Journal of Earth Science & Climatic Change
ISSN: 2157-7617

Research Article Open Access

Assessment of District Level Climate Vulnerability of Mizoram, India: Water Resources Approach

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Abstract

Mizoram, one of the north-eastern states in India, is predominantly of rugged hilly terrain with majority of tribal populations living in villages scattered along the upper reaches of hill ranges. The high dependency of people to natural resources, rainfed agricultural practices relying wholly of southwest monsoon makes the region highly vulnerable to climate change exacerbated by poor development infrastructure, land use and land cover change, forest loss and degradation. It is imperative that the vulnerability of the state is addressed to assist in developing practical and reliable plans to increase resilience against long term climate change. The intrinsic properties and infrastructures currently available which corresponds to the sensitivity and adaptive capacity of the state in terms of domestic water resources availability are focused here to assess the inherent vulnerability to unprecedented changes than can be caused by climate stress. The assessment approach follows analytical framework by selecting indicators that defines vulnerability criteria across all the districts in the state. Indicators were given weights are per the best reflection to ground reality with the help of stakeholder consultations. Composite Vulnerability Index (CVI) was calculated for each district from normalized weighted values across all indicators. Districts were ranked and categorized into high, medium, and low vulnerability based on their CVI values which were then represented in geo-spatial map. Important drivers of vulnerability across all districts were then determined by calculating the contributions of each individual indicator to overall vulnerability. The calculated CVI was highest for Champhai district making it the most vulnerable district. CVI was lowest for Mamit district making it the least vulnerable district. Across all districts, limited availability of ground water resources, less forest cover and water stress index were the top drivers of overall vulnerability.

Keywords: Mizoram; Water resources; Vulnerability; Sensitivity; Adaptive capacity; Climate change; Stakeholders

Introduction

Ever since the pre-industrial era, the concentration of greenhouse gases like carbon dioxide, methane and nitrous oxide has increased significantly in the earth's atmosphere largely due to emissions from anthropogenic activities. Their effects of such increases in greenhouse gases have been detected throughout the climate system and are strongly believed to have been the dominant cause of the observed global warming since the mid-20th century (IPCC AR5 2014). The whole state of Mizoram, locating in the adjoining areas of the southern foothills of the Indian eastern Himalayas has been experiencing changes in climate including rising temperature and changes is temporal and spatial distribution of rainfall. The effects of such changes have been evident in the increase events and intensity of climate related hazards and disasters in the state of Mizoram which can be perceived by a common man even without the support of scientific data.

The whole state of Mizoram is characterised by series of hill ranges, rough terrain with steep slopes and deep valleys. The region has diverse climate regimes which are highly dependent on Indian southwest monsoon. Majority of the crops in the state is under rain fed agriculture. The natural resources in the region are subjected to degradation and loss due to deforestation, unsustainable shifting cultivation practices, fragmentation and degradation. Due to the hilly terrain and cultivation of crops along the slopes, the soil resources are also subjected to erosion and loss [1]. Majority of the population in Mizoram are tribal community highly depending on natural resources are living in villages scattered along the upper reaches of hill ranges. Many areas face severe water scarcity during the summer months. As such, the state of Mizoram is highly vulnerable to climate change and climate variability exacerbated by poor infrastructure development in the region [2].

The risks of climate change impacts over different timescales can be reduced through Mitigation and adaptation which are complementary approaches for risk reduction of climate change impacts over different time period. The "first step towards adaptation to future climate change is reducing vulnerability and exposure to present climate variability" [3]. Thus, there is a pressing need to assess the vulnerability of natural ecosystems and or socio-economic systems to current climate risks and long-term climate change as it is a vital preceding step to develop adaptation policies, strategies and practices.

Vulnerability is linked to the intrinsic conditions of a society or system. Vulnerable systems may or may not face climate change risk depending on their exposure to hazards. Vulnerability is defined as the propensity or predisposition to be adversely affected It is an endogenous characteristic of a system and is determined by its sensitivity (degree to which a system is affected by or responsive to climate stimuli) and adaptive capacity (potential or capability of a system to adapt to climatic stimuli or their effects or impacts).

