.188	0.491	0.092 (37.2%)
Reduction in forest area	Area-proportion of forest lost from the originally notified	0.213	0.086	0.081 (7.4%)
Monoculture plantations	Area-proportion under monoculture plantations	0.085	0.067	0.006 (2.3%)
Occurrence of fire	Area-proportion impacted by fire annually	0.045	0.021	0.001 (0.4%)
	Sum of weights	1.0	VI value	0.248

2.16 Identification of Drivers of Vulnerability for Adaptation Planning – Step 12

2.16.1 Why Identify Drivers?

Vulnerability assessments are often designed to support and improve adaptation planning, with the overall objective of reducing vulnerability in the region or sector under consideration. A vulnerability assessment can also help to substantiate decision-making when it comes to selecting adaptation measures, based on the assessment of drivers of vulnerability with their index value. Thus, vulnerability assessments can be designed to assess the drivers of vulnerability for developing targeted adaptation planning to reduce vulnerability.

2.16.2 Identification of Drivers of Vulnerability

It is important to identify the drivers of vulnerability to prioritise adaptation strategies. Essentially, this means to identify the contribution of each indicator to vulnerability.

Example 1 – Drivers for Socio-economic Vulnerability of Households

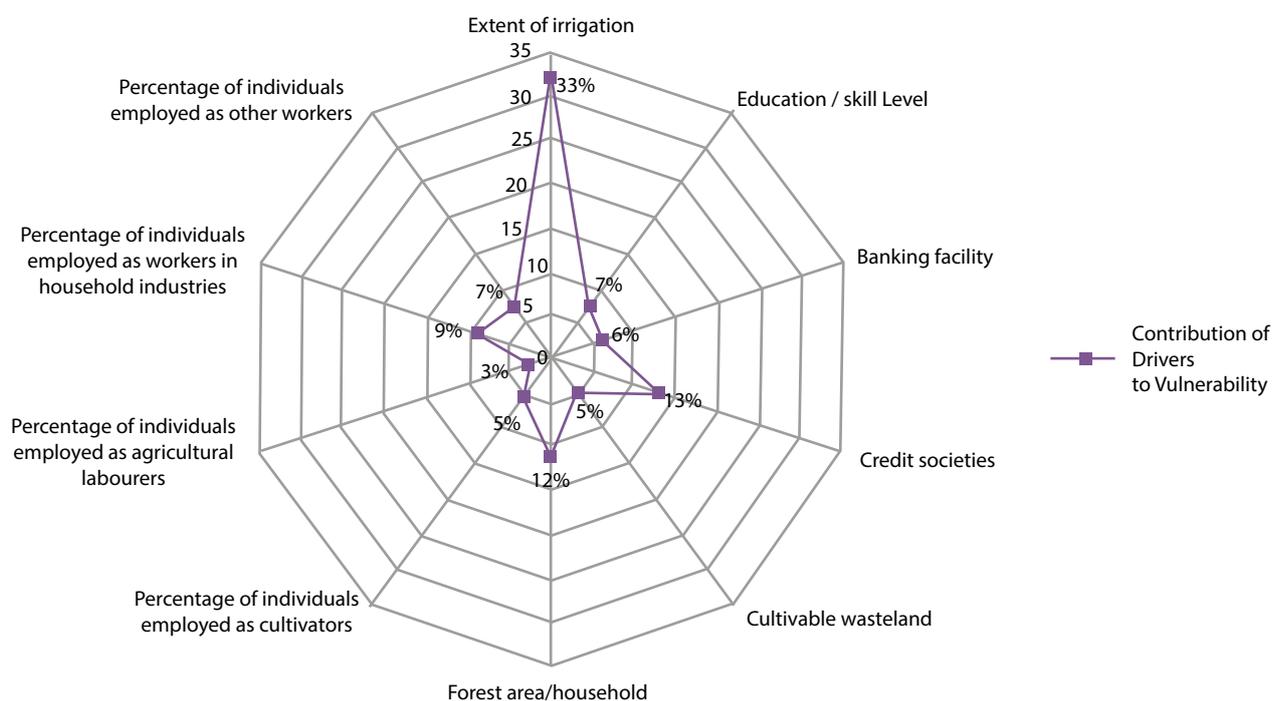
Figure 2.7 presents the drivers of socio-economic vulnerability of households at the village level. The

average socio-economic vulnerability index (SVI) value for the villages of Chikkaballapur district is 0.77 or 77%, ranking 4 on the SVI scale, indicating high vulnerability. Irrigation is known to provide a buffer to farmers in semi-arid regions to the effects of recurrent droughts and erratic rainfall patterns, reducing the vulnerability of agricultural production to such climate risks and variability.

The drivers of vulnerability or factors contributing to the assessed vulnerability index value expressed as percentages are as presented in Figure 2.7 and include:

- Reduced extent of irrigation contributed an average of 33 per cent to the average socio-economic vulnerability of the 1,220 villages in Chikkaballapur district
 - Majority of villages in Chikkaballapur district are predominantly rainfed with low percentage of area under irrigation, making them highly vulnerable to climate variation.
- Lack of diversification of income sources (23 per cent)
- Livelihood support institutions (20 per cent)
- Land available for grazing, collection of fuelwood and forest products (17 per cent)
- Low education/skill level (7 per cent)

Figure 2.7: Drivers of socio-economic vulnerability in Chikkaballapur district (Esteves et al. 2016)





Example 2: Drivers of Vulnerability of Aduvalli Protected Forest (300 ha), Karnataka

Table 2.24 presents the drivers of vulnerability from the case study presented in Section 2.7. Forest vulnerability index was estimated for the village forest patch.

Contribution of an indicator to vulnerability index was obtained as a product of its weight and measured value. In this case study, the different drivers of vulnerability and their contribution to it are as follows:

- Preponderance of invasive species contributed most (52.7 per cent) to the vulnerability index

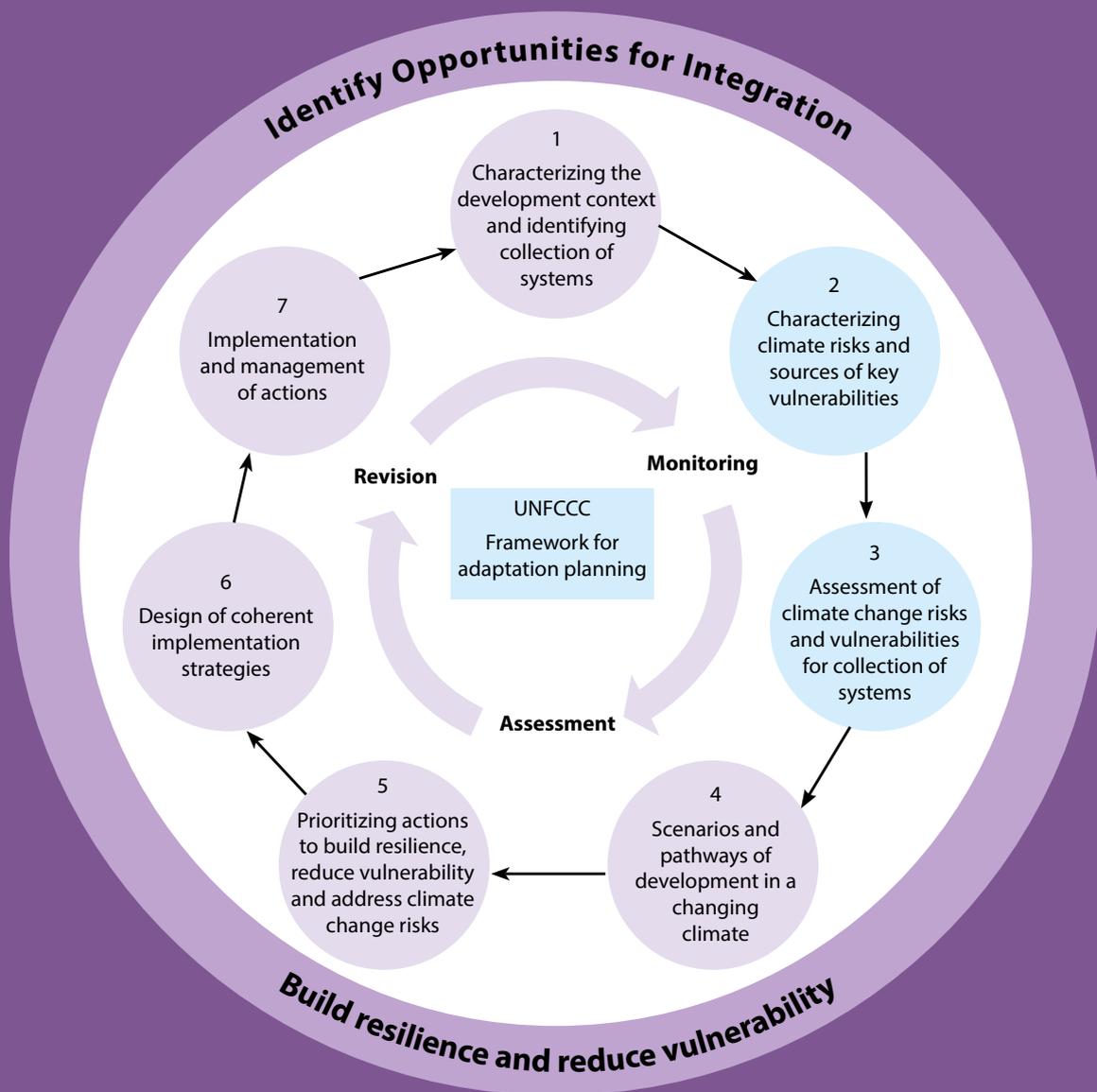
- Forest dependence of community (37.2 per cent)
- Reduction in forest area (7.4 per cent)
- Monoculture plantations (2.3 per cent)
- Occurrence of fire (0.4 per cent)

Thus, a critical utility of vulnerability assessment is the identification of the drivers or causes of vulnerability along with their proportional contribution to vulnerability. Information about the indicators or factors that contribute most to the aggregate vulnerability is useful in prioritising development and implementation of adaptation interventions.



