Report on

Preliminary Assessment of Vulnerability and Risk Associated with Climate Change on Water Resources Sector and Human Health in Mizoram.

A district wise assessment to represent the whole state of Mizoram and a comparative representation of projected future scenarios.

State Climate Change Cell
Mizoram Science, Technology and Innovation Council
Directorate of Science and Technology
Govt. of Mizoram

Catalyzed and supported
by
National Mission for Sustaining the Himalayan Ecosystem (NMSHE),
Department of Science and Technology, Govt. of India, New Delhi

ABOUT STATE CLIMATE CHANGE CELL

The State Climate Change Cell (SCCC) in Mizoram was established in late 2014 through the National Mission for Sustaining the Himalayan Ecosystem (NMSHE), by Department of Science and Technology, Government of India, New Delhi. It was established under Mizoram Science, Technology and Innovation Council (MISTIC). Directorate of Science and Technology, Govt. of Mizoram. Since then, several activities has been taking following the objectives of the project (which is the nature of the SCCC) in line with the objectives of the NMSHE. The NMSHE is one of the eight Major Mission of the National Action Plan on Climate Change (NAPCC), Govt. of India.

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REPORT

Preliminary assessment of Vulnerability and Risk Associated with Climate Change on Water Resources Sector and Human Health in Mizoram

A district wise assessment to represent the whole state of Mizoram

PREFACE

The Department of Science and Technology, Govt. of India, New Delhi catalyzed and supported the establishment of State Climate Change Cell and its activities in the Indian Himalayan Region (IHR) states through The National Mission for Sustaining the Himalayan Ecosystem (NMSHE), which is one of the eight major missions under the National Action Plan on Climate Change (NAPCC, Govt. of India). In Mizoram, the State Climate Change Cell was also established under the Mizoram Science, Technology and Innovation Council, Directorate of Science and Technology, Govt. of Mizoram. The Cell, through its project objectives and work plan, has been conducting a study on Vulnerability and Risk Assessment due to Climate Change in Mizoram on different sectors since late 2015. It has been felt the need to present the current achievement of the ongoing work in the form of a document so that the observations and findings are communicated to mainstream public, scientific communities and other stakeholders, etc. Thus, a report on Preliminary Assessment on Vulnerability and Risk Associated with Climate Change on Water Resources and Human Health Sectors in Mizoram is presented here in this booklet, it is hoped that this report serve as a sensitization material and baseline information about climate change in Mizoram.

This booklet explains the concept of vulnerability in climate change context and describe how vulnerability and risk of a system is assessed. A brief scenario of climate change in Mizoram is also represented. The vulnerability and risk due to climate change which are likely to happen to the water resources and health sector in the coming future projected from the result of the current study are presented in the form of self explanatory maps and figures.

The result of the work presented here are product of computer simulations using different software designed to represent the most likely scenario. Even so, the results are determined by certain environmental factors such as land-use, projected climate data from computer simulations, soil types, secondary information, etc. Therefore, it needs to be considered as factor dependent. Thus, the robustness of the simulations are limited to the ability of the computer programme to incorporate necessary environmental factors. Further, the certainty of the projected future scenario are subjected to change depending on the behavior and initiatives taken by human in the coming future.

Lastly, readers have to keep in mind that this work is a preliminary assessment which was carried out using readily available resources. Further in-depth and detailed assessment is being planned in collaboration with renowned National Institutions coordinated by Department of Science and Technology, Govt. of India, New Delhi.

Dated Aizawl
The 29th May, 2017

(Dr R.K LALLIANTHANGA)
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Our profound gratitude and great indebtedness to Dr. C. Vanlalramsanga, Secretary, Planning (Science & Technology), Government of Mizoram for his administrative guidance and enormous support to the project without which the publication of this report would not have been possible.

We would also like to thank officials and staff of Mizoram Remote Sensing Application Centre (MIRSAC) for their valuable help in GIS applications and supply of necessary data during the course of the study. We would like to mention Mr. Robert Lalchhanhima Sailo, Scientist, MIRSAC and express our special thanks for his generosity in sharing his knowledge and information, his valuable inputs and help as well as the unfathomable patience he showed to us.

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We sincerely thank to all the officials and staffs of MISTIC for their assistance and support to the State Climate Change Cell.

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State Climate Change Cell
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INTRODUCTION

The climate system is a complex, interactive system consisting of the atmosphere, land surface, snow and ice, oceans and other bodies of water, and living things. The atmospheric component of the climate system most obviously characterizes climate; climate is often defined as 'average weather'. Climate is usually described in terms of the mean and variability of temperature, precipitation and wind over a period of time, ranging from months to millions of years (the classical period is 30 years). the climate system evolves in time under the influence of its own internal dynamics and due to changes in external factors that affect climate (called 'forcing'). External forcings include natural phenomena such as volcanic eruptions and solar radiations, as well as human-induced changes in atmospheric composition. Solar radiation powers the climate system. There are three fundamental ways to change the radiation balance of the 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); and 3) by altering the longwave radiation from Earth back towards space (e.g., by changing greenhouse gas concentrations). Climate, in turn, responds directly to such changes, as well as indirectly, through a variety of feedback mechanisms.

The Synthesis Report (SYR) which was released on 2nd November 2014 in Copenhagen distils and integrates the findings of the three Working Group contributions to the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), the most comprehensive assessment of climate change undertaken thus far by the IPCC: *Climate Change 2013: The Physical Science Basis*; *Climate Change 2014: Impacts, Adaptation, and Vulnerability*; and *Climate Change 2014: Mitigation of Climate Change.* The SYR also incorporates the findings of two Special Reports on *Renewable Energy Sources and Climate Change Mitigation* (2011) and on *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* (2011).

The SYR confirms that human influence on the climate system is clear and growing, with impacts observed across all continents and oceans. Many of the observed changes since the 1950s are unprecedented over decades to millennia. The IPCC is now 95 percent certain that humans are the main cause of current global warming. In addition, the SYR finds that the more human activities disrupt the climate, the greater the risks of severe, pervasive and irreversible impacts for people and ecosystems, and long-lasting changes in all components of the climate system. The SYR highlights that we have the means to limit climate change and its risks, with many solutions that allow for continued economic and human development. However, stabilizing temperature increase to below 2°C relative to pre-industrial levels will require an urgent and fundamental departure from business as usual. Moreover, the longer we wait to take action, the more it will cost and the greater the technological, economic, social and institutional challenges we will face.

Concept of Vulnerability due to climate change

The most authoritative definition of the term "vulnerability" in the context of climate change has been put forth by the Working Group II of the Intergovernmental Panel on Climate Change (IPCC): Vulnerability is the degree, to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and its variation to which a system is exposed, its sensitivity, and its adaptive capacity

Assessing vulnerability to climate change is not only crucial for defining the risks posed by climate change but also for providing 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

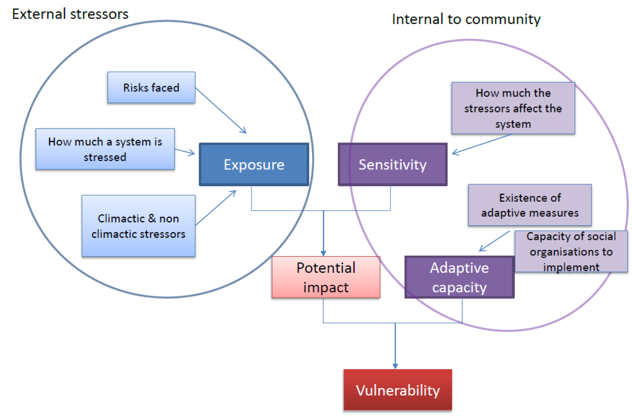


Figure 1: Graphical representation of climate change induced vulnerability components

Hence, vulnerability is a function of all the three terms. Mathematically, this can be denoted as,

Vulnerability = f (Exposure, Sensitivity, Adaptive Capacity)

Components of Vulnerability are:-

1. Exposure:

Exposure is defined as the degree of climate stress upon a particular unit area; it may be represented as long-term changes in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events (IPCC, 2001). Thus, it refers to the nature and degree to which a system is exposed to significant climatic variations

2. Sensitivity:

Sensitivity is the degree to which a system will be affected by, or responsive to climate stimuli (Smith et al., 2001). Sensitivity is basically the biophysical effect of climate change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise)

3. Adaptive Capacity:

Adaptive capacity refers to the potential or capability of a system to adjust to climate change, including climate variability and extremes, so as to moderate potential damages, to take advantage of opportunities, or to cope with consequences (Smit and Pilifosova, 2001). In other words, adaptive capacity is the capability of a system to adapt to impacts of climate change.

Approach in assessment of Vulnerability and risk due to climate change

There are two main approach to assess the vulnerability and risk of a system due to climate change viz. the top-down approach and the bottoms up approach (Dessai & Hulme, 2004). Top-down approaches start with an analysis of climate change and its impacts, while bottom-up approaches start with an analysis of the people affected by climate change (van Aalst, et al., 2008). It may also be distinguished as assessment of biophysical versus social vulnerability (O'Brien, et al., 2007). The choice of either of the two approach depend on the types of needs of assessment and resourced availability as well. Top-down approaches are usually employed at global, national and regional levels, while the bottom-up approaches start their analysis at the local level (e.g. households, villages, communities).

1. The top-down approach:

These studies are future-explicit (Wolf, et al., 2013), they make use of simulation models to project future impacts. Top-down studies tend to concentrate on biophysical effects of climate change that can be readily quantified. The main output from can be used to inform policy is an assessment of physical vulnerability for a specified time period (Dessai & Hulme, 2004).

Top-down approaches use Global or Regional Circulation Models (GCMs and RCMs) which project future climatic variables, e.g. mean annual precipitation, mean annual temperature, amount of monsoon precipitation, etc. These projected future scenarios are determined by the future socio-economic development of the world, size of human population and consumption patterns which in turn determine the quantity of green house gases that will be emitted in the future. Subsequently, the future state of the system of interest is evaluated according to previously defined criteria.

Top-down approaches lies in their ability to represent direct cause-effect relationships of climate stimuli and their biophysical impacts e.g. the relationship between rainfall and crop growth. Furthermore, top-down approaches are able to project the state of a system far into the future. Climate models can be coupled with sectorial models, e.g. agricultural, health or hydrological models, to assess how certain biophysical variables will develop in the future under different climate change scenarios. Even then, there are uncertainties that are inherent in every modeling exercise. Uncertainties about the future development of society and the economy are compounded by uncertainties about the climate system and the biophysical and socio-economic systems impacted.

2. Bottom-up approaches

Bottom-up approaches to vulnerability assessments provide an analysis of what causes people to be vulnerable to a given natural hazard such as climate change. Rather than putting the focus on the hazard itself, bottom-up approaches address the underlying development context of why people are sensitive and exposed in the first place. Moreover, bottom-up approaches explicitly take into account the fact that not all social groups are equally vulnerable to the negative impacts of climate change. Differences in vulnerability can stem from differences in class (including differences in wealth), occupation, caste, ethnicity, gender, disability and health status, age and immigration status and the nature and extent of social networks (Blaikie, *et al*., 1994).

Bottom-up approaches are conducted at local levels like households or rural communities. Unlike top-down approaches, most bottom-up approaches usually focus more on the assessment of current vulnerability rather than trying to estimate future vulnerability (Hinkel, *et al*., 2010).

Most methods and tools used for bottom-up vulnerability assessment are Participatory Rural Appraisal (PRA) tools. However, the outputs of bottom-up vulnerability assessments reflect many different voices, perceptions and experiences; as such, an ability to synthesize the results and identify priorities for action is required (Hinkel, *et al*., 2010).

Integration of top-down and bottom-up approaches

Top-down and bottom-up approaches can provide complementary information. Top-down approaches focus mostly on the biophysical impacts of climate change but say less about why, which and how people are vulnerable. Bottom-up approaches, on the other hand, mainly provide information about the vulnerability of different social groups. The latter type of vulnerability is by nature also linked to many other stimuli, e.g. a generally low status of rural development, and is difficult to distinguish completely from the impacts of climate change (Hinkel, *et al*., 2010). Consequently, bottom-up approaches are more suitable for assessing current vulnerabilities and adaptive capacities than for assessing the impacts of future climate change and vulnerabilities at larger scales. In contrast, top-down approaches are more appropriate for estimating large-scale climate change impacts and are less suitable on finer spatial scales and may fail to provide certain information, for example on extreme events (UNFCCC, 2011).

Comprehensively assessing vulnerability to rapid climate change requires an integration of both approaches. This demand is rooted in the fact that climate change vulnerability is multifaceted, with interactions between socioeconomic and biophysical aspects.

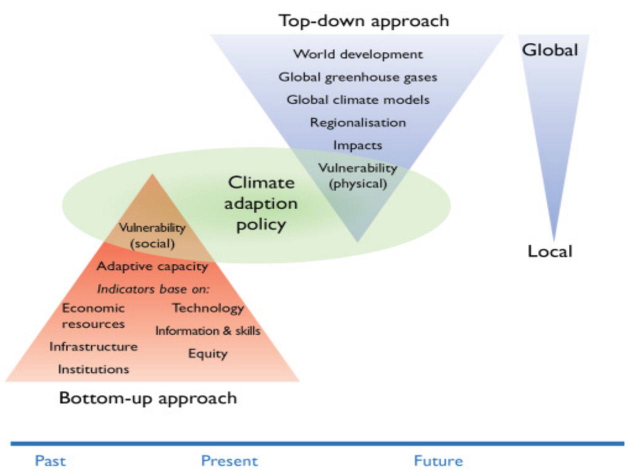


Figure 2: Graphical representation of top down and bottoms up approach in assessment of vulnerability due to climate change.

General Circulation Model (GCM) and Representative Concentration Pathways (RCP).

A general circulation model (GCM) is a type of climate model. It employs a mathematical model of the general circulation of a planetary atmosphere or ocean. It uses the mathematical equations on a rotating sphere with thermodynamic terms for various energy sources (radiation, latent heat). These equations are the basis for computer programs used to simulate the Earth's atmosphere or oceans. Atmospheric and oceanic GCMs (AGCM and OGCM) are key components along with sea ice and land-surface components. GCMs and global climate models are used for weather forecasting, understanding the climate and forecasting climate change.

GCMs represents physical processes in the atmosphere, ocean, cryosphere and land surface, they are the most advanced tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations.

GCMs depict the climate using a three dimensional grid over the globe (Fig 3), typically having a horizontal resolution of between 250 and 600 km, 10 to 20 vertical layers in the atmosphere and sometimes as many as 30 layers in the oceans. Their resolution is thus quite coarse therefore one may need to downscale these units into a finer resolution such as for example, on a scale of 25km to 25 km or even finer to suit the need for a particular area of interests which may be country, regional, state, provinces or districts and even to a small particular area. These downscaled units from GCMs are called Regional Circulation Models (RCM). The process of downscaling techniques can be two types, i.e. dynamic downscaling and empirical downscaling.

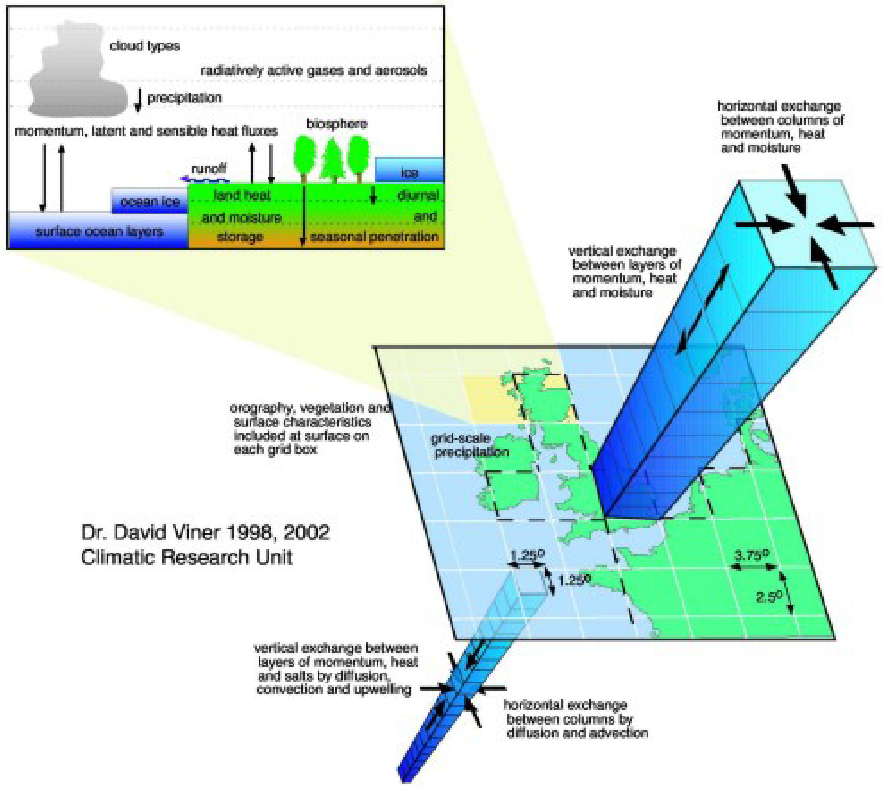


Figure 3. GCMs depicting climate using a three dimensional grid over the globe.

Atmospheric (AGCMs) and oceanic GCMs (OGCMs) can be coupled to form an atmosphere-ocean coupled general circulation model (CGCM or AOGCM). With the addition of sub-models such as a sea ice model or a model for evapo-transpiration over land, AOGCMs become the basis for a full climate model. Some examples of AOGCMs are the Canadian Global Climate Model version 3 (**CGCM3**); the NCAR Community Climate Model version 3 (**CCSM3**); the Geophysical Fluid Dynamics Laboratory (GFDL) Climate Model version 2.1 (**CM2.1**); and the United Kingdom (UK) Hadley Centre Climate Model version 3 (**HadCM3**), etc.

Coupled AOGCMs use transient climate simulations to project/predict climate changes under various scenarios. These are idealized scenarios (most commonly, CO2 emissions) based on recent history. They are basically trajectories of green house gas concentrations (not emissions) and the IPCC adopted such trajectories for its its fifth Assessment Report (AR5) in 2014 and are called the Representative Concentration Pathways (RCPs). It supersedes Special Report on Emissions Scenarios (SRES) projections published in 2000.

The pathways are used for climate modeling and research. They describe four possible climate futures, all of which are considered possible depending on how much greenhouse gases are emitted in the years to come. There are four RCPs, RCP2.6, RCP4.5, RCP6, and RCP8.5, are named after a possible range of radiative forcing values in the year 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and +8.5 W/m2, respectively).

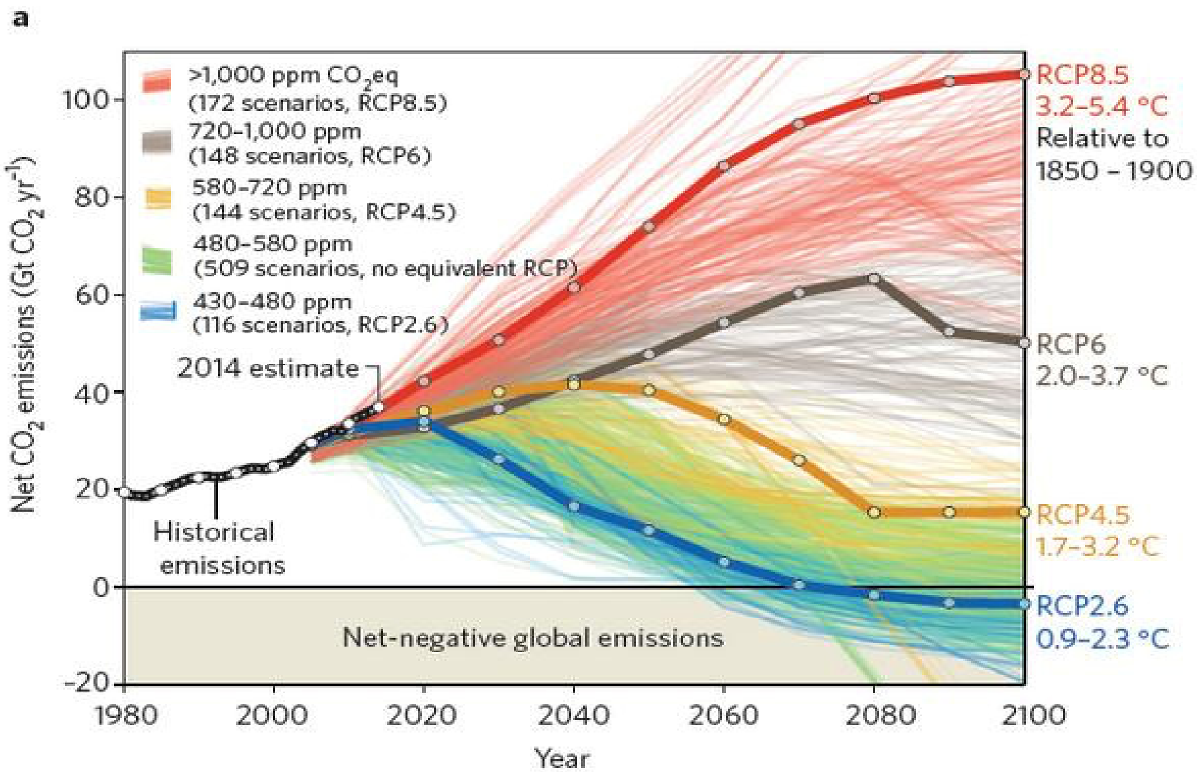


Figure 4: Graphical representation of Representative Concentration Pathways (RCPs)

STUDY AREA

Perching on the high hill of the extreme corner of the north-eastern states of India, lies Mizoram between 21° 57' and 24° 30' N latitude and 92° 15' and 93° 29' E longitude, bordering Myanmar in the east and south, Bangladesh in the west, Tripura, Manipur and Assam in the north. The total geographic area of Mizoram is 21,081 km², which is 0.6% of the country. The terrain is hilly and mostly undulating with altitude ranging from 500 to 800 m and maximum altitude is 2,157 m. Average annual rainfall is around 2500mm. During winter, the average temperature varies from 11° C to 24° C and in summer from 18° to 29° C.

