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Assessing Vulnerability and Resilience in the Face of Climate Change: A Case Study of North - East India

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Abstract
The North Eastern Region (NER) possesses ecological and strategic significance for India. Hence, socio- economic stability of the region is of utmost importance. However, the NER is critical from the climate change perspective due to the majority of the rural population and the economy based on natural resources and climate-sensitive sectors - agriculture, water resource, and forestry. The region is not properly equipped to handle the adversities of climate change impacts. Analysis of climate change impacts and vulnerabilities at the state level of North-East India is, therefore, necessary to develop adaptation strategies. In this backdrop, the present study assesses the climate change vulnerability of eight North-Eastern states - Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura to climate change impacts, using the Vulnerability-Resilience Indicators Model (VRIM after Moss et al. 2001). For this purpose, proxies have identified and used for various sectors of climate sensitivities and coping-adaptive capacity. The outcome has analyzed at the state level regarding relating the values of VRIM with the respective socio-economic situation to find out the sources of vulnerability. This methodological framework will help policymakers, analysts and stakeholders to systematically evaluate individual as well as sets of indicators to identify the vulnerable areas and sectors. Concluding section of this study offers some practical policy measures that would substantially reduce vulnerability to climate change and improve long-term resilience in the NER.

Keywords: Climate Change, Coping-Adaptive Capacity, North Eastern Region, Sensitivities, Vulnerability-Resilience Indicators Model

1. Introduction

Vulnerability to climate change is the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with the adverse impacts of climate change whereas, resilience is the degree to which geophysical, biological and socio-economic systems rebound, recoup or recovers from adverse effects of climate change (IPCC 2007). India is among the most critical countries in the world regarding climate change sources and impacts. Heavy dependency on the environment for food and livelihood make Indians vulnerable to the climate change impacts. Socio-economic set up of an area determines the extent and intensity of vulnerability to climate change in that area. A better understanding of the future behaviour of the climate variability is, therefore, necessary for disaster mitigation and for developing adaptation strategies. In this context, assessing the vulnerability to climate change in India is an essential component of formulating adaptation strategies especially in the areas and sectors where vulnerability is high.

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There are eight states in the North-East Region of India, covering about 26.2 million hectares of geographical area and approximates 40 million population (Ravindranath et al., 2011). Out of the total population, the rural community consists of 82 percent. Additionally low density of population, dominance of indigenous tribal communities (34-91 percent), dependence of the population on natural resources, and poor infrastructure development are some of the drawbacks of the region. The region relies on the southwest monsoon for agricultural purpose, which makes food production vulnerable to climate change.

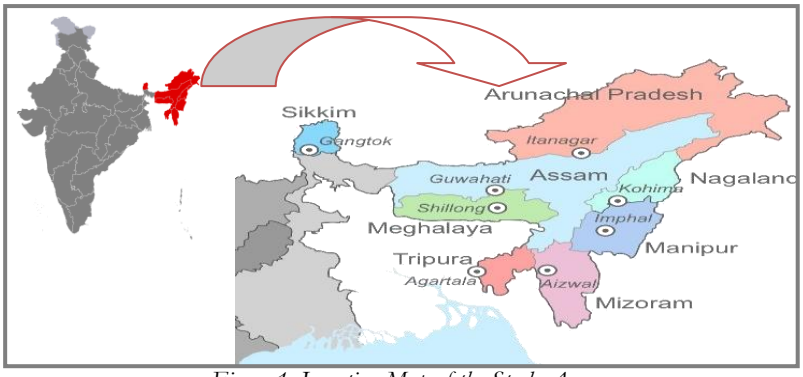

Figure 1: Location Map of the Study Area

Extensive deforestation, unsustainable jhum cultivation, land degradation, land fragmentation and biodiversity loss are threatening the natural resources of the states. Rural population growth, increase in livestock population, overgrazing, fuelwood extraction, mining, and forest fire, shortening of jhum cycle, lack of land ownership rights and rising horticulture are the major reasons of deforestation in North East India. Along with deforestation, hilly terrain and slope cultivation cause soil erosion and loss. Many districts face severe water crisis during the summer. In this article, the overall implications of climate change and vulnerability in each of the North East states has been assessed to identify the vulnerable sectors to climate change. State wise vulnerability profiles are developed for all the eight states. This is a first of its kind study conducted in North East India whereby the local scale of vulnerability assessment is utilized. Also, the Vulnerability-Resilience Indicators Model provides a comparable quantitative mechanism, which can be readily applicable to the other states of India.

