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Climate Vulnerability Assessment *for* Meghalaya

Using a Common Framework at District Level Assessment

(2018-2019)

IHCAP Indian Himalayas Climate Adaptation Programme

Indian Institute of Technology Mandi

Vulnerability Assessment

Climate change is resulting in new threats and uncertainties undermining the socio-economic development in Meghalaya. A comprehensive understanding of the key risks and vulnerabilities based on robust research is a pre-requisite for planning for adaptation. The multiplicity of challenges in the State at spatial level calls for the need of a coordinated and integrated approach for adaptation planning.

A common framework for vulnerability and risk assessment was developed by the Indian Institute of Science (IISc), IIT- Guwahati and IIT- Mandi. This common framework can be applied to understand and bring out a vulnerability profile of the each vulnerable sector.

The Meghalaya Climate Change Centre organised a 3 day programme on "Level 3: Training Programme for District Level Officials & Level 4: Training of Trainers Programme on Climate Change Adaptation" at Shillong. The training programme saw representatives from 14 State Government departments brought together to enhance their understanding about vulnerability and risk, availability and requirement of datasets and to map the vulnerability using the common framework.

The training programme highlighted:

1. Hands-on training in carrying out the vulnerability assessment and developing the vulnerability maps
2. Identifying a set of common indicators for district-level vulnerability assessment and mapping
3. Identifying a set of common indicators for block -level vulnerability assessment and mapping
4. Discussion on and finalization of the weights to be given to each of the indicators and finalization of the same
5. Departments carrying out a mock sector vulnerability assessment and presenting the results and receiving feedback

This manual along with the training conducted shall provide the necessary impetus to carry out a sectoral vulnerability assessment at district/block level (since data may be available prior to the bifurcation of districts we suggest that Block level data may be considered upon which statistically the blocks will be regrouped to create the 11 present districts). The Centre will provide all necessary assistance and will also act as a catalyst to ensure that a sectoral vulnerability index/map of the State is developed.

The primary aim for the departments will be to identify the important indicators (along with their rationale) for each sector, this will be followed by the assigning of weights to the indicators (again, along with the rationale).

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. 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. Need for Vulnerability Assessment (VA)

Vulnerability assessments help us to:

1. Identify the areas/systems/communities that are vulnerable.
2. Assess the extent of vulnerability.
3. Identify the drivers of vulnerability.
4. Plan adaptation actions.
5. 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
Identifying the need of VA	VA is required under following conditions: • Exposure to climatic stressors • Importance of the (vulnerable) system • Ability to take adaptive measures • Persistence of vulnerable conditions and degree of irreversibility (of consequences) • 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.
Region & unit of VA	The geographical area where VA is carried out and the units of assessment.
Defining the objectives	Identify the most vulnerable areas (i.e. regions/communities/systems) Gain direction for adaptation planning. A well-defined set of objectives is needed before framing the study procedure.
Identifying the stakeholders	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.

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 Sub-tropical pine forests in Meghalaya)

ii. Socio-economic vulnerability study (e.g., VA for agrarian community in Meghalaya)

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 manual will focus on integrated vulnerability study where each of the Departments 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 District-level VA map for Meghalaya 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.).	Departments may take up VA studies for the sub-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., state). It is feasible to do it for a scale in between.	Current VA will focus on 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 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 district-level VA in Meghalaya. 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 Meghalaya

