Vulnerability Assessment in the Indian Himalayan Region

Framework, Method and Guidelines

A Summary

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This is a summary of the Vulnerability and Risk Assessment Framework, prepared by Indian Institute of Science, Banglore for the Indian Himalayas Climate Adaptation Program (IHCAP). More specifically, this document is a summary of the "Manual and Guidelines" Section of the mentioned framework. While you are requested to go through the detailed manual, the summary document will be handy when you are actually performing the analysis. The main aim of this summary is to provide a brief sketch of the entire methodology for the vulnerability assessment and also to help you in brushing up the concepts and steps. We hope that you will find this summary useful.

Contents

1. What is vulnerability?

Intergovernmental Panel on Climate Change (IPCC) conceptualizes vulnerability as the propensity or predisposition of a system to be adversely affected. It includes sensitivity or susceptibility to harm and lack of capacity to cope and adapt. It is an internal property of a system and dynamic in nature. It has significant implications when discussed in the context of susceptibility of fragile ecosystems, such as the Himalayan Region, to climate stimuli. IPCC 4th Assessment Report (2007) considered 'exposure' as one of the three elements of 'vulnerability' other two being sensitivity and adaptive capacity. However, post 2007, this conceptualization of vulnerability has been modified and 'exposure' is no longer considered to be a component of 'vulnerability'. The IPCC 5th Assessment Report (FAR, 2014) has adopted this conceptual construct of vulnerability and presented 'exposure' separate from 'vulnerability' while representing 'risk'. Risk arises from interaction of hazard, exposure and vulnerability. For the current assessment, post-2007 framework has been followed.

Basically Risk is a function of hazard, exposure and vulnerability. In notations, it can be written like the following.

Risk = f (Hazard, Exposure, Vulnerability); where f depicts the functional relationship.

Vulnerability thus is a component of risk. In our study, to assess the risk we will focus on the 'vulnerability' component. Also vulnerabilities can be off different types. We are mainly considering the social vulnerabilities here.

- We define vulnerability here and also distinguish between social and biophysical
- We define current and future Vulnerability here and then in the later section we stick to current vulnerability only

2. Why Current Vulnerability Assessment (VA)?

Vulnerability assessments help us to:

1) Identify the areas/systems/communities that are vulnerable.
2) Create demand among stakeholders for adaptation action.
3) Assess the extent of vulnerability.
4) Identify the drivers of vulnerability.
5) Plan adaptation strategies
6) Disseminating awareness among the stakeholders.

It is useful to assess vulnerability under both the scenarios i.e. under current climate change and future (long-term) climate change scenarios. In the current assessment, we focus on the assessment of current climate vulnerability, as evolving adaptation strategy based on the current climate vulnerability assessment is a reliable and 'no-regret' approach to reduce current vulnerability and build long-term resilience under climate change. This is, in fact, the first step of any vulnerability assessment undertaken with the aim to reduce the risk under uncertain future.

3. What are the main steps in VA?

Step 1: Scoping and Objectives

First we need to identify the objective or purpose of the assessment and the target audience of any particular VA.

Table 1: Scoping and Objectives of VA

Steps of Scoping	Explanation	What will we do?
Identifying the need of VA	VA is required under following conditions: a) Exposure to climatic stressors. b) Importance of the (vulnerable) system c) Ability to take adaptive measures d) Persistence of vulnerable conditions and degree of irreversibility (of consequences) e) Presence of factors making societies vulnerable to cumulative stressors. We must remember that there is no hard and fast rule that all the five conditions must be present.	Indian Himalayan Region (IHR) is vulnerable to natural disasters, coupled with the impact of climate change and climate variability. This calls for the development and implementation of an immediate framework for VA in the area.
Region & unit of VA	The geographical area where VA is carried out and the units of assessment	Region: IHR; Unit of VA: State (all 12 states in IHR), and all districts in a state.
Defining the objectives	a) Identify the most vulnerable areas (i.e. regions/communities/systems) b) Gain direction for adaptation planning. A well-defined set of objectives is needed before framing the study procedure.	a) Prepare a state level vulnerability map for IHR b) Prepare district level vulnerability map (to be prepared by respective state governments). c) Suggest useful guidance for efficient adaptation planning.
Identifying the stakeholders	a) VA studies are done for several stakeholders. And they actually influence the objectives, types and rigor of the VA. So prior to any study it is must to identify the target audience and later the study must be confined in that domain.	Stakeholders are - Central government, respective state governments and the district level administrative bodies.

