CLIMATE CHANGE AND ITS ISSUES

MIZORAM CONTEXT

सत्यमेव जयते

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MISTIC MIZORAM

MIZORAM SCIENCE, TECHNOLOGY & INNOVATION COUNCIL

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PREFACE

Climate change is one of the most consequential threads in the tapestry of human history. This phenomenon, which was once a remote and abstract concern, has now become the central issue of our time. Its impact resonates around the world, affecting ecosystems, economies and the very fabric of human society. It illustrates a complex interaction of natural processes and human activities, demonstrating both our vulnerabilities and our capacity for resilience. The repercussions of global warming and shifting weather patterns are far-reaching, affecting everything from fresh water supply to food system stability.

In Mizoram, the effects of climate change are becoming increasingly evident. Shifting weather patterns, rising temperatures and more frequent and excessive rainfall are altering traditional agricultural methods, water resources and the livelihoods of communities that have long depended on the land. The once-reliable monsoon is becoming increasingly unpredictable and the increased frequency of extreme weather events endangers both infrastructure and natural ecosystems.

Climate change is an everlasting threat that is affecting people all over the world. Whether we contribute to it or not, it affects us nonetheless. Since this earth is the only place we have and cannot run away from it, we must try our best to mitigate climate change and adapt to its impacts.

This publication aims to untangle the intricacies of climate change by investigating its sources, effects, and the multiple strategies required to deal with it. We aim to clarify the route forward and motivate action by combining current research, real-world examples, and forward-looking perspectives.

As we embark on this path, remember that climate change is both a challenge and an opportunity—an opportunity to reconsider our relationship with the environment, innovate for sustainability and create a more secure future. Together, we can turn the tide and pave a path toward a more balanced and harmonious relationship with our planet.

Place: Aizawl

Date: 27.8.2024

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INTRODUCTION

In order to comprehend the term "climate", we must first understand what "weather" means. Weather is used to describe atmospheric conditions at specific point in time. For example, it might be raining in the morning, but it might be sunny and bright by noon, and the weather might turn windy or foggy in the evening of the same day. Weather can be classified into five main categories: sunny, rainy, windy, stormy, and cloudy. Nevertheless, a lot of these weather patterns can coincide and overlap. Wind, humidity, precipitation, and sunshine all affect the types of weather that we experience. Therefore, the atmospheric conditions present during a specific time period, such as an hour, day, month, or even a year maybe referred to as the weather of that particular area.

So, what is Climate? Climate can be defined as the typical weather over a period of time ranging from months to thousands or millions of years, including temperature, precipitation, wind, and other weather phenomena. According to the World Meteorological Organization, a period of at least 30 years is required for the standard averaging of these factors. Weather refers to short-term atmospheric conditions, whereas climate is the average weather in a certain place over a long period of time.

The Earth's climatic system is an interactive system made up of living organisms, the land surface, the atmosphere, ice and snow, oceans, and other bodies of water. Over time, the climate system changes as a consequence of both internal dynamics and changes to external factors (called 'forcings') that have an impact on the climate. In addition to human-induced changes in the composition of the atmosphere, natural phenomena like volcanic eruptions and shifts in the sun's rays also constitute external forcings. Solar radiation also powers the climatic system.

There are three primary means to change the radiation balance of Earth:

1) by changing the incoming solar radiation (e.g., by changes in Earth's orbit or in the Sun itself);
2) by changing the fraction of solar radiation that is reflected (called 'albedo'; e.g., by changes in cloud cover, atmospheric particles or vegetation);
3) by altering the longwave radiation from Earth back towards space (e.g., by changing greenhouse gas concentrations).

In turn, the climate reacts to these changes both directly and indirectly via a range of feedback mechanisms.

CLIMATE CHANGE - CONCEPT

Climate change refers to substantial and long-term variations in global temperatures and weather patterns. It is a change in the state of the climate that can be identified (for example, using statistical tests) by changes in the mean and/or variability of its attributes and that lasts for a long time, usually decades or longer.

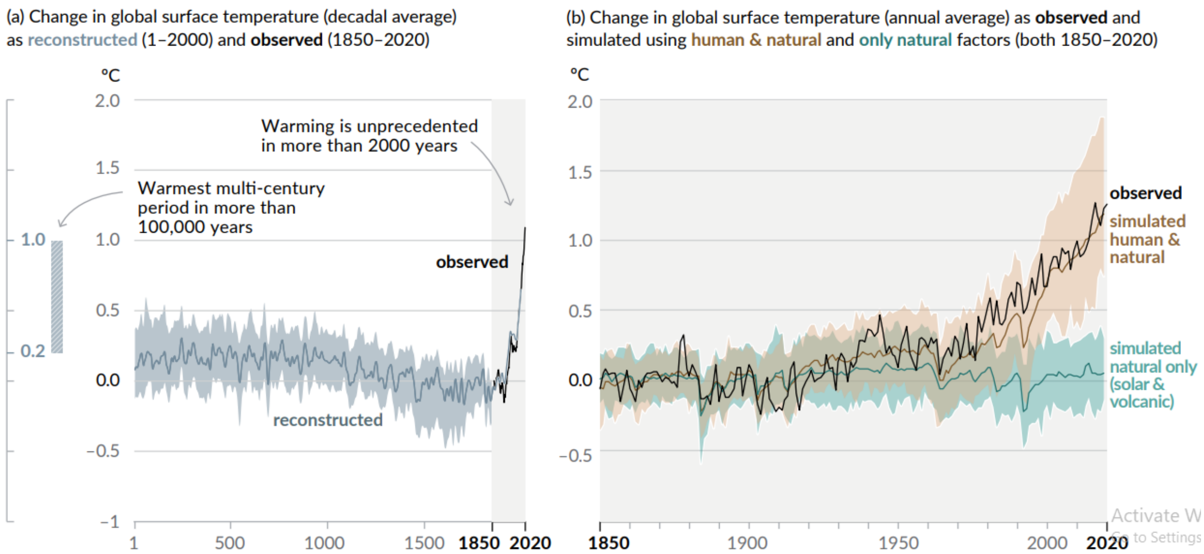
It is mostly caused by human activity, particularly the release of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from the combustion of fossil fuels, deforestation, and industrial operations. Natural internal processes or external forcings such as modulations of the solar cycles and volcanic eruptions also contribute to climatic changes. Addressing climate change requires international cooperation to reduce greenhouse gas emissions, adapt to its effects, and shift to more sustainable practices. This encompasses efforts to promote renewable energy, conservation, and policy changes at all levels of society.

According to Article 1 of The United Nation Framework Convention on Climate Change (UNFCCC), 1992, climate change is defined as: ‘a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods’. Thus, the UNFCCC distinguishes between climatic variability attributed to natural causes and climate change attributable to human activity changing the composition of the atmosphere.

EVIDENCE OF CLIMATE CHANGE (IPCC AR6 2022 Report)

The Intergovernmental Panel on Climate Change (IPCC) and other scientific organizations have extensively reviewed and synthesized evidence on climate change. Their reports consistently conclude that the increase in greenhouse gas (GHG) concentrations since the mid-18th century is unequivocally due to human activities. Thousands of peer-reviewed studies from numerous scientific fields also support the conclusion that human activities are the primary driver behind the rise in greenhouse gas concentrations and the resulting global warming.

The observation that each of the last four decades has been gradually warmer than any preceding decade since 1850 is a significant indicator of continuous global warming. The global surface temperatures were 1.09°C higher in 2011–2020 compared to the period 1850–1900 highlights the significant warming trend observed over the past century and a half. Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years (*Fig. a & b*).



The period around 1750 marks the beginning of the Industrial Revolution, a time of significant technological and industrial advancements. This era saw the widespread use of fossil fuels (coal, oil, and natural gas) for energy, which dramatically increased greenhouse gas (GHG) emissions. In addition to fossil fuel consumption, human activities such as deforestation, land conversion, and agriculture have all contributed to rising levels of greenhouse gases. These activities release stored carbon into the atmosphere, disrupting the natural carbon cycle.

Since 2011, greenhouse gas (GHG) concentrations in the atmosphere have been steadily rising, reaching substantial levels by 2019 (*Fig. c*). The following is an in-depth review of the annual average concentrations of GHG:

I. Carbon Dioxide (CO_2)

- **Concentration:** 410 parts per million (ppm) in 2019.

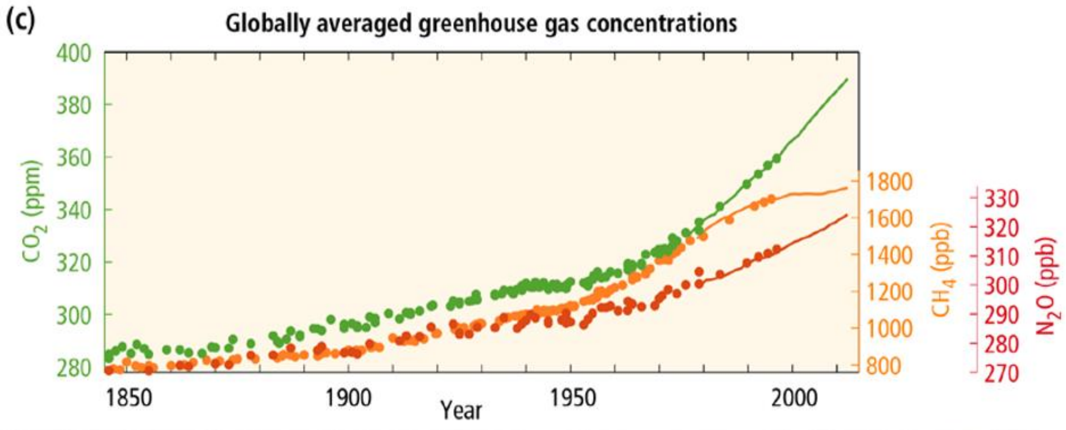
- **Significance:** This level of CO_2 is the highest in at least 800,000 years, based on ice core data. The continuous increase reflects the ongoing emissions from fossil fuel combustion, deforestation, and other human activities.

II. Methane (CH_4)

- **Concentration:** 1866 parts per billion (ppb) in 2019.
- **Significance:** Methane is over 25 times more effective at trapping heat in the atmosphere compared to CO_2 over a 100-year period. The high concentration is primarily due to agricultural activities, fossil fuel extraction, and landfills.

III. Nitrous Oxide (N_2O)

- **Concentration:** 332 parts per billion (ppb) in 2019.
- **Significance:** Nitrous oxide is a potent greenhouse gas with a global warming potential approximately 273 times greater than CO_2 over a 100-year period. Its increase is largely due to agricultural practices, particularly the use of nitrogen-based fertilizers, as well as industrial processes.