Indicators	Indicator Type	Rationale	Relationship with Vulnerability	Data source
Population Density (PD)	Socio-economic	Pressure on available natural resources increases sensitivity.	Positive	Census of India Report (2011)
Below Poverty Line (BPL)	Socio-economic	Higher percentage of BPL indicates lesser adaptive capacity.	Positive	HDR Meghalaya (2008)
Female Literacy Rate (FLR)	Socio-economic	Educated individuals and societies (especially with high female literacy) have better preparedness and response to disasters, suffer lower negative impacts, and are able to recover faster and hence have higher adaptive capacity.	Negative	Census of India Report (2011)
Infant Mortality Rate (IMR)	Socio-economic	Infant Mortality Rate is an indicator of the overall state of the public health, access to improved water, sanitation and medical infrastructure. Higher value implies lack of adaptive capacity.	Positive	Census of India Report (2011)
Food grain Yield Variability	Bio-physical	High variability in yield indicates fluctuations in agro-climatic conditions over time. Agriculture sector has high contribution to the State Domestic Products and employment for the states in IHR. High yield variability reflects lack of adaptive capacity.	Positive	data.gov.in
Percentage of area under forest (%)	Bio-physical	Forests provide safeguard ecological processes, provide biophysical stability and alternate livelihood options through extraction of fodder, fuel wood, and NTFPs. It enhances adaptive capacity.	Negative	FSI Report (2017)
Average person days per household under NREGS	Institutional	Provides alternate sources of income and enhances adaptive capacity.	Negative	http://nrega.nic.in
% area with Slope >30%	Bio-physical	Steep topographical feature implies lack of availability of flat land and difficulty in access; likely to be adversely affected during floods, landslide, cloudburst, etc. and increases sensitivity.	Positive	GIS lab, MBDA

i. *Positive relationship implies that higher the value of the indicator, greater is the level of vulnerability.*

ii. *Negative relationship implies that higher the value of the indicator, lower is the level of vulnerability.*

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 eight indicators for 7 districts of Meghalaya.

Table 5: Actual Value of Indicators in Meghalaya Vulnerability Assessment

Districts	% Area with Slope >30%	% Area under Forest	Yield Variability	PD	FLR	IMR	BPL	Average man-days under NREGS
West Garo Hills	2.81	77.16	2.27	175	62.70	384	53.71	78.81
East Garo Hills	6.65	87.05	2.22	122	70.05	126	55.94	80.13
South Garo Hills	8.84	89.45	0.26	76	66.90	86	45.33	49.93
West Khasi Hills	10.98	75.43	2.29	73	77.19	251	47.66	62.29
East Khasi Hills	21.20	63.72	0.19	300	83.81	900	46.74	37
Ri Bhoi	8.57	87.54	0.16	106	74.49	93	49.94	46.23
Jaintia Hills	7.37	65.54	2.06	103	65.06	308	39.51	65.66

Step 7: Normalization of Indicators

i. All the 8 indicators are quantified/measured in different units. Thus, next step in the Assessment is to normalize the values of each indicator to make them unit-free.

ii. The normalization process varies, depending on the nature of relationship of that particular indicator to Vulnerability.

iii. *Output of this step*: Normalised Value (NV) generated against each indicator's Actual Value (AV).

For e.g., **Actual Value (AV)** of % area under Forest in West Garo Hills = 77.16%

Normalized Value (NV) of % area under Forest in West Garo Hills = 0.48

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.

***Case I**: The indicator has positive relationship with vulnerability:*

$$Normalized\ Value\ (NV) = \frac{(Actual\ indicator\ value - Min.\ indicator\ value)}{(Max.\ indicator\ value - Min.\ indicator\ value)} \quad \text{...............(1)}$$

***Case II**: The indicator has negative relationship with vulnerability*

$$Normalized\ Value\ (NV) = \frac{(Max.\ indicator\ value - Actual\ indicator\ value)}{(Max.\ indicator\ value - Min.\ indicator\ value)} \quad \text{...........(2)}$$

Applying the above rule we calculate the Normalized Value (NV) of each indicator for the 7 districts.

Table 6: Normalized Value of Indicators in Meghalaya Vulnerability Assessment

Districts	Indicator (Type of Relationship with Vulnerability)							
	% Area with Slope >30% (+)	**% Area under Forest (-)**	**Yield Variability (+)**	**PD (+)**	**Female Literacy Rate (-)**	**IMR (+)**	**BPL (+)**	**Average man-days under NREGS (-)**
West Garo Hills	0.00	0.48	0.99	0.45	1.00	0.37	0.86	0.03
East Garo Hills	0.21	0.09	0.97	0.22	0.65	0.05	1.00	0.00
South Garo Hills	0.33	0.00	0.05	0.01	0.80	0.00	0.35	0.70
West Khasi Hills	0.44	0.54	1.00	0.00	0.31	0.20	0.50	0.41
East Khasi Hills	1.00	1.00	0.01	1.00	0.00	1.00	0.44	1.00
Ri Bhoi	0.31	0.07	0.00	0.15	0.44	0.01	0.63	0.79
Jaintia Hills	0.25	0.93	0.89	0.13	0.89	0.27	0.00	0.34

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.