Step 2: Selection of VA Type

All VA studies come under one of the following three categories.

i) Biophysical vulnerability study(e.g., VA for Himalayan sub-tropical pine forests in India)

ii) Socio-economic vulnerability study (e.g., VA for freshwater fishermen community in Himalayan river basin).

iii) Integrated vulnerability study (A combination of the above two categories).

It is easily understood that integrated studies are most common, as they provide a comprehensive picture compared to the other types. The present program will focus on integrated vulnerability study where each of the states will take into consideration their respective bio-physical and socio-economic indicators.

Step 3: Selection of Tier Methods

A VA study can be done by using primary or secondary data or by using a possible combination of the two. Also GIS data, climate model outputs or other spatial remote sensing data can be used. The methodological rigor employed and the type of data used defines the tier level of a VA study. The three tier levels for undertaking VA studies are presented in table 2.

Table 2: Different Tier Methods for VA

Different Methods	Definition	Advantages/Disadvantages
Tier 1	It is a top down approach based largely on secondary data.	Data can be collected easily, in less time and at less cost. However, data accuracy or relevance may be low. Useful preliminary level assessment can be undertaken using Tier 1 methodology. In fact it is easiest to follow, as only elementary level of skills and least resources are required.
Tier 2	It involves both top down and bottom up approaches. So both secondary and primary data is needed. It requires higher level of skills and resources.	Data is more accurate but takes more time and is more costly. VA results provide useful inputs for evolving adaptation strategies/approach.
Tier 3	It involves both top down and bottom up approaches along with GIS data and spatial remote sensing. It is most rigorous and requires high level of skills and resources.	Data is more accurate and multidimensional but takes more time and is more costly. VA results provide detailed and direct inputs for developing adaptation plans and measures.

The state-level VA map for IHR will be based on Tier 1 approach. The district level/ village level studies carried out by each state will be based mostly on tier 2 approach. They can even base their study on Tier 3 approach, if data and other resources are available. The choice of tier for any VA study depends on the objective of the study, availability of skills, time, funding and data.

Step 4: Restricting Area of Application

This stage is very crucial to make the study practically doable and useful. We fix the following points prior to indicator selection.

Table 3: Area of Application in a VA

Particularities of Study	Idea	What will we do?
Sector	VA study is carried out for particular sector(s) (e.g., Forestry, watershed, agriculture). A sector can be divided in several subsectors (e.g., Agricultural sector can be divided into subsectors such as cash crop, fruit, horticulture etc.).	States may take up VA studies for the sector that they consider to be vulnerable.
Scale	VA study can be carried at a micro scale (e.g., household) or at a macro scale (e.g., country). It is feasible to do it for a scale in between.	Current VA will focus on state level and district level. However, depending on availability of data, a state can carry out further micro level study (e.g., Village level)
Period	Under climate change scenario vulnerability can be measured for current or future climate.	Since here our objective is to study current climate vulnerability, the time scale is not considered

Step 5: Identify the Necessary Indicators

In any VA we have indicators of different types (i.e., Bio-Physical, Socio-economic and Institutional). Considering the objectives and scale of the study, adopted tier method, availability of necessary data, indicators are carefully chosen. One has to be absolutely clear about the rationale behind selecting a particular indicator. Usually, a longer list of indicators can be chosen to begin with, which is reduced to 8-10 indicators finally to undertake the study. Selection of appropriate indicators is the art of and central to a VA study. Indicators may capture 'sensitivity' or lack of 'adaptive capacity' of a system. Higher the sensitivity, higher will be vulnerability and lower the adaptive capacity higher will be the vulnerability. Table 4 presents the indicators chosen to carry out a state-level VA in IHR. It shows the various indicators used, the category to which particular indicator belongs to, its relation with the vulnerability, the way it is defined and the data sources. (This is only for demonstration purpose.)