Global data suggest that average precipitation over land has been increasing since 1950. This trend is associated with rising global temperatures and changes in atmospheric moisture. The rate of increase in precipitation has accelerated since the 1980s. This is likely related to increased atmospheric moisture content due to higher global temperatures. Warmer air can hold more moisture, leading to more intense and frequent precipitation events. As global temperatures rise, the atmosphere can hold more moisture. According to the Clausius-Clapeyron equation, for every 1°C increase in temperature, the atmosphere's moisture-holding capacity increases by about 7% which can lead to more precipitation.

Mid-latitude storm tracks are the paths that cyclonic storm systems (e.g., extratropical cyclones) follow across the mid-latitudes of both hemispheres. These storms are driven by the interaction between different air masses and are a key feature of the mid-latitude climate. Observational data show that storm tracks in both the Northern and Southern Hemispheres have shifted poleward since the 1980s. This means that storm systems are moving towards higher latitudes (closer to the poles) compared to their historical positions. Climate models and observational studies support this trend, showing that the movement of storm tracks is linked to changes in atmospheric conditions.

Glaciers all over the world have also been receding faster since the 1990s. This is a result of the melting of glaciers being accelerated by rising global temperatures. The Arctic sea ice cover in September has decreased by about 40% from the period 1979–1988 to 2010–2019 when it is typically at its minimum. This reflects a dramatic reduction in the extent of summer sea ice. While the sea ice cover in March, when it is typically at its maximum, has fallen by around 10% over the same time span. Although the decrease is less noticeable in March, it still signifies a significant reduction in winter ice cover.

Volume and surface area are the units used to quantify the melting of glaciers. Research indicates that the pace at which glaciers are losing ice mass is a major factor in the rise in sea level. For instance, according to data from the World Glacier Monitoring Service (WGMS), glaciers have been steadily losing mass in recent years. Glaciers melt quicker as temperatures rise than they can be replenished by snowfall. In certain areas, decreased snowfall as a result of altered precipitation patterns also plays a role in the receding of glaciers. Snowfall is essential for glaciers to replenish lost ice.

Snow cover has decreased significantly in the Northern Hemisphere during the spring months since 1950. This trend is evident from satellite data and historical snow records, showing that snow cover has been decreasing over the past several decades. The months of March, April, and May in particular serve as critical time for observing changes in the amount of snow cover. These months experience less snowfall accumulation and faster melting, resulting in less snow cover.

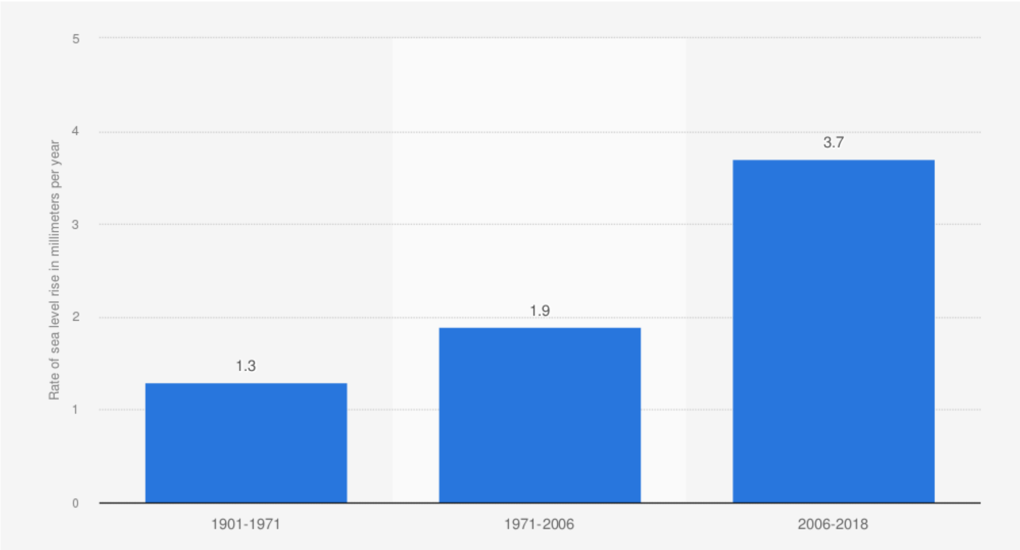
Scientific data have shown that temperature of the upper ocean (0-700 meters) has consistently increased since the 1970s. This warming pattern has been verified using a combination of ship-based measurements, buoy data, and satellite observations. The warming is being tracked using temperature profiles from Argo floats, which detect ocean temperatures at various depths, as well as previous ship-based measurements. Warmer ocean temperatures lead to coral bleaching, which happens when corals eject the symbiotic algae that dwell within their tissues, causing coral death and disrupting marine ecosystems. Many other marine species are also susceptible to temperature variations. It can cause alterations in species distributions, impacting food webs and biodiversity. Some species may even relocate to milder climates or undergo changes in reproductive behaviours.

According to investigations, ocean oxygen levels have already decreased by 1-2% since the mid-20th century. This may seem like an insignificant percentage, but given the size of the ocean, it represents a substantial depletion of oxygen, affecting marine life and ecosystems. Model simulations have indicated that the global ocean oxygen concentration could decrease by up to 7% during the next century. This reduction in oxygen levels is mostly attributed to global warming, which reduces oxygen solubility in warmer waters, as well as increased ocean stratification, which inhibits the mixing of oxygen-rich surface waters with deeper layers. The persistence nature of this decline over a thousand years or more demonstrates the long- term nature of oceanic changes, mostly impacted by ongoing human activity. Efforts to mitigate climate change and reduce greenhouse gas emissions could help slow down or lessen some of these impacts, but the trajectory of ocean oxygen levels will undoubtedly remain an important issue for the foreseeable future.

The World Meteorological Organization (WMO) has reported that the global mean sea-level increased by 0.20m (20 centimetres) between 1901 and 2018. The average rate of sea level rise was 1.3 mm/yr between 1901 and 1971, increasing to 1.9 mm/yr between 1971 and 2006, and further increasing to 3.7 mm/yr between 2006 and 2018 (*Fig. d*). The rate of sea level rise has accelerated in recent decades as a result of the intensified effects of climate change. Projections for the future differ, but if current patterns continue, sea levels are predicted to rise faster, potentially by several meters by the end of the century, depending on greenhouse gas emissions and other factors. The melting of the Greenland and Antarctic ice sheets has become a major issue in recent decades. Ice sheets store an enormous amount of the Earth's freshwater, and their loss contributes significantly to sea level rise.

Rising sea levels may accelerate coastal erosion, endangering property, infrastructure, and natural habitats along coastlines. When storms and high tides occur, coastal areas become more prone to flooding. Additionally, saltwater intrusion into freshwater aquifers can impact agricultural irrigation and drinking water supplies. Communities residing in low-lying coastal areas may face displacement due to the loss of land and increased risk of flooding. The Netherlands, China, Bangladesh, and India are among those who are seriously threatened by sea level rise. It poses a serious threat to cities throughout the globe, including Shanghai, Dhaka, Bangkok, Jakarta, Mumbai, Maputo, Lagos, Cairo, London, Copenhagen, New York, Los Angeles, Buenos Aires, and Santiago, according to a recent assessment from the World Meteorological Organization (WMO).

Fig. d. Average rate of mean sea level rise worldwide between 1901 and 2018 (in millimeters per year)



POSSIBLE CLIMATE FUTURES (IPCC AR6 2022 Report)

According to climate projections, global surface temperatures are expected to continue rising at least until the mid-century, regardless of the emissions scenarios considered. Without considerable reductions in CO_2 and other greenhouse gas emissions, global warming is projected to exceed 1.5°C and potentially reach 2°C above pre-industrial levels by the end of the 21st century. The Paris Agreement intends to keep global warming below 2°C over pre-industrial levels, with efforts to limit the increase to 1.5°C since exceeding these thresholds may result in severe and potentially irreversible impacts on ecosystems, weather patterns, and human societies. Current global emission trajectories, based on current and expected greenhouse gas emissions, indicate that the 1.5°C threshold will most likely be exceeded within the next few decades if no significant changes are taken to reduce emissions.

Implications for Different Emissions Scenarios:-

I. Low-Emissions Scenarios:

Even with aggressive reductions in emissions, temperatures will continue to rise for several decades due to the existing levels of greenhouse gases. However, the rate of increase can be significantly reduced compared to higher-emission scenarios.

II. Moderate-Emissions Scenarios:

Under moderate emissions, temperatures will rise at a higher rate and will likely exceed 1.5°C above pre-industrial levels by mid-century. The impacts will be more pronounced, affecting ecosystems, weather patterns, and sea levels.

III. High-Emissions Scenarios:

In scenarios with continued high emissions, temperatures could rise significantly, potentially exceeding 3°C above pre-industrial levels by mid-century. This could lead to severe impacts, including extreme weather events, widespread ecological disruption, and significant challenges for human societies.

Possible Consequences of Exceeding 1.5°C and 2°C:-

I. 1.5°C Warming:

- **Heatwaves:** Increased frequency and intensity of heatwaves.
- **Sea Level Rise:** Accelerated sea level rise, impacting coastal communities.
- **Ecosystem Disruption:** A higher risk to biodiversity, with significant stress being placed on vulnerable habitats such as coral reefs and polar ecosystems.
- **Extreme Weather:** A higher chance of experiencing extreme weather conditions, such as prolonged droughts and heavy rainfall.

II. 2°C Warming:

- **Significant Risks:** Increased likelihood of severe effects include higher rates of extreme weather events, extensive flooding, and intensified droughts.
- **Ecosystem Loss:** Increased risk of extensive loss of ecosystems and species, with many reaching critical tipping points.
- **Human Impacts:** Increased challenges for food and water security, health risks, and displacement of populations due to environmental changes.