2. Objectives

The present study has the following objectives:
(1) to assess the degree of vulnerability of India's North Eastern Region to climate change.
(2) to relate the vulnerability of each state with their respective socio-economic scenario.
(3) to compare the states regarding vulnerability to climate change.
(4) to offer practical policy measures to reduce vulnerability to climate change and improve long-term resilience.

3. Methodology and Data Sources

To assess the vulnerability and resilience capacity of North–East states to climate change impacts, this study aims to follow the method guided by Moss et al. (2001) to identify proxies for five sectors of climate sensitivities and three sectors for coping and adaptive capacity. Table: 1 lists the proxy variables that were used in constructing the subcomponents of the Vulnerability-Resilience Indicators Model (VRIM).

Table 1: Data-based sectors, indicators, and proxies for sensitivity and coping/adaptive capacity (After Moss et al. 2001)

	Sector	**Indicators/Data**	**Proxy for**
	Settlement or infrastructure sensitivity	Population without access to sanitation	Accessibility to basic services is buffer against climate change impacts
Sensitivity	Food Security	Cereals production/ cropland area	Availability of food offers a buffer against climate change impacts
		Protein consumption/ capita	Availability of alternate food sources during shortfalls in food crop
	Ecosystem Sensitivity	Percent of land managed	The degree of human interference into nature and land fragmentation/degradation
		Fertiliser use/cropland	Nitrogen/Phosphorous loading of ecosystem and stresses from pollution
	Human Health Sensitivity	Completed fertility Life expectancy	Composite of conditions affecting human health (nutrition, exposure to death risk) and access to health facilities
	Water Resource Sensitivity	Renewable supply and inflow Water use	Water supply from internal renewable sources and inflow from rivers Withdrawals to meet current or projected needs
Coping and Adaptive Capacity	Economic Capacity	GDP (market/capita)	Duration of access to markets, technology, and other resources required for adaptation)
		Gini Index (a measure of income equity)	The potential economic contribution of all people
	Human and Civic Resources	Dependency ratio	Availability of socio-economic resources after meeting other present requirements
		Literacy	Human capital and adaptability of the labour force
	Environmental Capacity	Population density	Population pressure and stresses on ecosystems
		Sulfur dioxide (SO_2)emissions/ state area	Air quality
		Percent of land unmanaged	Fragmented landscape

Reliable data is essential to maintain the validity, reliability, and generalizability in qualitative research. This study is based on secondary data (government statistics), extremely useful both in defining the population and in structuring the sample. Table: 2 provides proxy wise detail of data sources.

Table 2: Data Sources

Indicator	***Sector***	***Proxy***	***Data Source***
Sensitivity	Settlement/Infrastructure	Percent population without access to sanitation	Census of India 2011
	Food Security	Cereal production/ agricultural land	Agricultural Statistics at a Glance 2014, Ministry of Agriculture, GoI
		Protein consumption/capita	The 68th round of National Sample Survey Office (NSSO), Ministry of Health and Family Welfare, GoI
	Human Health	Completed fertility	Census of India 2011
		Crude Death Rate	Census of India 2011
	Ecosystems	Percent of land managed	Indiastat 2014
		Fertilizer use/ cropland area	Indian Fertilizer Scenario 2013, Department Of Fertilizers, Ministry of Chemicals and Fertilizers, GoI
	Water Resources	Renewable supply and inflow of water	Central Ground Water Board, Hydrology Project, Ministry of Water Resources 2014, GoI
Coping-Adaptive Capacity	Economic Capacity	GDP per capita	CSO 2014
		Gini Index	Planning Commission 2014, GoI
	Human and Civic Resources	Dependency ratio	Social And Cultural Tables, Census of India 2011
		Literacy	Census of India 2011
	Environmental Capacity	Percent of non-managed land	Indiastat 2014
		SO_2/area	Central Pollution Control Board 2014 and State Pollution Control Board 2014
		Population density	Census of India 2011