The forest cover is 18,430 km² which constitutes 87.42% of the total geographic area. The climate, terrain and heavy precipitation have resulted in landscape rich semi-evergreen forests. According to Champion and Seth (1968), the forests of Mizoram can be classified as Tropical wet evergreen, Tropical semi-evergreen and Sub-tropical hill forest.

The whole state of Mizoram is targeted as the study area, district political boundaries are used as an unit of measurement. Thus, there are 8 units of measurement which are separately assessed to represent the whole state of Mizoram (Table 1).

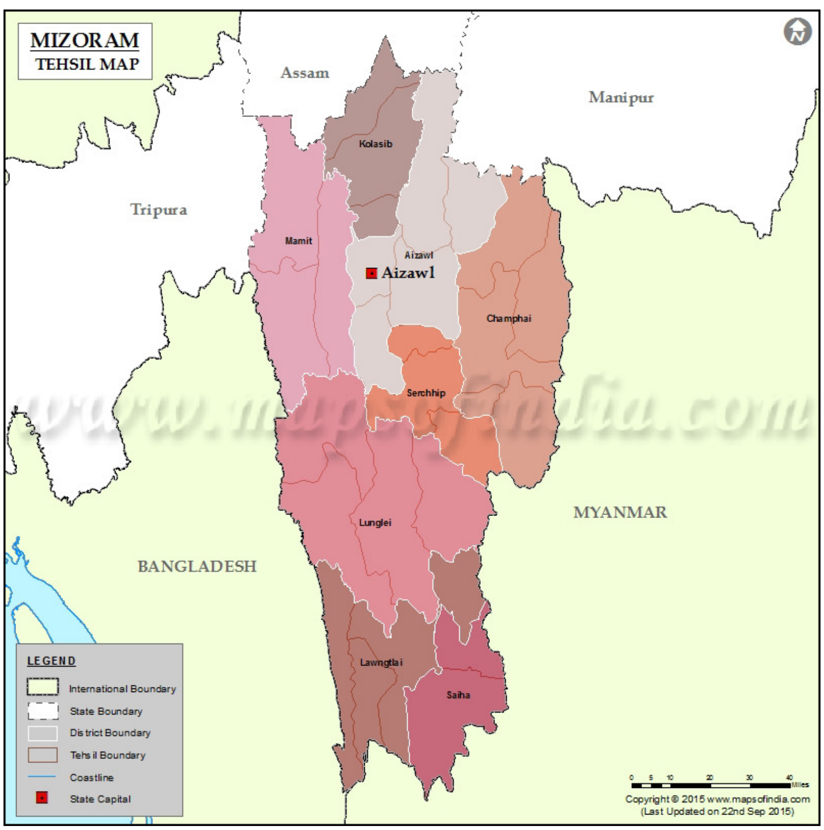


Figure 5: Map of Mizoram showing districts, states and international political boundaries.

Table 1. District wise population of Mizoram as per 2011 Census.

District	Population			Density (per SqKm)	Sex Ratio	Literacy %
	Male	Female	Total			
Mamit	44567	41190	85757	28	924	60
Kolasib	42456	40598	83054	60	956	94.54
Aizawl	201072	202982	404054	113	1009	98.50
Champhai	63299	62071	125370	39	981	93.51
Serchhip	32824	32051	64875	46	976	98.76
Lunglei	79252	74842	154094	34	944	89.40
Lawngtlai	60379	57065	117444	46	945	66.41
Saiha	28490	27876	56366	40	978	88.41
MIZORAM	**552339**	**538675**	**10,91,014**	52	875	**91.85**

Economy of Mizoram is based on agriculture, horticulture, forest products, industry, mineral, and tourism sectors. Among these, agriculture, industry and service sector are the main backbone of Mizoram economy. More than 70% of the people of the state are engaged in agriculture sector, service sector absorbed the second largest working force of the total population. Service sector contribute more than 60 % of the economy and the remaining major portion are from agriculture and industry sectors. The people follow the method of shifting cultivation which is also known as Jhumming method of cultivation, The major crops that are grown in Mizoram are rice, cotton, oilseeds, pulses, maize, sesame, and sugarcane, etc which are mostly seasonal, which makes the agriculture sector especially in rural areas mostly vulnerable to natural and man-made induced hazards which are likely to be exacerbated by climate change.

CLIMATE SCENARIO OF MIZORAM

Meteorological data collected by State Meteorological Center, Directorate of Science and Technology, Govt. of Mizoram shows that there has been a changes in the amount and pattern of rainfall of Mizoram, which provide evidence that the water cycle is already changing. Over the past 30 years, there has been a steady decrease in rainfall trend (Figure 6). The mean temperature shows a slight increasing trend, while the temperature range increases considerably (Figure 7).

Figure 6. Regression of rainfall (mm) of Mizoram by time

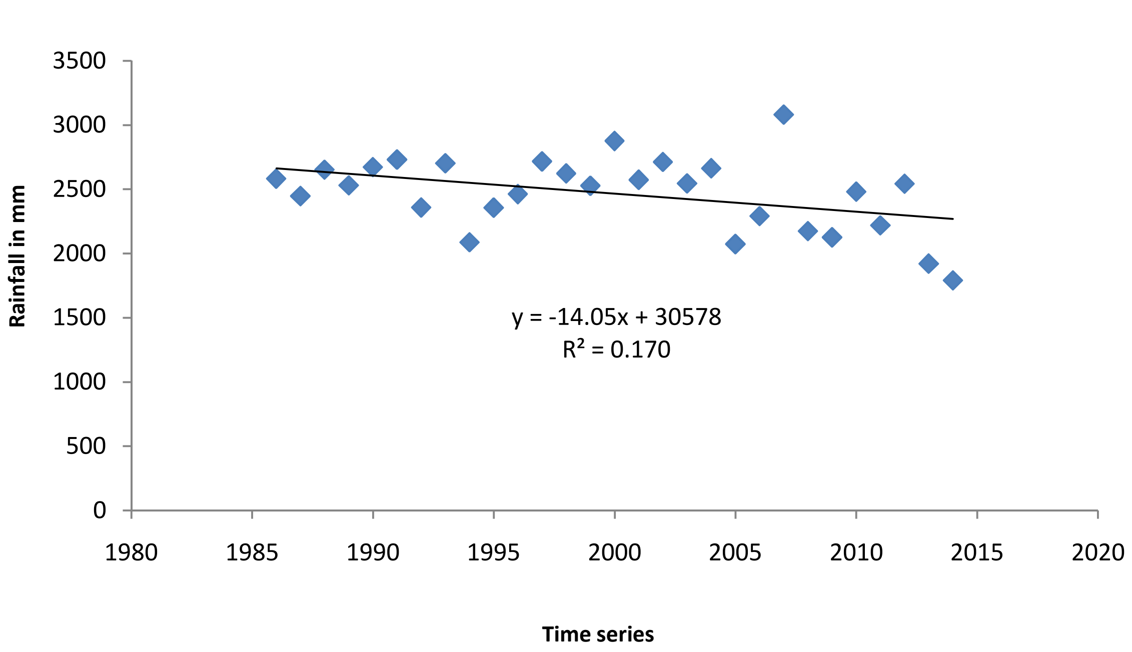
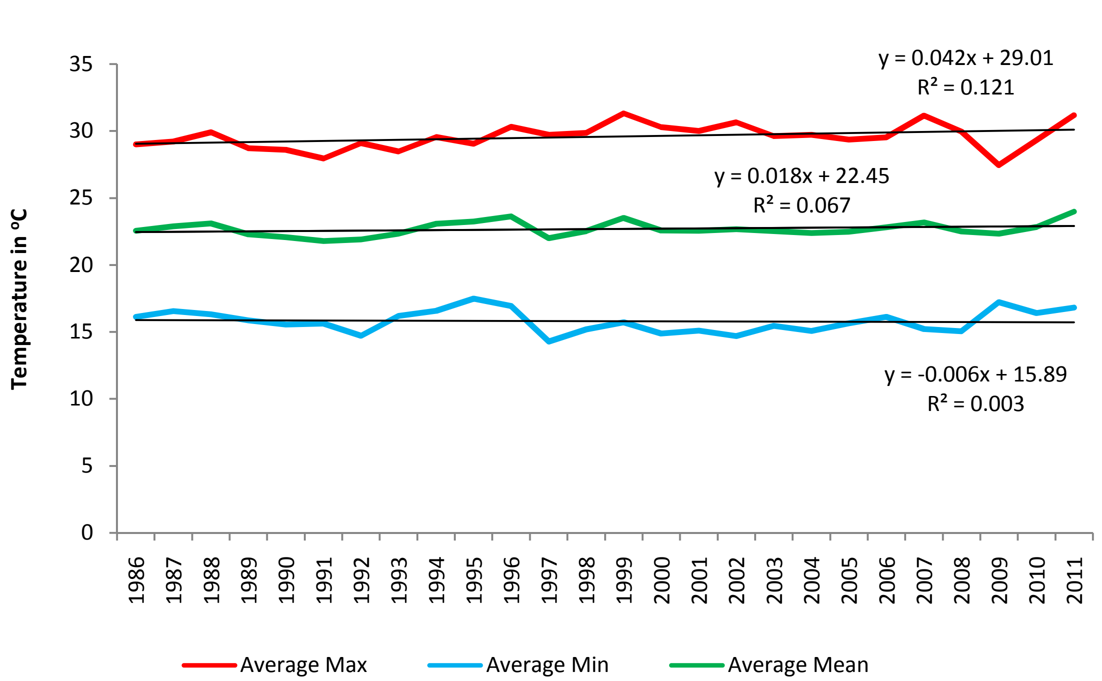


Figure 7. Average yearly temperature of Mizoram (in ºC) from 1986 to 2011



Even though there has not been any detailed study on the actual changing pattern of climate and their effects, it can be observed through this time span that agriculture and the water sectors are already being affected. Other sectors which may not be readily witnessed are also no doubt directly or indirectly affected. Thus, any kind of study or initiatives towards the aspects of climate change needs to be a priority so that at least a baseline data is generated so that any further studies could have a pre-required information for a systematic planning and scientifically robust design.

CLIMATE CHANGE STUDY IN MIZORAM

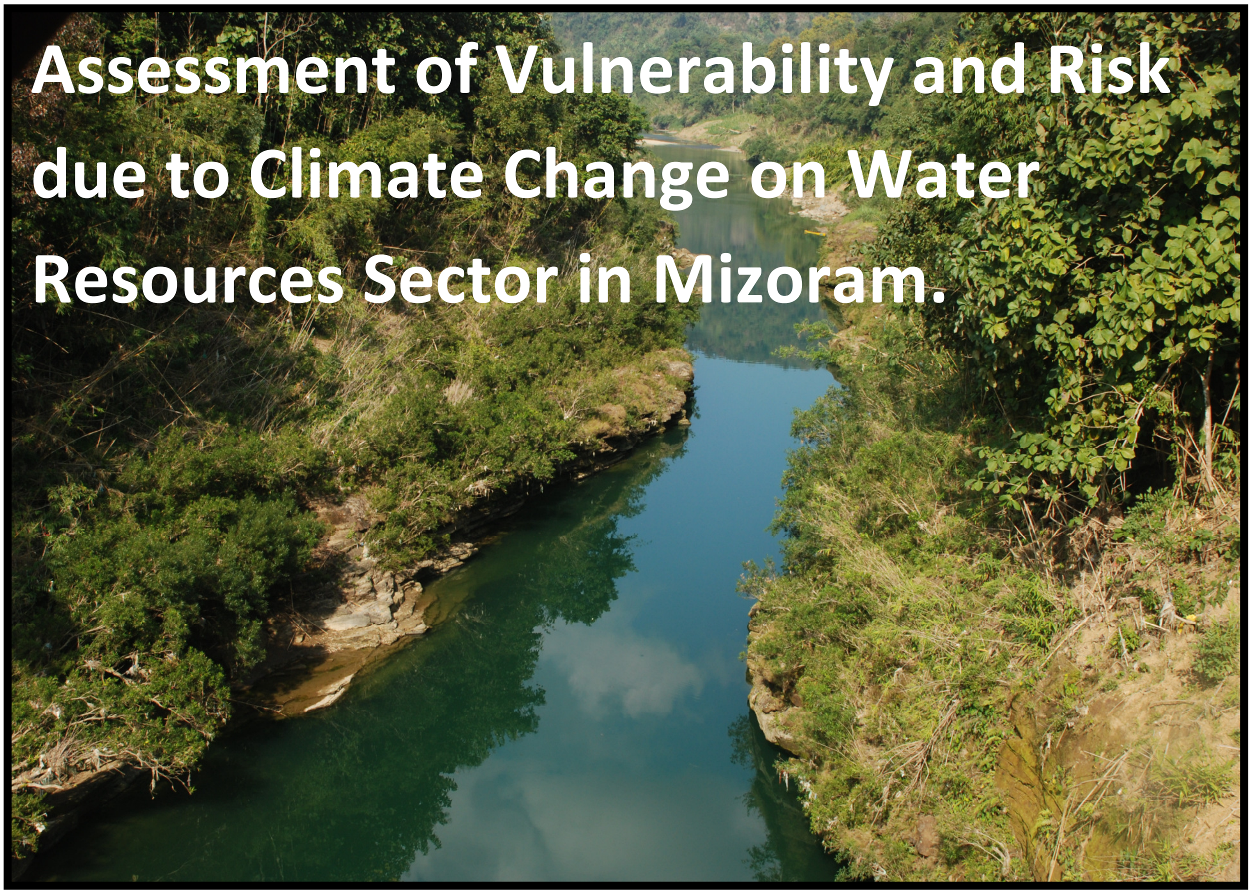
The State Climate Change Cell (SCCC) of Mizoram under the Mizoram Science, Technology and Innovation Council (MISTIC) has been established under the support of National Mission for Sustaining the Himalayan Ecosystem (NMSHE), Department of Science and Technology, Govt. of India. The SCCC was equipped to work in 2015. Since then, it has been collecting data and information about the meteorological conditions in Mizoram from various sources, and has been analyzing them to have a meaningful representation of the climate condition in Mizoram.

The SCCC has also been organizing workshops, seminars and awareness programmes by inviting resource persons to study several topics on climate change and its associated impacts on certain sectors. Different stakeholders were invited at different occasions with respect to the target groups.

The vulnerability and risk assessment of climate change is also being carried out to study on how the climate of Mizoram is changing and to what extent does different sectors are being effected and will be effected in the future. In this booklet, result extract of the vulnerability and risk assessment of water resources and health sectors are presented, which is a part of the ongoing study on vulnerability and risk assessment of climate change.

The availability of resources and data collected for this study are very limited, further, unavailability of sufficient real time data compels to the use of simulated weather data. Therefore, the results presented here which are subjected to the work of computer models and simulations, are needed to be validated by further investigations. However, it is assumed to be a very probable scenario to represent an ideal situation. Furthermore, it is expected to be a fairly dependable baseline information and knowledge building material for Decision makers/policy makers, scientists as well as laymen, etc.

Assessment of Vulnerability and Risk due to Climate Change on Water Resources Sector in Mizoram.



Prepared by

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Catalyzed and Supported by

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Abstract

Vulnerability of the water resources in eight districts of Mizoram were determined for both mid century and end century scenario by assessing the overall change in major five water balance components such as Precipitation, Evapo-transpiration, Ground Water Recharge, Surface Runoff and Base flow. Majority of Mizoram were classed as moderately vulnerable in Mid Century while few areas are classed as low vulnerability. The pattern is almost same at the end century except for a few areas in the south eastern part where vulnerability are extremely high.

BACKGROUND

The Hydrosphere

The Earth is made up of a series of components – the hydrosphere or the water component, atmosphere or the air component, lithosphere or the soil and rock component, and biosphere or the living component. These function as systems that are constantly interacting and adjusting to both internal and external factors. It is the continuous alterations to these cycles that produce the environmental conditions that we experience.

Among the four component of the earth, the hydrosphere is a defining characteristic of the Earth. It is the only planet in our Solar System with a hydrological cycle. This includes salt waters (oceans and seas), freshwater (rivers, lakes, and groundwater) and the cryosphere (where water exists as a solid – ice or snow – such as within ice sheets, glaciers and permafrost/frozen ground. These are also major stores of freshwater). The hydrosphere and cryosphere are also frequently recognized as two separate 'spheres'. Together, all of these water sources are vital for almost all forms of life on Earth, and they are the reason that Earth is often termed the 'water planet'.

Approximately 71% of earth is covered in water. Of these, salt water accounts for approximately 97.5% and the remaining 2.5% are freshwaters. Of the freshwaters, about 68.9% are locked in the cryosphere, about 30.8% are in below the surface or ground waters. Only 0.3% of fresh waters on earth are readily accessible in the form of surface water.

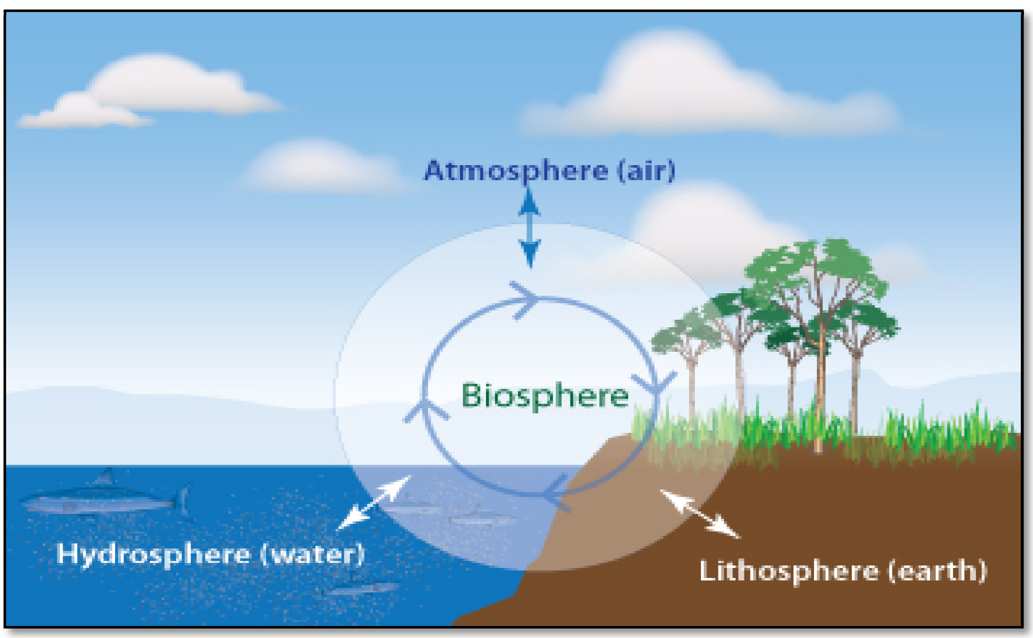


Figure 8: Components of Biosphere

Water resources and climate change

Water resources in human context are those sources of water that are useful to humans. They are important to both society as well as ecosystems. We depend on a reliable, clean supply of drinking water to sustain our health. We also need water for agriculture, energy production, navigation, recreation, and manufacturing. Virtually, all activities of human requires fresh water. Though fresh water is a renewable resource like soil and air, water demands exceeds its supply in many parts of the world due to increasing human population, thus, being is one of the most critical resources, it is under threat.

Water resources can be divided into two distinct categories:-

1. Surface water resources:- Surface waters are water in rivers, lakes and fresh water wetlands. They are naturally replenish by precipitation and naturally lost through discharge to the sea, evaporation and sub-surface seepage.

2. Ground Water Resources:- Sub-surface waters are freshwaters located in the pore spaces of soils and rocks. They are also waters that are flowing within the aquifers blow the water table.

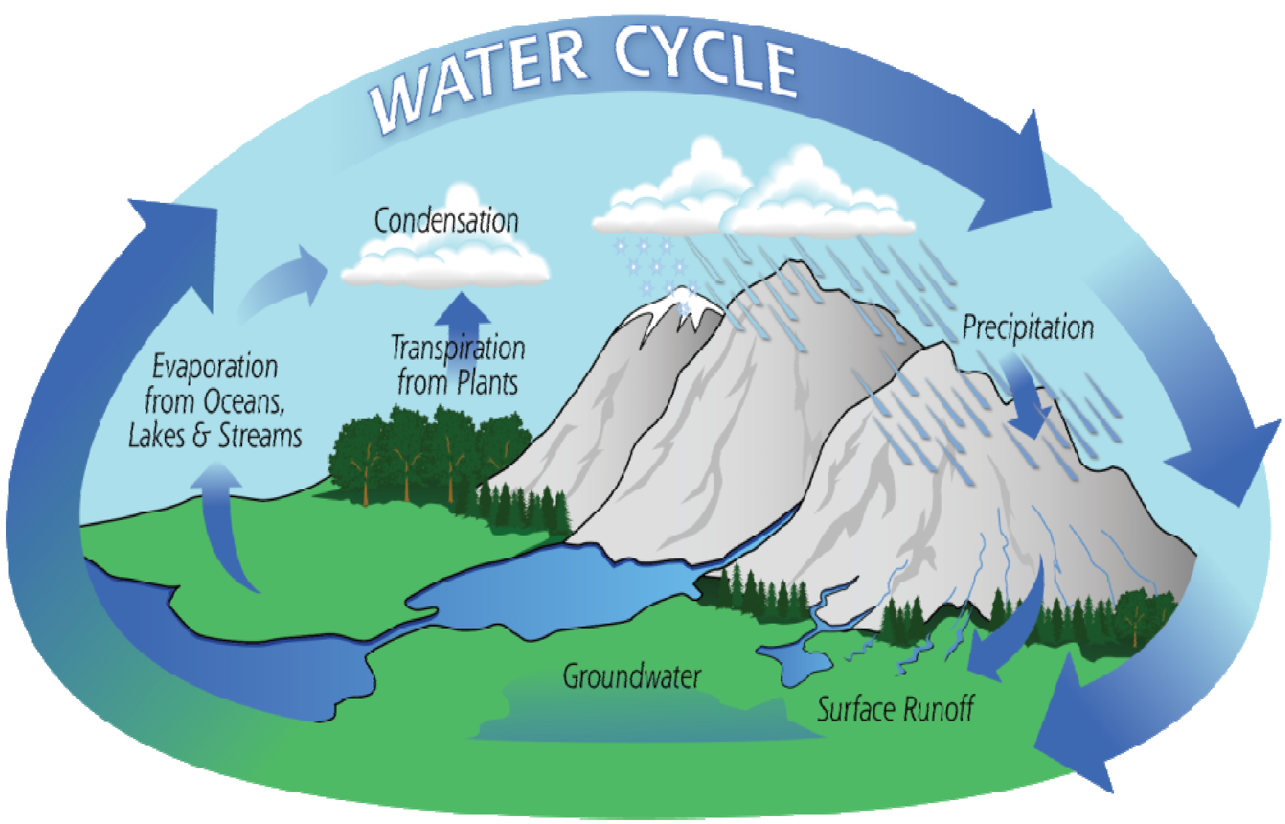


Figure 9: Diagram of Water Cycle showing different steps or the water balance components.