Shared Socioeconomic Pathways (SSPs) are five standard trajectories that depict potential future socioeconomic growth in global or regional societies. These pathways, known as SSP1 through SSP5, comprise scenarios such as Sustainability, Middle of the Road, Regional Rivalry, Inequality, and Fossil-fuel Development. They are used to evaluate and quantify the problems of mitigation and adaptation in various socioeconomic circumstances. The names of these scenarios include the SSP on which they are based (SSP1-SSP5), as well as the predicted level of radiative forcing in the year 2100 (1.9 to 8.5 W/m^2). This results in scenario names SSPx-y.z as listed in *Table a*:

Table (a). Shared Socioeconomic Pathways in the IPCC 6th Assessment Report

SSP	Scenario	Estimated warming (2041–2060)	Estimated warming (2081–2100)	Very likely range in °C (2081–2100)
SSP1-1.9	very low GHG emissions: CO_2 emissions cut to net zero around 2050	1.6 °C	1.4 °C	1.0 – 1.8
SSP1-2.6	low GHG emissions: CO_2 emissions cut to net zero around 2075	1.7 °C	1.8 °C	1.3 – 2.4
SSP2-4.5	intermediate GHG emissions: CO_2 emissions around current levels until 2050, then falling but not reaching net zero by 2100	2.0 °C	2.7 °C	2.1 – 3.5
SSP3-7.0	high GHG emissions: CO_2 emissions double by 2100	2.1 °C	3.6 °C	2.8 – 4.6
SSP5-8.5	very high GHG emissions: CO_2 emissions triple by 2075	2.4 °C	4.4 °C	3.3 – 5.7

SSP1 and SSP5 envision relatively optimistic trends for human development, with "substantial investments in education and health, rapid economic growth, and well-functioning institutions". They differ in that SSP5 predicts this will be driven by an energy-intensive, fossil fuel-based economy, whereas SSP1 anticipates an increasing transition toward sustainable practices. SSP3 and SSP4 are more pessimistic about future economic and social development, citing low investment in education and health in poorer nations, as well as a rapidly growing population and rising inequality. SSP2 is a "middle of the road" scenario in which past development trends are carried over into the 21st century. Although the likelihoods of the scenarios were not estimated in the IPCC Sixth report, a 2020 commentary characterized SSP5–8.5 as highly unusual, SSP3–7.0 as unlikely, and SSP2-4.5% as likely. The description of the different SSPs are as follows:

SSP1 **Sustainability – Taking the Green Road (Low challenges to mitigation and adaptation)**

The world shifts gradually, but pervasively, toward a more sustainable path, emphasizing more inclusive development that respects perceived environmental boundaries. Management of the global commons slowly improves, educational and health investments accelerate the demographic transition, and the emphasis on economic growth shifts toward a broader emphasis on human well-being. Driven by an increasing commitment to achieving development goals, inequality is reduced both across and within countries. Consumption is oriented toward low material growth and lower resource and energy intensity.

SSP2 **Middle of the Road (Medium challenges to mitigation and adaptation)**

The world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns. Development and income growth proceeds unevenly, with some countries making relatively good progress while others fall short of expectations. Global and national institutions work toward but make slow progress in achieving sustainable development goals. Environmental systems experience degradation, although there are some improvements and overall the intensity of resource and energy use declines. Global population growth is moderate and levels off in the second half of the century. Income inequality persists or improves only slowly and challenges to reducing vulnerability to societal and environmental changes remain.

SSP3 **Regional Rivalry – A Rocky Road (High challenges to mitigation and adaptation)**

A resurgent nationalism, concerns about competitiveness and security, and regional conflicts push countries to increasingly focus on domestic or, at most, regional issues. Policies shift over time to become increasingly oriented toward national and regional security issues. Countries focus on achieving energy and food security goals within their own regions at the expense of broader-based development. Investments in education and technological development decline. Economic development is slow, consumption is material-intensive, and inequalities persist or worsen over time. Population growth is low in industrialized and high in developing countries. A low international priority for addressing environmental concerns leads to strong environmental degradation in some regions.

SSP4 **Inequality – A Road Divided (Low challenges to mitigation, high challenges to adaptation)**

Highly unequal investments in human capital, combined with increasing disparities in economic opportunity and political power, lead to increasing inequalities and stratification both across and within countries. Over time, a gap widens between an internationally-connected society that contributes to knowledge- and capital-intensive sectors of the global economy, and a fragmented collection of lower-income, poorly educated societies that work in a labor intensive, low-tech economy. Social cohesion degrades and conflict and unrest become increasingly common. Technology development is high in the high-tech economy and sectors. The globally connected energy sector diversifies, with investments in both carbon-intensive fuels like coal and unconventional oil, but also low-carbon energy sources. Environmental policies focus on local issues around middle and high income areas.

SSP5 **Fossil-fueled Development – Taking the Highway (High challenges to mitigation, low challenges to adaptation)**

This world places increasing faith in competitive markets, innovation and participatory societies to produce rapid technological progress and development of human capital as the path to sustainable development. Global markets are increasingly integrated. There are also strong investments in health, education, and institutions to enhance human and social capital. At the same time, the push for economic and social development is coupled with the exploitation of abundant fossil fuel resources and the adoption of resource and energy intensive lifestyles around the world. All these factors lead to rapid growth of the global economy, while global population peaks and declines in the 21st century. Local environmental problems like air pollution are successfully managed. There is faith in the ability to effectively manage social and ecological systems, including by geo-engineering if necessary.

CLIMATE CHANGE IN MIZORAM

Mizoram is well-known for its steep terrain and extensive forests. The bulk of its residents live in rural areas, and the state's low population density can be attributed in part to its rugged environment. It is mostly populated by indigenous tribal populations, who have distinct languages, customs, and traditions. These communities generally live in small, scattered settlements on hilltops, which enables them to continue their traditional way of life while remaining connected to their natural environment.

The local economy relies heavily on natural resources, including agriculture, forestry, and handicrafts. The cultivation of crops like rice, bamboo, and various fruits is common, and traditional practices such as shifting cultivation (jhum) have been a significant part of the local agricultural system. As a result of its hilly terrain, the area is especially vulnerable to soil erosion. When forests are cleared for agriculture, the protective cover provided by vegetation is lost, resulting in increased runoff and erosion. This process can deteriorate the soil, reducing its fertility and impacting agricultural productivity

The region experiences a monsoon climate, with heavy rainfall during this season, which typically lasts from June to September. This ample rainfall is crucial for agriculture in Mizoram, where many farmers rely heavily on rain-fed irrigation rather than controlled irrigation systems. Although it receives significant rainfall during the monsoon season, it might face severe water scarcity during the summer months. The combination of soil erosion, deforestation, and uneven rainfall distribution all have an impact on water retention and availability. Reduced forest cover and soil degradation can reduce the land's ability to retain and filter water, leading to water shortages during the dry season. Addressing these issues frequently involves implementing sustainable land management practices, reforestation initiatives, and improving water conservation techniques in order to better manage natural resources and offset the negative effects of environmental degradation. Due to such characteristics in addition with limited infrastructure in terms of roads, irrigation systems, and water storage facilities makes it challenging to adapt to and mitigate the effects of climate change.

It is estimated that more than 70% of the total population is engaged in some form of agriculture. Many people who live in rural areas engage in the ancient practice of Jhum cultivation on an annual basis. This method is particularly suited to the region's hilly terrain. Commonly grown crops include rice, maize, potatoes, and various vegetables. The ash from the burned vegetation enriches the soil, offering a temporary boost in fertility.

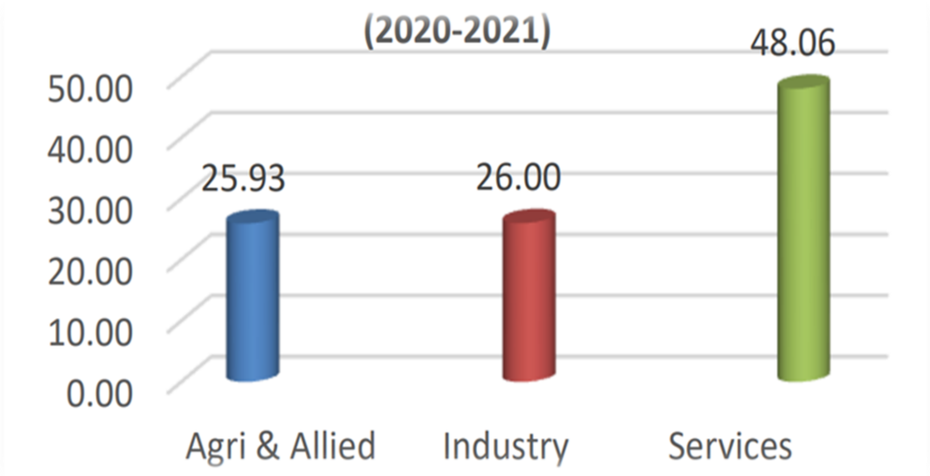
With only about 5% of the total area under cultivation, Mizoram's agricultural land is quite limited. This low percentage of cultivated land is partly due to the region's hilly terrain, which restricts the amount of land suitable for farming. It is evident from the fact that only

11.47% of the total cultivated area is irrigated that rain-fed agriculture is heavily relied upon. Due to its restricted irrigation coverage, agriculture may be particularly vulnerable to changes in temperature and rainfall patterns.

The total area of land having slope of 0 to 15% where there is a possibility of Wet Rice Cultivation (WRC) is 74,644 Ha which is merely 2.8% of Mizoram. Wet rice production is not feasible in a place with severe topographical constraints because it usually requires generally flat or slightly sloping ground with access to sufficient water. The total area of land with a slope of 10 to 33% is also only 509,365 Ha. Lands with such slopes are less suitable for conventional farming due to its steeper gradient. Such slopes are more prone to soil erosion, runoff, and can be difficult to manage for crops that require level or gently sloping land, like wet rice. Farming on these slopes often necessitates specialized techniques such as terracing, contour ploughing, or agroforestry to prevent erosion and effectively manage water.

According to the *fig. e*, the primary sector in Mizoram, which includes agriculture and allied activities, contributed 25.93% (2020 - 21) to the Gross State Value Added. With agriculture accounting for more than half of our population's income, faster expansion is required to boost their earnings. Rising agricultural revenues will also boost non-agricultural income in rural regions, so helping overcome the rural-urban imbalance.

Fig. e. Sectoral share in GSVA (2020 – 21)



Understanding rainfall average and variability is crucial for managing water resources, agriculture, and infrastructure, especially in the context of climate change. Rainfall variability refers to the fluctuations or changes in the amount and distribution of rainfall over time. It includes both temporal variability (changes over time) and spatial variability (differences across locations). Temperature variability refers to the fluctuations in temperature that occur over different timescales and across various locations. Understanding temperature variability is important for various fields, including agriculture, where it can impact crop yields, and in urban planning, where it affects energy consumption and infrastructure design.

Data acquired from the State Meteorological Center between 1986 and 2017 indicated the average rainfall and temperature fluctuation of different districts within the state (*Table. b*). Mizoram received an average of 2551.88mm of rainfall during this time period. Champhai had the lowest average rainfall of 2161.66mm, while Lunglei had the highest (3204.73mm). Despite receiving more rainfall than the Mizoram average, Lawngtlai and Serchhip districts experience the most variability (fluctuation). This indicates that they are highly sensitive to climate change, particularly in terms of agricultural and crop productivity, given most farmers rely primarily on rainfall volume and pattern.