Following Moss and Malone (2012), the method to obtain VRI is hierarchical (Table: 3) with four levels. The vulnerability index (level 1) is derived from two indicators (level 2) - sensitivity (how systems could be affected by climate change) and coping-adaptive capacity (the capability of a society to minimize the loss or maximize gains for welfare). Again, sensitivity and adaptive capacity are composed of sectors (level 3, the left-hand column of the table: 1). Each of these sectors is made up of 1 to 3 proxies (level 4, the middle column of the table). Next to this, table: 3 shows the method to calculate the final index. The values of each of the hierarchical level are obtained from the geometric means of the participating values. The values for VRIM for the NER states are obtained from the geometric mean of all the sector values.

Table 3: Method to construct the VRIM for North-East India, 2013-14

Steps in the hierarchy	- geometric mean of proxies > sector indices - geometric means of indices > sensitivity or coping-adaptive capacity - geometric mean of sensitivity and coping-adaptive capacity indices > Vulnerability-Resilience Index
Sensitivity Index	kept as positive value
Log Transforms	applicable when there are extremely high or low values in the data sets
Normalization of data	Z Score, $z = (x - \mu) / \sigma$ Where x= value, μ= mean, σ= standard deviation

4. Limitations and Scope of the Study

The study has the following limitations:
(1) Moss et al. (2001) identified 17 proxies for the construction of VRIM. However, data on "Population at flood risk from sea level rise" is not available for the North-Eastern states as these states are inland states; hence to maintain the continuity in the assessment, author removed this proxy and used 16 proxies.
(2) Since Life Expectancy data is not available for all of the North-East States, Crude Death Rate has considered as the proxy for Life Expectancy following the criteria are given by The Ministry of Development of North Eastern Region, Government of India.
(3) The author has used the data of 2013-14 for all of the proxies, which the latest data provided by the government source.
There is further scope for research in these limitations.

5. Sensitivity Index Analysis for the North Eastern States

5.1 Sensitivity Assessment for the Settlement/Infrastructure Sector

The population is vulnerable to climate variabilities when they don't have/ have less access to basic infrastructural facilities - clean water and sanitation. In Assam, maintenance of cleanliness and personal hygiene is an age-old practice, and environmental sanitation is also part and parcel of rural lifestyle of some of the communities. Open defecation is not practiced in rural areas. As per Census of India 2011, the percentage of service latrines in rural areas of NER states is much higher than all India average. Against the national figure of 1.2 percent, the statistics for NER states are high for the states of Manipur (9.4 percent), Arunachal Pradesh (5.3 percent), and Meghalaya (4.3 percent). The service latrines in urban areas are also higher than the all India average in some of the NER states. As against the national average of 1.6 percent of urban households using service latrines the percentage is as high as Arunachal Pradesh (11.6 percent), Manipur (9.3 percent) and Meghalaya (5.1 percent). Sikkim, Mizoram, Nagaland, Manipur, and Meghalaya are among the top ten cleanest (based on the percentage of households having sanitary toilets and using them) states in India (PTI, Livemint, 2016). Access to basic and essential services acts as a buffer against climate variability and change. In the case of NER, the entire region is safe regarding possessing secure and safe settlement infrastructure (Figure: 2).

5.2 Sensitivity Assessment for the Food Security Sector

Food Security is a factor which enables the population to withstand the effects of climate change on their lives. Food security is relied on the agricultural productivity and access of farmers to mechanisms ensuring the protection of crops from the climate variability and change. Rice is a staple food of the entire NER. Assam, Tripura, Manipur, and Nagaland are leading rice-producing states among the NER. In spite of the acidic nature of soils in the states, pulse production is not encouraging. However, Assam (68.55 thousand tonnes) followed by Manipur (26.85 thousand tonnes) and Nagaland (34.63 thousand tonnes) are the top pulse producers in the NER. Regarding food grains production, the increase was highest in Manipur (66 percent in 2014 compared to between 2003). Northeastern India is a non-milk-drinking region; hence the demand for protein diet is supplemented by consuming eggs, meat, and fish, especially in the Assam, Tripura, Manipur, and Nagaland (Lewis, 2016). Hence, these states are more food secure than other NER states (Figure: 2).