Part 3

Integration of Climate Change Vulnerability and Risk Assessment into Adaptation Planning







3.1 Adaptation to Reduce Vulnerability

According to IPCC 2014, climate change is already evident from multiple observations, especially in the recent decades, with increased warming, sea level rise and occurrence of extreme events. Further, IPCC 2014 also concluded that the observed climate change of the recent decades is adversely impacting both the natural ecosystems and the socio-economic systems. The observed extreme events in the recent years have led to significant disastrous impacts on human society as well as natural ecosystems. There is also increasing evidence that the intensity of climate change is becoming more severe and the world will soon cross the threshold of 1.5°C or even 2°C of the global mean temperature. Thus, there is a need for adaptation now. Assessment of vulnerability of both the biophysical and socio-economic systems and developing and implementing adaptation strategies to the current climate trends and variability is necessary. Adaptation strategies are required not only to cope with the increasing current climate variability and extremes, but also for coping with long-term climate change. In Part 1 and Part 2 of this Manual, the concepts, framework, methods and guidelines are provided to assess vulnerability, to enable development of adaptation plans. In this Part of the Manual, a broad approach to mainstream vulnerability assessment in adaptation planning is provided. There are no readily available practical guidelines for integrating vulnerability into adaptation planning.

3.2 Vulnerability Assessment for Adaptation Planning

The risk-impact assessment framework of IPCC 2014 has three components, namely Hazard (H), Exposure (E) and Vulnerability (V). Vulnerability has two components, namely Sensitivity (S) and Adaptive Capacity (AC). Vulnerability is considered as independent of hazard and exposure in the IPCC risk-impact framework. The relevance of the three components of the risk-impact framework for adaptation planning is presented below:

- **Hazard:** Hazard is the potential occurrence of natural or human-induced physical events such as droughts, floods, heat stress, hurricanes and cyclones. Climate change is a hazard which may lead to increased frequency and intensity of heat stress, droughts, floods and hurricanes. These hazards adversely impact the biophysical systems and socio-

economic systems. The occurrence of hazards (for example, droughts and cyclones) is beyond the control of individuals, communities and national governments.

- **Exposure:** Exposure is the presence of people, livelihoods, species and infrastructure in a place or a region that could be adversely affected by the hazard. It is always a challenge to manage the exposure component. For example, it is not feasible to relocate millions of people living on mountain slopes, flood plains and coastal areas.
- **Vulnerability:** Vulnerability is the propensity or predisposition to be adversely affected by the hazard. Human societies can manage the two components of vulnerability, namely sensitivity and adaptive capacity. For example, it is possible to provide irrigation in drought-prone areas, promote agro-forestry and alternative and provide crop insurance to cope with the impacts of droughts. Thus, to cope with climate variability and projected climate change, governments, civil society organisations, multilateral agencies and scientists could address the two components of vulnerability; reduce sensitivity and enhance adaptive capacity of the systems.

IPCC Working Group II SPM (2014) concluded that “a first step towards adaptation to future climate change is reducing vulnerability and exposure to present climate variability.” Available strategies and actions can increase resilience across a range of possible future climates while helping to improve human health, livelihoods, social and economic well-being and environmental quality. Further, IPCC 2014 states that “effective risk reduction and adaptation strategies consider the dynamics of vulnerability and exposure and their linkages with socio-economic processes, sustainable development, and climate change.” Thus, assessment of vulnerability is a critical step in adaptation planning. Vulnerability assessment would assist communities and governments in developing adaptation strategies to address sensitivity and adaptive capacity components of vulnerability.

3.3 Frameworks and Toolkits for Mainstreaming Vulnerability in Adaptation Planning

Adaptation planning requires knowledge and information on vulnerability of the systems or communities. But the challenge is how to incorporate

or utilise vulnerability assessment findings in adaptation planning. There is no single practical framework or approach or guidelines for integrating vulnerability assessment in adaptation planning. There are several frameworks, tools, toolkits and methodologies to assist in selecting, designing, implementation and monitoring adaptation strategies, programmes and projects. Brief information on some of the adaptation tools and toolkits developed by international agencies are presented in Annexure 4. They include:

- Designing Adaptation Initiatives Toolkit (UNDP 2010)
- Tracking Adaptation and Measuring Development – TAMD (IIED 2011)
- Ecosystem Based Adaptation Decision Support Framework - Moving from Principles to Practice (UNEP 2012)
- Adaptation Monitoring and Assessment Tool – AMAT (GEF 2014)
- A Guiding Toolkit for Increasing Climate Change Resilience (IUCN 2014)
- Monitoring and Assessing Progress, Effectiveness and Gaps under the Process to Formulate and Implement National Adaptation Plans: The PEG M&E tool (LDC Expert Group – UNFCCC 2015)
- Self-evaluation and Holistic Assessment of Climate Resilience of Farmers and Pastoralists – SHARP tool (FAO 2015)
- Resilience Index Measurement and Analysis II – RIMAI (FAO 2016)
- The Stocktaking for National Adaptation Planning – SNAP Tool (GIZ 2016)
- Community-based Risk Screening Tool – Adaptation and Livelihoods – CRISTAL (IUCN, IISD, SEI and HIS)
- UNFCCC Framework for Adaptation Planning
- ALivE - Adaptation, Livelihoods and Ecosystems Planning Tool (IISD 2016)

Attempts have been made to utilise these tools at national, sub-national and project levels. For example,

SNAP is the most widely used tool in the GIZ's catalogue of approaches and has been implemented in Albania, Grenada, Guyana, Mauritania, Thailand, Togo and Uttarakhand¹. FAO's SHARP tool has been piloted in 10 countries across sub-Saharan Africa (Angola, Burkina Faso, Burundi, Mali, Mozambique, Niger, South Sudan and Uganda)². AMAT, developed by GEF, is used for monitoring adaptation outcomes of all programmes and projects financed by LDCF and SCCF - two funds under the UNFCCC, managed by GEF³. TAMD framework, by IIED, was used to provide a method for assessing the quality of climate risk management, resilience building and impacts of interventions in a case study conducted in Tanzania⁴.

All the above-mentioned tools and toolkits utilise vulnerability assessment information for selection, design and monitoring of adaptation strategies. For example, Designing Adaptation Initiatives Toolkit developed by UNDP uses vulnerability assessments as one of the approaches to analyse climate change related problems, which is the first step in the framework for designing an adaptation initiative. Similarly, A Guiding Toolkit for Increasing Climate Change Resilience, developed by IUCN is a six-step framework that employs vulnerability assessment in Step 2 - Resilience Assessment, and the results feed into Step 3 - Resilience Strategy Development. It must be noted that many of these toolkits are still academic in nature and a lot of experience needs to be generated with practical application. Among the toolkits, two approaches are briefly presented in the following sections.