Each of these categories are part of the world's water circulatory system called the Hydrological Cycle or The Water Cycle. The water cycle is a delicate balance of precipitation, evaporation, and all of the steps in between (Fig 9).

The equilibrium of such state is being altered due to pressures by increasing human population and stresses that are likely to be exacerbated by climate change as well.

For instance, warmer temperatures increase the rate of evaporation of water into the atmosphere, in effect increasing the atmosphere's capacity to "hold" water. Increased evaporation may dry out some areas and fall as excess precipitation on other areas.

As temperatures rise, people and animals need more water to maintain their health and thrive. Many important economic activities, like producing energy at power plants, raising livestock, and growing food crops, also require water. The amount of water available for these activities may be reduced as Earth warms and if competition for water resources increases.

The impacts of climate change on water availability and water quality will affect many sectors, including energy production, infrastructure, human health, agriculture, and ecosystems

Climate change is changing our assumptions about water resources. As climate change warms the atmosphere, altering the hydrologic cycle, changes to the amount, timing, form, and intensity of precipitation will continue. Other expected changes include the flow of water in watersheds, as well as the quality of aquatic and marine environments. These impacts are likely to affect the programs designed to protect water quality, public health, and safety.

DISTRICT WISE ASSESSMENT OF VULNERABILITY AND RISK DUE TO CLIMATE CHANGE ON WATER RESOURCES.

Assessing the profile of system of Interest: There are eight districts in the state of Mizoram as mentioned before in the study area. These are the units of measurement and are determined separately to represent the whole state of Mizoram.

Assessment of the observed climate

Historical data: Long term historical climate data for Mizoram was downloaded from https://globalweather.tamu.edu by defining the area of interest within the website. The source of the data, i.e., The National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) completed simulated assessment of the world's climate over 36-year period of 1979 through 2014. The CFSR was designed and executed as a global, high resolution, coupled atmosphere-ocean-land surface-sea ice system to provide the best estimate of the state of these coupled domains over this period.

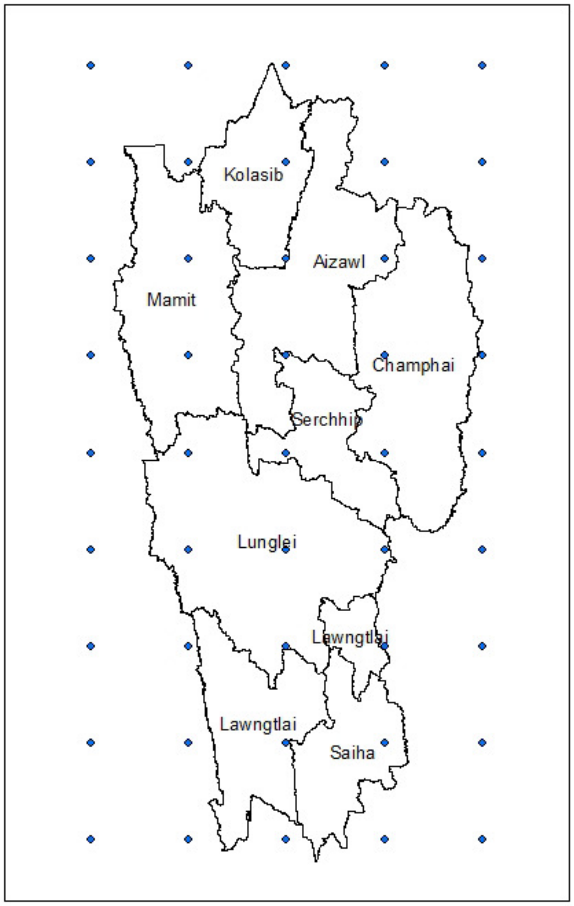
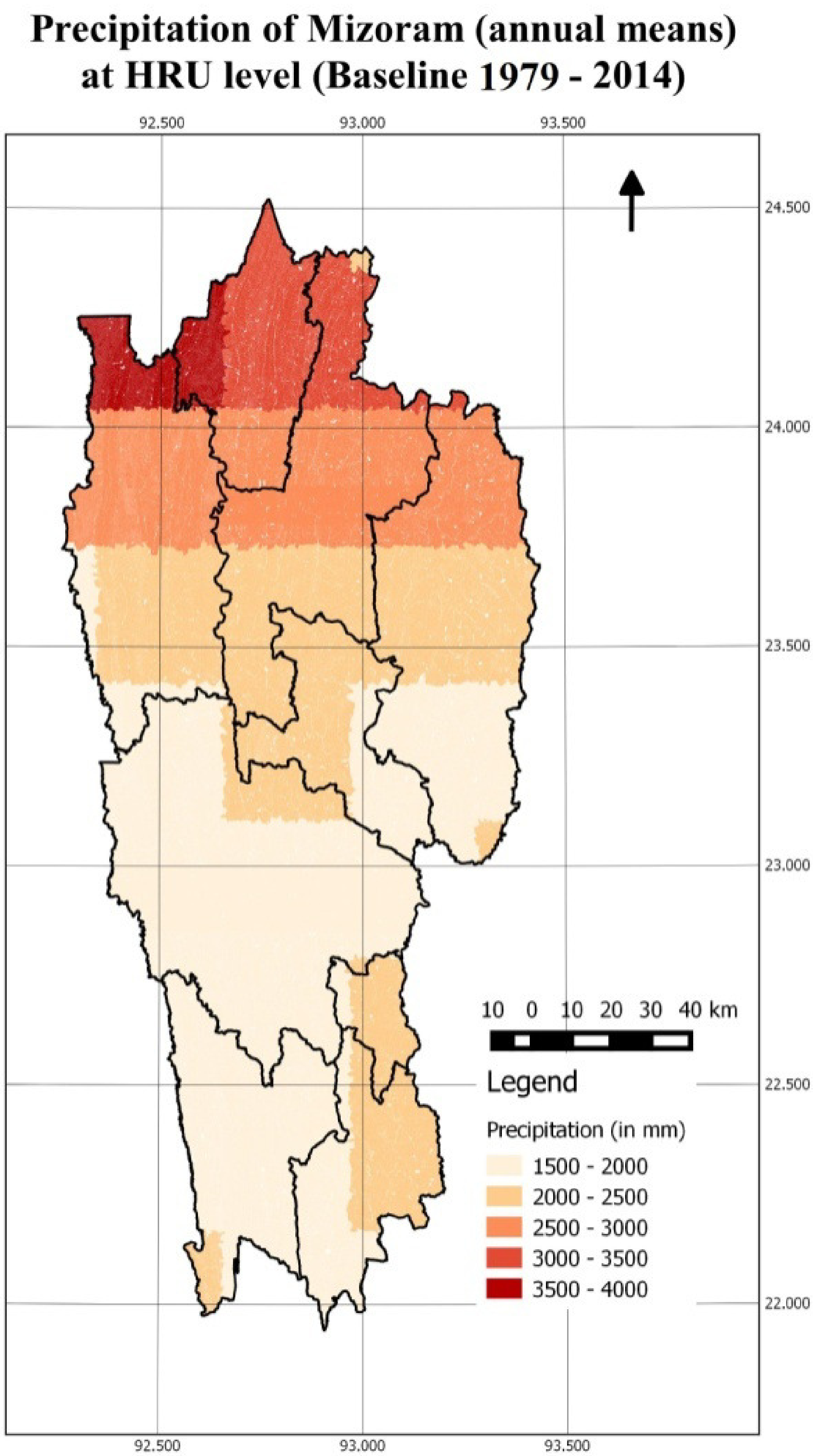


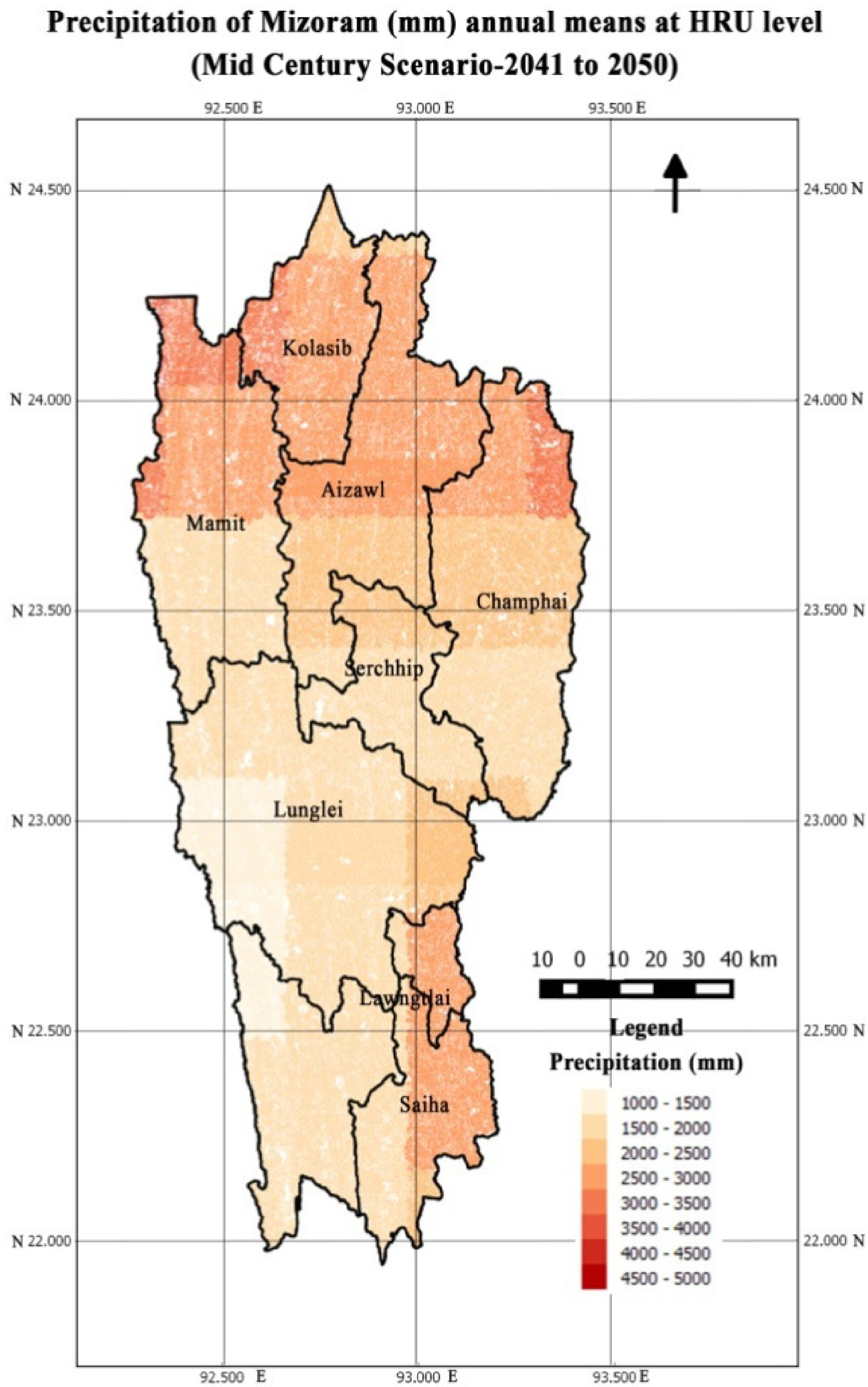
Figure 10: 45 Weather Station of CFSR covering the state of Mizoram

The CFSR data are of 5 different climate parameters namely precipitation (mm), temperature (^oC), solar radiation (MJ/m^2), relative humidity (fraction) and wind speed (m/s). The whole state of Mizoram was covered by 45 stations with a distance of approximately 20 minutes each. These data are used due to unavailability of systematic and consistent real time data from local source and also due to the unavailability of gridded format which is needed for further assessment to study the sensitivity of the system to climate exposure.

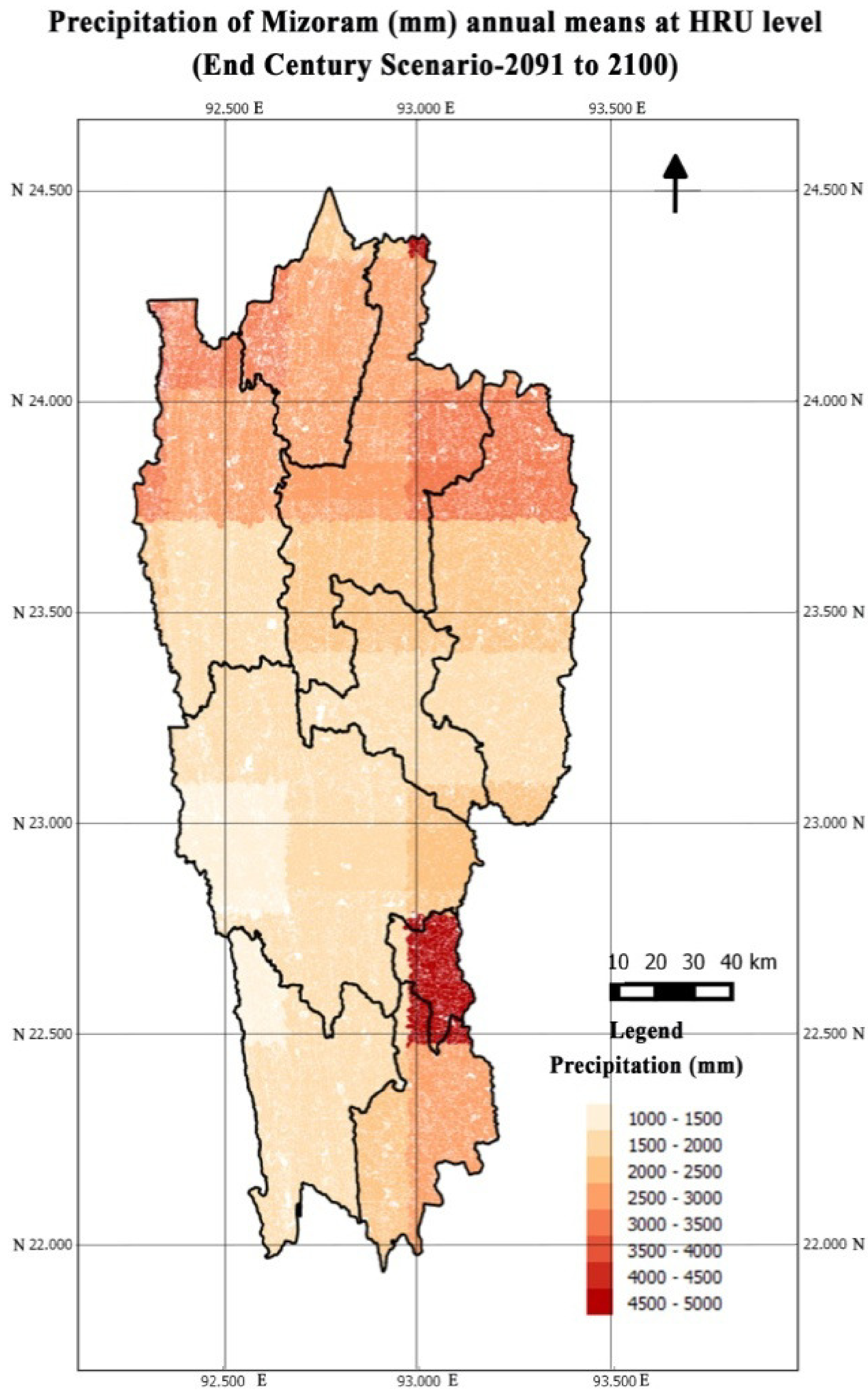
Future climate data: SIMClim AR5 2013, an RCM software, product of Climate Systems Ltd., New Zealand was used to generate patterns of future climate data. The historical data for each above mentioned 45 stations over a period of 36 years were feed into SIMClim. There are 40 models and 4 RCPs having low, medium and high sensitivity scenario settings incorporated within the software to project future climate data. HadCM3 model using RCP 4.5 at medium sensitivity was used to project and generate data for Mid Century (2041 - 2050) and End Century (2091 - 2100) scenarios.



Figures 11 (a): Climate exposure (Precipitation) of Mizoram for baseline (1979 - 2014)



Figures 11 (b): Climate exposure (Precipitation) of Mizoram Mid Century Scenario simulated using HadCM3 RCP 4.5 Mid Sensitivity



Figures 11 (c): Climate exposure (Precipitation) of Mizoram End Century Scenario simulated using HadCM3 RCP 4.5 Mid Sensitivity

Assessment of the effect of climate stimuli on the system of interest (sensitivity).

The effect of climate stimuli on the water resources sector of Mizoram was assessed with the help of variables indicating the water balance components i.e., water cycle. The selection of indicating variables of the water cycle was based on a literature review and subject to other works done elsewhere around the world. The change in five major water balance components viz. Precipitation, Evapo-transpiration, Ground Water Recharge, Surface Runoff and Base-flow, from current scenario to mid century scenario and from current to end century scenario were assessed using Soil and Water Assessment Tool (SWAT) developed by USDA Agricultural Research Service (USDA-ARS) and Texas A&M AgriLife Research.

SWAT is a small watershed to river basin-scale model to simulate the quality and quantity of surface and ground water and predict the environmental impact of land use, land management practices, and climate change. SWAT is widely used in assessing soil erosion prevention and control, non-point source pollution control and regional management in watersheds. SWAT uses a two-level disaggregation scheme; a preliminary sub-basin identification is carried out based on topographic criteria, followed by further discretization using land use and soil type considerations. Areas with the same soil type and land use form a Hydrologic Response Unit (HRU), a basic computational unit assumed to be homogeneous in hydrologic response to land cover change. For the current assessment, the water balance components were represented at the HRU level.

There are several version of SWAT that can be used on different GIS (Geographical Information System) application as an interface. SWAT itself is a free open source software which can be downloaded from http://swat.tamu.edu/. Due to the availability of QGIS as open source GIS application, QSWAT 1.4 on QGIS 2.6.1 was used for the assessment.

The following are the data used for assessing the water balance components using SWAT:-

1. Climatic data (viz. Rainfall, Temperature, solar radiation, wind speed, relative humidity)
   a. Current / historical (http://swat.tamu.edu/media/99082/cfsr_world.zip)
   b. Future/Projected (produced from SIMCLIM AR5 2013)
2. Digital Elevation Map-SRTM 30m (http://earthexplorer.usgs.gov/)
3. Land-use data (http://www.waterbase.org/download_data.html)
4. Soil data (http://www.waterbase.org/download_data.html)

Three different simulations for Current, Mid-Century and End-Century Water Cycle Scenarios was done using the software. The climate data from three different time scenarios were the determining factors of the water cycle scenarios of the system of interest; current climate data determines the current water cycle scenario and the future climate data was used to determine the future water cycle scenario. Thus, three different conditions; one current and two probable future conditions of water cycle in Mizoram were generated. Percent change from current to Mid-Century (figure 12 to 16) and from current to end-century scenarios (figure 17 to 21) were then calculated further with the another GIS application Arc GIS 10.1. Thematic maps of different districts of Mizoram showing projected changes in water balance components are produced.