Table 4: Indicators for State Level VA in Indian Himalayan Region

Indicators	Indicator type	Relationship with vulnerability[1]	Measurement procedure	Data source
Percentage of area under forest (FOREST)	Bio-Physical	Negative	(Total forest cover divided by state's total area)multiplied by 100	Forest Survey of India Report (2017)
Per Capita Income (2014-15) at constant prices of 2011-12[2] (PCI)	Socio-economic	Negative	State Domestic Product (SDP) divided by Total population of the state	NITI Aayog
Population Density (2011)[2] (POP)	Socio-economic	Positive	Number of persons living in per km^2	NITI Aayog: State Statistics
Percentage of marginal land holders (2010-11)[3] (MARLAND)	Socio-economic	Positive	(Total no. of marginal land holders divided by Total no. of land holders) multiplied by 100	Agricultural Census Report (2010-11), Department. of Agriculture and Co-operation, Ministry of Agriculture, Government of India (2014)
Average days of employment per household under MGNREGA (2014-15-16) (MGNREGA)	Institutional	Negative	Average of average no. of workdays per household in each district	Open Govt. Data(OGD) platform : https;//data.gov.in
Road network density – Kuchcha / Pucca[4] (ROAD)	Institutional	Negative	Ratio of length of state's total road network to the state's land area	Ministry of Road Transport And Highways Transport Research Wing, Government of India.

[1]Positive (Negative) relationship imply the higher the value of the indicator the higher (lower) the level of vulnerability.

[2]All population related data is based on Indian Census of 2011.

[3]A land holder with land size up to 1 hector or 2.5 acres.is considered a marginal land holder.

[4]Unit of states area is square km and unit of road length is km. Normalization technique is needed to make these numbers unit free. Then only calculating road density is possible. We will discuss normalization later.

Step 6: Quantification of Indicators

We must express all indicators in terms of numbers so that we can apply mathematical operations to these. The following table shows the data entries of all the six indicators for all the twelve states of IHR.

Table 5: Value of State Indicators in Indian Himalayan Region VA[5]

States	FOREST	PCI	POP	MARLAND	MGNREGA	ROAD
Jammu and Kashmir (J&K)	10%	52831	56	46.51	36	0.16
Himachal Pradesh	26%	105269	123	28.63	42	0.91
Uttarakhand	46%	116557	189	36.23	32	0.98
Sikkim	47%	177441	86	13.88	43	0.79
Meghalaya	77%	58488	132	16.08	48	0.54
Tripura	75%	58888	351	49.03	88	2.79
Mizoram	90%	70552	52	28.79	22	0.54
Manipur	76%	43348	128	23.36	22	0.86
Nagaland	79%	58998	119	0.31	22	2.12
Arunachal Pradesh	80%	82874	17	19.63	14	0.18
West Bengal	19%	78903*	1028	52.47	33	3.55
Assam	35%	45692	398	25.83	22	3.62

*Figure based on 2004-05 data.

Step 7: Normalization of Indicators

VA indicators are expressed in different units (e.g., MGNREGA is measured in terms of days/year; PCI is measured in Indian National Rupee/year while FOREST is unit free), thus we cannot simply add them up. Furthermore, VA is also about ranking. If we say that vulnerability of A is 70, vulnerability of B is 65 and so on, standalone it will imply nothing, unless we find a way to compare those units of VA i.e. A, B etc. We must develop a framework where we can say A is more (or less) vulnerable than B. Basically we need to rank those units of VA study according to their respective degrees of vulnerabilities (i.e., value of the vulnerability indices). To address these issues, we have to normalize the indicator values.

Normalization yields two advantages. Firstly, normalized values are unit free, which can be readily combined to arrive at the Vulnerability Index (VI) value. Secondly, they all lie between 0 and 1 (0 implies least vulnerability and 1 implies the highest vulnerability) and can be related to ranking thus enabling comparison and prioritization.

The formula used for normalization depends on whether the indicator has positive or negative relationship with vulnerability.