The average temperature variability of Mizoram was +0.04^{o}C, at maximum it was +0.01^{o}C and +0.08^{o}C at minimum. The table also illustrates the different temperature variability among the districts giving the maximum, minimum and average readings. Understanding these types of temperature variability is crucial for various applications, including weather forecasting, climate studies, and preparing for seasonal or extreme weather conditions. It helps in assessing climate impacts on agriculture, infrastructure, and energy needs.

Table (b). Rainfall and Temperature variability of districts within Mizoram

DISTRICTS	RAINFALL (MM)		TEMPERATURE VARIABILITY (° C)		
	Average	Variability	Maximum	Minimum	Average
Aizawl	2394.96	- 3.99	+ 0.05	- 0.12	- 0.04
Champhai	2161.66	- 1.66	- 0.28	- 0.34	- 0.31
Kolasib	2787	- 2.8	- 0.01	+ 0.09	+ 0.04
Lawngtlai	2361.12	- 29.17	+ 0.03	+ 0.15	+ 0.09
Lunglei	3204.73	+ 8.53	- 0.03	+ 0.13	+ 0.05
Mamit	2649.38	+ 19.19	NA		
Serchhip	2369.48	- 28.03	NA		
Siaha	2486.55	+ 5.77	NA		
MIZORAM	**2551.88**	**- 5.22**	**+ 0.01**	**+ 0.08**	**+ 0.04**

Data from a rural village survey conducted from December 2022 to January 2023 (*Table c and Fig. f*) reveals that 45.29% of the total households rely on Jhum agriculture for livelihood, 13.09% on wet rice cultivation, and 6.91% on orchards. Only 11.67% of the total households are salaried, the majority of whom are government employees, while 23.03% work in businesses, retail outlets, or as day labourers.

Climate change has a direct impact on households that are dependent upon Jhum cultivation, which accounts for approximately half of the village population means that these communities are particularly vulnerable to the effects of climate change. This change affects all sectors except the salaried, either directly or indirectly.

Table (c): Excerpts of information (data) collected from village survey during December 2022 to January 2023

Sl No	Khaw hming	Total HH	Salaried	Jhum	WRC	Orchards	Others
1	Mualkawi	166	45	14	7	20	80
2	N Hruaikawn	50	10	35	5		0
3	O Hruaikawn	101	16	47	30	8	0
4	Sazep	130	19	95	9	2	5
5	Dilkawn	212	12	190	1	1	8
6	Buang	101	8	88	3	2	0
7	Khuangleng	415	40	230	10	3	132
8	Kelkang	255	13	179	2	20	41
9	Melbuk	300	35	5	4	5	251
10	Zokhawthar	700	70	20	3	6	601
11	Vanzau	163	5	135	16	3	4
12	Bungzung	254	30	101	66	52	5
13	Zawngtetui	50	0	45			5
14	Leithum	124	22	45	22	8	27
15	Sesih	287	30	182	70	5	0
16	Vangchhia	172	39	110	15	5	3
17	Lianpui	156	22	70	14	30	20
18	Bungzung	177	18	67	80	6	6
19	Dungtlang	210	11	177	11	11	0
20	Hnahlan	795	120	0	350	250	75
21	Khuangphah	142	15	80	6	10	31
22	N Diltlang	78	12		15		51
23	Pamchung	83	14	57	6	6	0
24	Lungphunlian	88	14	60	4	10	0
25	Selam	237	18	100		60	59
26	Tualcheng	175	29	95	49	2	0
27	Vapar	205	16	20	35	10	124
28	Murlen	98	14	35		4	45
29	Ngur	356	23	6	63	60	204
30	Ruantlang	374	30	20	10	20	294
31	Champhai Zote	352	20	40	30	10	252
32	Champhai Tlangsam	130	13	65	26	26	0
33	Champhai Zotlang	620	107		145	20	348
34	Hmunhmeltha	337	32	105	200		0
35	N Khawbung	244	29	195	10	8	2
36	Tuipui	118	10	80	7	10	11

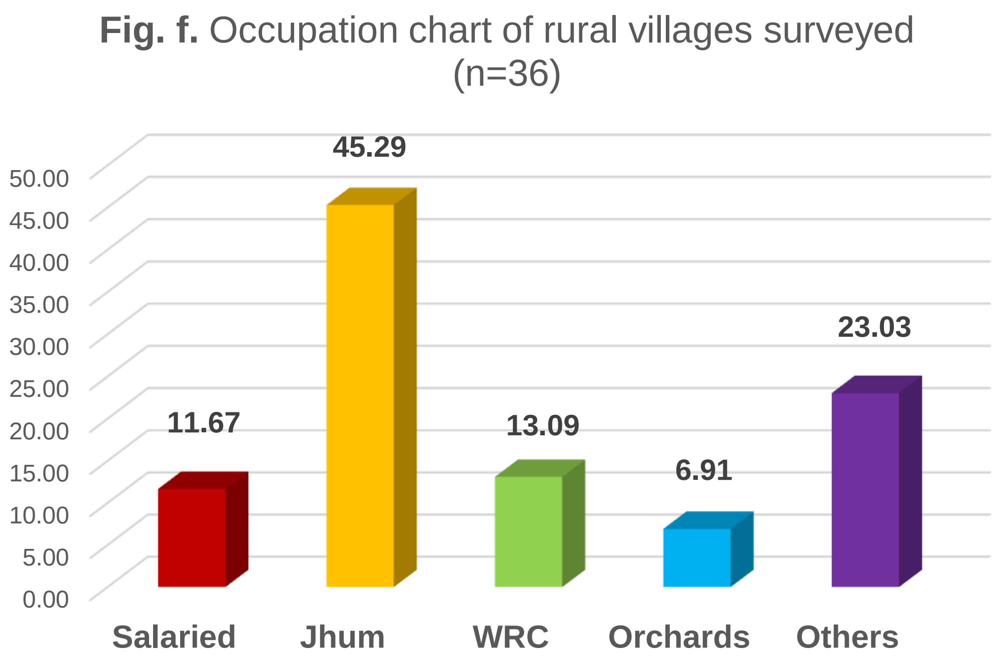
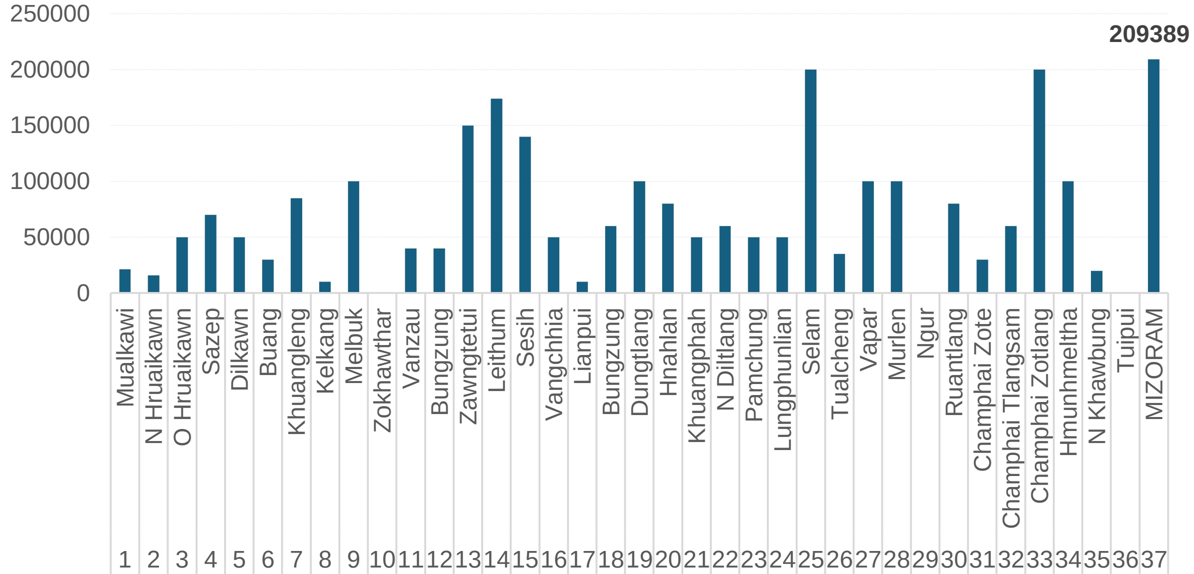


Fig. g. demonstrates that the average per capita income in Mizoram is 2,09,389. Each of the studied villages had a lower average per capita income than Mizoram's average. Selam and Champhai Zotlang villages may have stronger infrastructure and resources than other villages because their per capita incomes are nearly identical to Mizoram's average. They may be in a somewhat better position to handle the effects of climate change as a result. Nonetheless, the per capita income of the remaining communities is far lower. These villages are especially susceptible since the poorest people in countries/communities are projected to bear the most severe impacts of the economic consequences of climate change.

Villages with lower per capita incomes frequently have lesser resources to invest in climate adaption strategies. This means they may lack the capacity to deal with extreme weather events, rising sea levels, or changes in agricultural conditions, so increasing their vulnerability. Climate change may pose significant health concerns for the poorest members of these communities, including heat stress, vector-borne infections, and malnutrition. These health consequences can exacerbate limited resources and reduce productivity, perpetuating a cycle of poverty and vulnerability. Planning and executing climate adaptation strategies with the aid of the indigenous populations can lead to more effective and culturally appropriate solutions thus boosting the community readiness for climate-related disasters.