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Received: 16-Feb-2022, Manuscript No. jescc-22-54591; **Editor assigned:** 18-Feb-2022, PreQC No. jescc-22-54591 (PQ); **Reviewed:** 04-Mar-2022, QC No. jescc-22-54591; **Revised:** 10-Mar-2022, Manuscript No. jescc-22-54591(R); **Published:** 17-Mar-2022, DOI: 10.4172/2157-7617.1000609

Citation: Lalthanpuia, Laldinpuii H, Lalmalsawma S, Hrahsel JL (2022) Assessment of District Level Climate Vulnerability of Mizoram, India: Water Resources Approach. J Earth Sci Clim Change, 13: 609.

Vulnerability information enables practitioners and decision-makers to identify the most vulnerable areas, sectors and social groups. In turn, climate change adaptation options can be targeted at specified contexts which then can be developed and implemented [4-6]. Assessing vulnerability to climate change also provide a starting point for identifying measures to adapt to climate change impacts and to efficiently allocate financial and other resources to the most vulnerable regions, people and sectors. Furthermore, climate change vulnerability assessments can be used to monitor and evaluate the success of adaptation measures as well [7].

With the above background, this paper attempts to construct the vulnerability index of different districts of Mizoram by employing the indicator method of quantifying vulnerability. Some indicators from the whole set of potential indicators will be selected and then systematically combining them to indicate the levels of vulnerability [8]. The analysis was carried out for comparative representation of vulnerability at district level in terms of domestic water resources availability.

Materials and methods

Based on the conceptualizations of climate change-related risk from Risk management and assessment framework published in the of IPCC [9-10] developed step by step methods and guidelines for assessing vulnerability following the IPCC AR4 2014 risk assessment framework which was followed and adopted for this study. The following point's shows the step-by-step approach adopted in this study for assessing the district level climate vulnerability of Mizoram in domestic water resources perspective.

1. Scoping of vulnerability assessment (VA): The whole state of Mizoram is vulnerable to natural disasters, coupled with the impact of climate change and climate variability. This calls for a scientific and robust assessment of vulnerability of the state at different levels to identify most vulnerable areas and their drivers of vulnerability for policy makers and planners so that they can prioritize areas for adaptation plans and investment at limited resources.

2. Selection of type of vulnerability assessment: This assessment will be vulnerability assessment of Mizoram at district level on integrated Biophysical and Socio-economic Sectors.

3. Selection of Tier methods: This assessment was conducted using Tier 1 approach which utilizes mainly secondary data from various sources and geo-spatial data.

4. Selection of Spatial scale and period for vulnerability assessment: The spatial scale for this assessment is the political boundary of the pre-existing eight districts of Mizoram. This assessment will be inherent vulnerability under current climate condition. Therefore, data were collected one time during variable years for each unit of measurement to represent the current scenario.

5. Identification, definition and selection of indicators for vulnerability assessment: Identification of indicators was done through literature review, stakeholders and expert consultations. The screening and selection of such identified indicators based on their importance and relevancy to indicate vulnerability were determined through the same processes (Table 1).

6. Quantification and measurement of indicators: All indicators were expressed in terms of numerical numbers that quantifies the values for each district so that mathematical operations can be applied to them. Numerical numbers for certain indicators are input directly from the source of data. For other indicators, further calculations from the data sources were required which utilizes simple mathematical formula to complex Geo-spatial techniques using GIS software.

7. Normalization of indicators: Different indicators were expressed in different units thus cannot be simply used for calculations. To address these issues, indicator values were normalized across all units of measurement. Normalized values are unit free, and they all lie between 0 and 1 (0 implies least vulnerability and 1 implies the highest vulnerability) and can be used for ranking and comparison. The following formulae were used for normalization which depends on whether the indicator has positive (sensitivity indicators) or negative relationship (adaptive capacity indicators) with vulnerability.

Case I: The indicator has positive relationship with vulnerability

$$N\,V = \frac{Actual\ I.V. - Minimum\ I.V.}{Maximum\ I.V. - Minimum\ I.V.}$$

Case II: The indicator has negative relationship with vulnerability

$$NV = \frac{Maximum\ I.V. - Actual\ I.V.}{Maximum\ I.V. - Actual\ I.V.}$$

Where N.V. is Normalized value and I.V. is Indicator value

Table 1: List of indicators selected relevant to districts, rationale for selection, Indicator type, sources of data and weights assigned to them.