[5]For units of measurement, refer to Table 4

Case I: The indicator has positive relationship with vulnerability

$$Normalizedvalue = \frac{(Actualindicatorvalue - Minindicatorvalue)}{(Maxindicatorvalue - Minindicatorvalue)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(1)}$$

Case II: The indicator has negative relationship with vulnerability

$$Normalizedvalue = \frac{(Maxindicatorvalue - Actualindicatorvalue)}{(Maxindicatorvalue - Minindicatorvalue)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(2)}$$

Applying the above rule we calculate the normalized value of each indicator for all the states.

Normalization of POP indicator for J&K (Positively related to vulnerability)

The maximum and minimum values are respectively 1028 (West Bengal) and 17 (Arunachal Pradesh).
So, the denominator is (X_{max} - X_{min}) = (1028-17) = 1011. [Note that the denominator will be identical for all states under consideration]
The numerator for J&K is (X_{actual} -X_{min}) = (56-17) =39.
Hence, the normalized value of the indicator POP for J&K = 39/1011 = 0.039. Note that the normalized value is between 0 and 1 and is unit free.

Similarly, we can calculate the normalized values of each of the positive indicators for each of the states by applying the same normalization method given above.

Normalization of PCI indicator for West Bengal (Negatively related with vulnerability)

The maximum and minimum values are respectively 177441 (Sikkim) and 43348 (Manipur).
So, the denominator is (X_{max} - X_{min}) = (177441- 43348) =134093. [Note that the denominator will be identical for all states under consideration]
For West Bengal the numerator is (X_{max} - X_{actual}) = (177441-78903) = 98538.
Hence, the normalized value of PCI for West Bengal is (98538/134093) =0.735.

Similarly, we can calculate the normalized values of all the negative indicators for all the states by applying the same normalization method given above.

To clearly demonstrate the process of transforming actual values into normalized values, let us consider the following two indicators.

Following above method we have calculated the normalized values of all six indicators.

Table 6: Normalized Values of Six Indicators

States	FOREST	PCI	POP	MARLAND	MGNREGA	ROAD
J&K	1.000	0.929	0.039	0.886	0.703	1.000
Himachal Pradesh	0.798	0.538	0.11	0.543	0.622	0.785
Uttarkhand	0.555	0.454	0.170	0.689	0.757	0.763
Sikkim	0.537	0.000	0.069	0.260	0.608	0.819
Meghalaya	0.166	0.887	0.114	0.302	0.541	0.891
Tripura	0.190	0.884	0.331	0.934	0.000	0.240
Mizoram	0.000	0.797	0.035	0.546	0.892	0.892
Manipur	0.178	1.000	0.110	0.442	0.892	0.798
Nagaland	0.146	0.883	0.102	0.000	0.892	0.434
Arunachal Pradesh	0.125	0.705	0.000	0.370	1.000	0.996
West Bengal	0.890	0.735	1.000	1.000	0.743	0.020
Assam	0.687	0.983	0.377	0.489	0.892	0.000

Step 8: Assigning Weights to Indicators

Weights are assigned to each indicator according to their importance in determining vulnerability of a system. The total weight always should add up to 1. Assigning proper weights is very crucial for obtaining reliable (reflecting the reality most) results. We often consult experts or survey the stakeholders to judge the actual importance of different indicators. However, here we are assigning equal weight to each indicator to make the case simple. So, each indicator is assigned weight as 1/6 (as the total 6 indicators are taken into account), which is approximately 0.167.

Step 9: Aggregation of Indicators and Developing Vulnerability Index (VI)

The normalized indicators can be aggregated to come up with a VI. If different weights are attached to different indicators then a weighted average will be taken to calculate the VI (i.e. normalized values are to be multiplied by their respective weights and then added up). However, in this case, since equal weights are given, a simple arithmetic mean will do. For example let us consider the case of Meghalaya.

So, VI $=\frac{1}{6}(0.17 + 0.89 + 0.11 + 0.30 + 0.54 + 0.89)$ = 2.9/6 =0.48.

Step 10: Vulnerability Ranking

Once VIs are calculated for all the states, a comparative ranking is carried out based on the index value. Higher the value of VI of a particular state, higher will be the vulnerability. This vulnerability rankings are usually presented in tabular form. Here, we have ranked the 12 states according to their VI based on the six indicators that we have considered.