Fig. g. Per capita income of villages surveyed



Impacts of Climate Change on villages surveyed: From the 36 villages surveyed a large number of villages reported problems concerning their yield of agricultural crops caused by change in climate (*Fig.h*). From the survey, the problem reported by each village was the reduction of water resource. Since majority of the farmers practice Jhum cultivation they rely heavily on monsoon rain. Therefore when rainfall decreases it greatly impacted their agricultural yields. Other problems reported involving crops included:

i) Ginger (*Zingiber officinale*) - Crop loss

ii) Stink bean (*Parkia speciosa*) - Crop loss; decay

iii) Passion fruit (*Passiflora edulis*) - Disease ridden

iv) Orange (*Citrus deliciosa*) - Crop loss; stink bug; disease ridden

v) Rice (*Oryza sativa*) - Grubs, disease ridden; fall army worm; depletion of water resource leading to low productivity; destroyed by rain and hail

vi) Corn (*Zea mays*) - Fall army worm

vii) Chilli - Leaf curling; ripening problems; continuous low production

viii) Crops - Pest problems

ix) Grape - Decay, disease ridden

x) Potato (*Solanum tuberosum*) - Crop loss

xi) Cabbage (*Brassica oleracea*) - Stop cultivating

Some short term benefits of climate change are also reported in some cases:

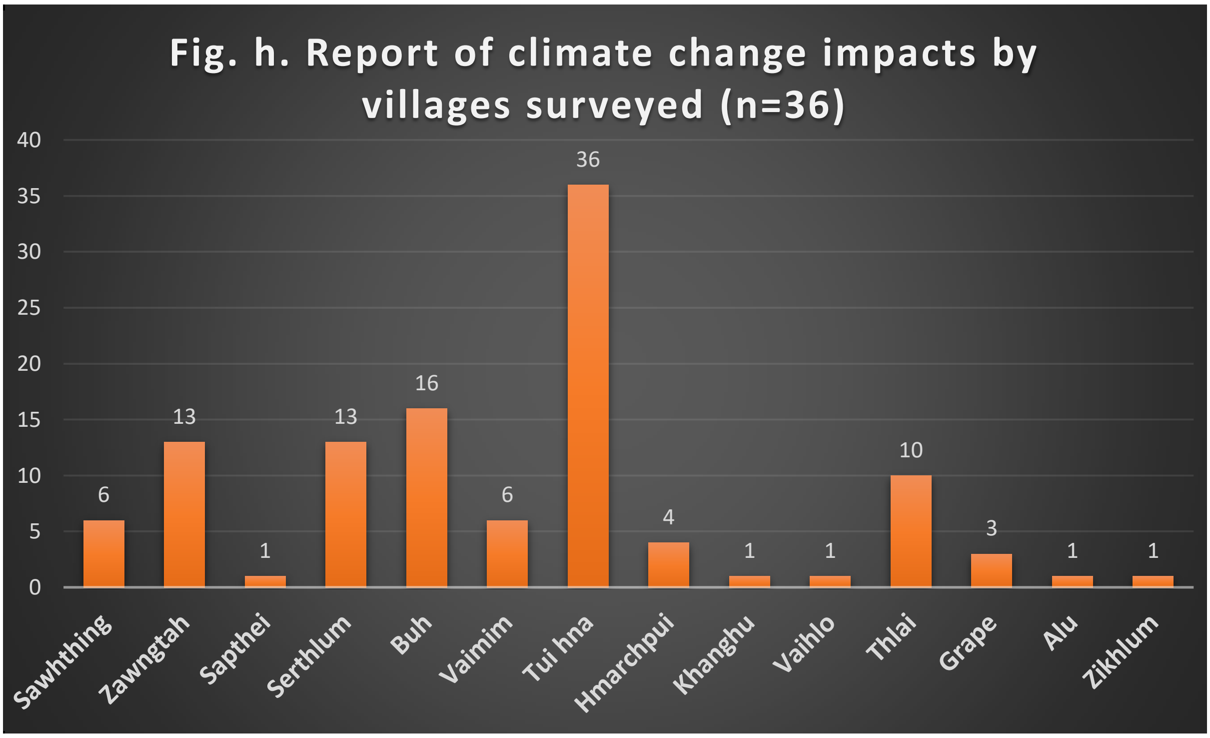
i) Four (4) villages reported that Stink Beans has started fruiting.

ii) One (1) village reported fruiting of oranges.

iii) Production area of tobacco has increased in one (1) village

iv) Two (2) villages reported that different fruits like mango, banana, tomato, butterfruit etc. have started fruiting.

Five (5) villages have reported adapting to new livelihoods as a result of climate change. They have abandoned growing bananas, tobacco, apples, and other crops and have begun raising pigs and mithun for a living instead.



WHAT CAN BE DONE TO TACKLE CLIMATE CHANGE

Mitigation and adaptation are two key strategies for dealing with climate change, each addressing different elements of the issue. Mitigation refers to efforts aimed at slowing the rate of climate change by reducing or preventing greenhouse gas emissions and enhancing carbon sinks (e.g. increasing the area of forests). It focuses on addressing the underlying causes of climate change. Key strategies for mitigating climate change comprises of methods such as:

- **Shifting away from Fossil Fuels:** As fossil fuels are the primary source of greenhouse gases, shifting to modern renewable energy sources such as solar, wind, and geothermal power, as well as promoting sustainable means of transportation, is crucial.
- **Enhancing Energy Efficiency:** Reducing the total amount of energy used in industries, buildings, public and private areas, energy generation and transmission, and transportation all contributes to a reduction in emissions.
- **Reforestation and Afforestation:** Planting trees and restoring forests to absorb CO^2 and reducing the overall concentration of greenhouse gases from the atmosphere since they act as carbon sinks.

Adaptation is the process of adjusting to the present or predicted future climate. The goal is to reduce our vulnerability to the negative effects of climate change (such as sea-level rise, more severe extreme weather events, and food insecurity). It also includes making use of any potential benefits of climate change (such as longer growing seasons or higher yields in particular regions). It entails changing social, economic, and environmental practices to reduce the damage caused by climate change. The purpose is to strengthen resilience to current or anticipated changes. Some options for adjusting to climate change includes:

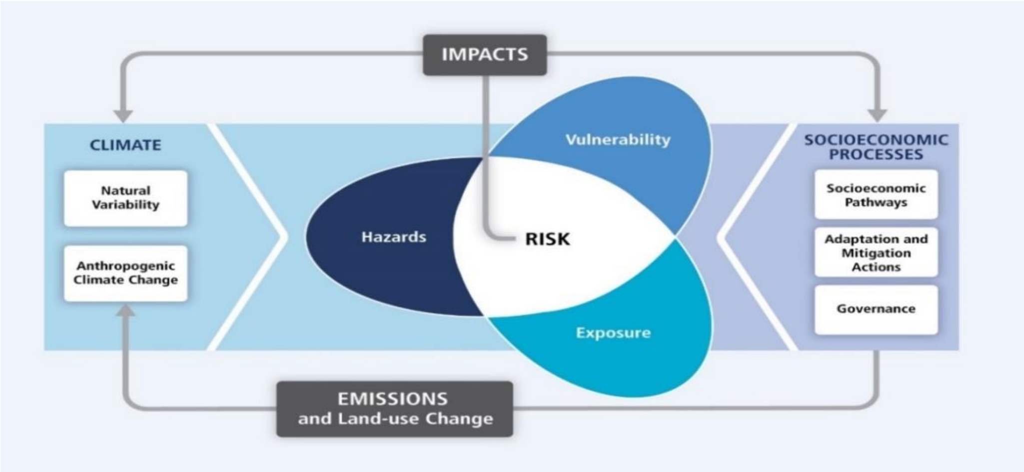
- **Building Resilient Infrastructure:** Designing and constructing buildings, roads, and bridges to withstand extreme weather events.
- **Water Management:** Adapting better water management and conservation techniques to deal with future droughts and shifting patterns of precipitation. It includes collecting and storing rainwater from roofs and other surfaces for use in irrigation and non-potable applications, utilizing greywater collected from washing machines, sinks, and showers for toilet flushing and irrigation.
- **Agricultural Adaptation:** Developing and adopting crop varieties that are more tolerant to climate extremes, as well as modifying farming procedures to maintain productivity. It is crucial in the face of climate change, as it helps ensure food security and sustainability.

The "first step towards adaptation to future climate change is reducing vulnerability and exposure to present climate variability" (IPCC, 2014). Communities can improve their resilience to future changes by addressing present vulnerabilities and exposure to climate-related hazards. This proactive strategy not only helps to manage immediate consequences, but it also builds the groundwork for long-term adaptability and sustainability. Throughout history, people and communities have adjusted to climate variability and dealt with its extremes to varied degrees of success. Currently, various adaption processes are being planned, but only a few are being implemented.

Why do we undertake vulnerability assessments with specific emphasis? When evaluating risk components, we cannot alter the course of nature. Climate hazards will continue to occur. At the same time, people, groups, or regions exposed (exposure) to climatic hazards cannot be relocated to safer locations because the process would need insurmountable resources that no government could afford. As a result, managing risk and exposure is next to impossible. On the other hand, vulnerability refers to the core characteristics of a system/community/region. They may be managed with effective adaptation planning and expertise to reduce harm caused by climate-induced hazards. Vulnerability studies are frequently conducted regardless of whether they are exposed to climate change or not. Therefore, special emphasis is often placed on vulnerability assessments because they are a proactive measure that helps organizations manage and reduce risk. By regularly identifying and addressing vulnerabilities, organizations can better protect themselves against evolving threats and ensure their systems and data remain secure.

Assessing vulnerability and risk 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. Assessing which regions, industries, or populations are most at risk allows policymakers and planners to prioritize actions where they are most needed. This guarantees that resources are used efficiently and effectively. This assessment helps to identify the specific threats that individual communities face, such as flooding, drought, heatwaves, or sea-level rise. This insight enables personalized adaptation methods that address the specific problems of each place. The interaction between climate-related hazards (such as dangerous trends and events) and the susceptibility and exposure of natural and human systems produces the risk of climate-related consequences. Changes in the climatic system (left) and socioeconomic activities, such as adaptation and mitigation (right), trigger hazards exposure, and vulnerability (*Fig.i*).

Fig. i. Vulnerability impact assessment



When we discuss vulnerability in the context of climate change, it emphasize how different systems, communities, and ecosystems are at risk from the impacts of a changing climate. Vulnerability in this sense refers to a variety of characteristics, including exposure to climate-related risks, sensitivity to those hazards, and the ability to adapt or respond. In other words, it is a concept that describes how strongly people or ecosystems are likely to be affected by climate change. It encompasses two primary components:

1) **Sensitivity:** The degree to which a system is affected by exposure to climate hazards. Sensitivity depends on factors such as the characteristics of the system (e.g., an area having steep slope will be sensitive than gentle slope to climate stimuli) and the inherent vulnerability of the people, ecosystems, or infrastructure involved.
2) **Adaptive Capacity:** The ability of a system, community, or ecosystem to anticipate, prepare for, and respond to the adverse effects of climate change (e.g., an area with high forest cover will have better adaptive capacity in response to climate change). This includes the availability of resources, technology, and knowledge, as well as institutional support and social capital.