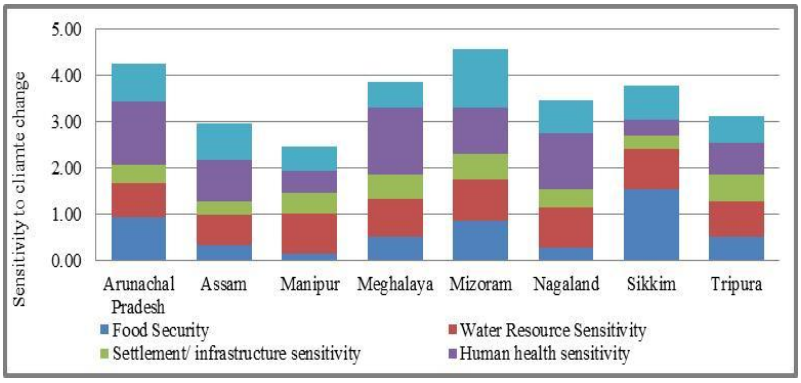

Figure 2: Sensitivity Index for North-East India, 2013-14

5.3 Sensitivity Assessment for the Human Health Sector

Total fertility rate and crude death rate represent the status of human health regarding nutrition, exposure to disease risks, and access to health facilities. Human health, if poor, is prone to be severely affected by climate change. North East is still backward from the point of modern health care services in many states in the region is still an issue. Hence, high fertility and high death rate are indicative of poor health status in the NER. Meghalaya and Nagaland have high levels of fertility. Whereas, the awareness of women to family planning is found to be rated highest in Sikkim with 88.0 percent followed by Manipur 80.8 percent (Singh, n.d.). Sikkim has the lowest fertility rate in India (NITI Aayog, 2017). Many of the NER states are yet to satisfy the existing population coverage norms in one or the other types of health centers. In many states, health centers lack essential facilities and equipment such as operation theatres, X-ray machine, labour rooms, stabilization units for newborn babies, water supply, electricity supply, communication and most importantly well-trained doctors, nurses and health workers. (Saikia and Das, 2014, p. 98). The availability of public health care throughout Arunachal Pradesh is very poor regarding insignificant private participation in the health sector, inaccessibility of the remote, vulnerable poor inhabitants to modem health service facilities,

followed by low life expectancy at birth (Saikia and Das, 2014, p. 86). In Assam, public health and healthcare are still weak. It has over 22 percent shortfall of doctors at Primary Health Center (PHC) level and nearly 43 percent shortfall of specialists at Community Health Centre (CHC) level, antenatal checkups coverage below 50 percent and 50 percent of all new mothers still bereft of post-natal services (MoHFW, 2015). In India, the maternal mortality rate is highest in Assam (Kalita, 2016). Tripura is the bottom 8th state in India regarding total fertility rate, but the death rate is 4.8 percent. Hence the states except for Sikkim and Manipur, are more sensitive to climate change impacts due to prevalent poverty, lack of fresh water and underdeveloped health sector (Figure: 2).

5.4 Sensitivity Assessment for the Ecosystems Sector

The sensitivity of an ecosystem is determined by the degree of human interference into the natural landscape and the use of fertilizer in the cropland area. Increase in both of these factors makes the ecosystem more vulnerable to the impacts of climate change. NER accounts for merely 0.1 percent of the total fertilizer consumption in India (Chanda, 2013). Higher use of fertilizer creates pressure on the resource of the environment followed by environmental degradation. Fertilizer use is the lowest at 2.29 kg/hectare in Arunachal Pradesh (Barah, 2001, p. 18). Arunachal Pradesh ranks first among the NER states regarding total area under Jhum Cultivation, which is 700 km^2. However, it is gradually doing away with the environment deteriorating the age-old practice of jhum cultivation or shifting cultivation (PTI, Times of India, 2013). Also, this state has least population density – only 17 people/km^2. In Assam, fertilizer consumption is 89 kg/hectare and has 696 km^2 of land under Jhum cultivation (North Eastern Secretariat, 2002, p. 42). The entire NER region is ecologically sensitive especially because of jhum cultivation tradition which is a high degree of human interference with the natural landscape. Mizoram's area under shifting cultivation is currently 63 thousand hectares. However, the total Jhum area and the total number of Jhumia families in Mizoram during 2010-11 are 28562 hectares and 68433 respectively (Economic Survey, GoM, 2016, p.45). As a consequence of the implementation of New Land Use Policy (NLUP), there was about 20.75 percent decrease in Jhum areas and 14 percent decrease in the number of Jhumia families in 2013-14 compared to 2010-11 (Planning and Programme Implementation Department, GoM, 2015, p.10). Being hilly region and mostly rural population, the NER accounts for the very low amount of SO_2 emissions. Arunachal Pradesh, Assam, and Mizoram are little more ecologically sensitive than others due to fertilizer use and shifting cultivation system (Figure: 2).