- UNFCCC Framework for Mainstreaming Adaptation
- ALivE - Adaptation, Livelihoods and Ecosystems Planning Tool

3.3.1 UNFCCC Framework for Mainstreaming Adaptation

UNFCCC in response to a request from parties or governments prepared a technical paper titled

1. https://www.adaptationcommunity.net/?wpfb_dl=362

2. <http://www.fao.org/in-action/sharp/on-the-ground/en/>

3. <http://www.oecd.org/env/cc/48332185.pdf>

4. <https://www.climatelearningplatform.org/case-study-approaches-supporting-pastoralist-groups-facing-climate-change-effects-tanzania>

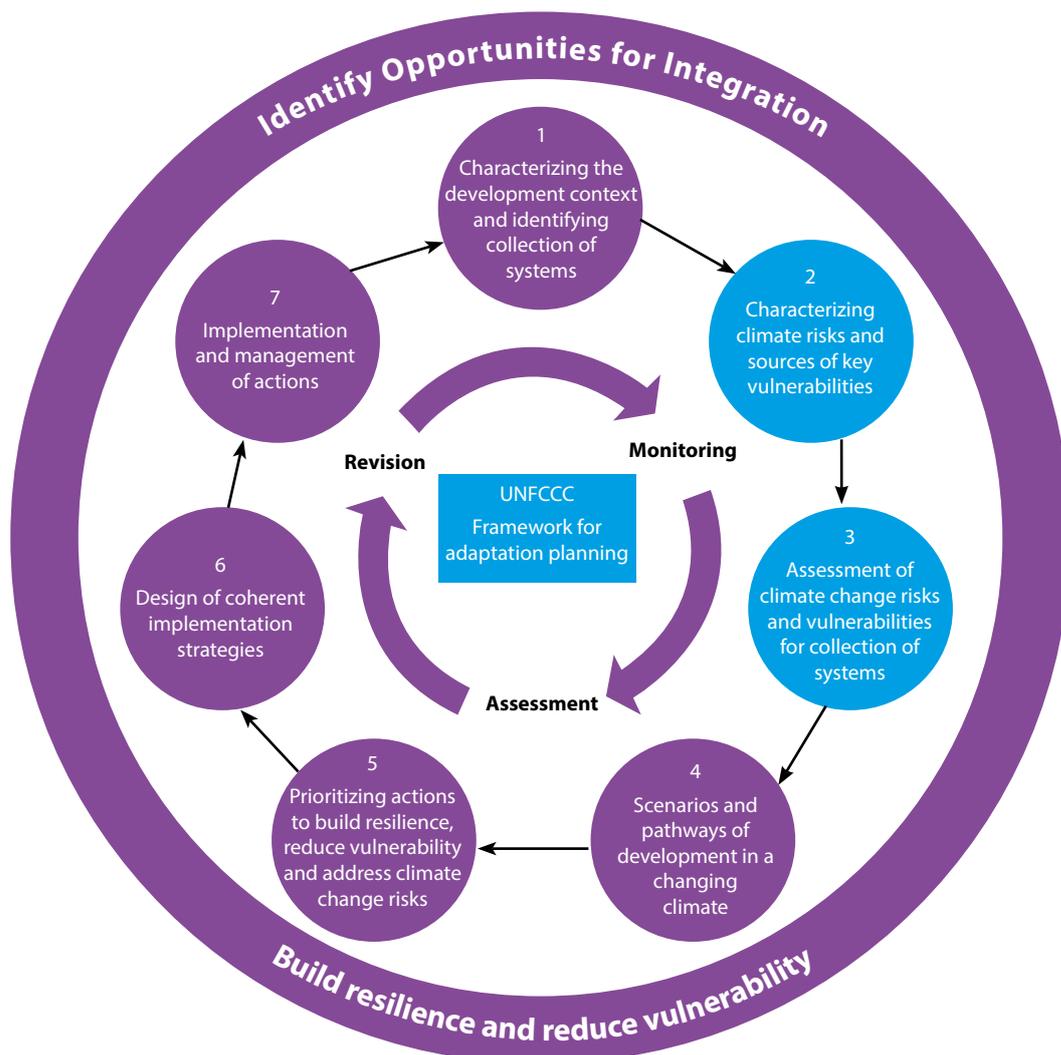


Opportunities and Options for Enhancing Adaptation Actions and Supporting their Implementation: Reducing Vulnerability and Mainstreaming Adaptation (UNFCCC 2016). The objective of this technical paper was to provide an initial exploration of opportunities and options for reducing vulnerability to climate change impacts and mainstreaming adaptation. Further, UNFCCC 2016 states that “assessment of current vulnerability and risks provides a starting point in informing the development of adaptation actions and is especially important when information on future climate impacts is not available owing to the lack of location-specific climate change scenarios and/or lack of experience in interpreting uncertainties of climate projections.”

The UNFCCC approach for incorporating the vulnerability and risk assessment in adaptation planning is shown in Figure 3.1.

The technical paper of UNFCCC 2016 states that “assessment of impacts, vulnerability, risk and resilience is often a starting point for adaptation planning and can be updated on a regular basis as new data, information and methods of analysis emerge. Assessments require knowledge of historical climate trends and projections of future climate, as well as the capacity in data analysis and interpretation. In addition, involvement of all potentially affected stakeholders is necessary in order to develop an accurate understanding of vulnerabilities.”

Figure 3.1: Adaptation planning and implementation process (Source: Adapted from FCCC/SBI/2015/INF.14, Figure 3)



This UNFCCC framework aims to identify opportunities for integration of vulnerability and risk into adaptation planning and also develop an approach to build resilience and reduce vulnerability to climate risks. The framework provides a 7-step procedure (Figure 3.1). The first three steps include:

1. **Step 1:** Identification of the collection of systems (villages, panchayats, blocks and watersheds) and characterise the systems that are vulnerable to and likely to be impacted by climate risks
2. **Step 2:** Characterisation of the climate risks and sources of key vulnerabilities
3. **Step 3:** Assessment of climate change risks and vulnerability of the selected systems

According to this UNFCCC framework, information on climate risks (historical) and source of vulnerability along with assessment of climate change risks and vulnerabilities for the selected systems is an integral and critical component of adaptation planning.

3.3.2 Adaptation, Livelihoods and Ecosystems Planning Tool (ALivE)

Adaptation, Livelihoods and Ecosystems Planning Tool (ALivE) is a computer-based tool designed to support its users in organising and analysing information to plan effective Ecosystem-based Adaptation (EbA) options within a broader EbA planning process. It is a rapid qualitative assessment technique that can be applied in any ecosystem using the framework represented in Figure 3.2.

ALivE is organised into three modules and five steps that build on each other. The five steps are presented below:

Step 1: Understand the context. This involves describing the study area, project goals and objectives; describing the livelihood context in the study area; assessing livelihood dependence on ecosystem services; describing the major ecosystems in the study area; identifying ecosystems needed for livelihood activities; and identifying how ecosystems reduce impacts from natural hazards.

Step 2: Analyse risks to ecosystems and livelihoods.

This involves documenting observed and projected climate change in the study area; assessing impacts of climate change on ecosystems important for livelihoods; analysing impacts of climate change on ecosystems important for livelihoods; assessing impacts of non-climatic stressors on ecosystems; analysing impacts of climatic and non-climatic stressors on livelihoods; and identifying social groups that are particularly vulnerable.

Step 3: Identify and prioritise ecosystem-based adaptation (EbA) options.

This involves identifying adaptation outcomes for vulnerable livelihood strategies; identifying EbA options for vulnerable livelihood strategies; prioritising effective EbA options for vulnerable livelihood strategies; listing of effective EbA options; changing or adding new EbA options; identifying evaluation criteria to assess the feasibility of EbA options; evaluating feasibility of EbA options based on chosen criteria; listing of feasible EbA options; and identifying key actions that are needed for implementation of priority EbA.

Step 4: Design project activities to facilitate implementation of EbA options.

This step involves identifying required inputs for prioritised EbA options; identifying roles and responsibilities for priority EbA options; identifying opportunities and barriers that influence the implementation of priority EbA options and key actions; identifying project activities to support implementation of priority EbA options and key actions, taking into consideration required inputs, factors, responsibilities, opportunities and barriers.

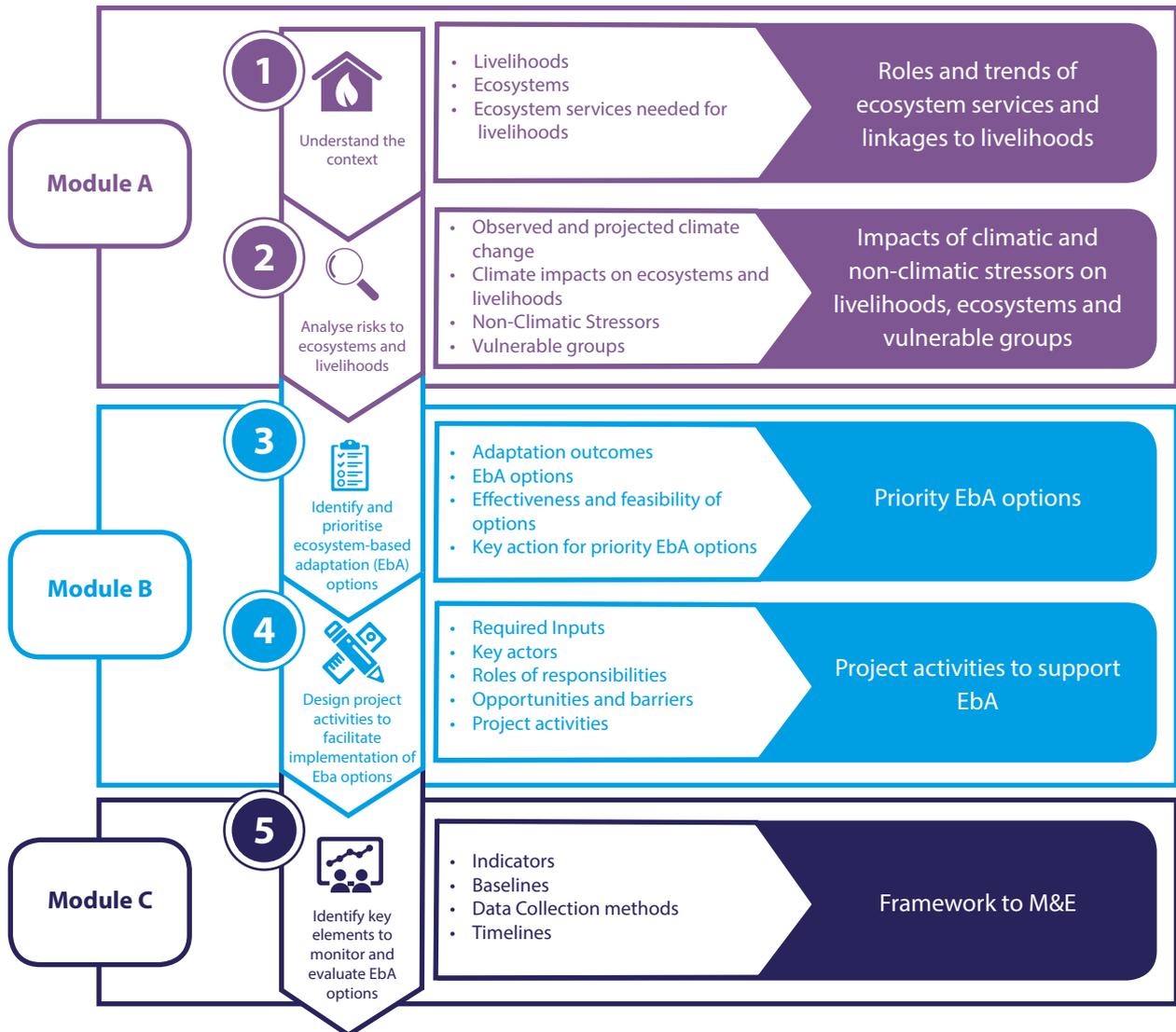
Step 5: Identify key elements to monitor and evaluate EbA options.