Table 7: Assigned weights against each of the Indicators

Indicators	Weight Assigned **(out of 100)***	Weight Assigned (w) **(out of 1)**	Rationale behind selecting this weight
Population Density	1	0.01	Denser population reflects higher pressure on resources
Below Poverty Line (BPL)	17	0.17	Larger the no. of BPL, higher will be the vulnerability due to low adaptive capacity. Poor economic condition limits/hamper their coping mechanism/measures.
Female Literacy Rate	0.5	0.005	Higher the no. of female literates better is their preparedness & response to calamities, improved decision making ability and enhanced income opportunities.
Infant Mortality Rate (IMR)	3.5	0.35	IMR is an indicator of the overall state of the public health, access to improved water, sanitation & medical infrastructure. Higher IMR indicates poor health conditions in the region.
Food grain Yield Variability	30	0.30	Higher variability in food grain production signifies an upset production leading to farmers' stress and food insecurity.
% area under forest	18	0.18	Forests provide safeguard to ecological processes, biophysical stability and alternative livelihood options. Thus, reduction in forest area leads to lower adaptive capacity.
Average person days per household under NREGS	10	0.10	Low enrolment depicts lower AC of the community and will increase economic disparity
% area with Slope >30%	20	0.2	Higher slope proportion contributes to higher soil erosion and sedimentation, inaccessibility and cause more damage during disasters and extreme climate events.

*while allotting weights to the indicators

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). For example let us consider the case of West Garo Hills.

Table 8: Aggregation of Normalized Indicators & deriving Vulnerability Index Value

Districts	% Area with Slope >30%	% Area under Forest	Yield Variability	PD	Female Literacy Rate	IMR	BPL	Average man-days under NREGS	Vulnerability Index (VI) (∑ NV*w)
West Garo Hills	0	0.48	0.99	0.45	1	0.5	0.86	0	
Assigned Weight (w)	0.2	0.18	0.30	0.01	0.005	0.35	0.17	0.10	
Aggregate **(= NV*w)**	0	0.09	0.30	0.00	0.01	0.01	0.15	0	**0.56**

Step 10: Vulnerability Ranking

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

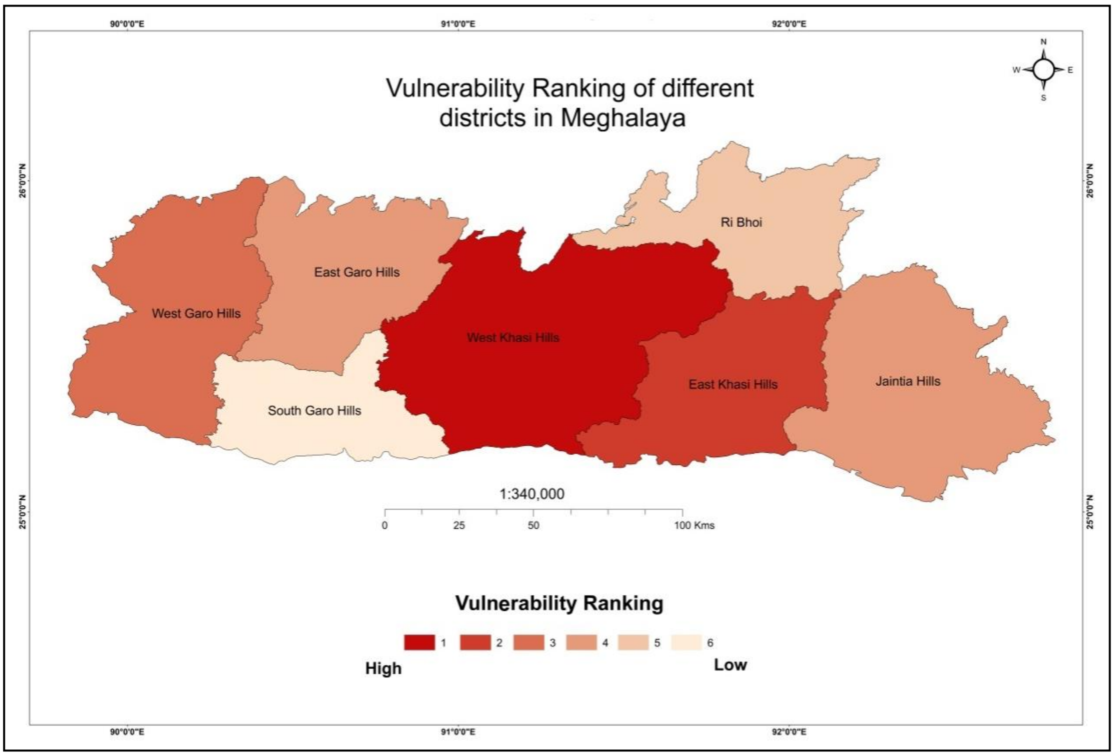
Table 9: Vulnerability Ranking of Districts in Meghalaya