Change in Precipitation (%) of Mizoram (District Wise) from Baseline (1979 - 2014) to Mid Century (2041-2050) using HadCM3 RCP 4.5

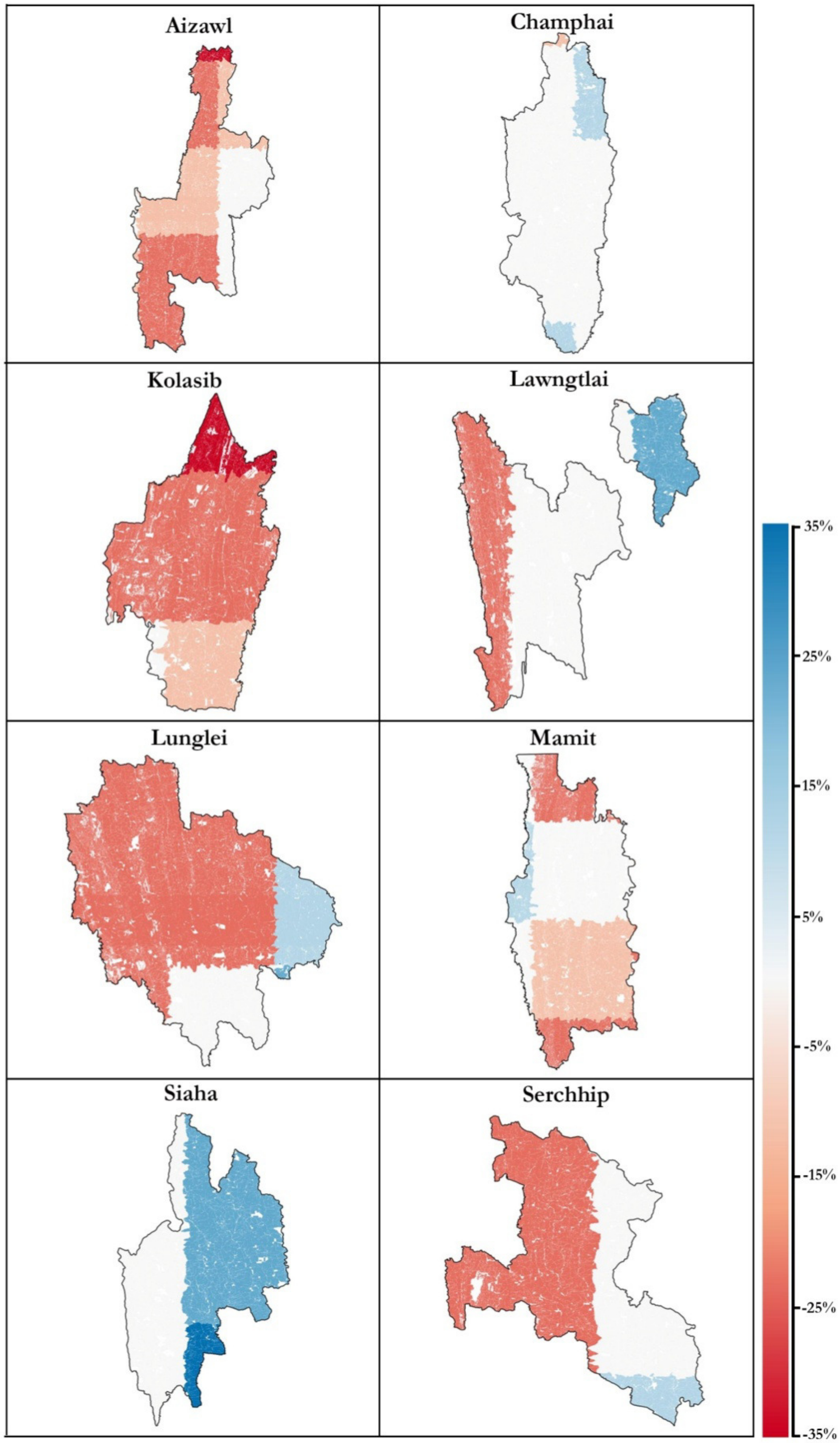


Figure 12

Change in Evapotranspiration (%) of Mizoram (District Wise) from Baseline (1979 - 2014) to Mid Century (2041-2050) using HadCM3 RCP 4.5

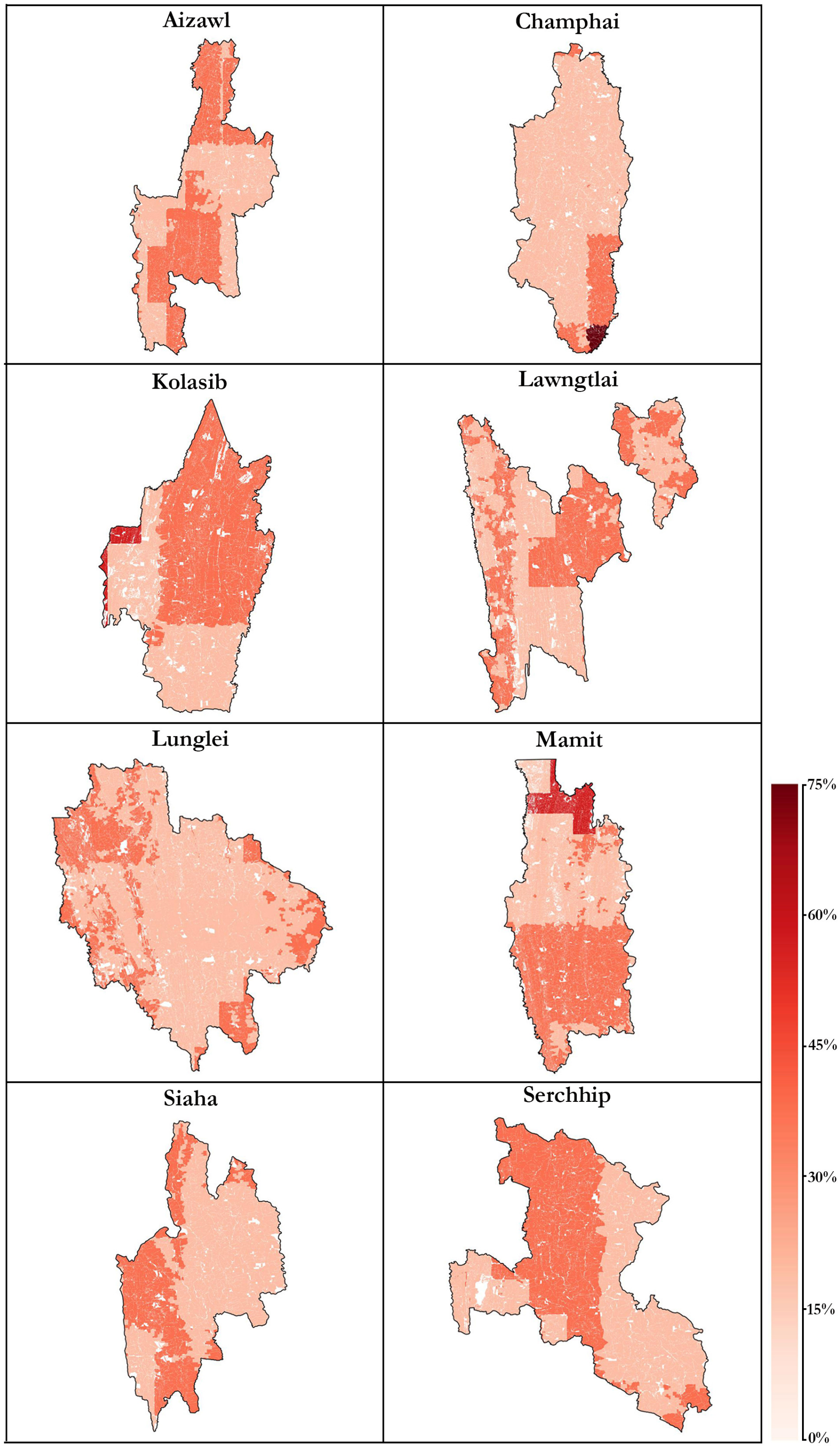


Figure 13

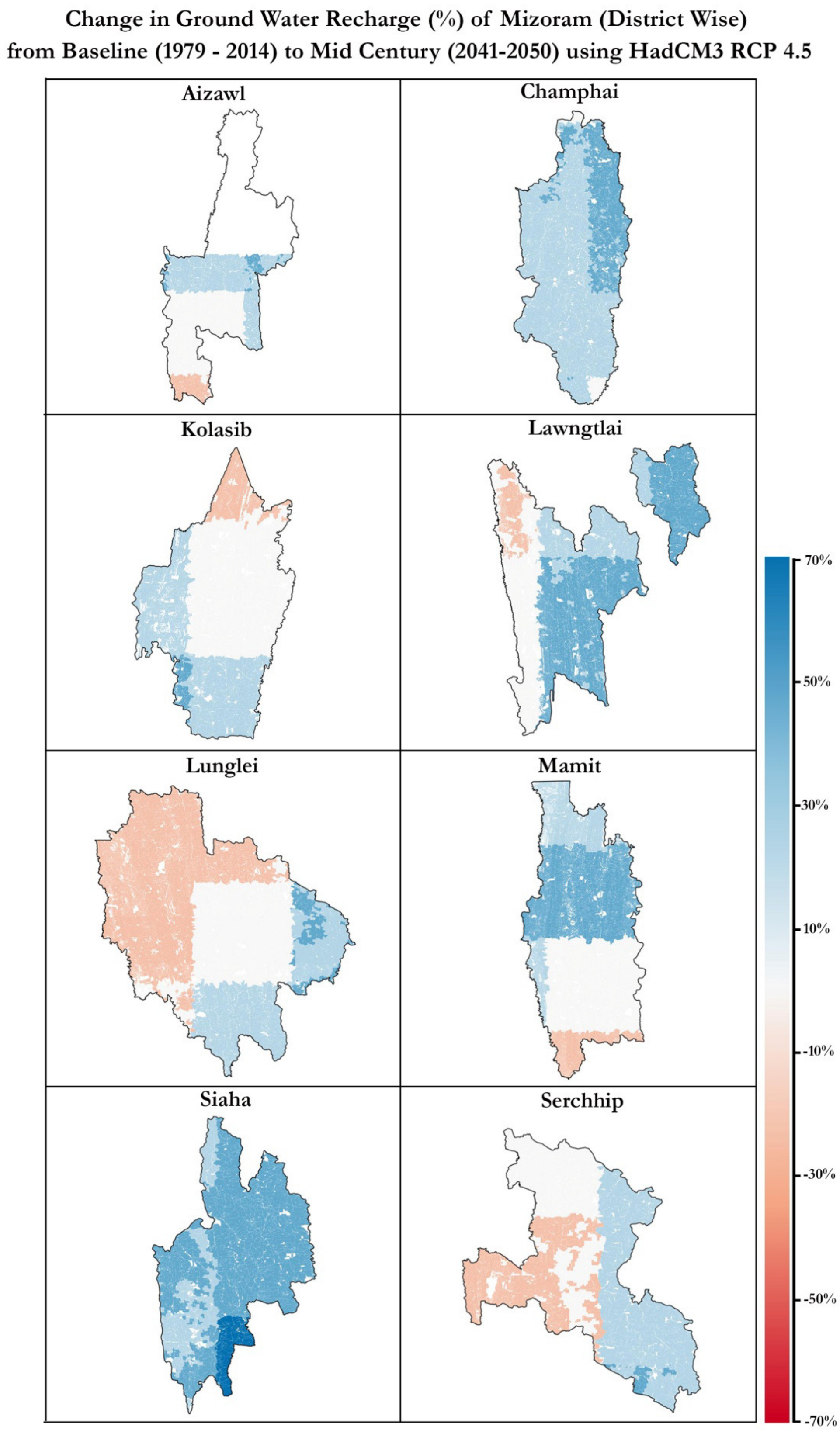

Change in Ground Water Recharge (%) of Mizoram (District Wise)
from Baseline (1979 - 2014) to Mid Century (2041-2050) using HadCM3 RCP 4.5
Aizawl
Champhai
Kolasib
Lawngtlai
Lunglei
Mamit
Siaha
Serchhip
70%
50%
30%
10%
-10%
-30%
-50%
-70%

Figure 14

Change in Surface Runoff (%) of Mizoram (District Wise) from Baseline (1979 - 2014) to Mid Century (2041-2050) using HadCM3 RCP 4.5

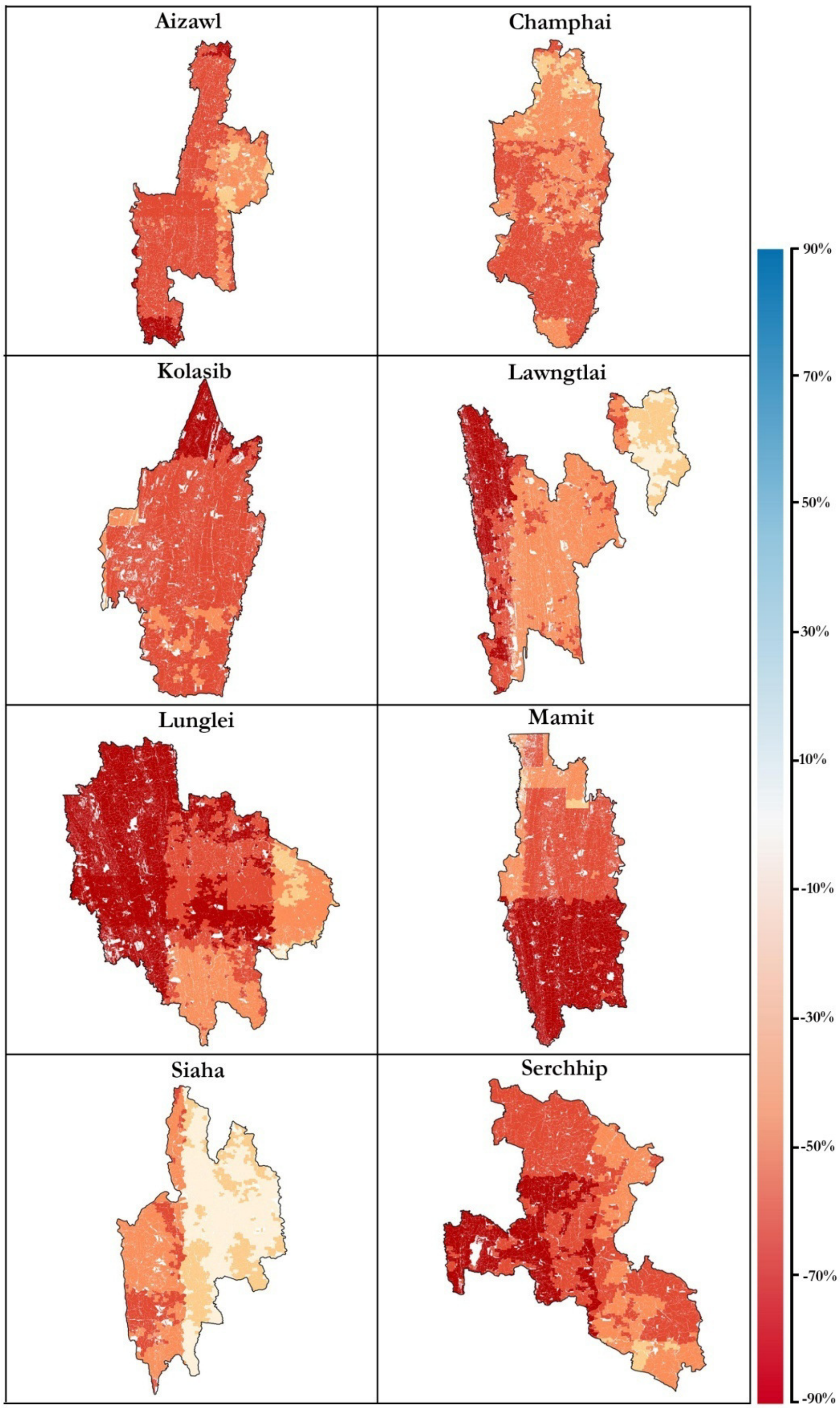


Figure 15

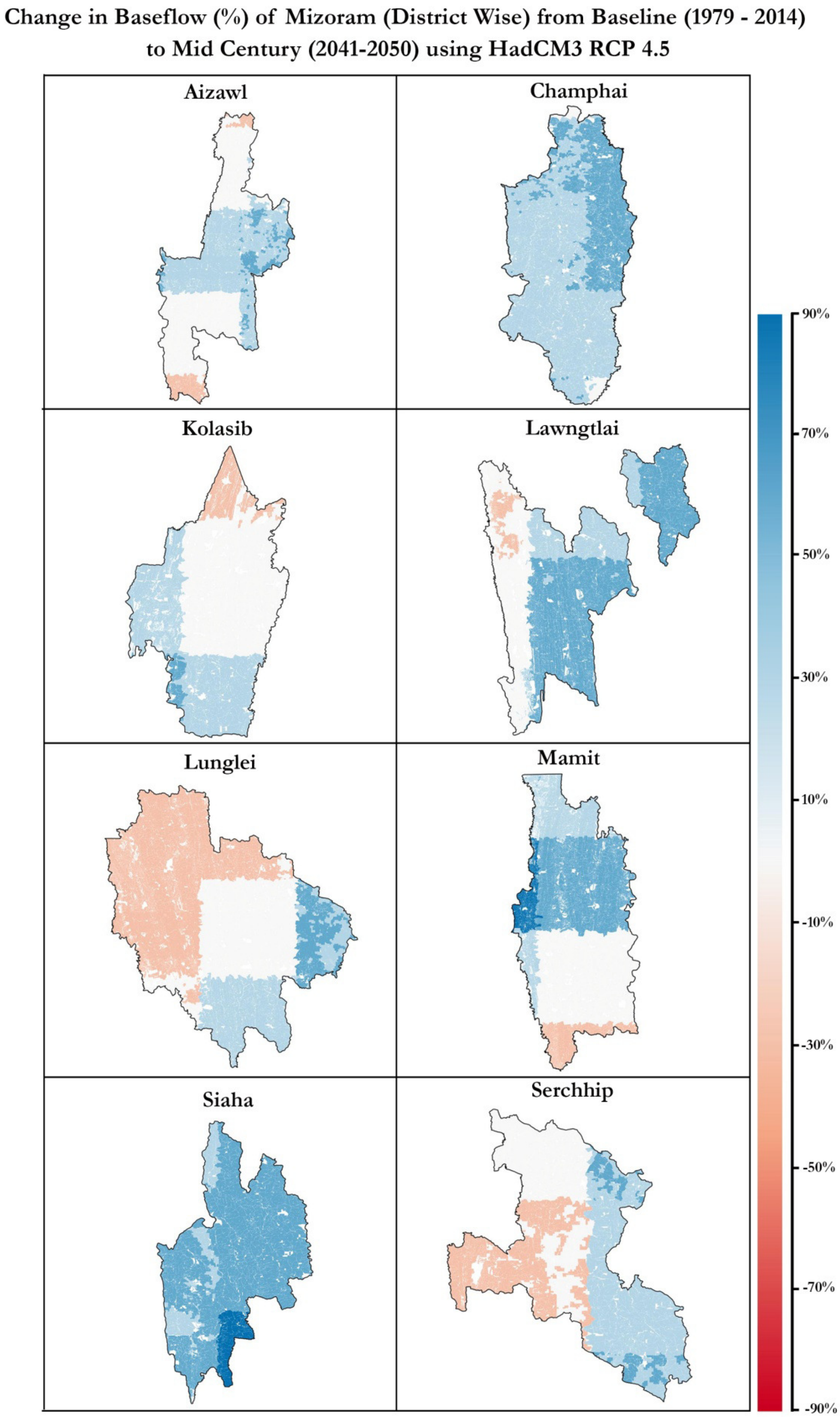

Change in Baseflow (%) of Mizoram (District Wise) from Baseline (1979 - 2014)
to Mid Century (2041-2050) using HadCM3 RCP 4.5
Aizawl
Champhai
Kolasib
Lawngtlai
Lunglei
Mamit
Siaha
Serchhip
90%
70%
50%
30%
10%
-10%
-30%
-50%
-70%
-90%

Figure 16

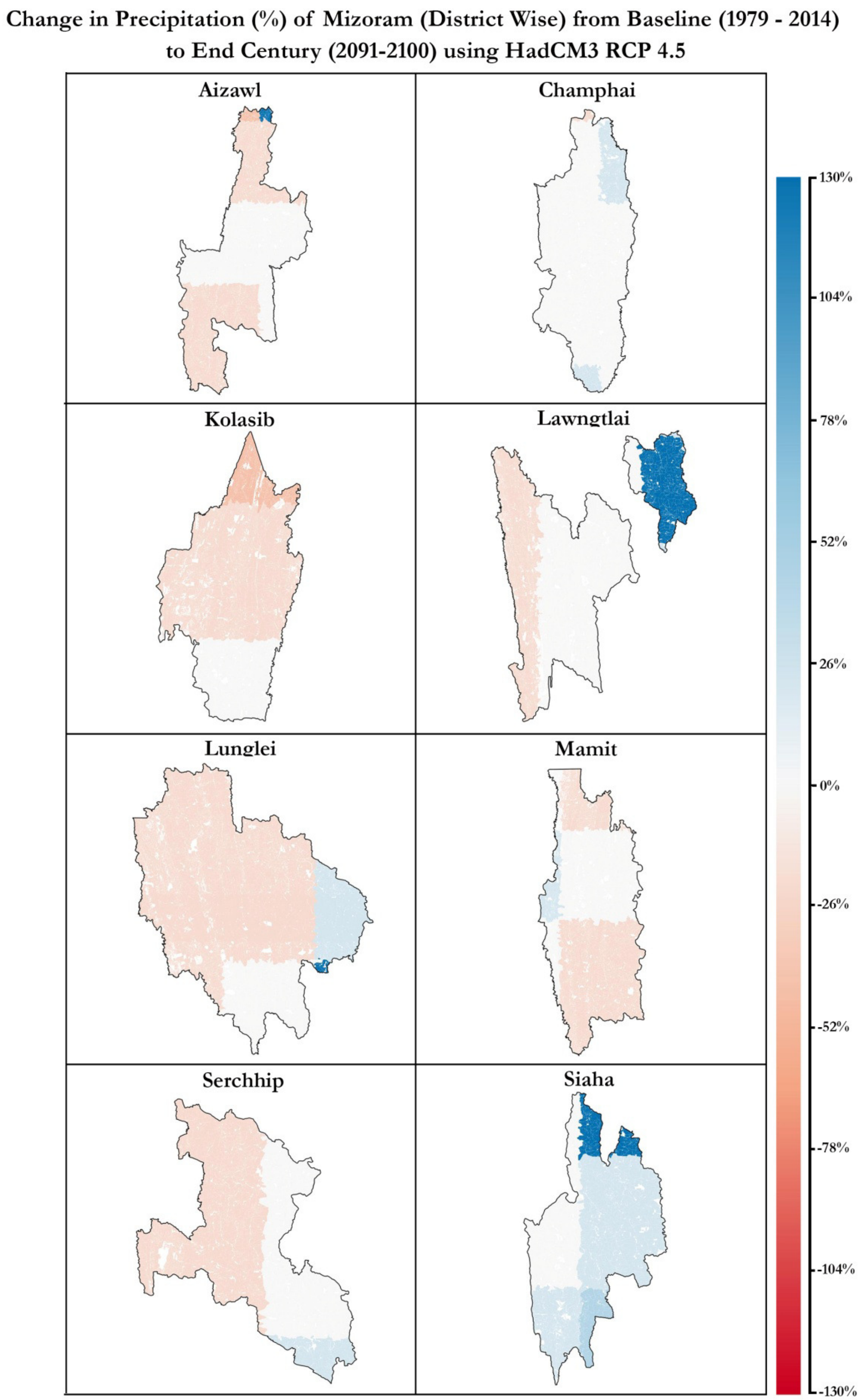

Change in Precipitation (%) of Mizoram (District Wise) from Baseline (1979 - 2014)
to End Century (2091-2100) using HadCM3 RCP 4.5
Aizawl
Champhai
Kolasib
Lawngtlai
Lunglei
Mamit
Serchhip
Siaha
130%
104%
78%
52%
26%
0%
-26%
-52%
-78%
-104%
-130%