Indicators	**Rationale for selection**	**Indicator type**	**Source of data**	**Weights assigned**
Available ground water resource in (million cum) w.r.t total geographical area	Ground water is a source of high-quality fresh water and plays a central part in sustaining ecosystems and enabling human adaptation to climate variability and change (Taylor et al. 2013).	Adaptive Capacity	Public Health Engineering Department, Government of Mizoram (2019)	25
% household piped water connection	Piped water supply can improve drinking water security when coupled with safety norms to reduce water contamination (Global water forum post 2015 agenda)	Adaptive capacity	Public Health Engineering Department, Government of Mizoram (2019)	13
No of perennial springs available per household	The mountain people depend largely on spring water for their sustenance. The mountain springs are also the natural discharges of groundwater from various aquifers. (Tambe et al 2012)	Adaptive Capacity	Public Health Engineering Department, Government of Mizoram (2019)	20
% Forest cover	Forest cover dynamics are an important indicator for climate change and can have a substantial impact on local water resources (Sahin and Hall, 1996: Arnold et al. 2020)	Adaptive Capacity	India State of Forest report 2019	30
Regional Water Stress Index (WSI) $RWSI = 1 - \left(\frac{ET}{ETwet}\right)$ *(ET= Evapotranspiration ETwet = Potential Evapotranspiration)*	The regional water stress index (RWSI) is a part of drough assessment index. It index is an indicator for the regional water deficit. (Sahoo et al. 2019, Gao et al. (2011)	Sensitivity	NOAH land surface model predicted data in Global Land Data Assimilation System. (2019)	12

8. Assigning weights to indicators: Unequal weights were assigned to each indicator in such a way that the total weight of the 5 selected indicators sums up to 100 (Table 1). This was done by a process of consulting with stakeholders and experts which would best reflect the ground reality and relevance for the state of Mizoram.

9. Aggregation of indicators and development of vulnerability index: The normalized values of each indicator were multiplied by their respective weights which produces weighted values for all indicators across all units of measurements. The vulnerability index of each district was determined by aggregating their respective weighted values across all indicators.

10. Vulnerability ranking of the districts in the state: Once Vulnerability Indices (VI) is calculated for all the districts; a comparative ranking was carried out based on the index value. Higher the value of VI of a district, higher will be its rank in vulnerability; rank 1 being the most vulnerable district.

11. Representation of vulnerability; spatial maps, charts and tables of vulnerability profiles and index: 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. Spatial maps with gradient of colours indicating the level of vulnerability will be used along with graphs, charts and tables. The different spatial units measured were also represented below categorically based on their Vulnerability Index relative value between 1 to 4; 1 being low to 4 being very high vulnerability.

12. Identification of drivers of vulnerability for adaptation planning: Most vulnerability studies are conducted as 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. Vulnerability assessment helps in selecting adaptation measures based on the assessment of the drivers of vulnerability. Drivers of vulnerability are indicators used for vulnerability assessment which are expressed as sensitivity or lack of adaptive capacity. Their respective contributions to Composite Vulnerability Indices are quantified and represented as their magnitude. For determining the drivers of vulnerability for the whole state of Mizoram, the weighted values across all districts were averaged for each indicator thereby resulting in every indicator having their own weighted values. The percentage score of the weighted value an indicator from the sum of weighted values of all indicators was then considered as the percent contribution of that indicator to the overall vulnerability (drivers of vulnerability); higher percent score indicates higher contribution to vulnerability. The drivers of vulnerability for each district were also calculated separately by taking the percentage score of their respective weighted value in each indicator from the sum of their respective weighted values across all indicators.

Results and Discussion

a. **Vulnerability profile and ranking of districts**

(Table 2) above and (Figure 1) below shows that Champhai district have the highest vulnerability index value (0.782) comparatively to the other seven districts in the state of Mizoram which place it in vulnerability rank 1 indicating it to be the most vulnerable district against climate variability and climate change in terms of domestic water resource availability. Similarly, Siaha district scored the vulnerability index value of 0.777 and was placed in rank 2 followed

Figure 1: Map showing Vulnerability index values and corresponding vulnerability ranks and categories of districts in the state of Mizoram against climate change and climate variability to water resources.