This involves identifying long-term indicators to measure adaptation outcomes; identifying short-term indicators to measure EbA options; describing the baseline situation for each adaptation outcome; data collection and methods – monitoring; and data collection and methods – evaluation.

Socio-economic vulnerability is incorporated in Module A - Step 2 of the tool, where social groups identified as most vulnerable through a socio-economic vulnerability



Figure 3.2: ALivE framework (Source: Terton and Dazé 2018)



assessment, e.g. women, smallholder farmers, children and elderly are keyed into the tool. The tool also provides a simplified guide for the selection of vulnerable groups based on where they live, their wealth, their gender, their religion or ethnicity and mobility challenges. The drivers of an agriculture or livelihood vulnerability assessment maybe considered while identifying and prioritising EbA strategies in Module 2, Step 3 of the tool. For example, if the indicator 'lack of irrigation' is a major driver in an agriculture vulnerability assessment, then adaptation strategies that address this driver may be prioritised,

i.e. rehabilitating and modernising local water bodies, investing in groundwater recharge structures and construction of new or rehabilitating existing canals.

Although the concepts of EbA and Livelihood Methods for Climate Change Adaptation have been applied to measure a community's resilience and to design efficient adaptation strategies, the ALivE tool is still in a pilot phase and there are no studies showcasing the practical application of this tool.

3.4 Practical Approach and Steps to Incorporate Vulnerability in Adaptation Planning

Based on the UNFCCC framework, a simplified approach to utilise the vulnerability assessment in adaptation planning is presented in Figure 3.3. This provides a seven step procedure:

- **Step 1:** Select systems (sectors or regions) for vulnerability assessment; villages/districts/watersheds/cropping systems
- **Step 2:** Conduct vulnerability assessment for current climate and/or climate change scenarios using the guidelines provided in Part 2 of the Manual
- **Step 3:** Vulnerability ranking of villages/districts/watersheds/cropping systems, etc., based on vulnerability index (Step 2) and prioritise these units
- **Step 4:** Identify the drivers/sources of vulnerability (examples provided in Figure 3.3)
- **Step 5:** Prioritise the most vulnerable systems; villages/districts/blocks/watersheds/cropping systems
- **Step 6:** Select the most vulnerable systems or hotspots and the most critical drivers/sources of vulnerability for detailed vulnerability assessment or adaptation planning
- **Step 7:** Develop adaptation package/matrix to address the drivers of vulnerability as well as climate-related stresses/impacts. Adaptation strategies could also be developed for:
 - Mainstreaming in the current developmental programmes; watershed programmes, MGNREGS, afforestation programmes and agriculture development programmes
 - Development of dedicated adaptation programmes and practices

- **Additional Step to Integrate Climate Risks along with Vulnerability Analysis for Adaptation Planning:** The vulnerable systems/hotspots identified using vulnerability framework and methods could be overlaid on climate stressed districts/blocks/watersheds/cropping systems to identify the 'Biophysical/Socio-economic Vulnerability plus Climate Hazard Stressed Regions/Communities' for prioritised adaptation planning. Adaptation strategies could incorporate:
 - Strategies to address drivers of vulnerability
 - Strategies to address climate stress-related concerns: droughts leading to water stress, floods leading to inundation of crop fields and settlements

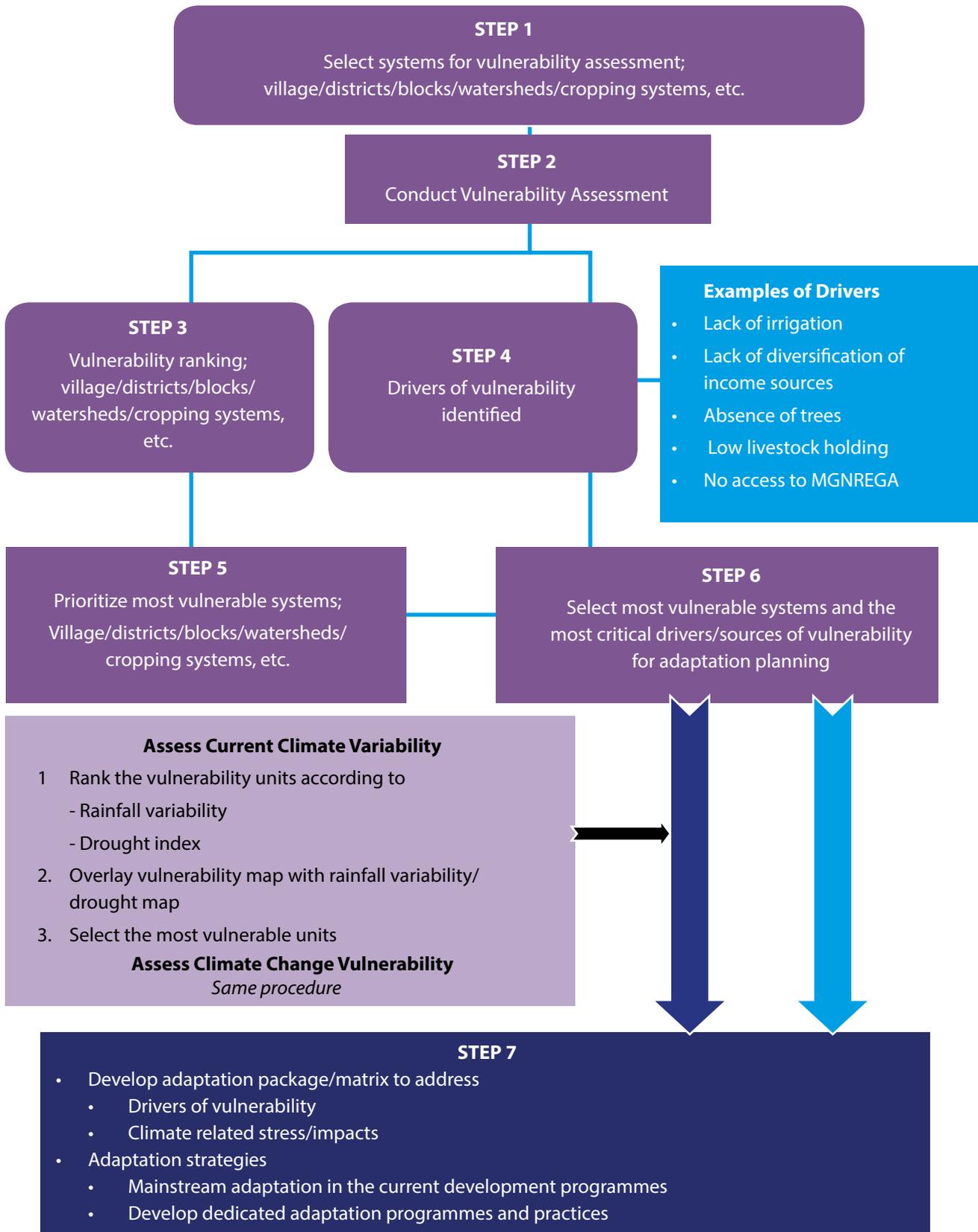
Adaptation strategies could be developed for two scenarios, utilising the results of the vulnerability assessment.