Figure 17

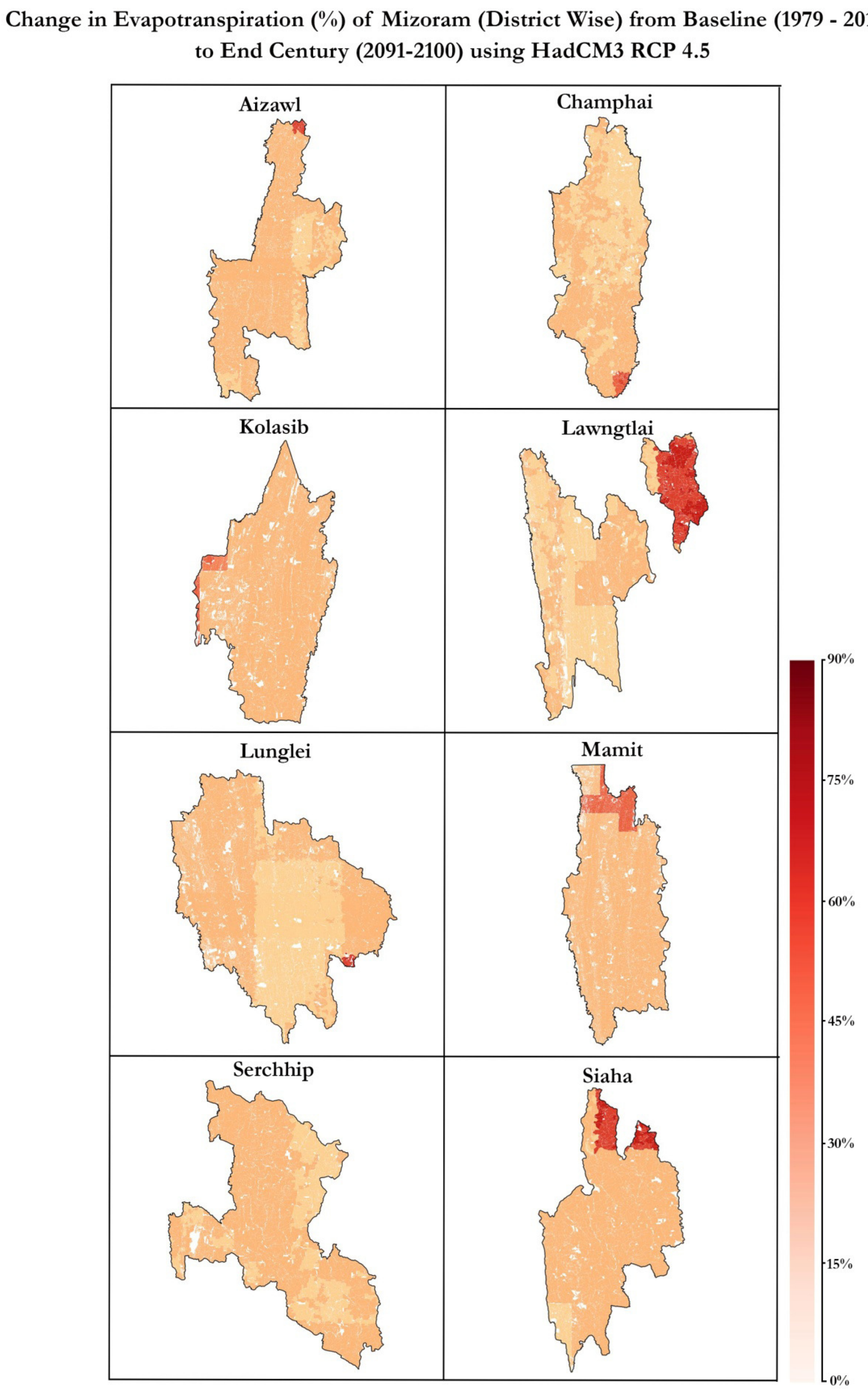

Change in Evapotranspiration (%) of Mizoram (District Wise) from Baseline (1979 - 2014)
to End Century (2091-2100) using HadCM3 RCP 4.5
Aizawl
Champhai
Kolasib
Lawngtlai
Lunglei
Mamit
Serchhip
Siaha
90%
75%
60%
45%
30%
15%
0%

Figure 18

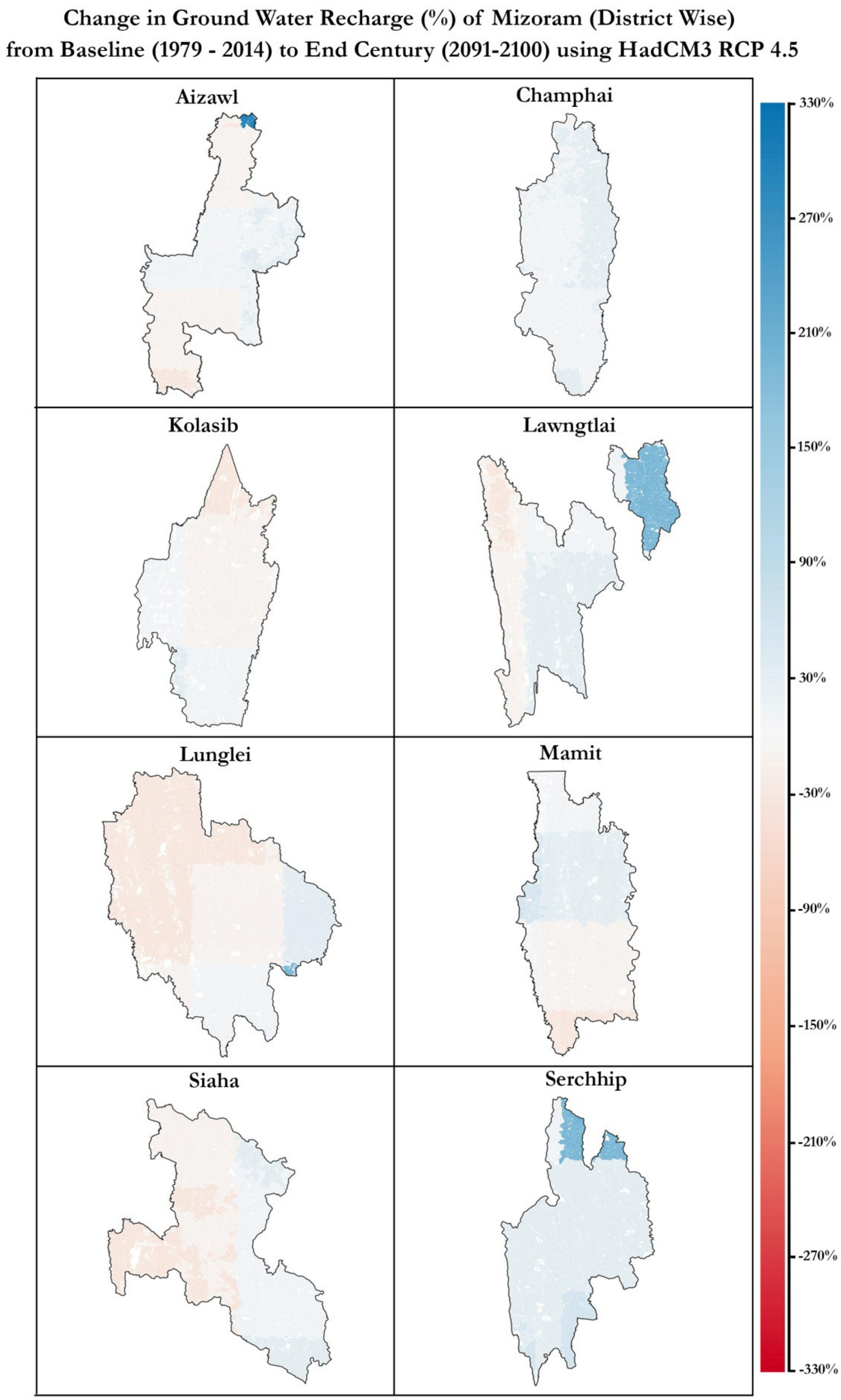

Change in Ground Water Recharge (%) of Mizoram (District Wise)
from Baseline (1979 - 2014) to End Century (2091-2100) using HadCM3 RCP 4.5
Aizawl
Champhai
Kolasib
Lawngtlai
Lunglei
Mamit
Siaha
Serchhip
330%
270%
210%
150%
90%
30%
-30%
-90%
-150%
-210%
-270%
-330%

Figure 19

Change in Surface Runoff (%) of Mizoram (District Wise) from Baseline (1979 - 2014) to End Century (2091-2100) using HadCM3 RCP 4.5

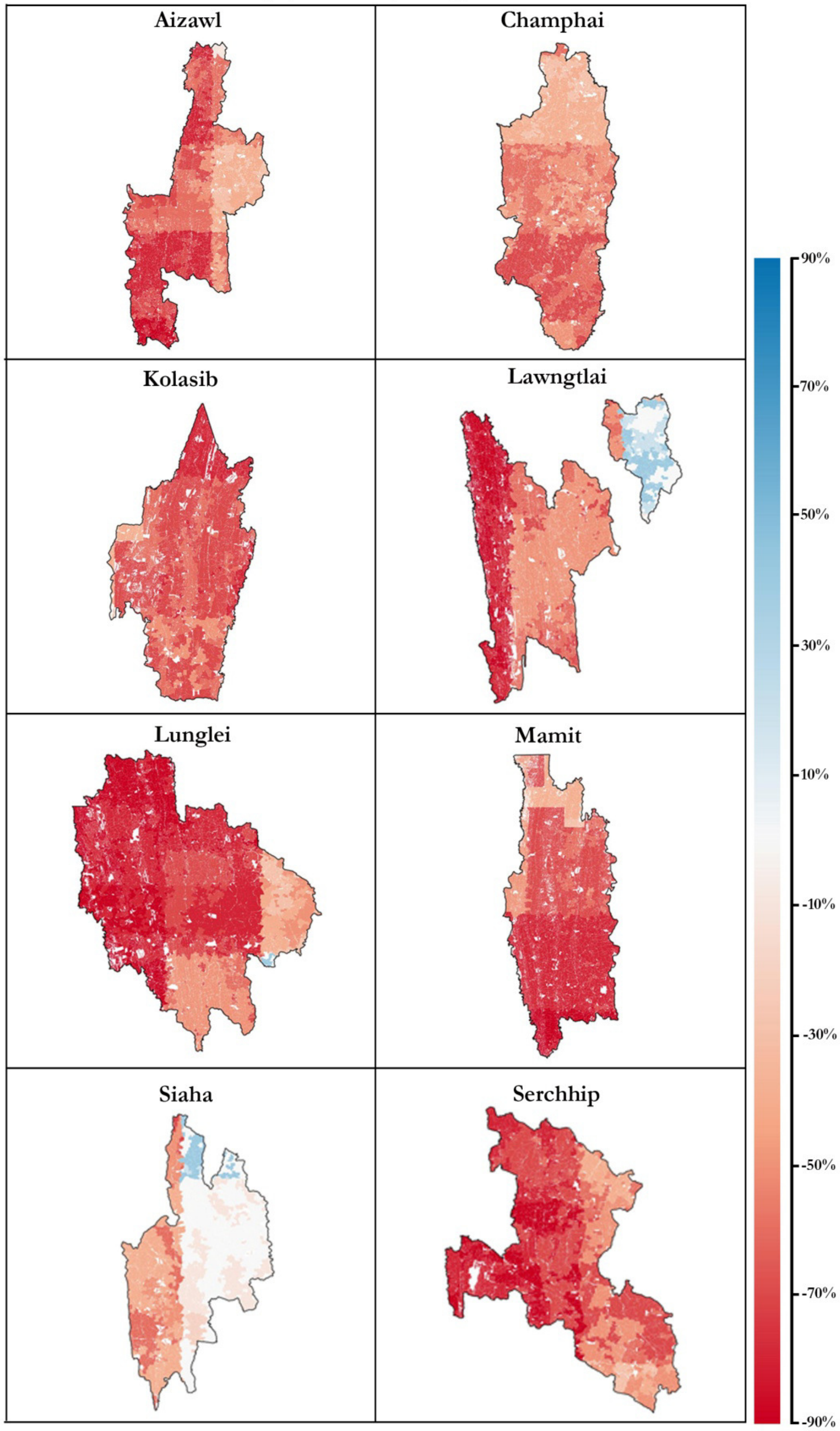


Figure 20

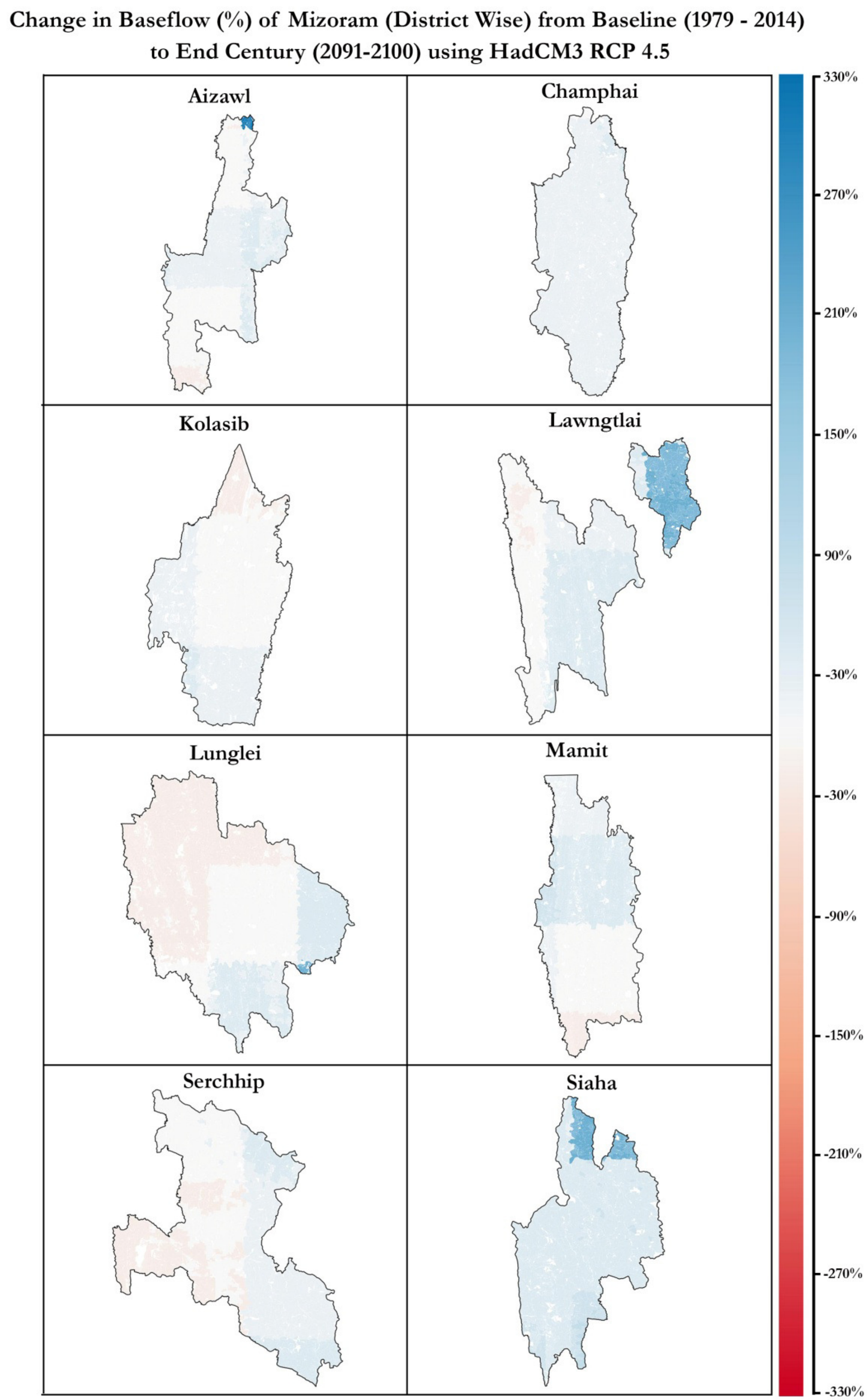

Change in Baseflow (%) of Mizoram (District Wise) from Baseline (1979 - 2014)
to End Century (2091-2100) using HadCM3 RCP 4.5
Aizawl
Champhai
Kolasib
Lawngtlai
Lunglei
Mamit
Serchhip
Siaha
330%
270%
210%
150%
90%
-30%
-30%
-90%
-150%
-210%
-270%
-330%

Figure 21

4. Assess the responses to climate variability and extremes (adaptive capacity)

The adaptive capacity of the system in response to the exposure and sensitvity of climate variability and extremes are subjected to the availability of surface water and ground water resources. The magnitude of effect caused by changes in water balance components may depend on the availability of such resources. Table 2 shows the availability of such data for the state of Mizoram. The spatial unit for the parameters of adaptive capapcity were at district level which were too large to incorporate into the present study measurement unit which are at HRU level. Therefore, regardless of the insufficient data, the available ones were not incorporated for the vulnerability index.

5. Assessment of overall vulnerability

The equation for calculating Climate change vulnerability may be represented as:

Vulnerability = sensitivity + exposure – adaptive capacity

To describe the state of the system whose vulnerability is to be indicated, relative weights were given to different variables that determine the values for climate exposure, sensitivity and adaptive capacity thus developing Composite Vulnerability Index (CVI) for a system being assessed. For this study of water resource vulnerability of Mizoram, due to insufficient data of adaptive capacity to incorporated in the equation, the sensitivity and exposure of the system was used to determine the vulnerability.

Table 2: Current water resource availability in Mizoram (District wise).

Sl. No	District	Geographical Area (sq. km)	Net Annual Ground Water Resources (mcm)	Surface Water Availability
1	Aizawl	3576.3	3.86	NA
2	Champhai	3185.8	8.10	NA
3	Lunglei	4538.0	5.53	NA
4	Mamit	3025.8	4.92	NA
5	Kolasib	1382.5	6.73	NA
6	Serchhip	1421.6	3.39	NA
7	Lawngtlai	2258.0	8.13	NA
8	Saiha	1399.9	2.91	NA
		TOTAL	**43.57**	

Table 3: Index of vulnerability and their relative weight

Sl No	Change Percent (Exposure + Sensitivity)	Relative Weight	Vulnerability
1	0 - 25	1	Low
2	25 - 50	2	Moderate
3	50 - 75	3	High
4	75 - 100	4	Very High
5	Above 100	5	Extremely High

The magnitude of projected change percent in water balance components, from current to future scenarios, whether positive or negative value are graded into different class, each class represents their relative weight to the magnitude of percent changes was used to give the index of vulnerability. The process of defining the index of vulnerability is shown in the Table 3.

The vulnerability index were given separately for two different scenarios:-

1. Projected future vulnerability at Mid Century (2041 - 2050):

The overall state of Mizoram was classed into moderately vulnerable except for a few areas in Eastern and Western part of Aizawl district, Northern part of Champhai district and the central part of Lunglei district which were projected as the lowest class of vulnerability. In the sensitivity maps, even though some parameters of the water balance components seems to change at high percentage level for some or all districts, the overall average change of the water cycle do not go beyond 50 % for all the districts of Mizoram (Figure 22).

2. Projected future vulnerability at End Century (2091 - 2100):

Looking at the end century scenario, the projection doesn't change much. But, there is a particular continuous area encompassing a small portion in the south eastern part of Lunglei district, major portion of the eastern Lawngtlai district and northern part of Siaha district, which is projected to change considerably to more than 100% at the end century. The rest of the area over all Mizoram remains same as the scenario for Mid Century (Figure 23).