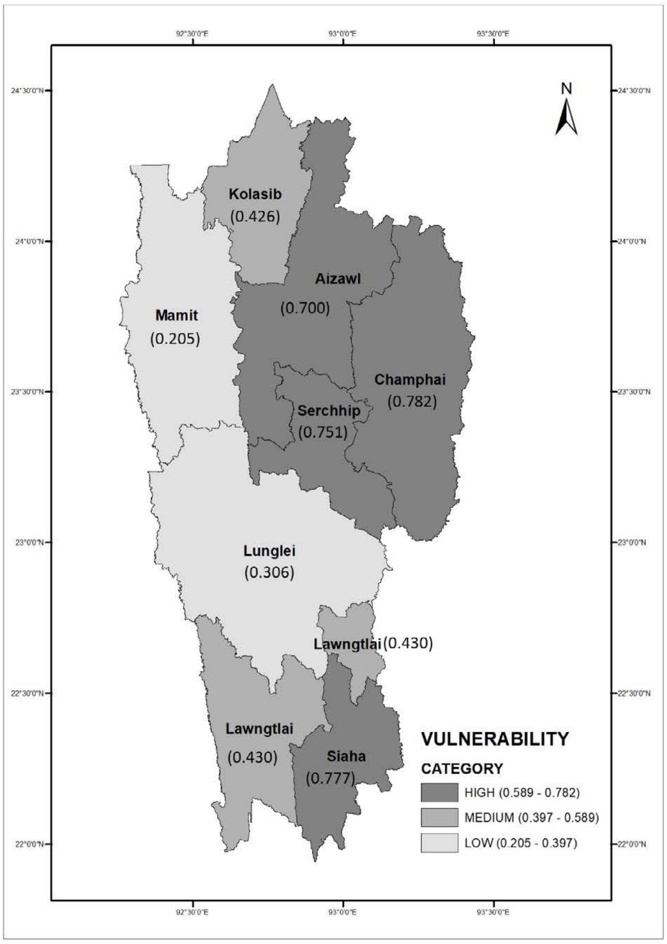


Table 2: Indicator Actual values and normalised values for each of the indicators, for all the districts in Mizoram.

Districts	Available ground water resource in (million cum) w.r.t total geographical area		% household piped water connection		No of perennial springs available per household		% Forest cover		Regional Water Stress Index (WSI)	
	AV	NV	AV	NV	AV	NV	AV	NV	AV	NV
Aizawl	0.39	1.00	4.52	1.00	0.00	0.94	86.52	0.35	0.99999983	0.17
Champhai	0.43	0.96	13.10	0.00	0.01	0.66	81.73	0.97	0.99999986	0.53
Kolasib	1.29	0.11	10.39	0.32	0.00	0.97	85.53	0.48	0.99999982	0.00
Lawngtlai	1.40	0.00	8.54	0.53	0.01	0.74	86.90	0.30	0.99999990	1.00
Lunglei	1.14	0.26	5.68	0.86	0.03	0.00	88.67	0.08	0.99999988	0.75
Mamit	1.40	0.00	12.72	0.04	0.01	0.74	89.26	0.00	0.99999985	0.35
Serchhip	0.53	0.87	5.79	0.85	0.00	1.00	86.13	0.40	0.99999990	1.00
Siaha	0.63	0.77	5.96	0.83	0.01	0.80	81.49	1.00	0.99999988	0.76

by Serchhip in rank 3 (0.751) and so on. Mamit district scored the least number of vulnerability index value (0.205) making it the least vulnerable district.

The ranking of districts based on the vulnerability index values are relative and comparative in nature. In other words, Mamit district is only least vulnerable to climate change as compared to other district and it does not mean that it is at all not vulnerable. It is also important to note that the comparative analysis is also based on a set of selected indicators to determine the vulnerability index values for different districts.

Each districts will have their own specific problems and an extent of their own level of vulnerability. Therefore, when looking at the result such as this study, it is important to consider the determinants (indicators used) of vulnerability index values, weights given and disparities in the value of indicators across districts which are the key factors of differences in the vulnerability index values across the districts.

Based on the three categorical divisions of vulnerability mentioned earlier in the methodology, Siaha, Serchhip Champhai and Aizawl districts were placed in High vulnerability category, Lawngtlai district in Medium category, while the other three districts; Kolasib, Lunglei and Mamit districts were all placed under low category. It is important to note that vulnerability category is a division based on mathematical class interval of the vulnerability index values and are relative in nature.

b. **Drivers of Vulnerability**

i. **Overall Vulnerability**

ii. **District Wise Drivers of Vulnerability**

Based on the percent contribution of each indicators across all districts to aggregated vulnerability index value of all indicators averaged across all districts, limited availability of ground water resources contribute highest (26.76%) to overall vulnerability followed by less forest cover (23.36%), water stress index (22.65%), limited availability of perennial spring per household (14.05%) and limited piped-water connection for household (13.18%) (Figure 2).