- **Scenario 1:** Development of adaptation strategies mainly based on vulnerability assessment for the identified vulnerable hotspots and the drivers or sources of vulnerability
- **Scenario 2:** Development of adaptation strategies by integrating hazard (climate variability and climate change) with vulnerability and exposure (selected systems such as villages/districts/watersheds/cropping systems)

The main goal of this Manual is not to develop adaptation planning framework and guidelines but to provide the concepts related to vulnerability, a vulnerability framework based on IPCC 2014 (Part 1), guidelines and methods for assessment of the vulnerability (Part 2) and finally an approach to integrate vulnerability assessment into adaptation planning (Part 3).



Figure 3.3: Broad approach and steps to mainstreaming vulnerability in adaptation planning



References

- 1) Allen, K (2003). Vulnerability Reduction and the Community-based Approach: A Philippines Study. In *Natural Disasters and Development in a Globalizing World*, ed. M. Pelling, 170–184, New York: Routledge.
- 2) Alwang J, Siegel P B, Jorgensen S L (2001). *Vulnerability: A View from Different Disciplines*. Discussion Paper Series No. 0115. Social Protection Unit, World Bank, Washington DC
- 3) Bhattachan, A, Tatlhego, M, Dintwe, K, O'Donnell, F, Caylor, K, Okin, G, Perrot, D, Ringrose, S and D'Odorico, P (2012). Evaluating Ecohydrological Theories of Woody Root Distribution in the Kalahari. *PLoS ONE*, 7(3), p. e 33996.
- 4) Bryan, E, Deressa, T T, Gbetibouo, G A and Ringler, C (2009). Adaptation to Climate Change in Ethiopia and South Africa: Options and Constraints. *Environmental Science & Policy*, 12, pp. 413-426.
- 5) Chaliha, S, Sengupta, A, Sharma, N, Ravindranath, N, (2012). Climate variability and farmer's vulnerability in a flood-prone district of Assam, *International Journal of Climate Change Strategies and Management*, 4(2), pp. 179-200.
- 6) CIDA (2004). *CIDA Evaluation Guide*. [online] Canada. Available at: <https://www.oecd.org/derec/canada/35135136.pdf>.
- 7) Cutter, S, Barnes, L, Berry, M, Burton, C, Evans, E, Tate, E and Webb, J (2008). A place-based model for understanding community resilience to natural disasters, *Global Environmental Change*, 18(4), pp. 598-606.
- 8) Das, A and Usamo, Y (2017). Wage Rates in Rural India, 1998–99 to 2016–17. *Review of Agrarian Studies*, 7(2). Available at http://www.ras.org.in/wage_rates_in_rural_india_1998
- 9) De Lange H J, Sala S, Vighi M et al. (2010). Ecological Vulnerability in Risk Assessment – A Review and Perspectives, *Science of the Total Environment*, 408: 3871-3879.
- 10) Downing T E, Butterfield R, Cohen S et al. (2001). *Climate Change Vulnerability: Linking Impacts and Adaptation*. University of Oxford, Oxford
- 11) Eckstein David, Künzel Vera and Schäfer Laura, (2018). *Global Climate Risk Index 2018 Who Suffers Most from Extreme Weather Events? Weather-related Loss Events in 2016 and 1997 to 2016*, Briefing Paper, German Watch.
- 12) Eriksen S H, Kelly P M (2007). *Developing Credible Vulnerability Indicators for Climate Adaption Policy*. *Mitigation and Adaptation Strategies for Global Change* 12: 495-524.
- 13) Esteves, T, K, Basu, Porsche Ilona, Sharma, Rajeev, Murthy, I, Rao, Shashanka, Sharma Nitasha, Vishal Patil, Bhan Singh Ajay, Jha Shashidhar, Rao Bhaskar, S Roy S, Sinha Bhaskar, K V Rao and H Ravindranath N (2013). *Agricultural and Livelihood Vulnerability Reduction through the MGNREGA*. *Economic and Political Weekly*, XLVIII. 52.
- 14) Esteves, T, Ravindranath, D, Bedamatta, S, Raju, K, Sharma, J, Bala, G and Murthy, I (2016). *Multi-scale Vulnerability Assessment for Adaptation Planning*. *Current Science*, 110(7).
- 15) Forrest, J, Wikramanayake, E, Shrestha, R, Areendran, G, Gyeltshen, K, Maheshwari, A, Mazumdar, S, Naidoo, R, Thapa, G and Thapa, K (2012). *Conservation and Climate Change: Assessing the Vulnerability of Snow Leopard Habitat to Treeline Shift in the Himalaya*. *Biological Conservation*, 150(1), pp. 129-135.
- 16) Füssel, H and Klein, R (2006). *Climate Change Vulnerability Assessments: An Evolution of Conceptual Thinking*. *Climatic Change*, 75(3), pp. 301-329.
- 17) GIZ/WRI (2011). *Making Adaptation Count Concepts and Options for Monitoring and Evaluation of Climate Change Adaptation*. [online] Available at: http://www.wri.org/sites/default/files/pdf/making_adaptation_count.pdf.
- 18) GIZ (2014). *Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), India. A Framework for climate change vulnerability assessment*. <https://www.weadapt.org/sites/weadapt.org/files/legacy-new/knowledge-base/files/1522/5476022698f9agiz2014-1733en-framework-climate-change.pdf>



- 19) Hinkel, J (2011). Indicators of Vulnerability and Adaptive Capacity: Towards a clarification of the Science–policy Interface, *Global Environmental Change*, 21(1), pp. 198-208.
- 20) Holman, I P, Naess, L O (2008). Vulnerability Assessments in the Developed World: The UK and Norway. In: *Assessing Vulnerability to Global Environmental Change-Making Research Useful for Adaptation Decision Making and Policy*, Earthscan
- 21) IPCC (2007). *Climate Change 2007: Impacts, Adaptation and Vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Parry M L, Canziani O F, Palutikof J P, van der Linden P J and Hanson C E, Eds. Cambridge University Press, Cambridge, UK, p. 976
- 22) IPCC (2012). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field C B, Barros V, Stocker T F, Qin D, Dokken D J, Ebi K L, Mastrandrea M D, Mach K J, Plattner G K, Allen S K, Tignor M and Midgley P M (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, p. 582
- 23) IPCC (2014). *Summary for Policymakers*, In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field C B, Barros V R, Dokken D J, Mach K J, Mastrandrea M D, Bilir T E, Chatterjee M, Ebi K L, Estrada Y O, Genova R C, Girma B, Kissel E S, Levy A N, MacCracken S, Mastrandrea P R and White L L (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32
- 24) IPCC (2016). *Opportunities and Options for Enhancing Actions and Supporting their Implementation: Reducing Vulnerability and Mainstreaming Adaptation*.
- 25) Ives, J D, and Messerli, B (2004). Mountain Geocology: The Evolution of Intellectually-based Scholarship into a Political Force for Sustainable Mountain Development. In M. Sala, honorary theme editor, *Geography*, in *Encyclopaedia of Life support system (EOLSS)*, developed under the auspices of UNESCO, Oxford, UK: EOLSS publishers <<http://www.eolss.net>>
- 26) Ives, J (2006). *Himalayan Perceptions: Environmental Change and the Well-being of Mountain Peoples*. *Himalayan Journal of Sciences*, 2(3).
- 27) Iyengar, N S and Sudarshan, P (1982). A Method of Classifying Regions from Multivariate Data. *Economic and Political Weekly*, 17, pp. 2048-2052.
- 28) Jurgilevich A, Räsänen A, Groundstroem Fand Juhola S (2017). A Systematic Review of Dynamics in Climate Risk and Vulnerability Assessments. *Environ. Res. Lett.* 12, 013002. doi:10.1088/1748-9326/aa5508.
- 29) Kelly, P and Adger, W (2000). Theory and Practice in Assessing Vulnerability to Climate Change and Facilitating Adaptation. *Climatic Change*, 47: pp. 325–352.
- 30) Klein, R and Patt, A (2012). *Assessing Vulnerability to Global Environmental Change*. Hoboken: Taylor and Francis, pp. 43-57.
- 31) Mainz, J (2003). Defining and Classifying Clinical Indicators for Quality Improvement. *International Journal for Quality in Health Care*, 15(6), pp. 523-530.
- 32) Murthy IK, Tiwari R, Ravindranath N H (2011). *Climate Change and Forests in India: Adaptation Opportunities and Challenges*. *Mitigation and Adaptation Strategies for Global Change* 16: pp. 161-175
- 33) Negi P, *Integrated Vulnerability Assessment to Climate Change in Semi-arid Area of Maharashtra*, (unpublished master thesis, TERI University, 2016).
- 34) O'Brien, K, Eriksen, S, Nygaard, L and Schjolden, A (2007). Why Different Interpretations of Vulnerability Matter in Climate Change Discourses. *Climate Policy*, 7(1), pp. 73-88.
- 35) Oppenheimer, M, Campos M, Warren R, Birkmann J, Luber G, O'Neill B, and Takahashi K, (2014). *Emergent Risks and Key Vulnerabilities*. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental