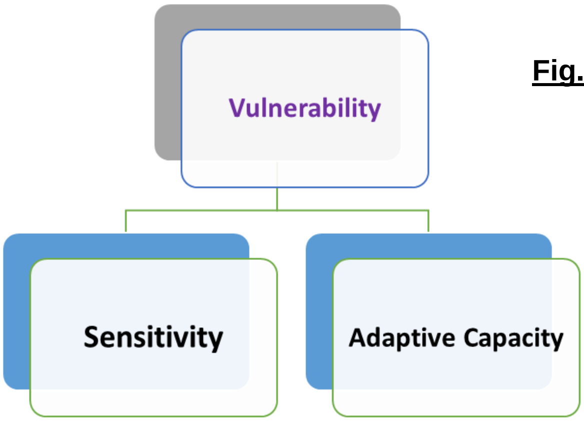


Fig. j. Vulnerability and its components

CLIMATE VULNERABILITY ASSESSMENT

Climate Vulnerability Assessment for the Indian Himalayan Region Using a Common Framework

During 2018-19, a climatic vulnerability assessment was conducted for the Indian Himalayan Region (IHR), which encompasses Jammu and Kashmir, Himachal Pradesh, Uttarakhand, West Bengal, Sikkim, Assam, Meghalaya, Arunachal Pradesh, Nagaland, Manipur, Mizoram, and Tripura (*Fig. k & l*). The Indian Himalayan Region is a complex and ecologically sensitive area with substantial climatic concerns. Vulnerability assessments in this region are crucial for determining the potential consequences of climate change and developing appropriate adaption plans. A vulnerability index is a method for quantifying and comparing the sensitivity of various locations, communities, or systems to certain hazards or risks such as those associated with climate change. The index usually combines multiple indicators into a single statistic to determine overall vulnerability.

Among the IHR states, the vulnerability index was highest for Assam at a value of 0.72 while Mizoram is ranked 2nd (0.71). Mizoram scores a high vulnerability index due to the following reasons:

- The state's agriculture sector is extremely sensitive, with poor connectivity, access to information, and infrastructure.
- In comparison to other states, the state has the biggest production variability, no crop insurance coverage, the largest area under open forests, and the largest area under slopes of more than 30%.
- Among the 12 states, it also has the third-lowest road density and the second-lowest percentage of land under irrigation.

Fig. k. Vulnerability index of IHR states

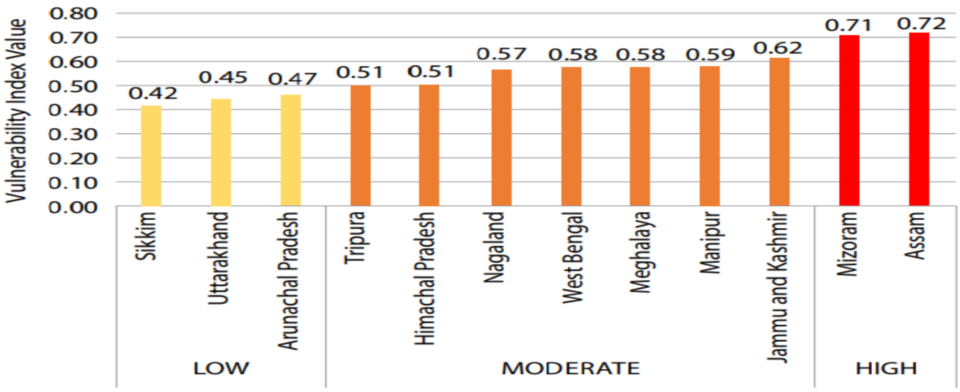
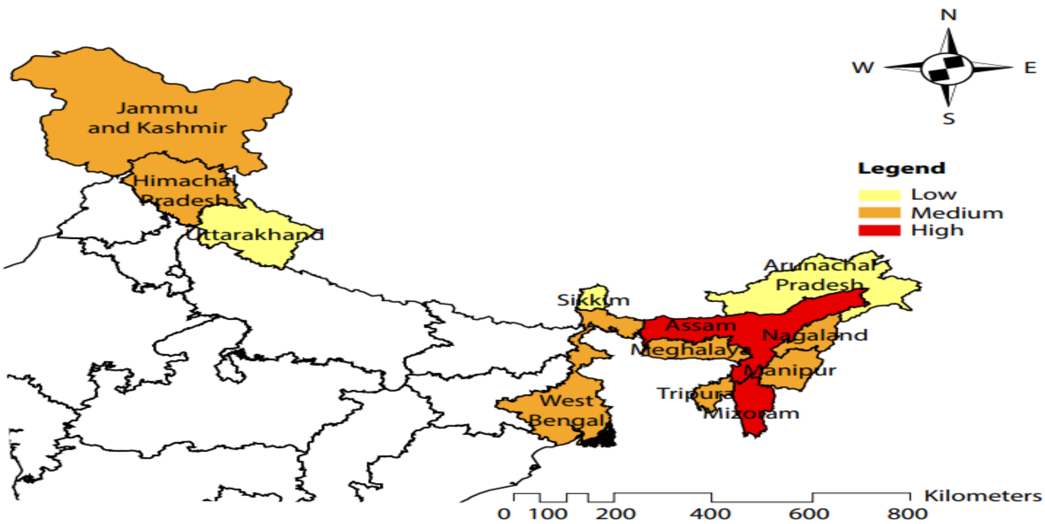
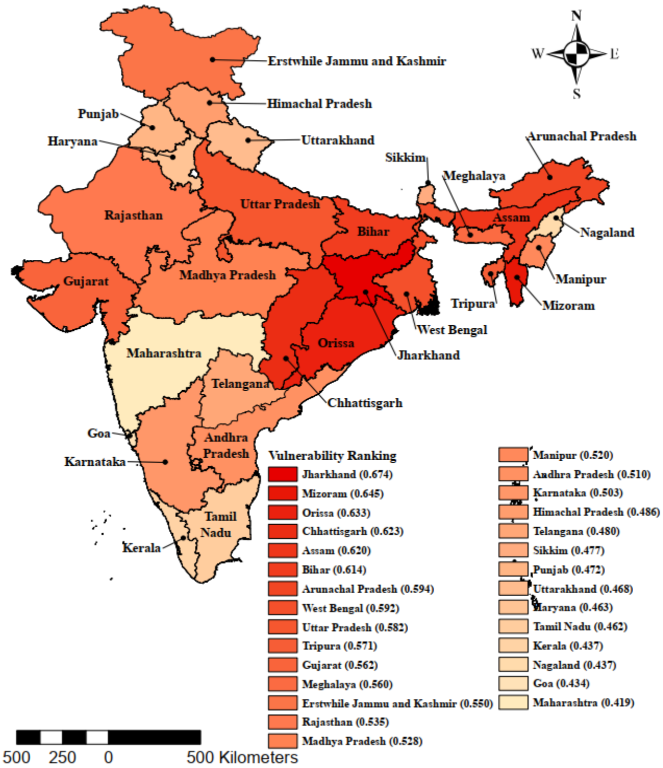


Fig. l. Map of vulnerability index for IHR states



Climate Vulnerability Assessment for Adaptation Planning in India Using a Common Framework

Fig.m. Vulnerability Assessment for Adaptation Planning



The climate vulnerability rank of Mizoram was 2nd highest (0.645) among all the

Indian states ranking just below Jharkhand (0.674) during 2019-20 (*Fig. m*). The major factors include food grain yield fluctuation, inadequate crop insurance coverage, prevalence of rainfed agriculture, and high incidence of vector-borne diseases. Other factors include: High share of income from natural resources (agriculture and related services), yet there is a lack of road density and a railway network. It should be noted that, while having the highest density of health care personnel per thousand population, less than 8% of them are doctors.

Climate vulnerability map and drivers of vulnerability of Mizoram on integrated Biophysical and Socio-Economic Sector

A district wise vulnerability index for Mizoram was created based on the biophysical and socio-economic sectors. The term biophysical refers to the physical and biological characteristics of the environment, as well as how they interact. Biophysical factors are important in the context of vulnerability and adaptation because they have a direct impact on the natural environment and human systems, determining how vulnerable or resilient a region or population is to environmental change and hazards. It includes different factors such as climate and weather patterns; soil and land properties; water resources; biodiversity and natural hazards. The socio-economic sector encompasses all aspects of society and the economy that influence or are influenced by socioeconomic conditions. This sector includes aspects such as human welfare, economic activity, and social structures. It involves factors like income and wealth distribution; employment; education; infrastructure etc.

Based on the biophysical and socio-economic sector, Lawngtlai district was revealed to be the most vulnerable, followed by Mamit and Lunglei districts. The different drivers of vulnerability are given in the figure below.

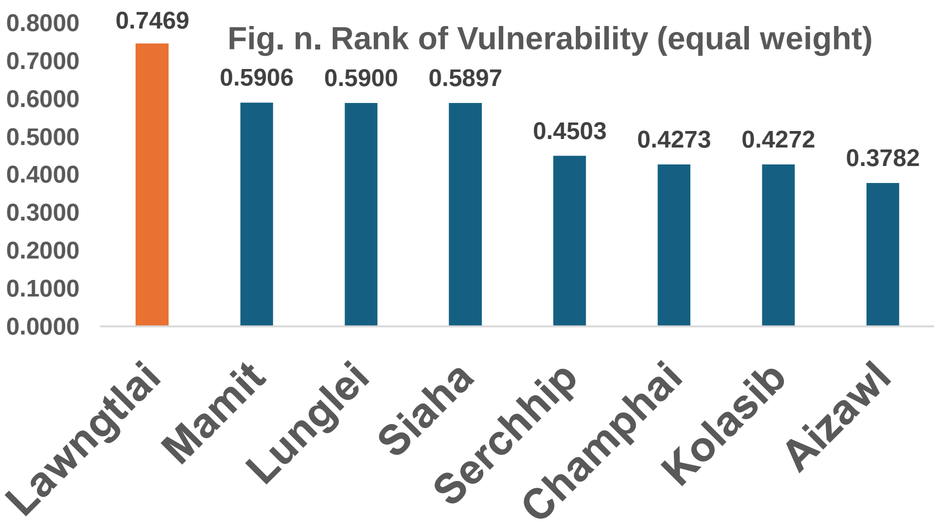


Fig. n. Rank of Vulnerability (equal weight)

Fig. o .Mizoram district wise vulnerability category (equal weight) for biophysical and socioeconomic sectors