District	VULNERABILITY INDEX (VI)								VI	District Rank VI
	% Area with Slope >30%	% Area under Forest	Yield Variability	PD	BPL	Female Literacy Rate	IMR	Average man-days under NREGS		
West Garo Hills	0.00	0.09	0.30	0.00	0.15	0.01	0.01	0.00	**0.56**	3
East Garo Hills	0.04	0.02	0.29	0.00	0.17	0.00	0.00	0.00	**0.53**	4
South Garo Hills	0.07	0.00	0.01	0.00	0.06	0.00	0.00	0.07	**0.21**	6
West Khasi Hills	0.09	0.10	0.30	0.00	0.08	0.00	0.01	0.04	**0.62**	1
East Khasi Hills	0.20	0.18	0.00	0.01	0.07	0.00	0.04	0.10	**0.60**	2
Ri Bhoi	0.06	0.01	0.00	0.00	0.11	0.00	0.00	0.08	**0.27**	5
Jaintia Hills	0.05	0.17	0.27	0.00	0.00	0.00	0.01	0.03	**0.53**	4

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 colour gradient indicating the level of vulnerability (darker shade indicating a higher level of vulnerability). Graphs, charts or tables too are widely used. Here, we are showing the 7 districts of Meghalaya under study according to their vulnerability ranking (Map 1) and grouping of districts according to their vulnerability (low, medium and high) (Map 2).