5.5 Sensitivity Assessment for the Water Resource Sector

The North East region possesses an enormous water resource potential which is 34 percent of India's total water resource (Sharma et al., 2010, p.3). The per capita and per hectare water availability in this region is the highest in India (PIB, Govt. of India, 2016). However, less than 5 percent of the existing water potential of the region is being utilized (Goswami, 2005, p. 1). Although the groundwater is available at a shallow depth of within 20 meter, so far only 4.3 percent of the existing groundwater resource has been developed (Mahanta, 2006, p.3) Here access to the groundwater is not a reality due to some physiological reasons. In this region, the thrust faults such as Main Boundary Fault

and Naga thrusts have intensified the steepness of the slope which in turn causes negligible infiltration of water (Islam, 2012, p.2). Expect some parts of Assam valley, most of the regions consist of hard crystalline granites, gneisses, and granulites that block infiltration of rainwater for groundwater recharge (Gupta, 2014). When the regions are already suffering from water availability, climate change can intensify this scarcity and make the community more vulnerable (Figure: 2).

6. Coping-Adaptive Capacity Index Analysis for the North Eastern States

6.1 Coping-Adaptive Capacity of the Economic Sector

Per capita GDP and income inequality have considered the two determinants of the strength or weakness of the economic sector. High GDP/capita indicates access to markets, technology, and other resources useful for adaptation to climate change. On the other hand, measures of income inequity (the Gini coefficient) represent the realization of the potential contribution of all people. Hence high GDP/capita is positively correlated with the coping capacity of a state whereas, Gini coefficients are negatively correlated. Both Sikkim and Mizoram have high per capita income even more than the national average (Rediff, 2012). Arunachal has high per capita income, with 3.5 lakh people living below poverty line. Arunachal has shown a dip of 6 percent in the poverty scale in 2013-14 than in 2004-05. In Tripura, around 6.3 lakh people are below the poverty line (Dey, 2013); however, there have been 23 percent decline in poverty scale in 2013-14 compared to 2004-05 (Chakravarty, 2012). In Manipur 12.5 lakh people are living below the poverty line and, poverty raised by 9.2 percent in 2013-14 than in 2004-05 (Staff Reporter, The Telegraph, 2012). For Meghalaya, per capita income is less than the national average. In Nagaland, although per capita income is pretty high, 4.1 lakh people live below the poverty line. Also, Nagaland has registered a rise of over 12 percent in poverty. Assam has 116.4 lakh persons living below the poverty line, and per capita income is also less than the national average (Staff Reporter, The Telegraph, 2012). Therefore, it can be summarised that Sikkim, Mizoram, Arunachal Pradesh and Tripura are economically more efficient to cope up with climate vulnerability than other NER states (Figure: 3).

6.2 Coping-Adaptive Capacity of the Human and Civic Resources Sector

In the present study, human and civic resources encompass dependency ratio and literacy rate as the determinants. Dependency ratio shows how much social and economic resources are available for adaptation after meeting the needs of dependents. Literacy rate shows the quality of the knowledge, skill, and competency of the labour force. Hence Coping-adaptive capacity tends to improve with declining dependency ratio in a society, whereas increased literacy rate represents skilled, efficient and competent workforce. According to Census of India 2011, the northeastern states have the least proportion of elderly population (people above 60 years) - Arunachal Pradesh is the lowest with 4.6 percent, followed by Meghalaya (4.7 percent), Mizoram (5.2 percent), Nagaland (6.3 percent), Sikkim and Assam (both 6.7 percent), Manipur (7.0 percent) and Tripura (7.69 percent). Tripura, Sikkim, Nagaland, and Mizoram are showing a high level of human and civic resources primarily due to high literacy rates. Assam and Arunachal

Pradesh lack of human and civic resource capacity due to relatively higher dependency ratio and lower literacy rate than other NER states (Figure: 3).