Similarly, drivers of vulnerability and their respective percent contribution for each districts were shown in Figure 3 (a to h) below in order of vulnerability ranking from 1 to 8. These Figures highlight differences in drivers of vulnerability from district to district in contrast to the overall picture for the whole state of Mizoram shown in Figure 2. For instance, %), limited availability of perennial spring per household is the top contributor of vulnerability for Champhai district whereas

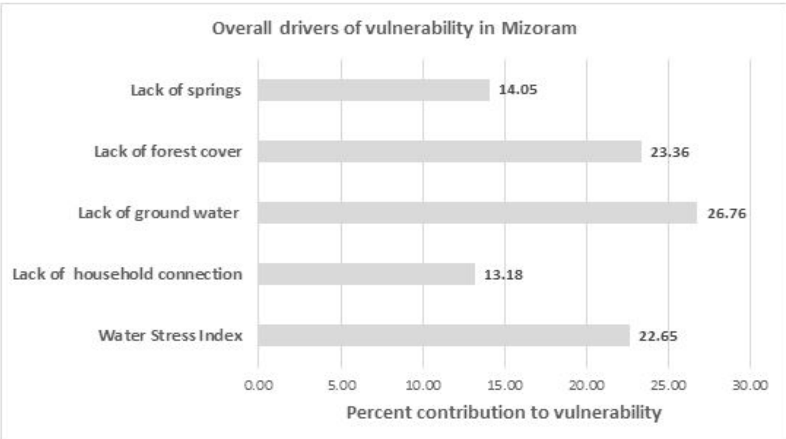
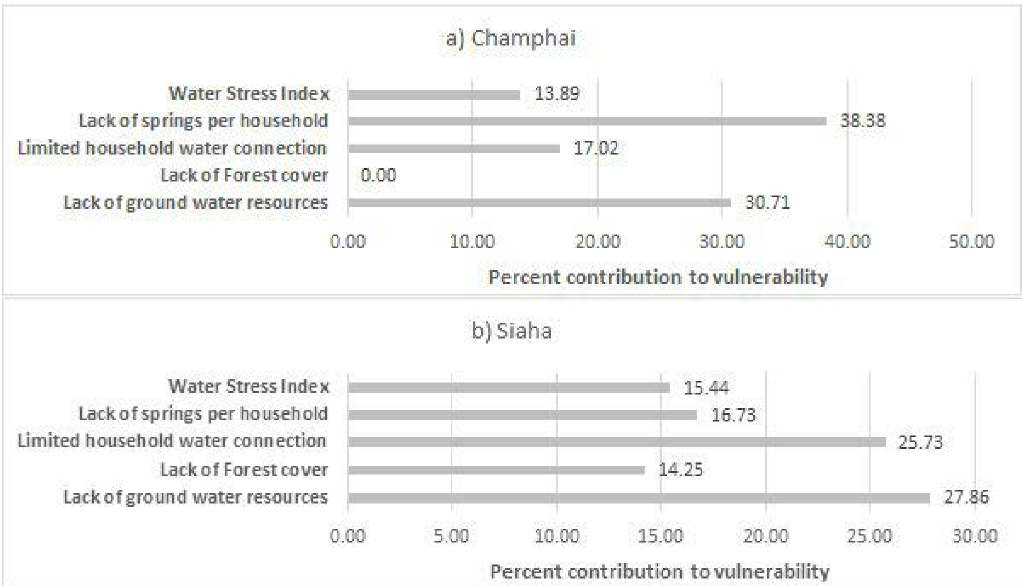


Figure 2: Bar diagram showing overall drivers of vulnerability: indicators and their corresponding percent contribution to overall vulnerability against climate change and climate variability to water resources for the state of Mizoram.