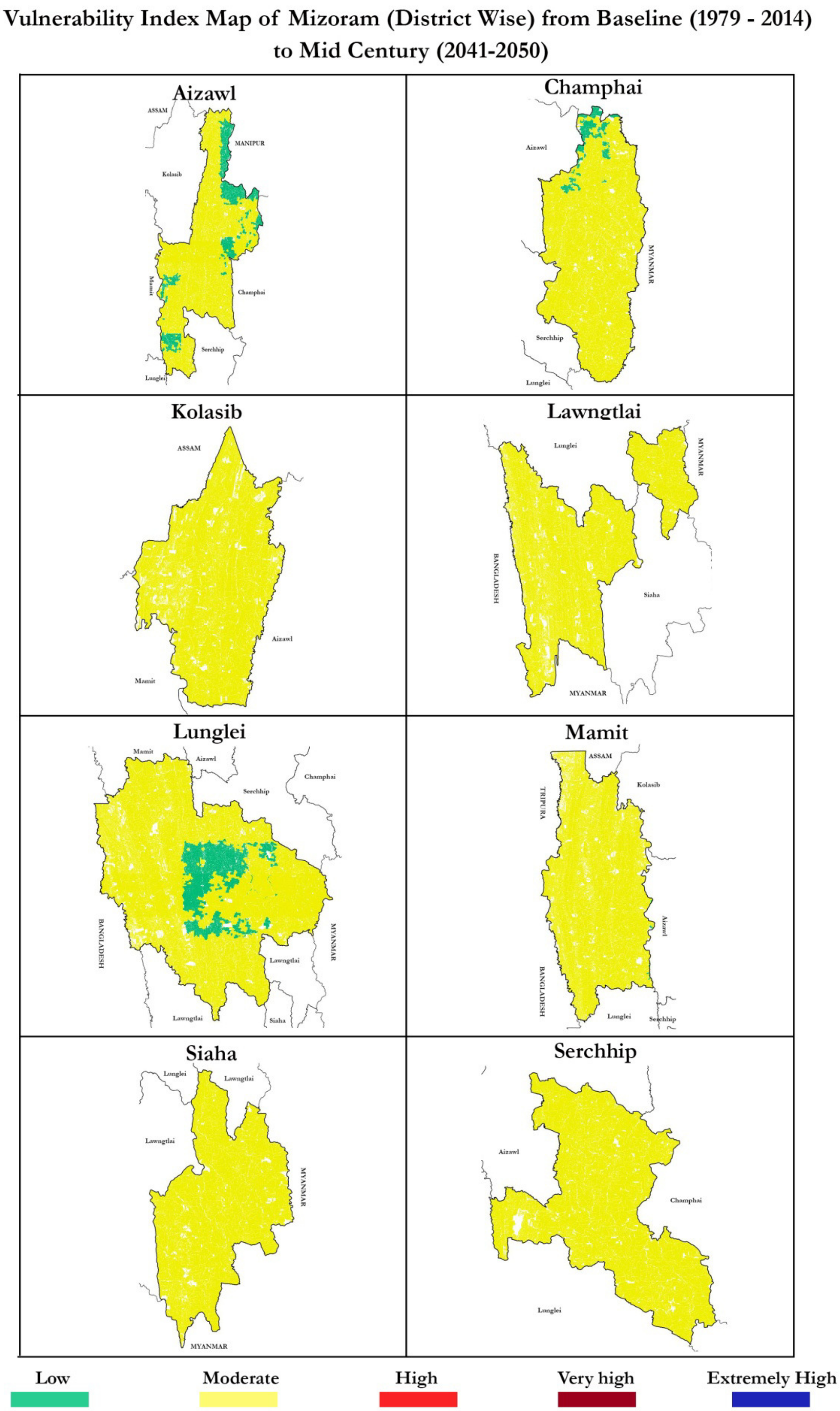

Vulnerability Index Map of Mizoram (District Wise) from Baseline (1979 - 2014) to Mid Century (2041-2050)
Aizawl
Champhai
Kolasib
Lawngtlai
Lunglei
Mamit
Siaha
Serchhip
Low
Moderate
High
Very high
Extremely High

Figure 22

Vulnerability Index Map of Mizoram (District Wise) from Baseline (1979 - 2014) to End Century (2091-2100)

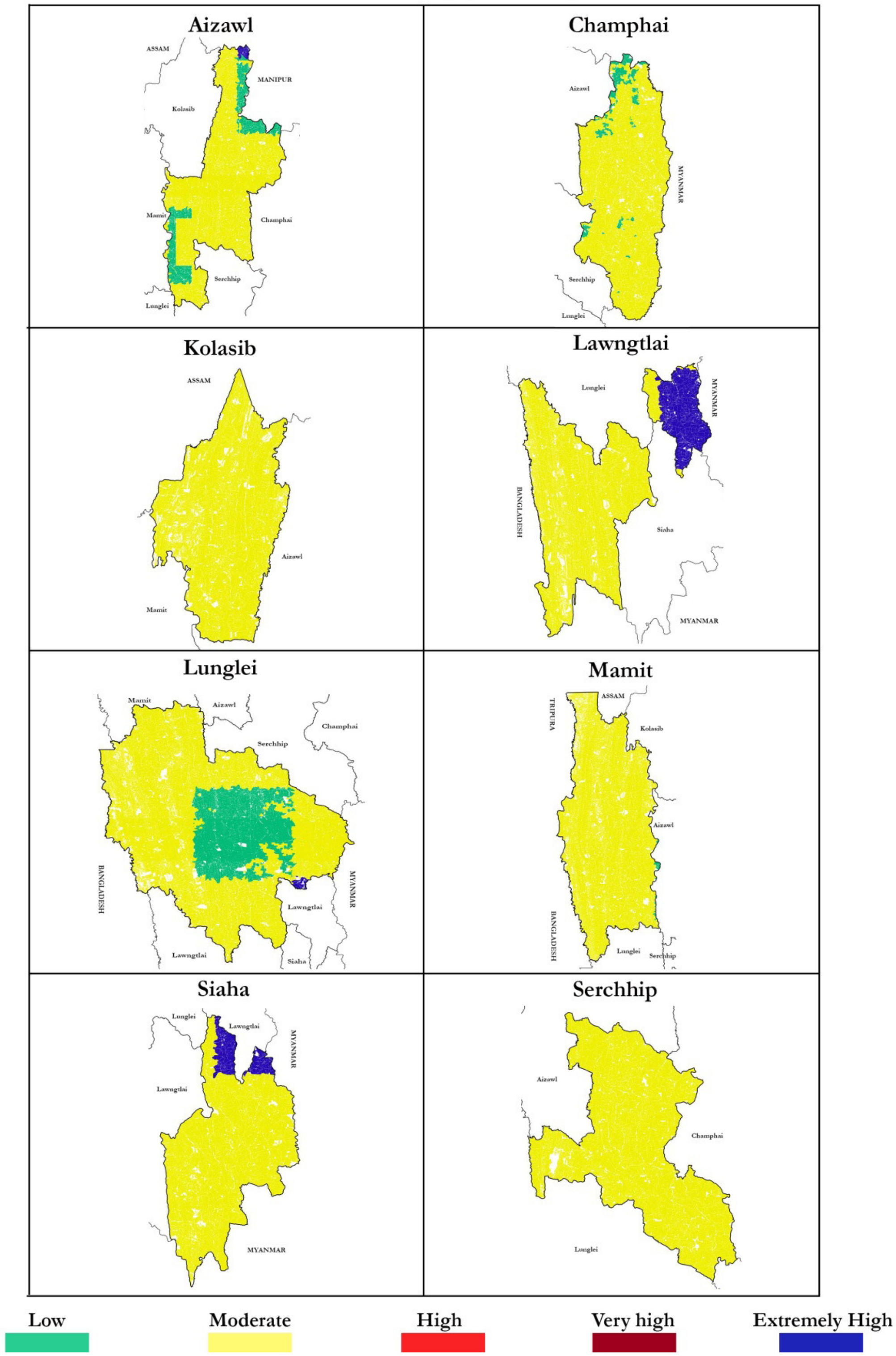


Figure 23

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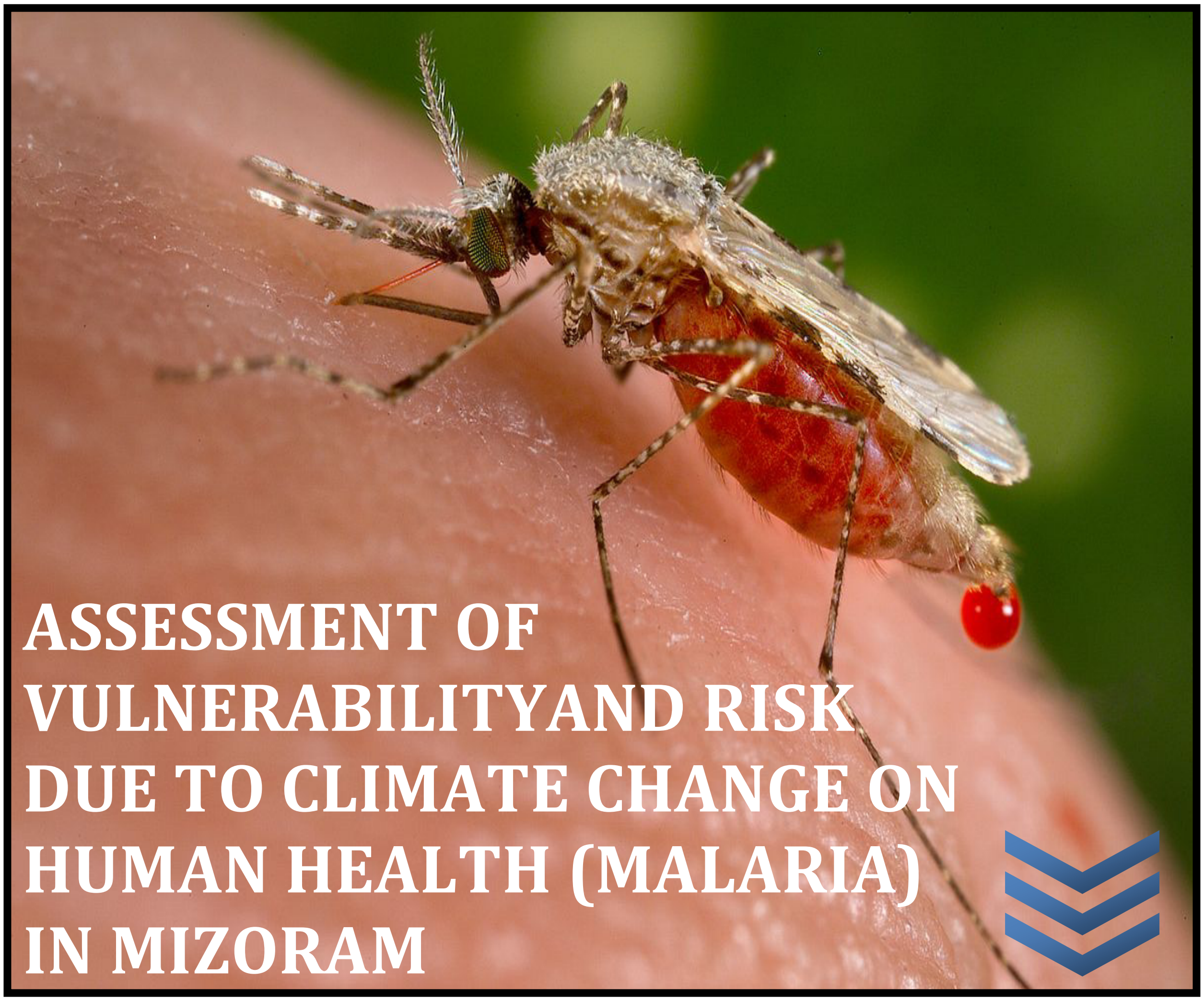

ASSESSMENT OF VULNERABILITYAND RISK DUE TO CLIMATE CHANGE ON HUMAN HEALTH (MALARIA) IN MIZORAM

Prepared by

State Climate Change Cell

Mizoram Science, Technology & Innovation Council (MISTIC)

Catalyzed and Supported by

National Mission for Sustaining the Himalayan Ecosystem (NMSHE)

2017

Abstract

The simulated data of DMC v 1.1 (Liverpool Malaria Model) predicts the ascending and spreading of malaria to new higher altitude areas for the state of Mizoram. The present study predicts high vulnerability of malaria prevalence in higher mountains of Mizoram such as Mt. Chalfilh, Mt. Lengteng, Mt. Phawngpui, Mt. Mawma and other higher altitudes in the futures (2050 AD, 2100 AD).

Background

Malaria, a mosquito-borne infectious disease caused by parasitic protozoans of the *Plasmodium* genus, has a highly detrimental socio-economic impact on affected countries, presenting a significant public health challenge. Globally, in 2012, an estimated 3.4 billion people in 99 countries were at risk of contracting malaria with approximately 207 million reported cases and an estimated 627,000 reported deaths [1].

India is the most populous country affected by malaria, representing over 400 million people threatened by infection [2,3]. Yet despite an extensive intervention campaign [4,5] that resulted in near-eradication of malaria in India in the 1960's, there are still between 1.6–15 million cases of malaria and between 1000–15,000 deaths reported per year [6,7]. Indeed, a wide discrepancy has emerged between these figures, from primary health care facilities and the World Health Organization (WHO), and the actual burden of malaria in India [3,6,7], with one estimate suggesting an order of magnitude higher mortality rates of around 200,000 deaths per year [8]. This disparity may be associated with under-reporting of malaria fatalities.

A warm and humid climate triggers several water-associated diseases, such as malaria. Vector-borne diseases are highly sensitive to global warming and associated changes in precipitation. Malaria is strongly influenced by warm and moist tropical atmospheric conditions. Meteorological variables turn out to be useful explanatory variables for the simulation of malaria. Various biological processes depend on temperature, rainfall, and humidity conditions. Climate- or weather-driven malaria models, therefore, allow for a better understanding of the dynamics of malaria transmission. More recently, the construction of dynamic vector models enabled the simulation of a time-dependent mosquito population.

Methodology

Vulnerability due to climate change with respect to health sector in Mizoram was done using an open source software *viz.,* Disease Model Cradle (DMC) Ver. 1.1. The DMC is an application which provides an interactive front-end to run disease model encapsulating Liverpool Malaria Model (LMM).

The LMM (Hoshen & Morse, 2004) [8] is a dynamic malaria model consisting of two coupled climate-driven components, a disease transmission model and a mosquito population model. The transmission of the parasite between human and mosquito hosts incorporates temperature-dependency in both the rate of development of the parasite within the mosquito (the sporogonic cycle) and the mosquito biting rate (the gonotrophic cycle). The mosquito population model incorporates both dependent on decadal (10 days) accumulations of rainfall, and the adult mosquito survival probability dependent on temperature.

- Climatic data (*viz.,* Rainfall and temperature)

  a. Current/historical (http://swat.tamu.edu/media/99082/cfsr_world.zip)

  b. Future/projected (produced from SIMCLIM AR5 2013)

- Application: Disease Model Cradle (DMC v1.1)
  - University of Liverpool (*https://www.liverpool.ac.uk*)
- Arc View 10.1 (GIS application)
- Input data:
  - Temperature & Precipitation (simulated data)
- Output data:
  - Malaria Incidence (Cases/100 persons/day)
  - Malaria Prevalence (Proportion of the human population infectious)
  - Gonotrophic cycle length (female reproductive-feeding cycle)
  - Sporogonic cycle length (multiplication of parasites inside the mosquito)
  - Number of adult mosquitoes
  - Entomological innoculation rate (Number of Infectious mosquito bites per human per time)
  - Number of larval mosquitoes
  - Human biting rate (Number of mosquito bites per human per time)
  - Mosquito daily survival probability
  - Transmission potential
  - Basic reproduction rate

The data generated from the LMM was then incorporated into Geographic Information System software Arc View 10.1. They are then processed to generate the simulated malaria data by interpolation to produce the final maps as given in the results.

Results

Malaria transmission

Integrating the temperature and precipitation data from the observational, reanalysis and forecast drivers through LMM results in the suitability for malaria transmission in different parts of Mizoram as follows:

Scenario 2050 AD

At Representation Concentration Pathway (RCP) 4.5, the Entomological Innoculation Rate (EIR) is predicted to be highest in the North-Western parts of Aizawl, Northern parts of Champhai and Eastern parts of Siaha district (Fig 1).

At RCP 8.5, the EIR is expected to spread from the Northern parts of Aizawl and Champhai Southwards within these two districts almost reaching Serchhip district while at the same time, the EIR is also expected to spread from Eastern parts of Siaha towards the Western parts of the district and reaching upto the Eastern Lawngtlai district (Fig 2).

The Human Biting Rate (HBR) is predicted to exhibit similar trend as that of EIR for both RCP 4.5 and RCP 8.5 with the highest HBR expected to affect North-Western parts of Aizawl, Northern parts of Champhai and Eastern parts of Siaha and Lawngtlai districts respectively (Fig 3 & 4).

The Transmission potential is the highest along the Western parts of Mizoram covering Mamit, Kolasib, Aizawl and some parts of Serchhip, Lunglei and Siaha district for RCP 4.5 (Fig 5).

For RCP 8.5, the Transmission potential is predicted to prevail in almost all the parts of Mizoram with high Transmission potential along the central part of the state running from North to South (Fig 6).

Scenario 2100 AD

At both RCP 4.5 and RCP 8.5, the EIR is predicted to be very high in the North Western parts of Aizawl, Northern parts of Champhai, Eastern half parts of Siaha and South Eastern parts of Lawngtlai East districts respectively (Fig 7 & 8).

In the case of HBR scenario, at both the RCP 4.5 and RCP 8.5 predicts a similar trends as that of the EIR scenario with the LMM simulations (Fig 9 & 10).

At RCP 4.5, the transmission potential of malaria predicts highest vulnerability in almost all parts of Aizawl while the rest of the districts with high-moderate vulnerability (Fig 11).

However, at RCP 8.5, this transmission potential is predicted to shifts towards the Eastern parts of Mizoram with the highest vulnerability in most parts of Champhai, Eastern parts of Serchhip, Lunglei, Lawngtlai East and Siaha district respectively (Fig 12).

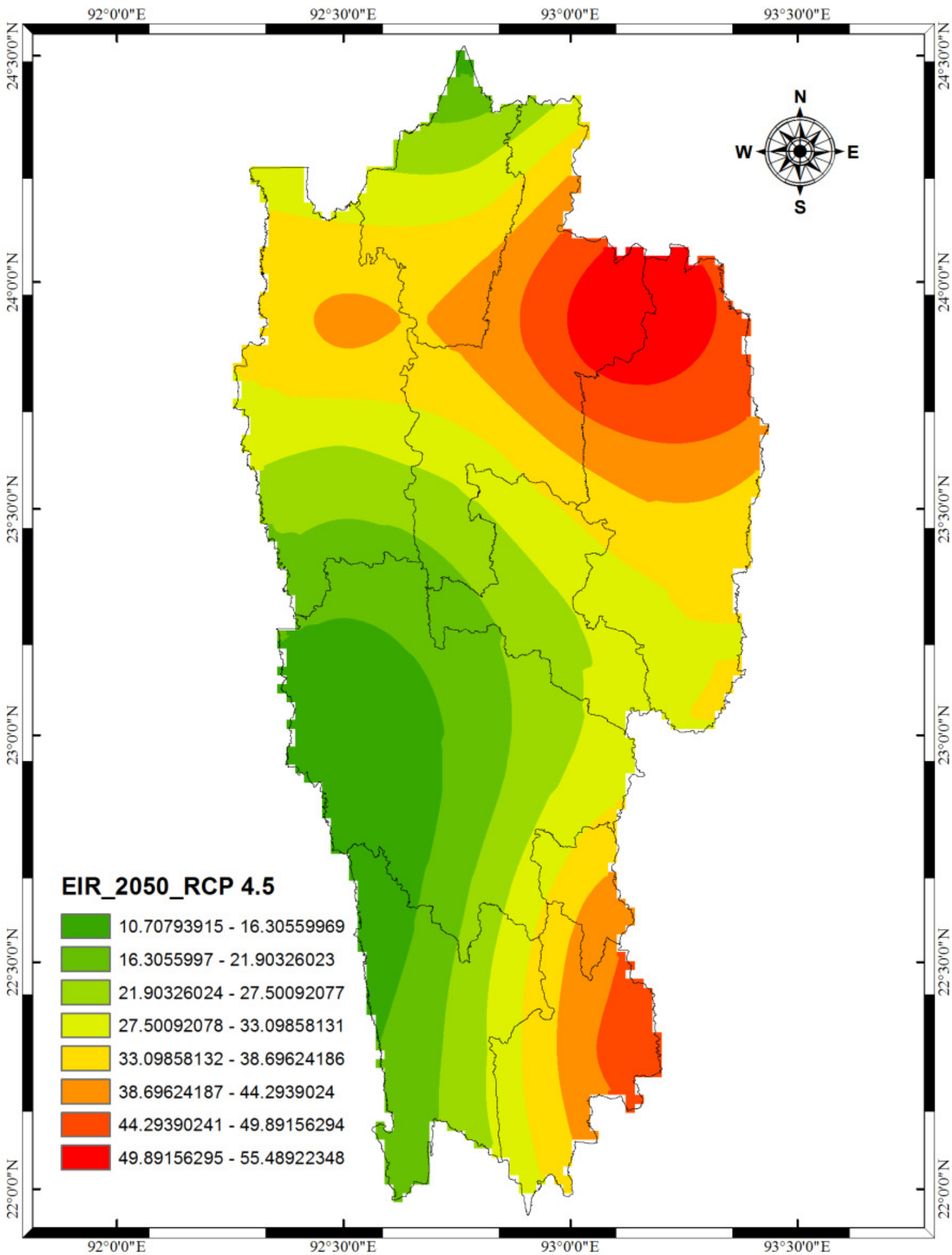

Fig 1. Entomological Innoculation Rate (2050 AD, RCP 4.5)

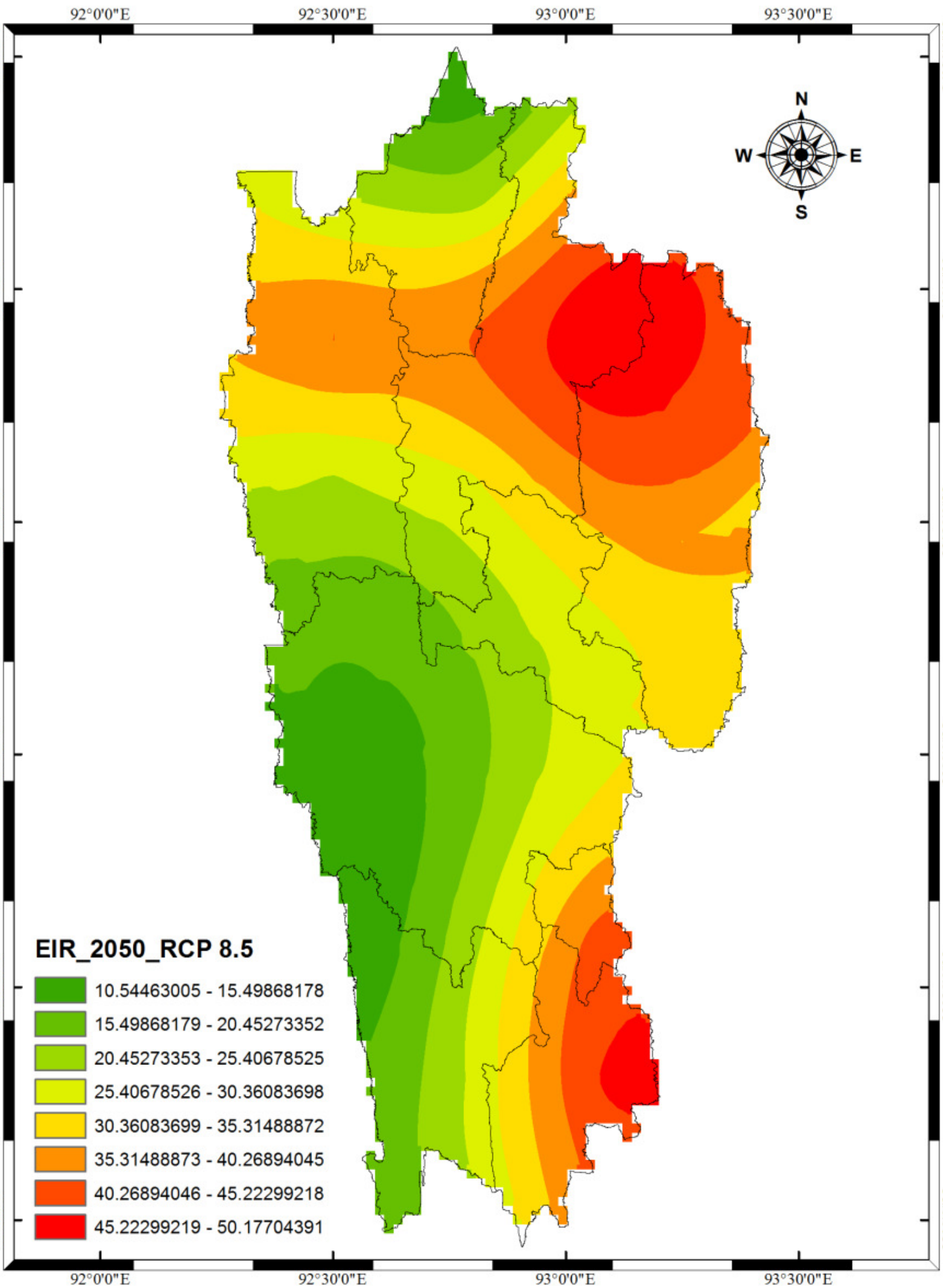

Fig 2. Entomological Innoculation Rate (2050 AD, RCP 8.5)