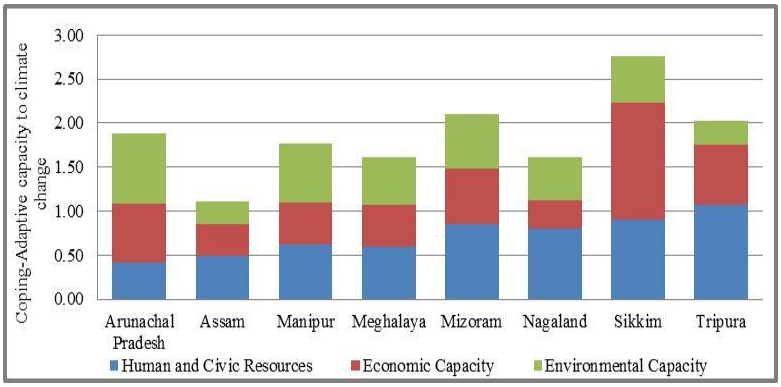

Figure 3: Coping - Adaptive Capacity Index for North-East India, 2013-14

6.3 Coping-Adaptive Capacity of the Environment Sector

This study takes into consideration the density of population, emissions of SO_2 and percentage of land unaffected by the anthropogenic activities as the driving factors of the coping-adaptive capacity of the environment of NER states. The environment becomes more vulnerable to climate change with increasing population density as population pressure and stresses the ecosystem. Also, SO_2 emissions increase pollution and stress the environment. On the contrary, less is the human interference into the land; more will be the resilience capacity of the ecosystem. Arunachal Pradesh (17 person/km^2), Mizoram (52 person/km^2), Sikkim (86 person/km^2) and Nagaland (119 person/km^2) are the bottom four states in the NER due to their remoteness and inaccessibility. These four states are endowed with a higher percentage of forest area to their respective total geographical area. Jhum cultivation system is also gradually reducing in Arunachal and Mizoram. Also, the northeast states have low SO_2 emissions owing to low industrial and transportation activity. However, Assam's coals contain high-sulfur compared to other states of India. The urban centers of Tripura have witnessed a significant increase in SO_2 in the air. Hence greater population density and relatively higher rate of SO_2 have contributed to the lower environmental coping-adaptive capacity for Assam and Tripura (Figure: 3).

7. Vulnerability-Resilience Indicators Model Analysis for the North-East India States

If we look at the VRIM model (Figure: 4), it can be seen that Mizoram, Sikkim and Arunachal Pradesh are showing higher vulnerability resilience than other NER states. These states are showing higher sensitivity than others. Still, these states have a higher coping-adaptive capacity, and therefore they are more. Still, these states have a higher coping-adaptive capacity, and therefore they are more resilient to vulnerability. Assam, Manipur, and Nagaland are less sensitive to climate change impacts however they have a lower adaptive capacity, and consequently, they are less resilient to climate change

vulnerability. Meghalaya and Tripura have a reasonable level of resilience capacity depending upon their coping-adaptive capacity.

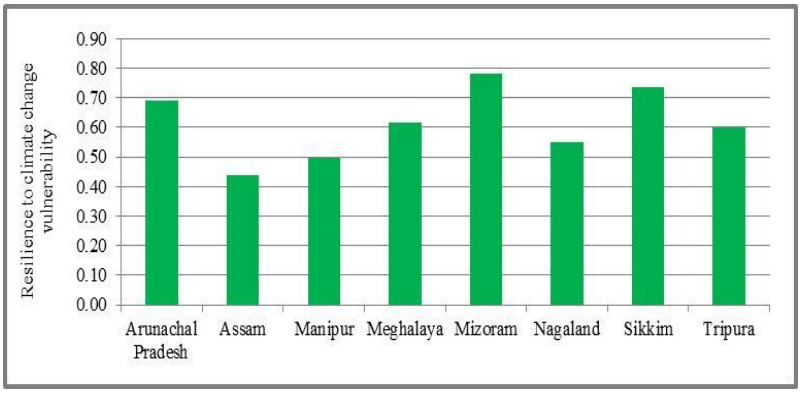

Figure 4: Vulnerability-Resilience Indicators Model for North-East India, 2013-14