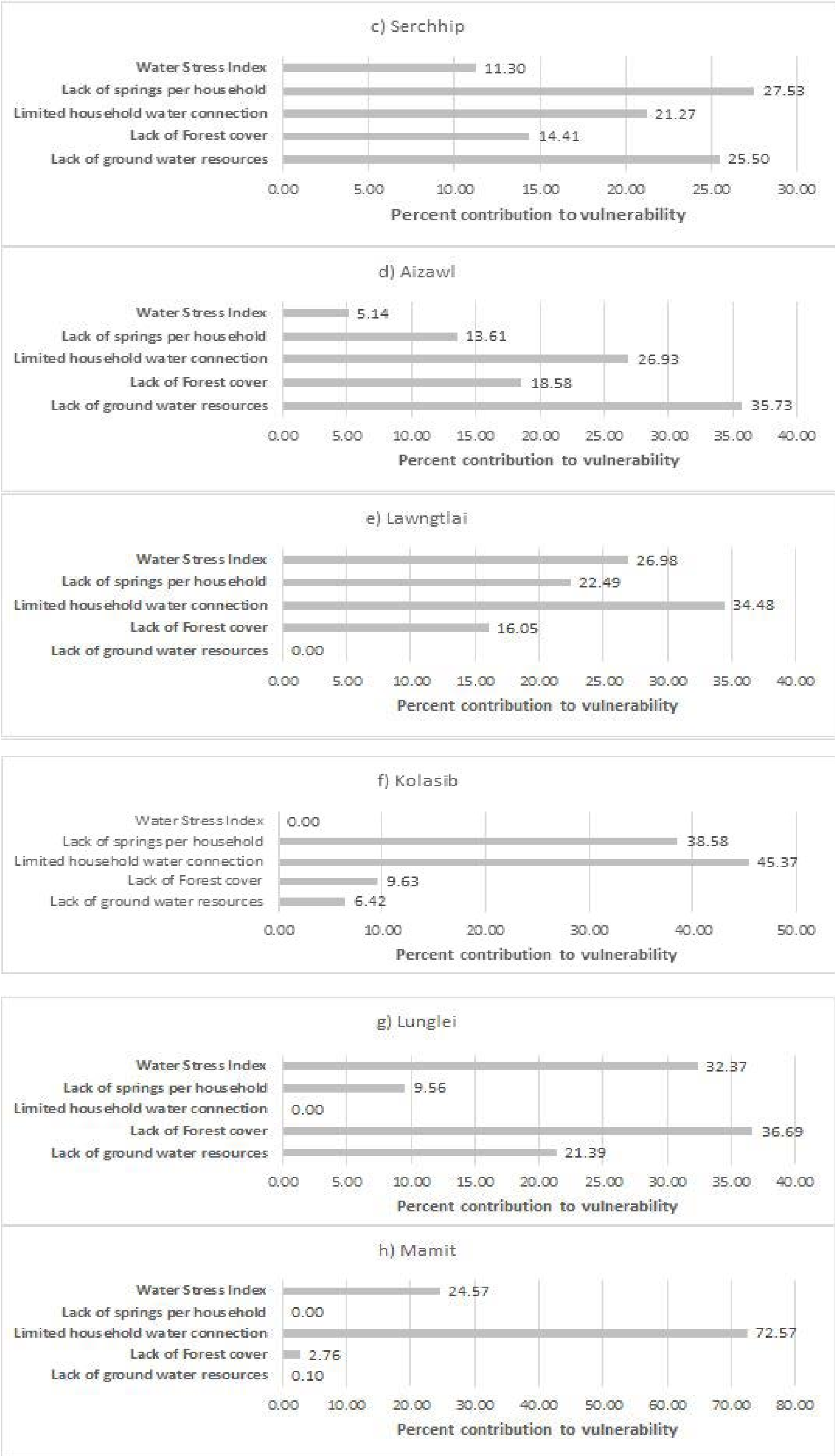


Figure 3 (a to h): Bar diagram showing drivers of vulnerability: indicators and their corresponding percent contribution to overall vulnerability for all districts in the state of Mizoram against climate change and climate variability to water resources.

limited availability of ground water resources is the top contributor of vulnerbility for Champhai district. Likewise, the top contributors and their relative comparison can be seen in the Figure 3 (a to h).

Conclusion

The result of vulnerability assessment can be highly subjective without careful examination of ground reality when assigning weights to indicators. Vulnerability is a relative measure i.e.; the above ranking is a comparative analysis between districts. Hence, it does not imply that districts having lower value of vulnerability indices are not vulnerable; they are comparatively less vulnerable than districts having high vulnerability index values. While measuring vulnerability using selected indicators, one should note that there can be other inherent characteristics that can be used as indicators to measure the vulnerability of the same study area. Therefore, it is important to carefully examine most suitable indicators. It is evident that the overall drivers of vulnerability are not homogeneous for each and every district. Districts may have specific problem or characteristics that need to be addressed separately. Therefore, vulnerability assessment does not end at this Tier 1 approach study, it is advisable that assessment of vulnerability should be repeated at finer resolution at block/village level/community level using primary data of location specific indicators

Acknowledgement

The authors would like to thank the SPLICE-CCP, Department of Science and Technology, Government of India for their support and provision of resources for the work.

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