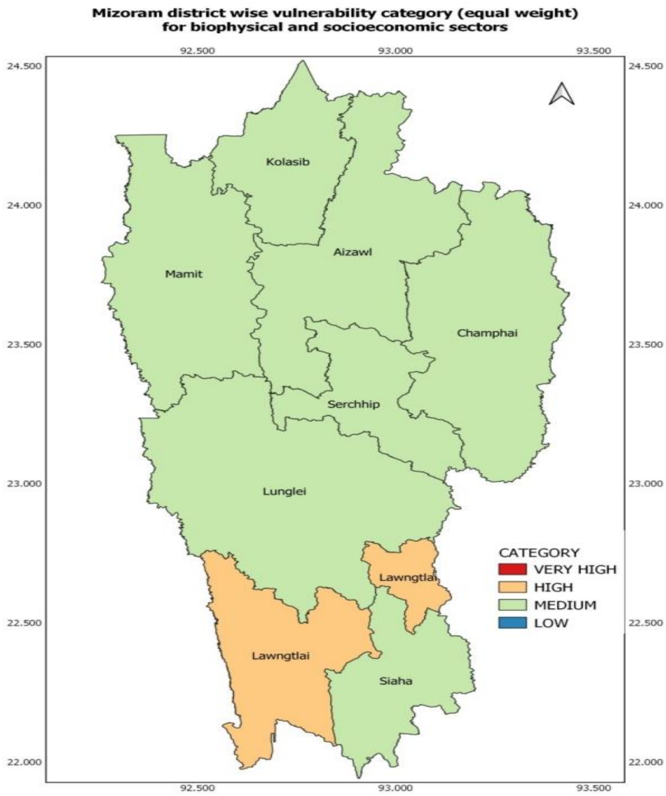
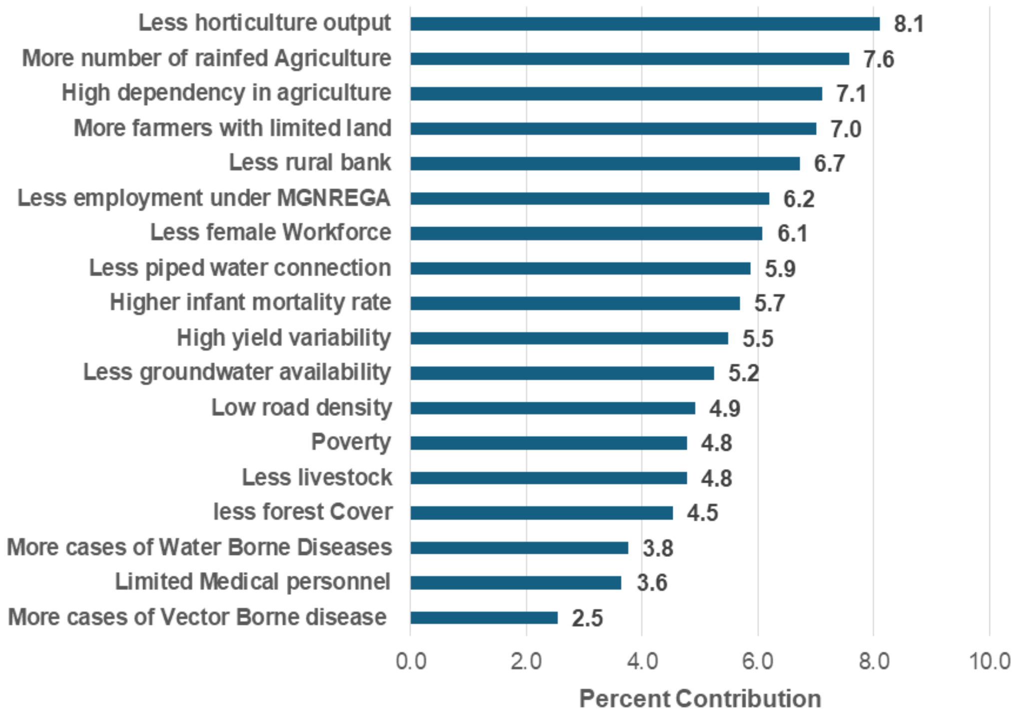


Fig. p. Drivers of vulnerability of Mizoram (equal weight)



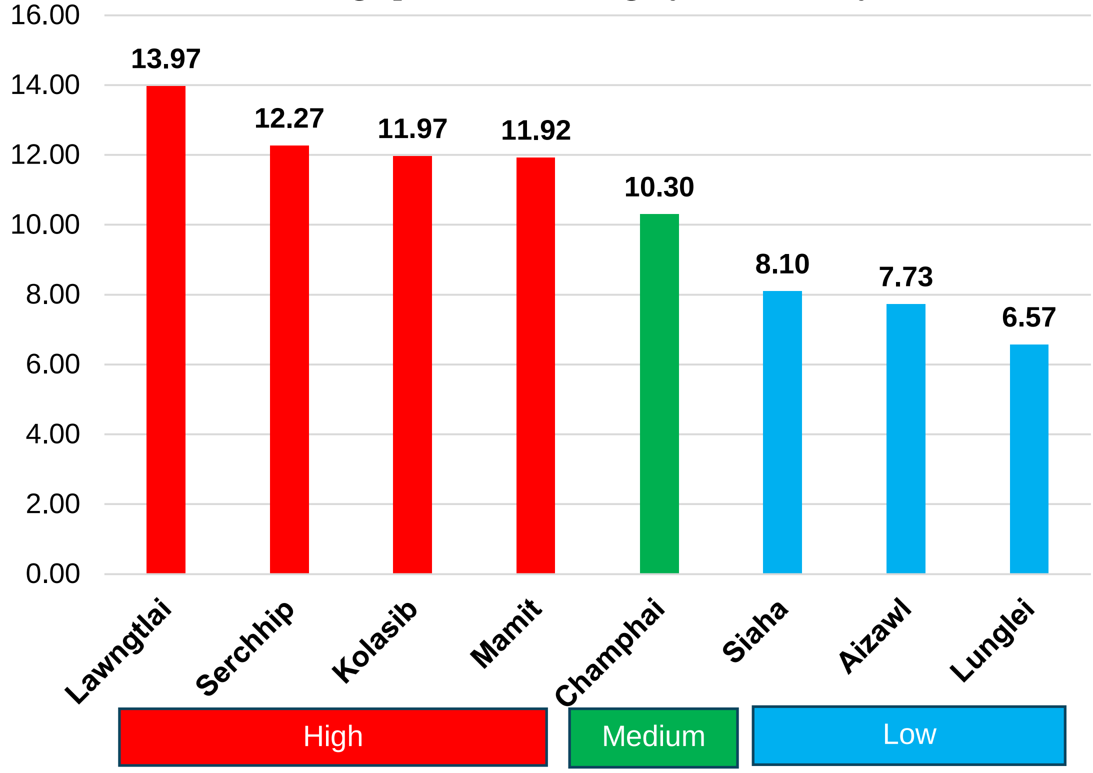
Climate vulnerability map and drivers of vulnerability of Mizoram on Health Sector

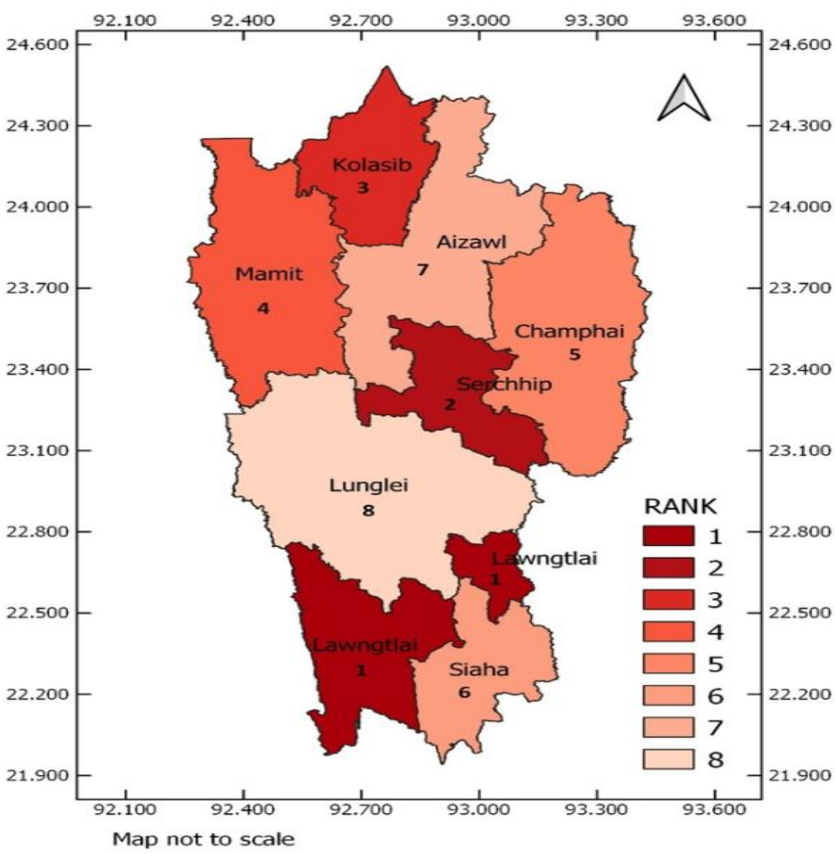
The health sector includes all aspects of maintaining and improving health, such as healthcare services, public health initiatives, and health policies. It is critical for addressing both immediate and long-term health effects. Different indicators were used as shown in *Table (d)* which was conducted in the districts of Mizoram. Vulnerability was high for four districts viz. Lawngtlai, Serchhip, Kolasib and Mamit. It was lowest in Lunglei (6.67) and highest in Lawngtlai (13.97).

Table d. Vulnerability indicators of Mizoram on health sector

Districts	Indicators											
	Malaria (API rate) per 1000 persons		Dengue (per 1000 persons)		Scrub Typhus (per 1000 persons)		No of Hospitals/PHC/CHC etc		No of Doctors/Nurse/HW etc		Infant Mortality Rate (per 1000 live births)	
	AV	NV	AV	NV	AV	NV	AV	NV	AV	NV	AV	NV
Mamit	9.27	0.45	0.01	0.05	0.76	0.24	51	0.95	328	0.95	25	0.77
Kolasib	1.35	0.06	0.12	0.47	0.24	0.04	43	1	333	0.95	25	0.77
Aizawl	0.69	0.02	0.25	1.00	2.77	1.00	206	0	2028	0	26	0.88
Champhai	10.04	0.48	0.10	0.41	0.26	0.05	106	0.61	520	0.84	24	0.66
Serchhip	0.14	0	0.02	0.06	7.78	2.91	44	0.99	329	0.95	23	0.55
Lunglei	9.18	0.44	0.11	0.44	2.00	0.71	108	0.60	697	0.74	18	0
Lawngtlai	20.41	1	0.02	0.07	0.98	0.32	71	0.82	253	1	27	1
Siaha	3.11	0.14	0.00	0.00	0.14	0.00	44	0.99	301	0.97	20	0.22

Fig. q. Rank and Category Vulnerability





Climate vulnerability map and drivers of vulnerability of Mizoram on Water Resources

According to *Fig. r.*, the Champhai district in Mizoram has the highest vulnerability index value (0.782), making it the most vulnerable to climate variability and change in terms of domestic water resource availability. Siaha district ranked second with a vulnerability rating of 0.777, followed by Serchhip in third place with 0.751. Mamit district had the lowest vulnerability index value (0.205), making it the least vulnerable district. The second figure shows the overall drivers of vulnerability: indicators and their corresponding percent contribution to an overall vulnerability against climate change and climate variability to water resources for the state of Mizoram.