- Panel on Climate Change [Field, C B, V R Barros, D J Dokken, K J Mach, M D Mastrandrea, T E Bilir, M Chatterjee, K L Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1039-1099.
- 36) Panday, P and Ghimire, B (2012). Time-series Analysis of NDVI from AVHRR Data over the Hindu Kush–Himalayan Region for the period 1982–2006. *International Journal of Remote Sensing*, 33(21), pp. 6710-6721.
- 37) Ravindranath, N H, Rao, S, Sharma, N, Nair, M and Gopalakrishnan, R, Rao, A, Malaviya, S, Tiwari, R, Sagadevan, A, Munsri, M, Krishna, N, Bala, G (2011). Climate Change Vulnerability Profiles for North East India. *Current Science*, 101 (3), pp. 384-394.
- 38) Ribot, J (2011). Vulnerability before Adaptation: Toward Transformative Climate Action. *Global Environmental Change*, 21(4), pp. 1160-1162.
- 39) Scheffers, B, De Meester, L, Bridge, T, Hoffmann, A, Pandolfi, J, Corlett, R, Butchart, S, Pearce-Kelly, P, Kovacs, K, Dudgeon, D, Pacifici, M, Rondinini, C, Foden, W, Martin, T, Mora, C, Bickford, D and Watson, J (2016). The Broad Footprint of Climate Change from Genes to Biomes to People. *Science*, 354(6313).
- 40) Schickhoff, U (2005). The Upper Timberline in the Himalayas, Hindu Kush and Karakorum: A Review of Geographical and Ecological Aspects, in: *Mountain Ecosystems. Studies in Treeline Ecology*, edited by: Broll, G and Keplin, B, 275–354, Springer, Berlin Heidelberg
- 41) Sharma, J, Chaturvedi, R, Bala, G and Ravindranath, N (2013). Assessing “Inherent Vulnerability” of Forests: A Methodological Approach and a Case Study from Western Ghats, India. *Mitigation and Adaptation Strategies for Global Change*, 20(4), pp. 573-590.
- 42) Sharma, J, Uppgupta S, Kumar R et al. (2015). Assessment of Inherent Vulnerability of Forests at Landscape Level: A Case Study from Western Ghats in India. *Mitigation and Adaptation Strategies Global Change*. DOI: 10.1007/s11027-015-9659-7.
- 43) Sharma, J, Uppgupta S, Jayaraman M et al. (2017). Vulnerability of Forests in India: A National Scale Assessment. *Environmental Management* DOI 10.1007/s00267-017-0894-4.
- 44) Terton, A and Dazé, A (2018). *Adaptation, Livelihoods and Ecosystems Planning Tool: User Manual Version 1.0*. International Institute for Sustainable Development & United Nations Environment Programme – International Ecosystem Management Partnership
- 45) UNFCCC (2016). Opportunities and Options for Enhancing Adaptation Actions and Supporting their Implementation: Reducing Vulnerability and Mainstreaming Adaptation. https://unfccc.int/files/adaptation/groups_committees/adaptation_committee/application/pdf/tp_adaptation_2016.pdf.
- 46) UNFCCC. [online] Available at: <https://cop23.unfccc.int/> [Accessed Nov. 2017].
- 47) Uppgupta, S, Sharma, J, Jayaraman, M, Kumar, V and Ravindranath, N (2015). Climate Change Impact and Vulnerability Assessment of Forests in the Indian Western Himalayan Region: A Case Study of Himachal Pradesh, India. *Climate Risk Management*, 10, pp. 63-76.



Annexures

Annexure 1: Indicator list by different studies

Scale of Study	Category	Indicators	Sub-indicators	Type of Vulnerability
Multi-scale Vulnerability Assessment for Adaptation Planning (Esteves et. al. 2016)				
District	Sensitivity	Population density		Socio-economic
		Percentage of SC and ST population		Socio-economic
	Adaptive capacity	Literacy rate (percentage)		Socio-economic
	Sensitivity	Percentage of marginal landholders (< 1 hectare)		Socio-economic
		Percentage of non-workers		Socio-economic
	Adaptive capacity	Livestock units/100,000 population		Biophysical indicators
		Per capita income (3-year average)		Socio-economic
	Adaptive capacity	Cropping intensity (percentage)		Biophysical indicators
		Percentage irrigated area to total cropped area (3-year average)		Biophysical indicators
	Adaptive capacity	Total area under fruit crops (hectares)		Biophysical indicators
Village	Sensitivity	Extent of irrigation	Percentage area irrigated in villages	Biophysical indicators
	Adaptive capacity	Education/Skill level	Literacy rate in villages (percentage)	Socio-economic
			Livelihood support institutions (Yes/No)	Banking facility
		Credit societies	Socio-economic	
	Sensitivity	Land available for grazing and collection of fuelwood and NTFP	Cultivable wasteland (hectares)	Biophysical indicators
			Forest area/household (hectare/household)	Biophysical indicators
	Adaptive capacity	Diversification of income sources	Cultivators (percentage)	Socio-economic
			Agricultural labourers (percentage)	Socio-economic
			Workers employed in household industries (percentage)	Socio-economic
			Other workers (percentage)	Socio-economic

Scale of Study	Category	Indicators	Sub-indicators	Type of Vulnerability
Household	Adaptive capacity	Diversification of income sources	Number of sources of income	Socio-economic
			<ul style="list-style-type: none"> Types of livestock owned (number) Total number of livestock owned 	Biophysical indicators
			<ul style="list-style-type: none"> Number of useful agro-forestry tree species grown Total number of useful agro-forestry trees owned 	Biophysical indicators
			<ul style="list-style-type: none"> Number of days of wage employment Percentage household income from other (non-agricultural) sources Participation in MGNREGS (Yes/No) 	Socio-economic
		Education/Skill level	Proportion of educated members (at least till class 7)	Socio-economic
			Proportion of employed members	Socio-economic
			Proportion of skilled labourers	Socio-economic
			Proportion of household members migrating seasonally	Socio-economic
		Livelihood support institutions	Financial institutions that provide loans (Yes/No)	Socio-economic
			Self help groups (Yes/No)	Socio-economic



Scale of Study	Category	Indicators	Sub-indicators	Type of Vulnerability	
Climate Change Vulnerability Profiles for North-East India (Ravindranath et al. 2011)					
District	Sensitivity	Agricultural vulnerability index	Area under rainfed/dryland crops	Biophysical indicators	
			Rural population density	Biophysical indicators	
			Number of agricultural landholdings less than 2 hectares	Biophysical indicators	
			Net sown area	Biophysical indicators	
			Area under irrigated crops	Biophysical indicators	
			Area under high-yielding varieties	Biophysical indicators	
			Amount of fertilisers consumed	Biophysical indicators	
			Amount of manure used	Biophysical indicators	
			Net annual groundwater availability	Biophysical indicators	
			Mean rainfed crop yield	Biophysical indicators	
			Water vulnerability index	Water availability	Biophysical indicators
			Forest vulnerability index	Disturbance	Biophysical indicators
				Biological richness	Biophysical indicators
				Fragmentation status	Biophysical indicators
Mapping Vulnerability to Multiple Stressors: Climate Change and Globalisation in India (O'Brien et. al. 2007)					
State/ District	Sensitivity	Presence of alternative economic activities	Percentage of the district workforce employed in agriculture	Socio-economic	
			Percentage of landless labourers in agricultural workforce	Socio-economic	
	Adaptive capacity	Human capital	Adult literacy rates	Socio-economic	
		Social capital	Degree of gender equality in a district	Socio-economic	

Scale of Study	Category	Indicators	Sub-indicators	Type of Vulnerability
Agricultural and Livelihood Vulnerability Reduction through MGNREGS (Esteves et.al. 2013)				
Household	Sensitivity	Groundwater depth (metres below ground level)		Biophysical indicators
		Irrigation intensity (percentage)		Biophysical indicators
		Net irrigated area (hectares)		Biophysical indicators
		Number of days of irrigation water availability		Biophysical indicators
		Area under food grains (hectares)		Biophysical indicators
		Cropping intensity (percentage)		Biophysical indicators
		Crop yields (ton/ hectares)		Biophysical indicators
		Soil organic carbon (percentage)		Biophysical indicators
		Soil erosion (ton/ha/yr)		Biophysical indicators
	Adaptive capacity	Livestock population		Biophysical indicators
		Migration (number of individuals migrating)		Socio-economic
		Wage rates (rupees)		Socio-economic
		Number of days of employment		Socio-economic
Climate Change Impact and Vulnerability Assessment of Forests in the Indian Western Himalayan Region: A Case Study of Himachal Pradesh, India (Uppgupta et. al. 2015)				
Forest	Adaptive capacity	Biological richness		Biophysical indicators
		Canopy cover		
		Slope		
	Sensitivity	Disturbance index		
		Forest dependence of rural communities (FD)	Rural population density per sq. km of forest area	