Table 7: Vulnerability Ranking of States in Indian Himalayan Region

States	VA Index Value	Obtained Vulnerability Ranking
J&K	0.76	**1**
Himachal Pradesh	0.57	**5**
Uttarkhand	0.56	**6**
Sikkim	0.38	**12**
Meghalaya	0.48	**9**
Tripura	0.43	**10**
Mizoram	0.53(0.5271)	**8**
Manipur	0.57(0.5700)	**4**
Nagaland	0.41	**11**
Arunachal Pradesh	0.53(0.5327)	**7**
West Bengal	0.73	**2**
Assam	0.57(0.5712)	**3**

From the ranking we know which state is relatively more vulnerable. For example, we can see while J&K is the most vulnerable state in the IHR, Sikkim is the least based on the indicators considered. Also, Meghalaya (rank 9) is less vulnerable than Himachal Pradesh (rank 5) but more vulnerable than Tripura (rank 10).

Step 11: Representation of Vulnerability

The basic idea behind representation of vulnerability is to convey the information about the state of vulnerability and the associated risks to the policy making bodies and other stakeholders. The most common way is to use spatial map with a gradient of colours indicating the level of vulnerability. Graphs, charts or tables too are widely used. Here, we are showing the 12 IHR states under study according to their vulnerability ranking (Map 1) and grouping of states according to their vulnerability (low, medium and high) (Map 2).

Calculations for Categorization

Max VA index value = 0.76 & Min VA index value = 0.38.

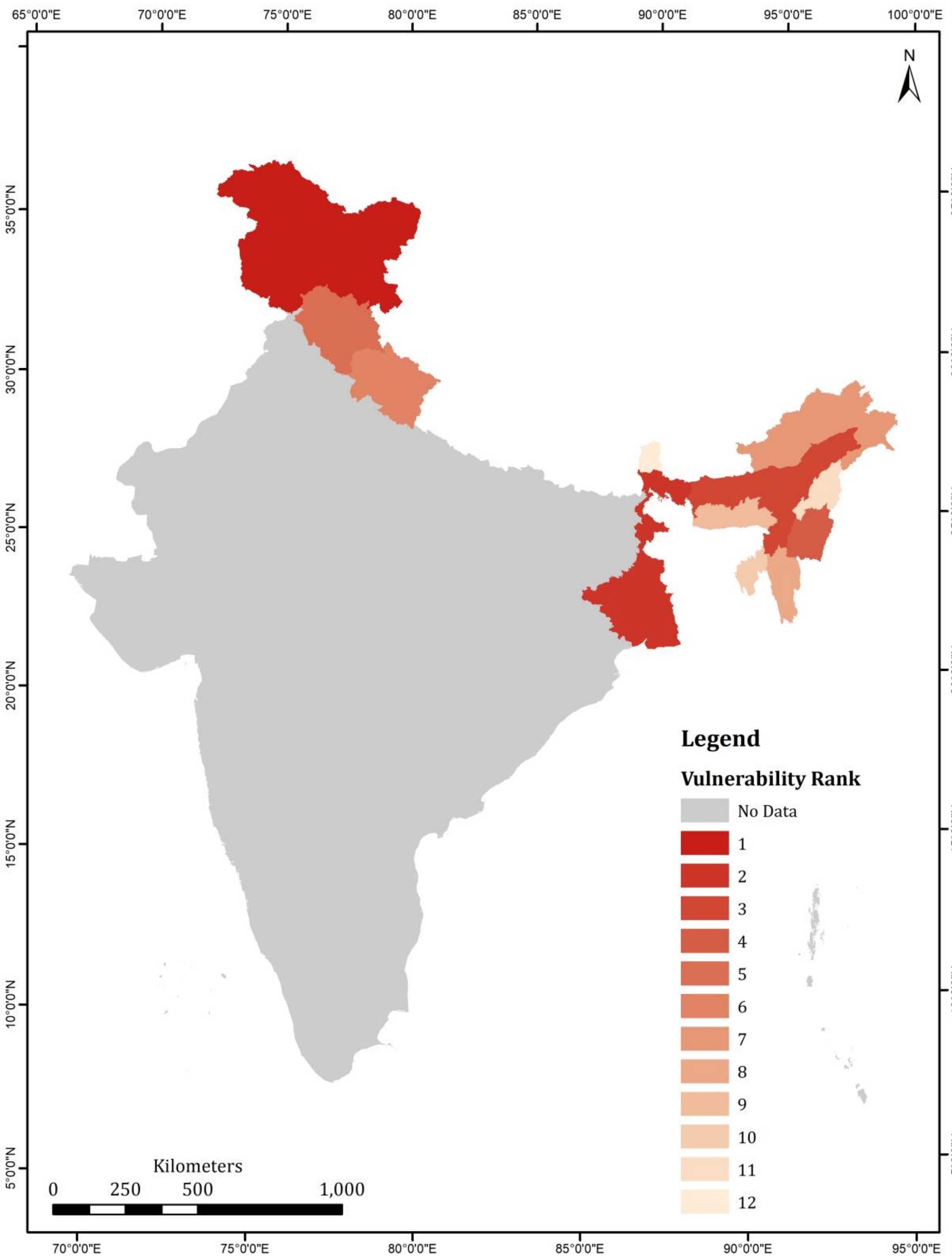
Range = 0.76 - 0.38 = 0.38. We want to categorize all states in three categories. 0.38/3 = 0.1267(Approx.)