Fig. r. Vulnerability of Mizoram on water resources

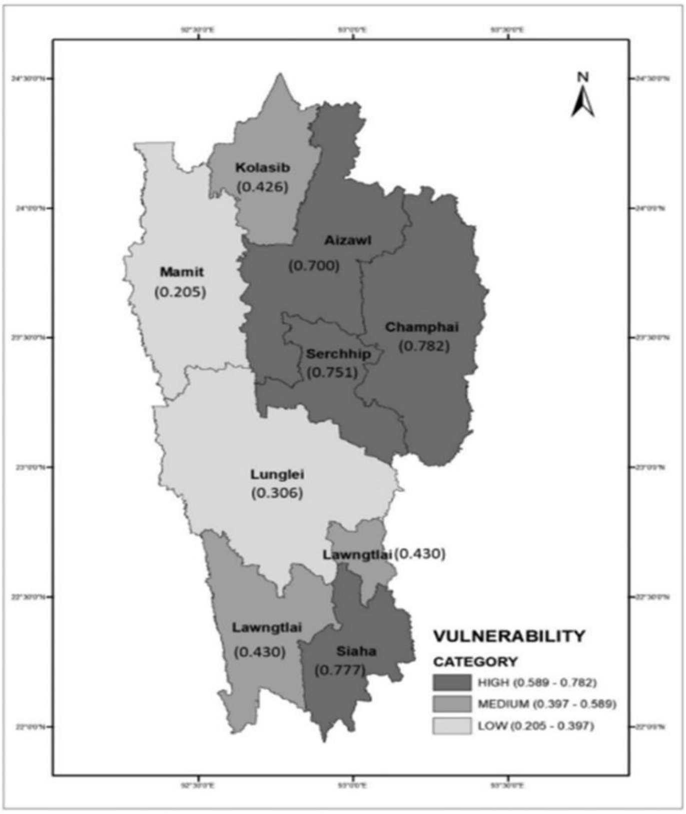
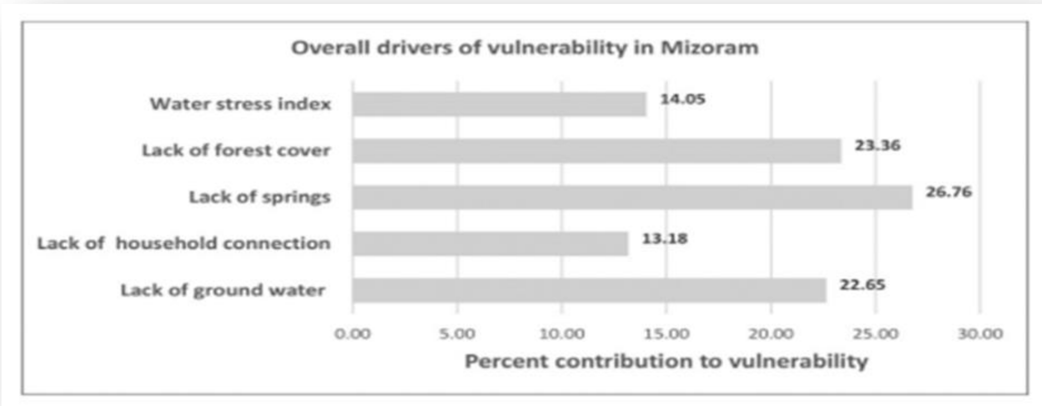


Fig. s. Overall drivers of vulnerability in Mizoram



Climate vulnerability map and drivers of vulnerability of Mizoram on Agriculture Sector

Creating a climate vulnerability map for Mizoram's agriculture sector entails identifying places and elements that increase the sector's vulnerability to climate change. Mizoram's distinct geography, climate patterns, and agricultural techniques result in specific vulnerabilities. The different drivers of vulnerability on agriculture sector are indicated in Figure 4.2.1. From *Table e*, Siaha district has the highest vulnerability index value (0.6647), followed by Champhai district (0.6498) and Mamit district (0.6229). The least vulnerable district in terms of agriculture sector is Kolasib district with an index value of 0.3204.

Table. e. Vulnerability index values and corresponding ranks and categories of districts in the state

DISTRICTS	VULNERABILITY INDEX VALUE	RANK	CATEGORY
Siaha	0.6647	1	HIGH
Champhai	0.6498	2	HIGH
Mamit	0.6229	3	MEDIUM
Lawngtlai	0.6202	4	MEDIUM
Serchhip	0.5811	5	MEDIUM
Lunglei	0.5420	6	MEDIUM
Aizawl	0.4774	7	MEDIUM
Kolasib	0.3204	8	LOW

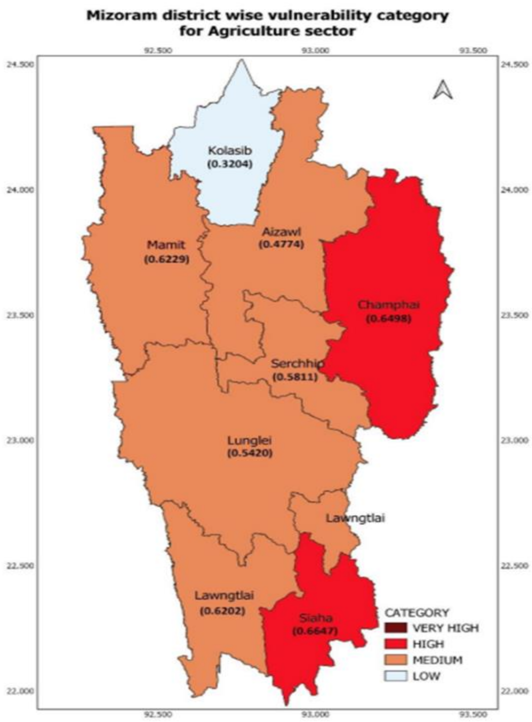
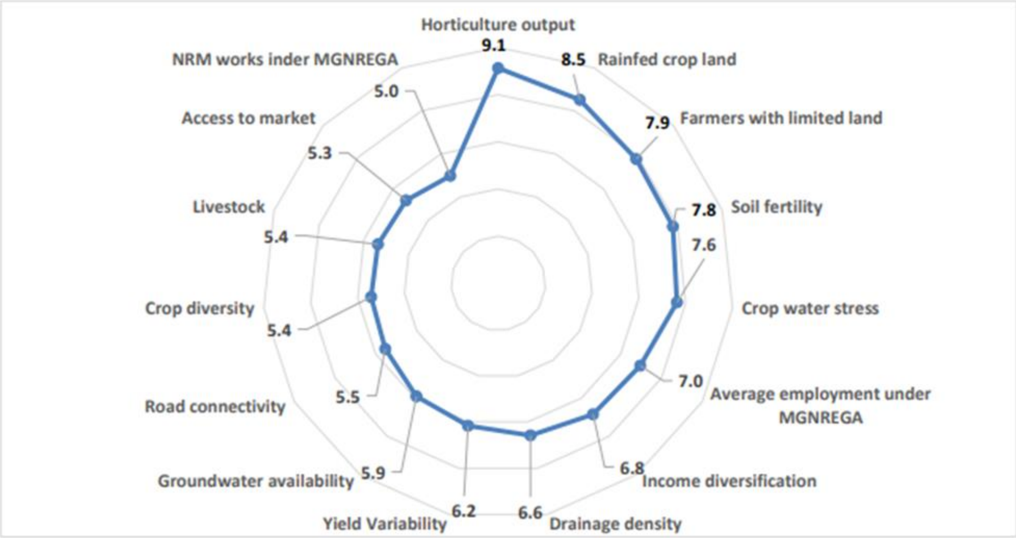


Fig. t. Overall vulnerability on agriculture sector



CONCLUSION

Climate change is a real phenomenon whose effects are being experienced on a global, regional, and local scale. Whether we like it or not, whether we contribute to climate change or not, impacts are happening all over and will continue to do so as it is a worldwide phenomenon with impacts on everyone, regardless of individual contributions or choices. Mitigation and adaptation are two fundamental strategies for addressing climate change. Each plays a distinct role in managing the impacts of climate change and ensuring long-term sustainability. Building a well-informed system allows communities and organizations to better plan for and adapt to climate change problems, ultimately increasing resilience and ability to thrive in the face of long-term consequences. Capacity building at all levels of stakeholders is critical for effectively addressing and adapting to climate change. Therefore, instilling knowledge at the grassroots level is critical to boosting climate resilience and ensuring that adaptation and mitigation policies are relevant and impactful.

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About NMSHE

The National Mission for Sustaining the Himalayan Ecosystem (NMSHE) is one of the eight missions under India's National Action Plan on Climate Change. The Mission is being coordinated by the Department of Science and Technology, Government of India. The broad objectives of NMSHE include – understanding of the complex processes affecting the Himalayan Ecosystem and evolve suitable management and policy measures for sustaining and safeguarding the Himalayan ecosystem, creating and building capacities in different domains, networking knowledge institutions engaged in research and development of a coherent data base on Himalayan ecosystem, detecting and decoupling natural and anthropogenic induced signals of global environmental changes in mountain ecosystems, studying traditional knowledge systems for community participation in adaptation, mitigation and coping mechanisms inclusive of farming and traditional health care systems and developing regional cooperation with neighbouring countries, generate a strong database through monitoring and analysis, to eventually create a knowledge base for policy interventions.

About Mizoram State Climate Change Cell

The State Climate Change Cell (SCCC) of Mizoram was created on 25th November, 2014 with the financial support from the Climate Change Programme (CCP) Division (the then Strategic Programme Large Initiatives Coordinated Actions Enabler (SPLICE) and Climate Change Programme (CCP) Division) of Department of Science & Technology, Govt. of India through the National Mission for Sustaining the Himalayan Ecosystem (NMSHE) of National Action Plan on Climate Change (NAPCC). The project Phase-I was completed by the end of FY2019-2020. The project Phase II (Strengthening the State Climate Change Cell under NMSHE (Phase 2) for the state of Mizoram) was then continued under the further support from the CCP division of DST, Govt. of India from FY 2021 to 2022. There are three project staff along with two project investigators currently working under the cell. The Mizoram SCCC has been functioning under the aegis of Mizoram Science, Technology & Innovation Council (MISTIC), Directorate of Science Technology, Govt. of Mizoram. The Cell concentrates in implementation of its own project objectives whilst meeting the requirements of the mission objectives of the NMSHE under the National Action Plan on Climate Change (NAPCC), Government of India. Simultaneously, the Mizoram SCCC has been given the responsibility of a leading role by Government of Mizoram to implement the mission objectives of the Strategic Knowledge Mission (SKM) under the Mizoram State Action Plan on Climate Change (SAPCC).