8. Conclusion and Recommendations

Depending upon each of the state's performance, following measures can be suggested to the Governments, NGOs, policymakers, and analysts to strengthen the state's vulnerability resilience capacity:

- Arunachal Pradesh needs to improve its literacy rate. Other NER states have provided a primary school within a distance of 1 km - 3km., which is a fundamental minimum requirement to access primary school education facility. Due to connectivity problems, drop-out is very high and severely affecting the efficiency of primary education there. Also, a pupil in this state takes more than seven years to produce a primary graduate than ideally required (5 years). The goal of 100 percent literacy rate cannot be achieved until and unless Arunachal improves the education system. State government should look upon these matters so that people can develop their knowledge and skills to combat climate change variability. Government and NGOs need to promote more and more people to leave the jhum cultivation system and make them stable agricultural people. The state government's focus on agriculture, horticulture, and allied sectors can not only boost the local economy but also protect the environment.
- For Assam, the focus should be given to its economic and environmental capacity to improve its vulnerability resilience to climate change. Assam needs to improve its GDP/capita. The growth rate of state income has remained low for several decades, and it is currently lower even than the national average. Real mean consumption expenditure is declining in the rural areas of Assam. Even, the egalitarian nature of income distribution has not helped Assam to reduce rural poverty. The government can adopt measures to attract private investment, maintain the critical role of the public sector in areas like irrigation, infrastructure and the role of social sectors where private investment might not come forward and, prioritize those sectors that have both comparative advantage and high linkages with other sectors. In Assam, Bongaigaon power projects (three units) are under construction. Also, the government is setting up a mega-thermal

power plant (1,600 MW) at Margherita in Tinsukia district, which would contribute to more SO_2 emissions in future. Measures should be adopted well in advance for removal of sulfur from coal before combustion, to meet the environmental safety.

- Manipur especially requires improving its economic capacity by reducing poverty. The Manipuri population is very much income poverty ridden. Employment in organized and other sectors is low in numbers, and there is no entrepreneurship worth its name. With predominantly tribal population, shifting agricultural economy, the absence of industries and least of urbanization, and improper implementation of Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA), the hill districts of Manipur present a scene of unemployment and poverty. The state and central government require to look after these issues. Improve economic condition would undoubtedly help the people to cope up with the climate vulnerability.
- Meghalaya requires to improve its per capita income (which is currently lower even than the national average). There has been a minimal effort by the state government to improve own generation as evident by the low tax GSDP ratio or to recover the huge loss of revenue to the state on account of evasion of taxes. But no sincere efforts have been made by the state government in this regard. The government has not been very proactive in effective and productive expenditure management. There is a dearth of measures to improve the technical and allocative efficiency in public expenditure. The Government of Meghalaya needs to bring accountability and transparency in the budgets, public funds, and projects. The government should support the cultivation of indigenous rice varieties and Eri silk production.
- Jhum cultivation in Mizoram, one of the main form of agriculture and livelihood of the villagers, is the sources of deterioration of air quality. State government should arrange for alternate means of livelihood for the people and promote them to adopt the stabilized lifestyle.
- Nagaland is suffering in acute poverty. Difficult terrain and poor infrastructure are the major reason behind chronic poverty in this state. Government and NGOs could adopt proper measures to develop infrastructure and reduce poverty as far as possible. Central Government should give special concession for investment in these regions, and More Public Sector Undertakings should be established in these states.
- The government needs to come forward to take proper measures to reduce SO_2 emissions in the thermal power plants in Tripura.

For the overall development of vulnerability resilience of the North - East region, preparation and assistance in implementing State Action Plans on Climate Change, training and awareness building programmes on climate change, proper implementation of water policies and water security plans at village level and inputs for the integrated land and water resources management can be proved fruitful.

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