Annexure 2: Principal Component Analysis

Principal Component Analysis (PCA) is a multivariate technique for finding patterns in data of high dimension. Once the patterns hidden in data are identified, PCA helps to compress the data by reducing the number of dimensions without much loss of information. In the language of linear algebra, it is a linear transformation of the original variables. PCA allows us to compute a linear transformation that maps data from a high dimensional space to a lower dimensional space. In a large database, variables may be correlated and PCA is useful to transform them into uncorrelated variables. The essential steps in the computation of principal components are as follows:

- Arrange the data in the form of a matrix, rows say, representing regions (M) and columns are indicators (K). Let us call this matrix as X. Then X has dimension $M * K$
- For each variable, compute its mean across all observations and subtract the mean from each observation. This produces a new matrix, $X - \bar{X}$ in which sum of all elements in each column is zero.
- Compute the covariance matrix using the formula $(X - \bar{X})^T (X - \bar{X}) / m$. In this matrix, the diagonal elements are the variances of the respective variables and off diagonal elements are the covariances between variables.
- Compute the Eigen values and Eigen vectors of the covariance matrix.
- Arrange the Eigen values in the descending order of magnitude. The Eigen vector corresponding to the highest Eigen value is the first principal component of the data set. Similarly the Eigen vectors of the

second, third highest values correspond to the second, third principal components and so on and so forth. In other words, the principal components are now arranged in the order of significance. We can retain Eigen vectors up to a desired level of significance and leave the remaining ones which are insignificant. This is because each Eigen value represents a portion of variance and we keep the first m Eigen vectors such that:

$$\frac{\sum_{i=1}^m \lambda_i}{\sum_{i=1}^k \lambda_i} > \text{Threshold level (normally 90 or 95\%)}$$

- A criterion usually followed is MINEIGEN criterion according to which we retain all the components with Eigen value > 1 .
- The Eigen vectors retained can be used to recalculate the values for each observation.

The method involves sophisticated calculations like Eigen values and Eigen vectors and hence software packages can be used. In determining the weights for the indicators, the weights are determined by the factors loadings of the first principal component. Bryan et. al. (2009) have applied this method to construct the vulnerability of South African farming sector. They identified a total of 19 indicators, 4 for exposure component, 6 for sensitivity component and 9 for adaptive capacity component. They retained the first principal component which explained about 33% of the variation and based on overall vulnerability index they classified the 9 farming provinces into 4 categories in terms of vulnerability as 'high', 'medium', 'low-medium' and 'low'.

Annexure 3: Indicators and secondary sources of data for vulnerability assessment

Category	Illustrative List of Indicators (Units)	Scale	Source of Data/ Website	
Land use and Land Use pattern	Total geographic area (hectares)	State/District/ Village	Census of India, http://censusindia.gov.in/ or India Stat https://www.indiastat.com/ District At A Glance, soft copies of latest versions maybe available on respective district websites, or hardcopies may be collected at statistical departments of district/block headquarters.	
	Area under agricultural crops (hectares)			
	Cropping intensity			
	Area (hectares) or percentage area irrigated			
	Area (in hectares) or percentage area under rainfed agriculture			
	Irrigation Intensity			
	Area under desert (hectares)			National Remote Sensing Centre, https://www.nrsc.gov.in/
	Area under fruit crop (hectares)			Census of India, http://censusindia.gov.in/ or India Stat, https://www.indiastat.com/
	Slope data (percentage)			DEM, https://earthexplorer.usgs.gov/
	Area under watershed (hectares)			India Stat, https://www.indiastat.com/
	Soil maps	FAO, http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/en/ NBSSLU, https://www.nbsslup.in/		
River boundary		India, WRIS http://www.indiawris.nrsc.gov.in/wrpinfo/index.php?title=Main_Page		
Climate Data	Weekly/Monthly rainfall (mm)	State/District/ Village	Indian Meteorological Department (IMD), http://www.imd.gov.in/Welcome%20To%20IMD/Welcome.php Aphrodite, http://www.chikyu.ac.jp/precip/english/	
	Temperature data (°C)		Climate Research Unit (CRU), https://crudata.uea.ac.uk/cru/data/hrg/cru_ts_3.23/	
	Climate change projections using models		Coordinated Regional Downscaling Experiment CORDEX http://cordex.org/ CMIP5 Coupled Model Inter-comparison Project https://cmip.llnl.gov/cmip5/data_portal.html	
	Disasters (number and type)	Area affected	National Disaster Management Authority, http://www.ndma.gov.in/en/	



Category	Illustrative List of Indicators (Units)	Scale	Source of Data/ Website
Demographic	Population density (number of people per sq. km.)	State/District	Census of India, http://censusindia.gov.in/ or District Census Handbook, 2011 Primary Census Abstract (PCA) Agriculture Census, http://agcensus.dacnet.nic.in/ NITI Aayog, http://niti.gov.in/
	Rural population density (number of people per sq. km in rural areas)		
	Urban population density (number of people per sq. km in urban areas)		
	Percentage of women		
	Percentage of men		
	Sex ratio		
	Number of villages		
	Literacy rate		
	Percentage of male literates		
	Percentage of female literates		
	Percentage of tribal households		
	Percentage of migrated population		
	Number of landholdings		
	Percentage of marginal farmers		
	Percentage of large farmers		
	Employment share of agriculture in labour force		
	Percentage or number of households below poverty line		
	Scheduled Castes and Scheduled Tribes population (percentage)		
	Age dependency ratio		
Percentage of non-workers			
Wage rates	Das and Usami, 2017		

Category	Illustrative List of Indicators (Units)	Scale	Source of Data/ Website
Health	Current use of family planning methods (percentage)	State/District	NITI Aayog, http://niti.gov.in/
	Children who received full vaccination (percentage)		
	Prevalence of anaemia in women aged 15-49years (percentage)		
Agriculture	Food production (t/hectare)	State/District	India Stat https://www.indiastat.com/ Agricultural Statistics at a Glance 2016, http://eands.dacnet.nic.in/PDF/Glance-2016.pdf 19 th Indian Livestock Census http://dahd.nic.in/documents/statistics/livestock-census Input Survey, http://inputsurvey.dacnet.nic.in/
	Cereal yield (t/hectare)		
	Number of livestock		
	Number of dairy cattle		
	Number of sheep/goats		
	Population to livestock ratio		
	Fertiliser use (unit per hectare)		
Institutional	Number of commercial banks	State/District	Census of India, http://censusindia.gov.in/ or NITI Aayog, http://niti.gov.in/
	Number of credit crop societies		
	Villages with primary health centre within 10km (percentage)		
	Number of hospitals		
	Number of schools		
Infrastructure	Kaccha road (km)	State/District	Census of India, http://censusindia.gov.in/ or NITI Aayog, http://niti.gov.in/
	Pucca road (km)		
	Number or percentage of households having electricity		
	Number or percentage of households with drinking water supply		
	Schools with electricity (percentage)		
	Schools with drinking water facility (percentage)		
	Number of cold storage units		National Horticulture Board, http://www.nhb.gov.in/csrlIndex.aspx



Category	Illustrative List of Indicators (Units)	Scale	Source of Data/ Website
Maps	Political		Census of India, http://censusindia.gov.in/
	Forests		
	Slope		DEM, Earth Data https://earthexplorer.usgs.gov/
	River basin		India, WRIS http://www.indiawris.nrsc.gov.in/wrpinfo/index.php?title=Main_Page
	Flood-prone area		
Presence of government	MGNREGS: Employment, works implemented (number of people present or absent)	Village	MGNREGA website, http://www.nrega.nic.in/netnrega/home.aspx
	Area afforested (hectare)	State/District	Government of India https://community.data.gov.in/progress-of-afforestation-from-2007-08-to-2014-15/
	Watershed programme (present or absent)	Area implemented	IWMP MIS, http://iwmpmis.nic.in/
Forest	Biological richness (number)	State/District/ Village	IIRS, Dehradun, http://bis.iirs.gov.in/
	Disturbance index (number)		IIRS, Dehradun, http://bis.iirs.gov.in/
	Canopy cover (percentage)		FSI, Dehradun/LPJ dynamic vegetation, http://fsi.nic.in/details.php?pgID=sb_6
Economic	Per capita income (rupees in lakh)	State/District	Planning Commission, Government of India, http://planningcommission.gov.in/

Annexure 4: Adaptation Tools and Toolkits

Adaptation Tool or Toolkit	Agency	Features	Application or Utilisation of Vulnerability Profile or Index	Quantitative or Qualitative Tool
Monitoring and assessing progress, effectiveness and gaps under the process to formulate and implement National Adaptation Plans: The PEG M&E tool ⁵	LDC EXPERT GROUP - UNFCCC (2015)	The tool is a set of metrics (process, input, output, outcome and impact) used to monitor and assess the process to formulate and implement NAPs. Based on 10 essential functions of which includes analysing climate data, assessing vulnerabilities to climate change and identifying adaptation options at the sector, sub-national, national and other appropriate levels.	Vulnerability assessment information is a key input metric.	Qualitative tool
Designing Adaptation Initiatives Toolkit ⁶	UNDP (2010)	It is a toolkit that provides a six-step approach for designing adaptation initiatives. It also catalogues several tools and resources that can be used for designing adaptation initiatives.	Vulnerability assessment is one of the approaches to analyse climate change-related problem which is the first step in the framework for designing an adaptation initiative.	Qualitative tool
Ecosystem-Based Adaptation Decision Support Framework - Moving from Principles to Practice ⁷	UNEP (2012)	The EBA-DSF centres around four iterative steps and strategic considerations: Setting Adaptive Context – Selecting Appropriate Adaptation Options – Design for Change – Adaptive Implementation. The EBA-DSF provides a capacity building platform to support the implementation of National Adaptation Plans (NAPs) and other adaptation actions.	Vulnerability assessment information is used in step one of the framework - Setting Adaptive Context	Qualitative tool