Category 1: High Vulnerable: 0.76 - 0.6333 (= 0.76 – 0.1267) i.e. for our purpose: 0.76 - 0.63

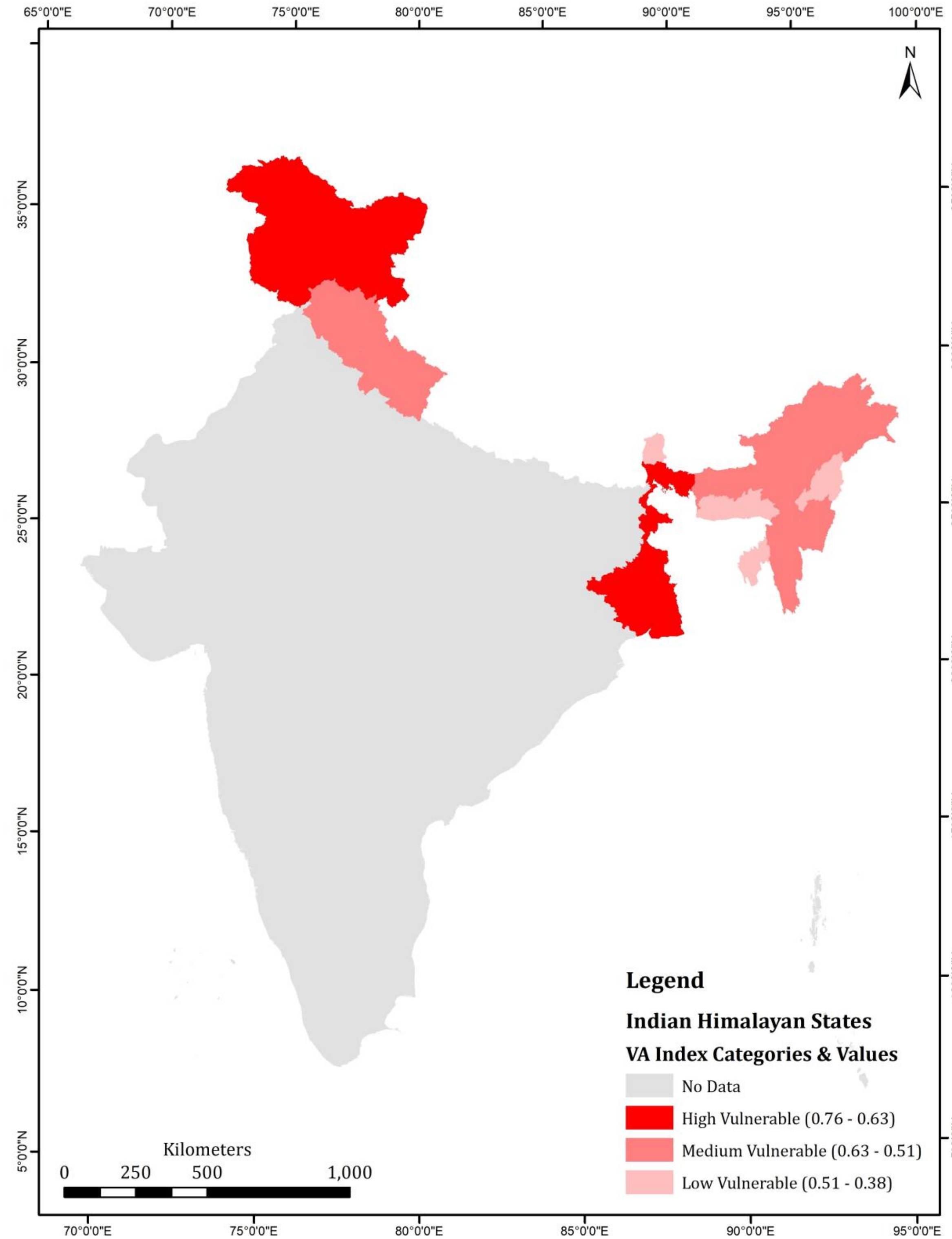
Category 2: Medium Vulnerable: 0.6333 - 0.5066 (=0.6333 – 0.1267) i.e. for our purpose: 0.63- 0.51