Map 1: Vulnerability Ranking of different districts in Meghalaya



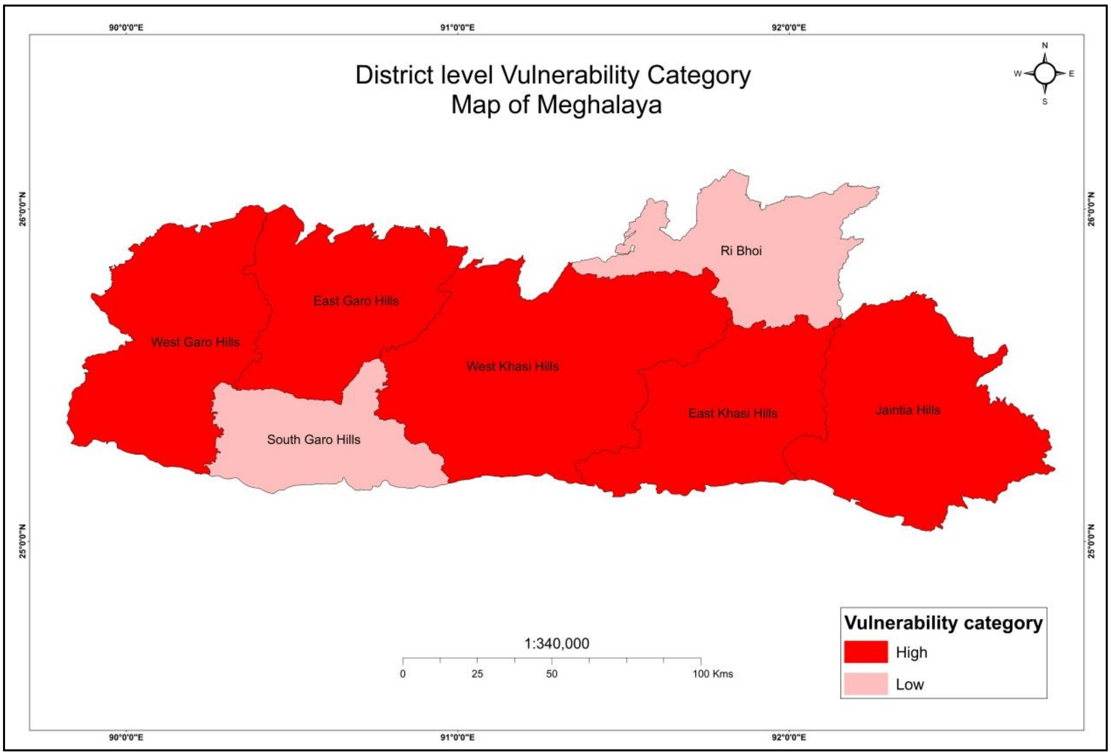
<u>Calculations for Categorization</u>

Max. VI value = 0.62; Min. VI value = 0.21; Range = (0.62 - 0.21) = 0.41

We want to categorize all districts into three categories: 0.41/3 =0.2 (Approx.)

Category 1: **Highly Vulnerable:** 0.5 - 0.7
Category 2: **Medium Vulnerable:** 0.3 - 0.5
Category 3: **Low Vulnerable:** 0.1 - 0.3

District	VI	Level of Vulnerability
West Garo Hills	0.56	High
East Garo Hills	0.53	High
South Garo Hills	0.21	Low
West Khasi Hills	0.62	High
East Khasi Hills	0.60	High
Ri Bhoi	0.27	Low
Jaintia Hills	0.53	High



Map 2: District level Vulnerability Category Map of Meghalaya

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 of the districts based on six chosen indicators.

District	VI Value								Aggregated VI
	Slope	**Forest**	**Yield Variability**	**PD**	**BPL**	**Female literacy**	**IMR**	**NREGS**	
West Garo Hills	0.00	0.09	0.30	0.00	0.15	0.01	0.01	0.00	0.56
East Garo Hills	0.04	0.02	0.29	0.00	0.17	0.00	0.00	0.00	0.53
South Garo Hills	0.07	0.00	0.01	0.00	0.06	0.00	0.00	0.07	0.21
West Khasi Hills	0.09	0.10	0.30	0.00	0.08	0.00	0.01	0.04	0.62
East Khasi Hills	0.20	0.18	0.00	0.01	0.07	0.00	0.04	0.10	0.60
Ri Bhoi	0.06	0.01	0.00	0.00	0.11	0.00	0.00	0.08	0.27
Jaintia Hills	0.05	0.17	0.27	0.00	0.00	0.00	0.01	0.03	0.53
AVG.#1	**0.07**	**0.08**	**0.17**	**0.00**	**0.09**	**0.00**	**0.01**	**0.05**	**0.47**
Drivers#2	**15**	**17**	**35**	**1**	**19**	**1**	**2**	**10**	100

#1 AVG. of Slope = ∑ (VI value of Indicator)/No. of Districts

[#2] Drivers = (Avg. of Indicator) / Aggregated VI * 100

Important findings

1. The districts of West Khasi Hills (0.62), East Khasi Hills (0.60), West Garo Hills (0.56), East Garo Hills (0.53) and Jaintia Hills (0.53) were found to be most vulnerable to climate change in the State.

2. Broadly, Vulnerability of Meghalaya arises from the socio-economic and biophysical factors.

3. The State has 4 major drivers of vulnerability –

- High Food grain Yield Variability (35%)
- High rate of BPL (19%)
- Lack of area under forest (17%)
- Steepness of slope (15%)

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