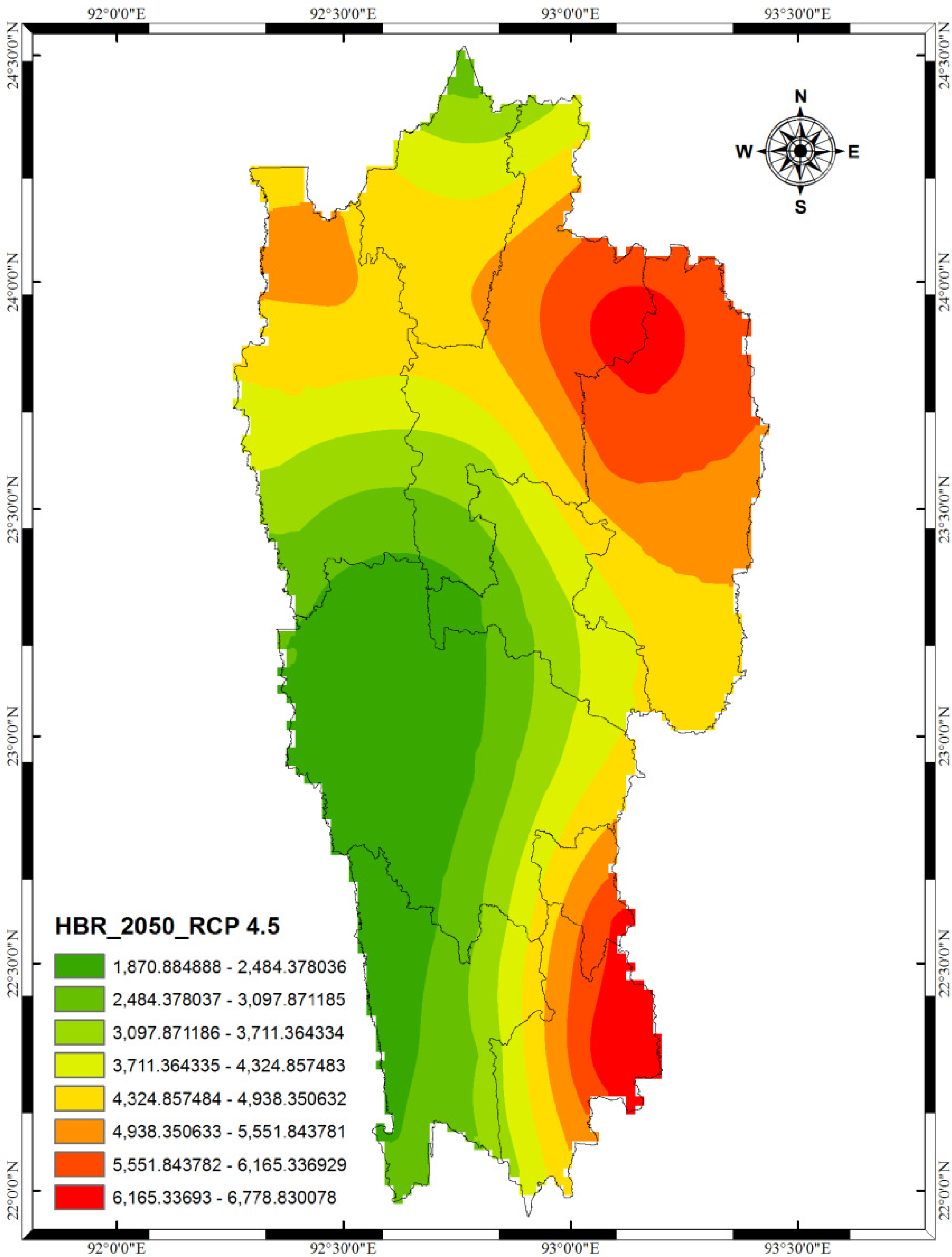

Fig 3. Human Biting Rate (2050 AD, RCP 4.5)

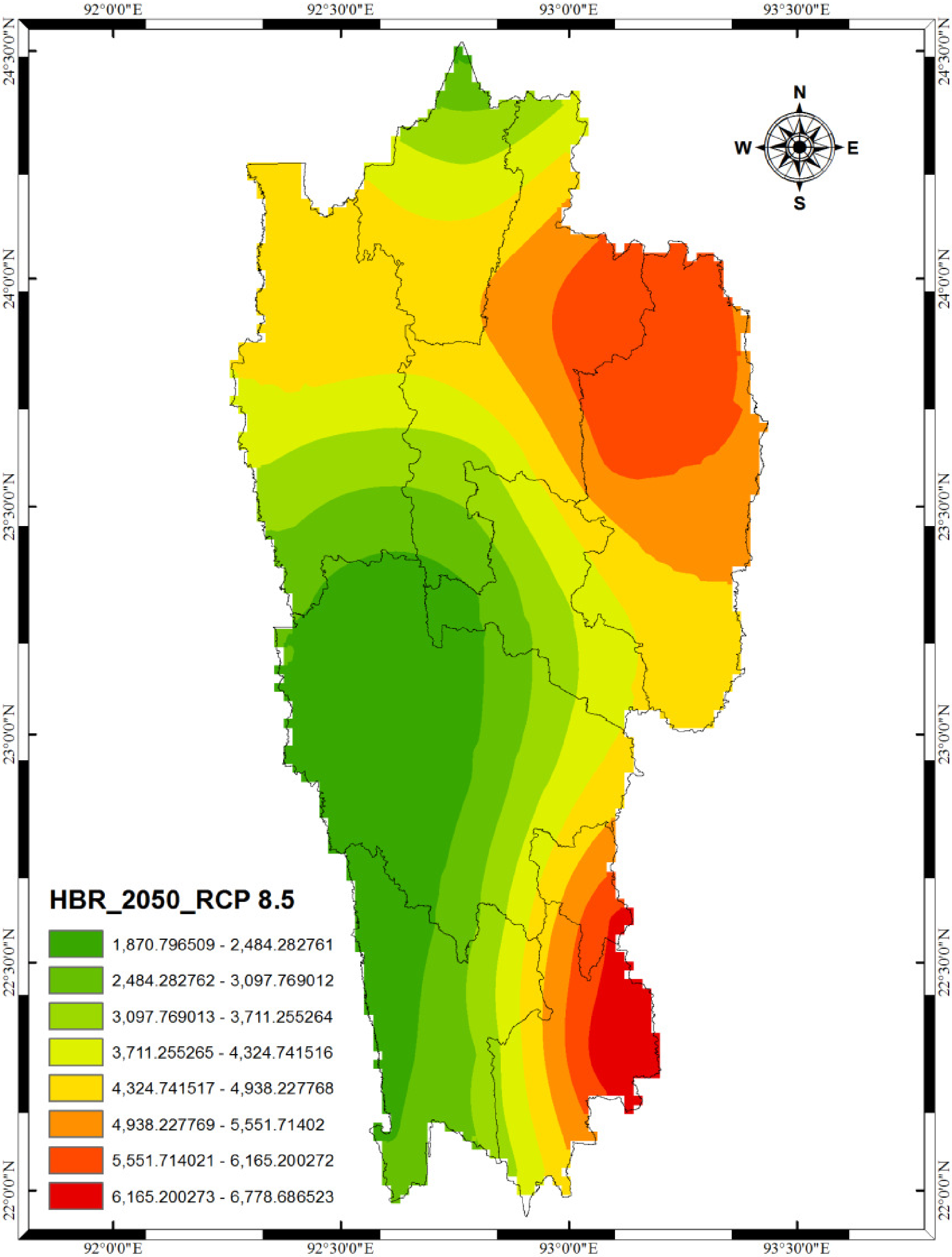

Fig 4. Human Biting Rate (2050 AD, RCP 8.5)

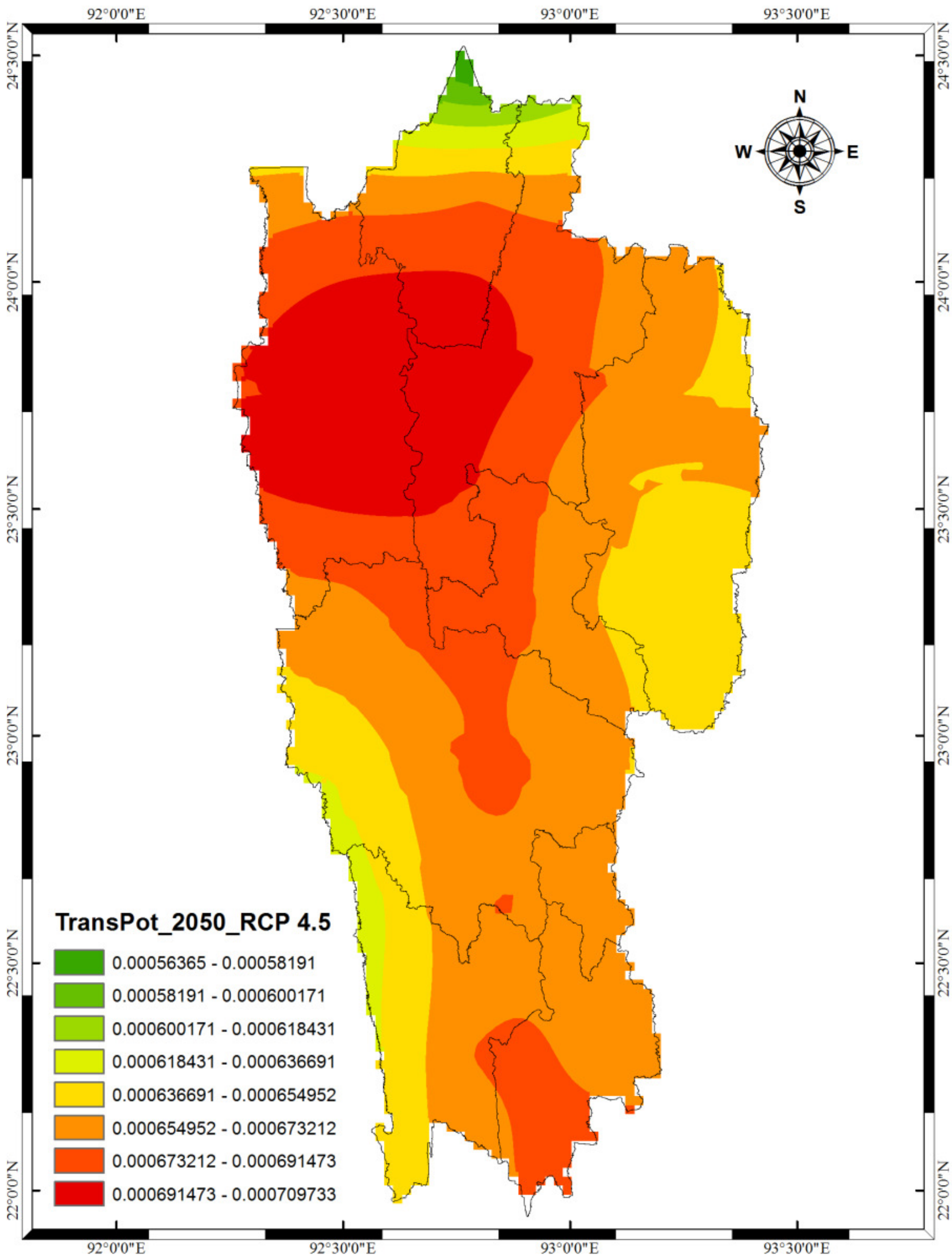

Fig 5. Transmission Potential (2050 AD, RCP 4.5)

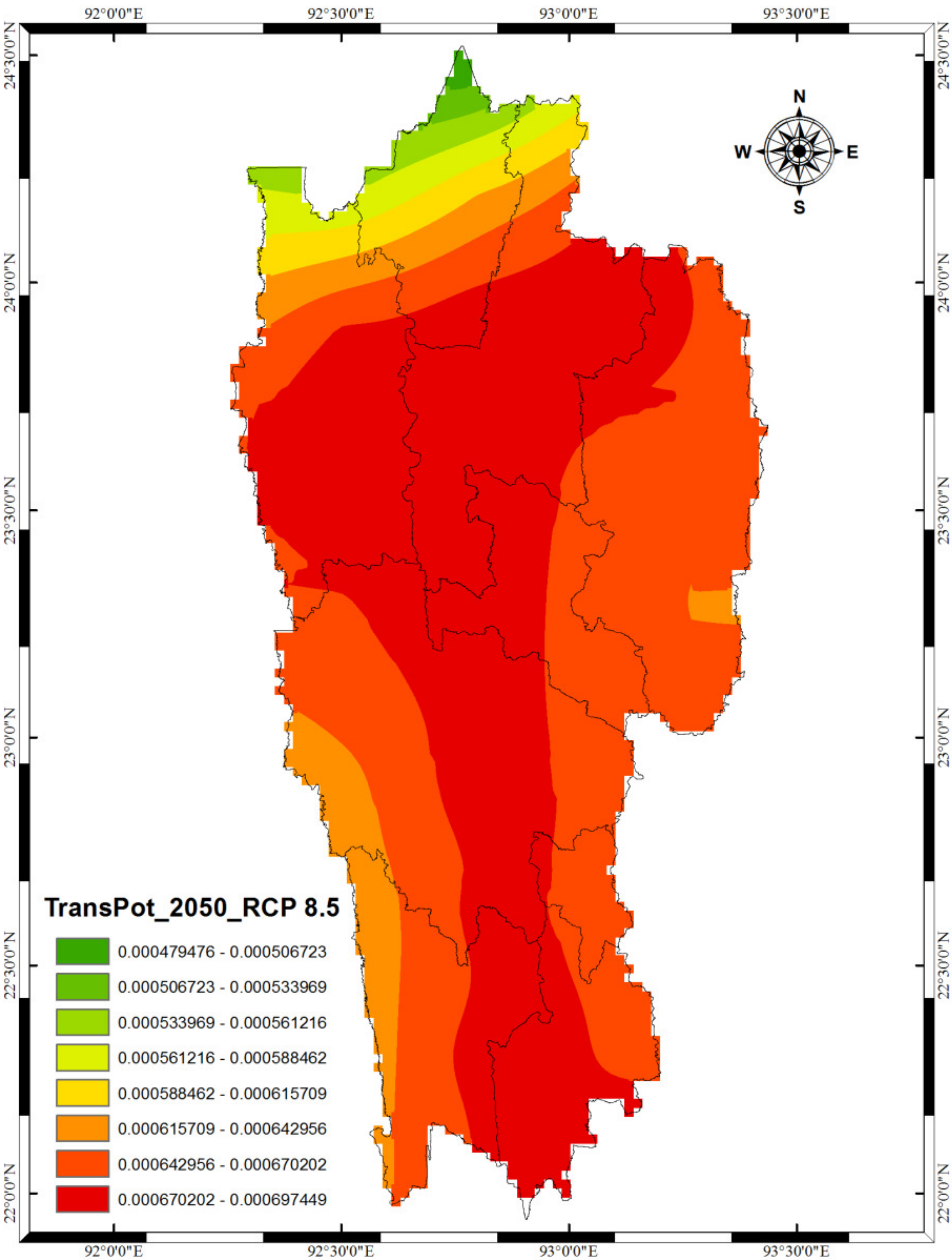

Fig 6. Transmission Potential (2050 AD, RCP 8.5)

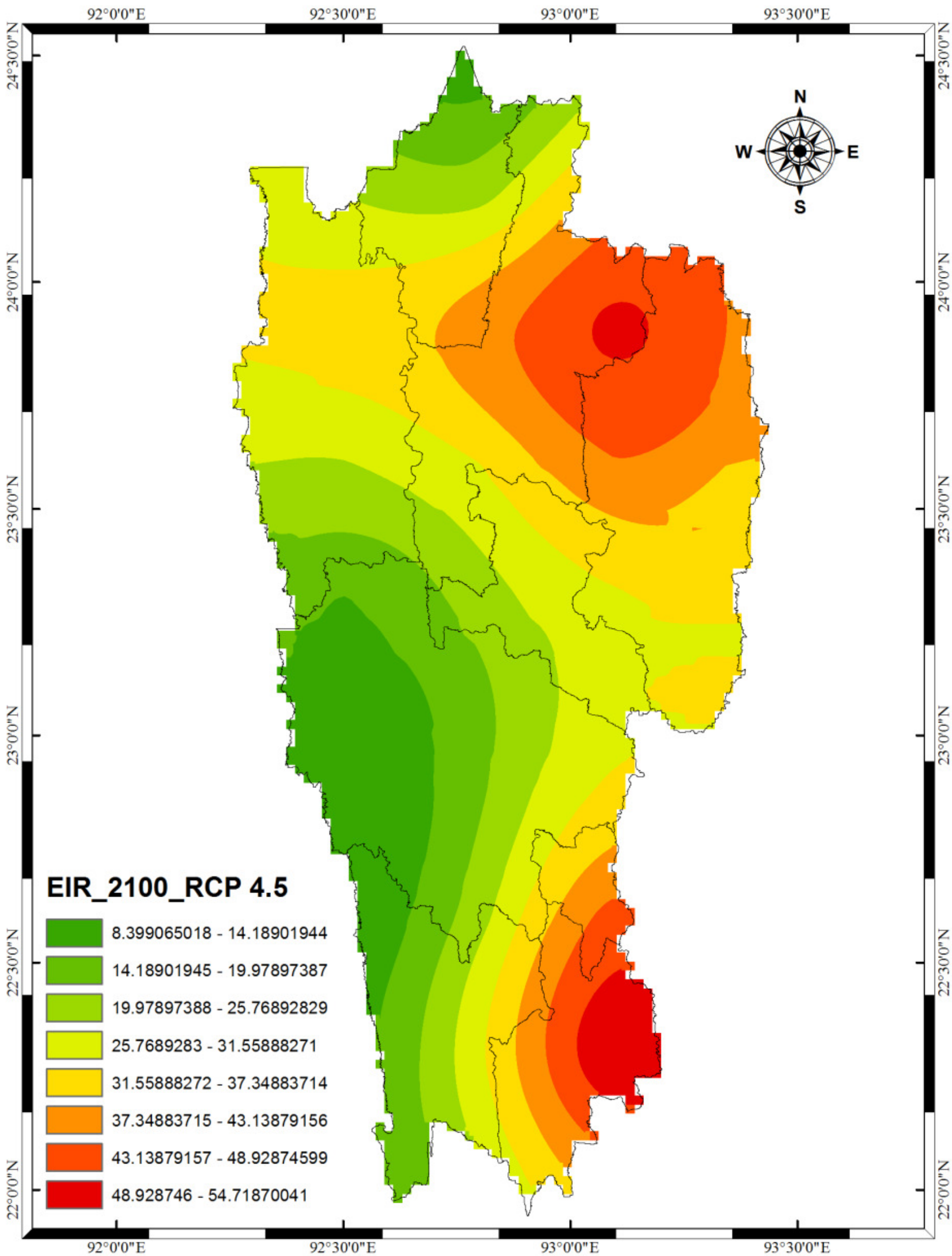

Fig 7. Entomological Innoculation Rate (2100 AD, RCP 4.5)

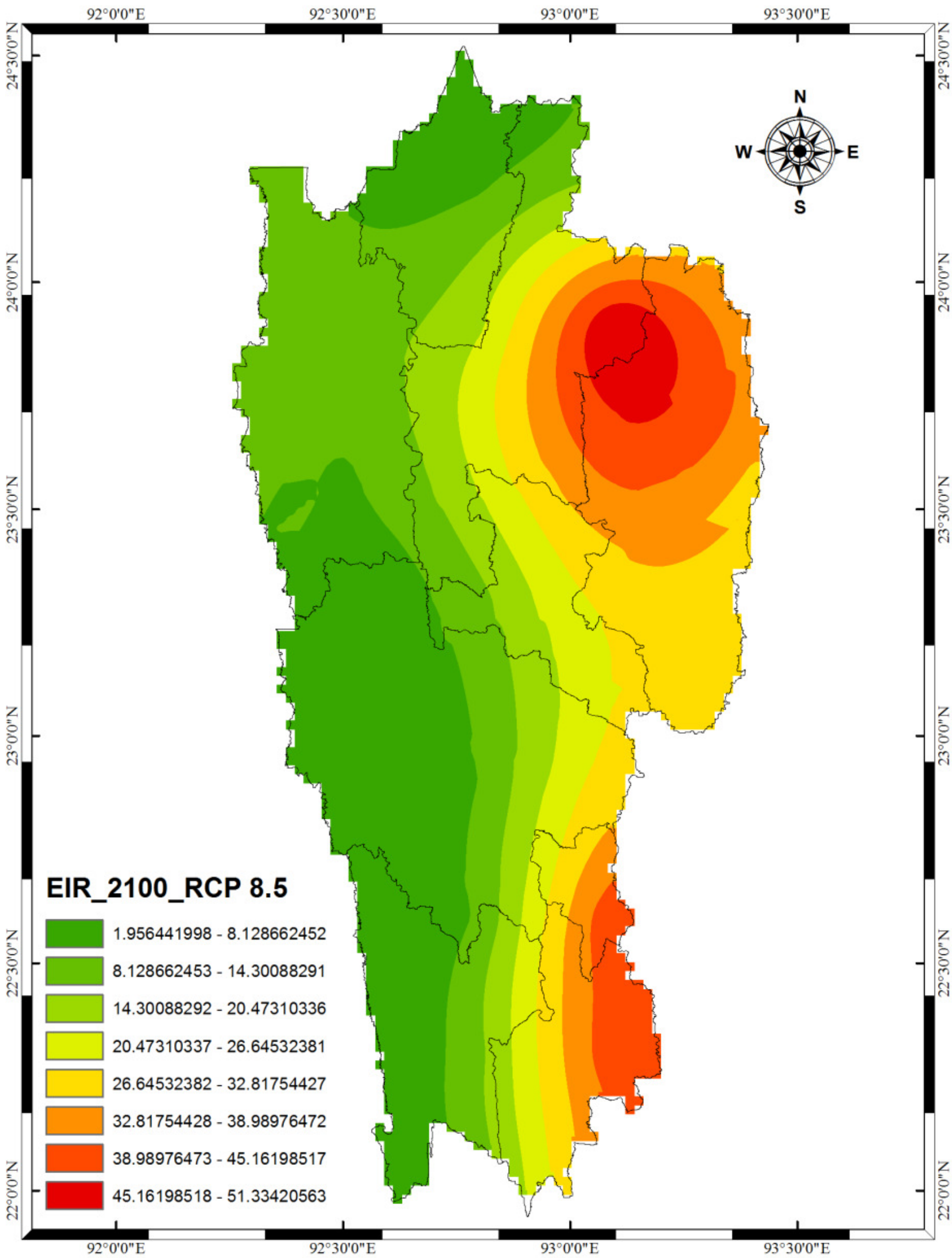

Fig 8. Entomological Innoculation Rate (2100 AD, RCP 8.5)