⁵http://www4.unfccc.int/nap/Documents%20NAP/50301_04_UNFCCC_Monitoring_Tool.pdf

⁶https://sustainabledevelopment.un.org/content/documents/951013_Toolkit%20for%20Designing%20Climate%20Change%20Adaptation%20Initiatives.pdf

⁷<http://www.unep.org/climatechange/adaptation/Ecosystem-BasedAdaptation/EBADecisionSupportFramework/tabid/102163/Default.aspx>



Adaptation Tool or Toolkit	Agency	Features	Application or Utilisation of Vulnerability Profile or Index	Quantitative or Qualitative Tool
Self-evaluation and Holistic Assessment of Climate Resilience of Farmers and Pastoralists (SHARP) Tool ⁸	FAO (2015)	<p>A tablet application with a self-assessment questionnaire based on resilience indicators that are relevant to the case of smallholder farmers and pastoralists which have been derived from Cabell and Oelofse's (2012) agro-ecosystem resilience indicators' framework.</p> <p>It is both a learning tool as well as a monitoring and evaluation tool that works by first identifying areas of poor resilience and providing a baseline upon which changes can be assessed.</p>	It is essentially a tool for assessing inherent vulnerability of smallholder farmers.	Quantitative tool
Resilience Index Measurement and Analysis II (RIMA II) ⁹	FAO (2016)	<p>It is an innovative quantitative approach which explains why and how some households cope better with shocks and stressors than others.</p> <p>It enables comparison between different types of households in a country or area and helps decision makers and other stakeholders to understand the dynamics of positive trends in resilience (and thus develop strategies that will yield positive results).</p> <p>It assesses change of the five pillars of resilience - Access to Basic Services; Assets; Social Safety Nets; Sensitivity; and Adaptive Capacity when exposed to a shock and considers the various coping strategies and their influence on the change in resilience.</p>	Considers the core elements of a vulnerability assessment – sensitivity and adaptive capacity.	Quantitative tool

⁸<http://www.fao.org/in-action/sharp/en/>

⁹<http://www.fao.org/3/a-i5665e.pdf>

Adaptation Tool or Toolkit	Agency	Features	Application or Utilisation of Vulnerability Profile or Index	Quantitative or Qualitative Tool
The Stocktaking for National Adaptation Planning (SNAP) Tool ¹⁰	GIZ (2016)	<ol style="list-style-type: none"> Lays the Groundwork and Address Gaps: Initiating and launching of the NAP process; identifying and assessing gaps and needs, addressing capacity gaps, assessing development needs and climate vulnerabilities Preparatory elements: Analysing climate risks; Assessing climate vulnerabilities; Reviewing adaptation options; Compiling and communicating a National Adaptation Plan; Integrating climate change adaptation into planning Implementation Strategies Reporting, Monitoring and Review 	Does include vulnerability/impact assessment data to provide a sense of the evidence upon which effective adaptation planning decisions can be based, and whether further information is needed, in order to focus on the early stages of the NAP process on such research and information-oriented activities.	Qualitative tool
Tracking Adaptation and Measuring Development (TAMD) ¹¹	IIED (2011)	<p>A framework to measure adaptation along two interrelated tracks.</p> <ul style="list-style-type: none"> Track 1, entitled 'Climate Risk Management' (CRM), focuses on monitoring processes, and concentrates on institutions, policies and capacities to manage climate risks. Track 2, 'Adaptation Performance', focuses on outcomes and assesses whether CRM (as a process) is improving the adaptive capacities of a population, and thus human well-being. <p>The TAMD framework includes indicators along both tracks and stipulates the development of a theory of change to illustrate the relationship between them.</p>	Vulnerability assessment information is used in Track 2 to track changes in the developmental status and vulnerability of the climate vulnerable poor.	Qualitative framework

¹⁰ 1. https://www.adaptationcommunity.net/?wpfb_dl=148; 2. https://www.adaptationcommunity.net/?wpfb_dl=362

¹¹ <http://pubs.iied.org/pdfs/10031IIED.pdf>



Adaptation Tool or Toolkit	Agency	Features	Application or Utilisation of Vulnerability Profile or Index	Quantitative or Qualitative Tool
A Guiding Toolkit for Increasing Climate Change Resilience ¹²	IUCN (2014)	<ol style="list-style-type: none"> 1. Resilience Vision: Situation analysis - The Resource, Infrastructure, Demand and Access (RIDA) methodology; Participatory Rapid Appraisal (PRA) and Rapid Appraisal of Agricultural Knowledge Systems (RAAKS); and Problem Tree 2. Resilience Assessment: CRISTAL; CVCA; Ecological Vulnerability; Sustainable Livelihood Approach; and Vulnerability Mapping 3. Resilience Strategy Development: Analysis and Refinement of Vision and Scenario workshop; Scenario Building workshop; Finalisation of Detailed Strategy (workshop) 4. Planning: Planning Workshop; Prioritisation and Ranking; Action Plans Development 5. Implementation: Pilot and Demonstration Projects; Accountability and Rights Analysis 6. Reflection: Multi-level, multi-stakeholder Platform Creation; Process Documentation; Information and Knowledge Management including communication; and M&E and feedback. 	Vulnerability assessment is a key component in the tool and results feed into the decision making or adaptation strategy development stage.	Quantitative and qualitative

¹² <http://web.cedare.org/wp-content/uploads/2016/01/SEARCH-Toolkit.pdf>

Adaptation Tool or Toolkit	Agency	Features	Application or Utilisation of Vulnerability Profile or Index	Quantitative or Qualitative Tool
Adaptation Monitoring and Assessment Tool (AMAT) ¹³	GEF (2014)	A tracking tool for climate change adaptation projects using a results-based management framework with clearly and explicitly defined units of measurement of 14 indicators.	Assesses vulnerability to address objective 1: Reduce the vulnerability of people, livelihoods, physical assets and natural systems to the adverse effects of climate change and also considers other vulnerability assessments carried out to address Objective 2: Strengthen institutional and technical capacities for effective climate change adaptation.	Quantitative tool (computer based)
Community-based Risk Screening Tool – Adaptation and Livelihoods (CRISTAL) ¹⁴	IUCN, IISD, SEI and HSI	A computer-based tool that helps users to: (i) understand the livelihoods and climate context of a community or area of interest; (ii) screen existing project activities to assess their impacts on livelihood resources that are important to climate adaptation, and revise these activities accordingly; (iii) plan new project activities that support climate adaptation; and (iv) support M&E.	Current and future vulnerability of community is considered in step 2 of the tool - Climate risk analysis	Quantitative tool
ALivE - Adaptation, Livelihoods, and Ecosystems Planning Tool ¹⁵	IISD (2016)	A computer-based tool with 3 modules and 5 steps – 1. understand the context; 2. analyse risks to ecosystems and livelihoods; 3. identify and prioritise ecosystem-based adaptation (EbA) options; 4. design project activities to facilitate EbA options; and 5. identify key elements to monitor and evaluate EbA.	Step 2 considers vulnerability assessment information	Quantitative tool

¹³ http://www.thegef.org/sites/default/files/council-meeting-documents/GEF-LDCF.SCCF_17-05%2C_Updated_RBM_Framework_for_Adaptation_to_Climate_Change%2C_2014-10-08_4.pdf

¹⁴ https://www.iisd.org/pdf/2012/cristal_user_manual_v5_2012.pdf

¹⁵ <https://www.iisd.org/project/ALivE>



About NMSHE

The **National Mission for Sustaining the Himalayan Ecosystem (NMSHE)** is one of the eight missions under India's National Action Plan on Climate Change. The Mission is being coordinated by the Department of Science and Technology, Government of India. 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 IHCAP

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

Published by Indian Himalayas Climate Adaptation Programme (IHCAP)

Copyright © IISc 2018. All Rights Reserved. Published in India

Cite as: Sharma J, Indu K Murthy, Esteves, T., Negi. P., Sushma S, Dasgupta S., Barua A., Bala G and Ravindranath N H., 2018. Vulnerability and Risk Assessment: Framework, Methods and Guideline, Indian Institute of Science.

This publication or parts of it may not be reproduced, stored by means of any system or transmitted, in any form or by any medium, whether electronic, mechanical, photocopied, recorded or of any other type, without the prior permission of IHCAP.

This report is available in the electronic form at:

<http://www.ihcap.in/resources.html>