Category 3: Low Vulnerable: 0.5066 – 0.38 i.e. for our purpose: 0.51- 0.38

Map 1: Vulnerability ranking of different States in the IHR under current climate



Map 2: Vulnerability category for different States in the IHR under current climate



Step 12: Identification of Drivers of Vulnerability

Most vulnerability studies are conducted as a prerequisite of making policies to prevent further degradation of environmental assets. To develop efficient adaptation planning technique, identifying the main drivers behind vulnerability is crucial. VA helps in selecting adaptation measures based on the assessment of the drivers of vulnerability.

Now we will show how to find main drivers of vulnerability with the help of our VA study of twelve Indian Himalayan Region (IHR) states based on six chosen indicators.

Table 8: Vulnerability Ranking of IHR States with Chosen Indicator Values

States	Vulnerability Ranking	FOREST	PCI	POP	MARLAND	MGNREGA	ROAD	Drivers of vulnerability
J&K	1	10%	52831	56	46.51	36	0.16	Lowest FOREST, high MARLAND and low ROAD.
Himachal Pradesh	5	26%	105269	123	28.63	42	0.91	A high PCI saves the state from being more vulnerable.
Uttarakhand	6	46%	116557	189	36.23	32	0.98	High PCI and modest FOREST are reducing vulnerability.
Sikkim	12	47%	177441	86	13.88	43	0.79	High PCI & low MARLAND make Sikkim the least vulnerable state.
Meghalaya	9	77%	58488	132	16.08	48	0.54	In spite of very low ROAD, low MARLAND and high FOREST have saved the state from becoming more vulnerable.
Tripura	10	75%	58888	351	49.03	88	2.79	High MARLAND is the main driver of vulnerability.
Mizoram	8	90%	70552	52	28.79	22	0.54	In spite of highest FOREST and modest PCI, the utter failure of MGNREGA causes much vulnerability.
Manipur	4	76%	43348	128	23.36	22	0.86	Lowest PCI and low MGNREGA are the main drivers of vulnerability for Manipur.
Nagaland	11	79%	58998	119	0.31	22	2.12	While MARLAND is very low, low PCI and low MGNEREGA act as drivers of vulnerability.
Arunachal Pradesh	7	80%	82874	17	19.63	14	0.18	Very low ROAD and MGNREGA have made the state so vulnerable.
West Bengal	2	19%	78903*	1028	52.47	33	3.55	Extremely high POP and MARLAND are the main drivers of vulnerability.
Assam	3	35%	45692	398	25.83	22	3.62	In spite of highest ROAD, modest POP and MARLAND, low MGNREGA, and FOREST has made the state so vulnerable.