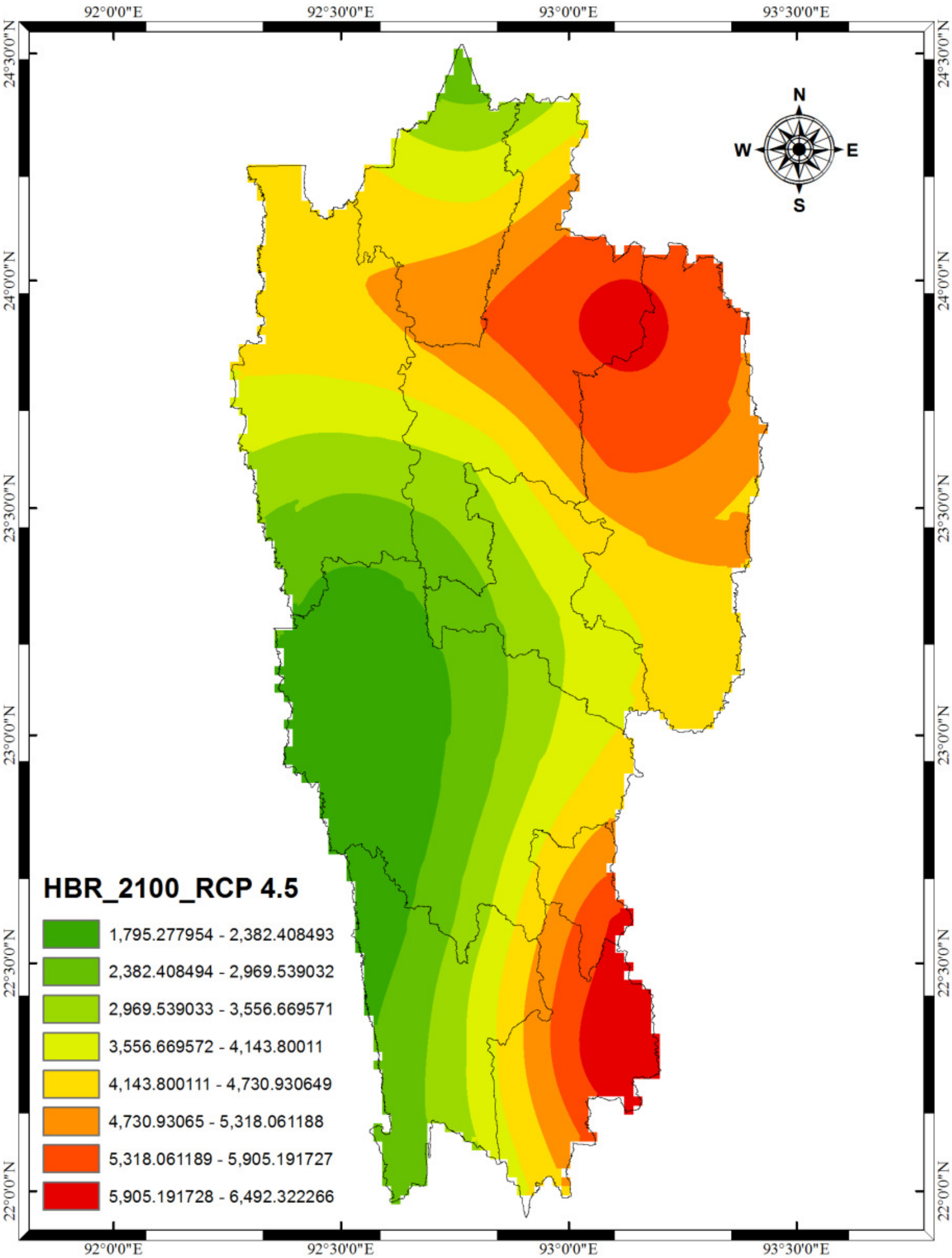

Fig 9. Human Biting Rate (2100 AD, RCP 4.5)

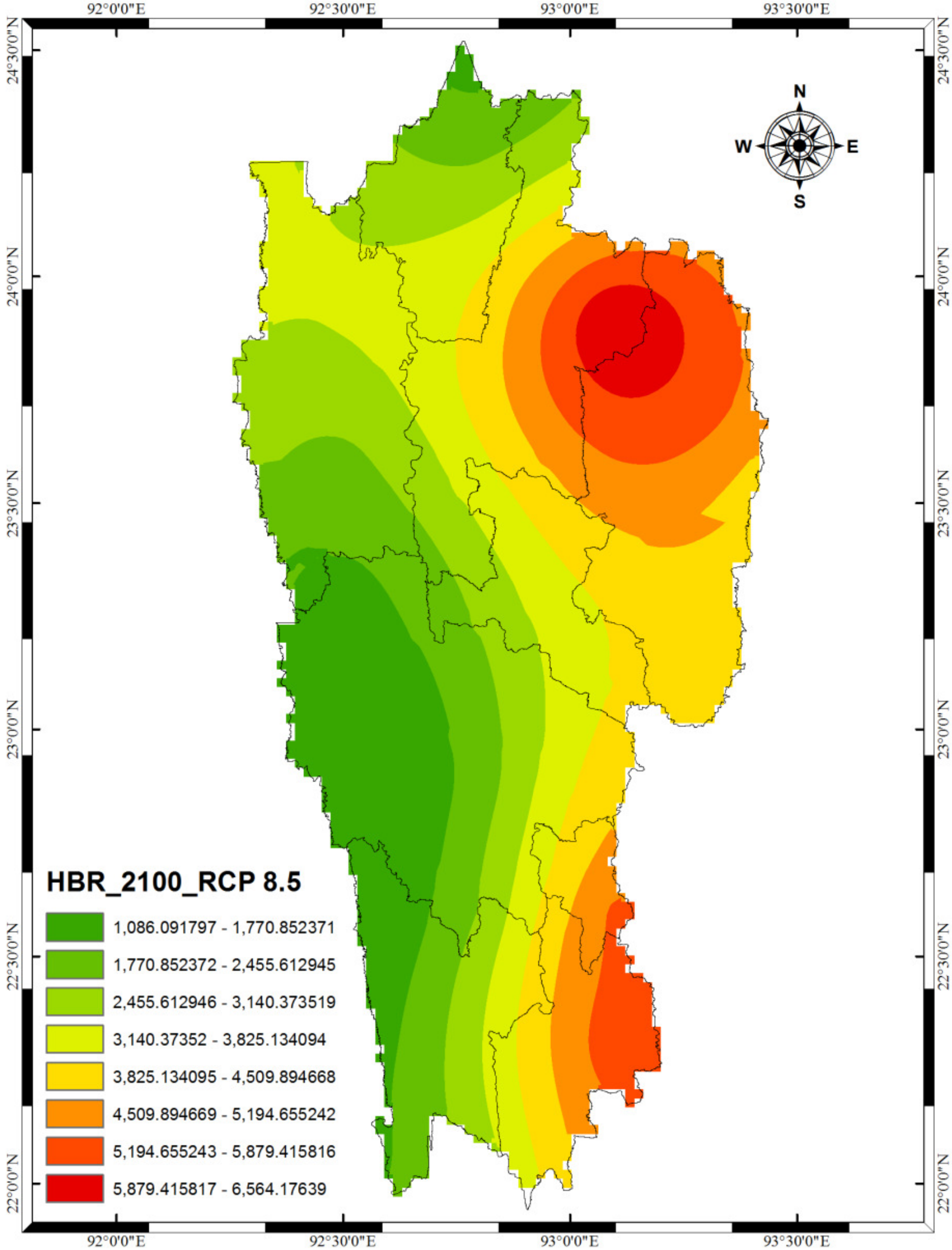

Fig 10. Human Biting Rate (2100 AD, RCP 8.5)

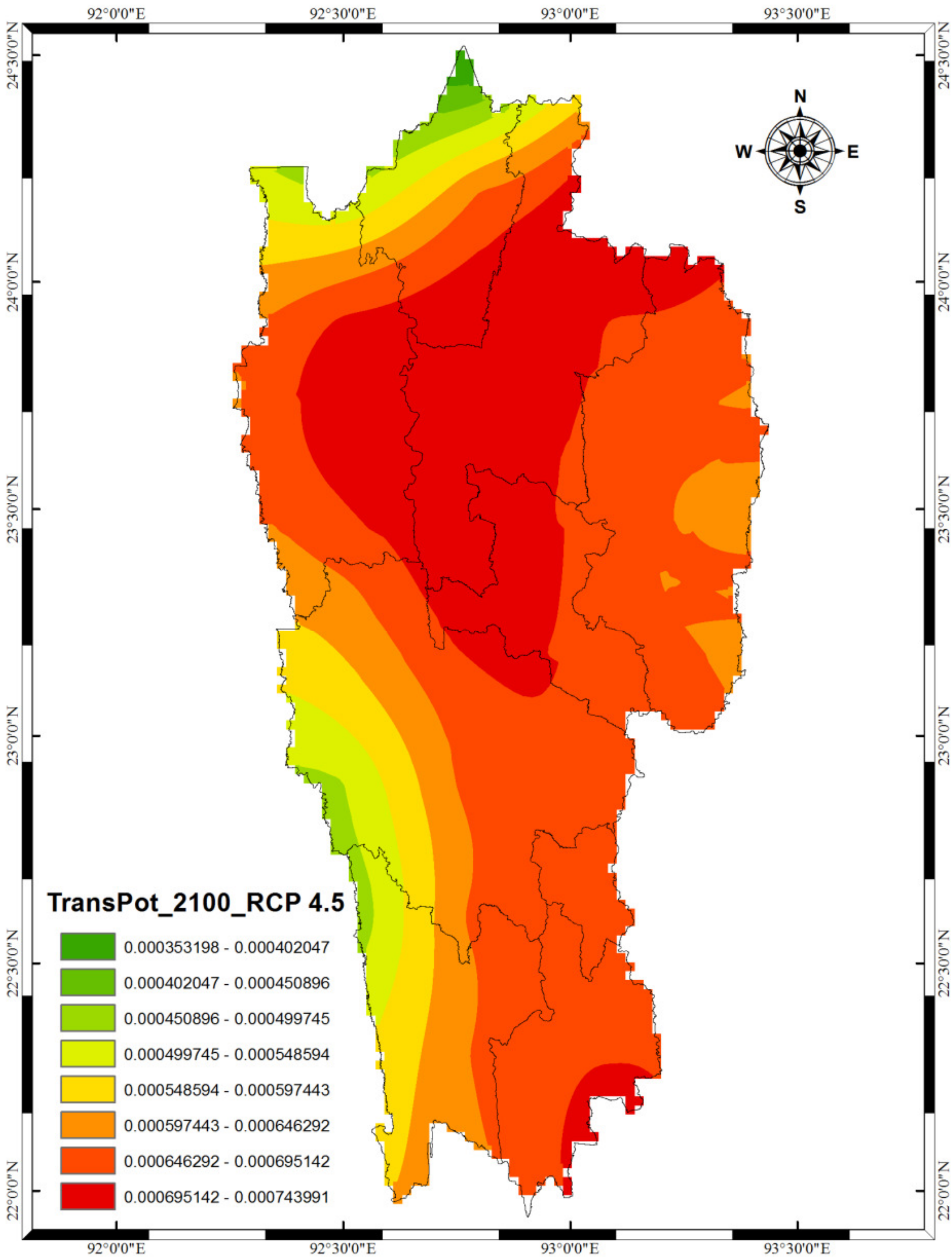

Fig 11. Transmission Potential (2100 AD, RCP 4.5)

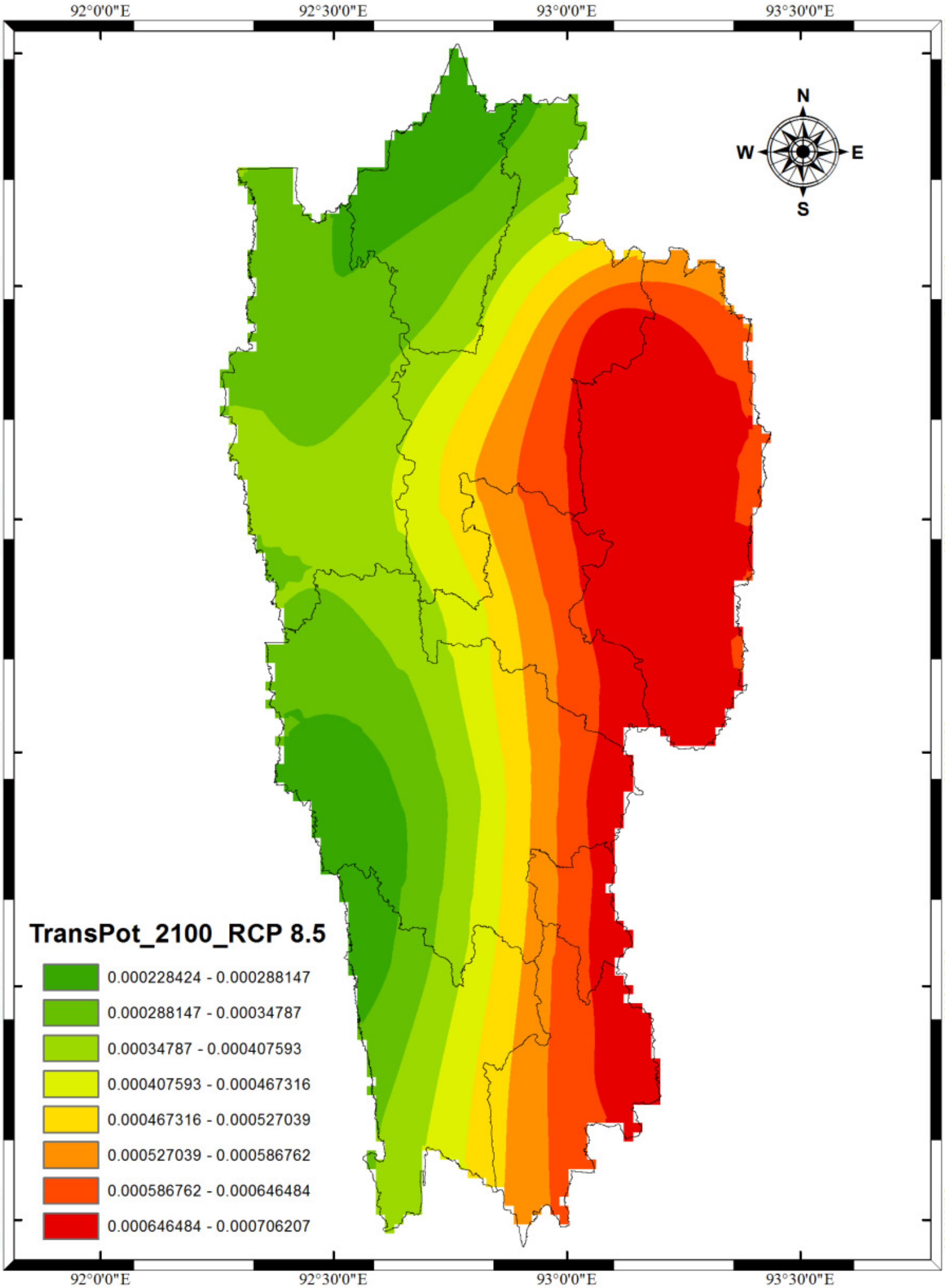

Fig 12. Transmission Potential (2100 AD, RCP 8.5)

Malaria Vulnerability Index

There are several methods for development of vulnerability index but most of them are having their own limitations. The limitation arises from the assumptions made about the indicators and assigning of weightage in the aggregate index.

To assess the malaria vulnerability of the districts in Mizoram a vulnerability index is developed by assigning different weights to the individual indicators (Entomological Innoculation Rate, Human Biting Rate and Transmission Potential) for each districts for both mid-century (2050 AD) and end-century (2100 AD).

The districts are then ranked based on

Table 1. District-wise ranking of simulated malaria scenario for 2050 AD.

Scenario 2050 AD					
Indicators / **Districts**	**EIR**	**HBR**	**TransPot**	**Total**	**Rank**
Aizawl	6	6	7	19	**II**
Champhai	7	7	6	20	**I**
Mamit	4	4	6	14	**III**
Kolasib	4	3	4	11	**IV**
Serchhip	2	2	4	8	**V**
Lunglei	1	1	4	6	**VI**
Siaha	5	5	4	14	**III**
Lawngtlai. W	1	1	3	5	**VII**
Lawngtlai. E	3	5	3	11	**IV**

Table 2. District-wise ranking of simulated malaria scenario for 2100 AD.

Scenario 2100 AD					
Indicators / **Districts**	**EIR**	**HBR**	**TransPot**	**Total**	**Rank**
Aizawl	6	7	7	20	**II**
Champhai	7	7	7	21	**I**
Mamit	4	3	5	12	**VI**
Kolasib	3	5	4	12	**VI**
Serchhip	4	4	6	14	**V**
Lunglei	1	1	4	6	**VIII**
Siaha	5	7	6	18	**III**
Lawngtlai. W	2	2	3	7	**VII**
Lawngtlai. E	4	6	6	16	**IV**

the summation of the aggregated weights allotted to the individual indicators for every districts. The district with the highest summation of indicator weightage values is ranked to be most vulnerable while the least summation values is ranked lowest vulnerable (Table 1 & 2).

These calculated indices are then grouped into four categories as follows:

Sl No.	Rank	Vulnerability categories
1.	I - II	Very High
2.	III - IV	High
3.	V - VI	Moderate
4.	VII - VIII	Low

Discussion

Based on the summation of allotted weightage of individual indicators, the malaria vulnerability categories for each of the district of Mizoram was simulated for both mid-century (2050 AD) and end-century (2100 AD) (Table 3 & 4).

For 2050 AD, Champhai and Aizawl district are simulated to exhibit very high vulnerability to malaria occupying Rank I and Rank II respectively as compared to other districts. On the other hand, Mamit and Kolasib district are also expected to high vulnerability, while Lawngtlai West is expected to have low vulnerability to malaria as compared to other district within Mizoram (Table 3).

Table 3. District-wise Vulnerability of simulated scenario for 2050 AD

SL No.	Districts	Rank	Vulnerability
1.	**Aizawl**	**II**	**Very High**
2.	**Champhai**	**I**	**Very High**
3.	**Mamit**	**III**	**High**
4.	**Kolasib**	**IV**	**High**
5.	**Serchhip**	**V**	**Moderate**
6.	**Lunglei**	**VI**	**Moderate**
7.	**Siaha**	**III**	**High**
8.	**Lawngtlai. W**	**VII**	**Low**
9.	**Lawngtlai. E**	**IV**	**High**

For 2100 AD, Champhai and Aizawl district are still simulated to exhibit very high vulnerability to malaria occupying Rank I and Rank II respectively as compared to other districts. On the other hand, Siaha and Lawngtlai East are expected to have high vulnerability, while Lunglei is expected to have low vulnerability to malaria as compared to other district within Mizoram (Table 4).

Table 4. District-wise Vulnerability of simulated scenario for 2100 AD

SL No.	Districts	Rank	Vulnerability
1.	**Aizawl**	**II**	**Very High**
2.	**Champhai**	**I**	**Very High**
3.	**Mamit**	**VI**	**Moderate**
4.	**Kolasib**	**VI**	**Moderate**
5.	**Serchhip**	**V**	**Moderate**
6.	**Lunglei**	**VIII**	**Low**
7.	**Siaha**	**III**	**High**
8.	**Lawngtlai. W**	**VII**	**Low**
9.	**Lawngtlai. E**	**IV**	**High**

Conclusion

From the DMC v 1.1 (Liverpool Malaria Model) simulated data, it is concluded that two of the most developed districts of Mizoram *i.e.,* Champhai and Aizawl are very likely to be highly vulnerable to malaria in the coming mid-century (2050 AD) and end-century (2100 AD).

The simulated data of DMC v 1.1 (Liverpool Malaria Model) predicts the ascending and spreading of malaria to new higher altitude areas for the state of Mizoram. The present study predicts high vulnerability of malaria prevalence in higher mountains of Mizoram such as Mt. Chalfilh, Mt. Lengteng, Mt. Phawngpui, Mt. Mawma and other higher altitudes in the futures (2050 AD, 2100 AD).

Such studies has been done by University of Michigan ecologists and their colleagues have reported for the first hard evidence that malaria does—as had long been predicted—creep to higher elevations during warmer years and back down to lower altitudes when temperatures cool [9]. The study, based on an analysis of records from highland regions of Ethiopia and Colombia, suggests that future climate warming will result in a significant increase in malaria cases in densely populated regions of Africa and South America, unless disease monitoring and control efforts are boosted and sustained.

They further stated that, "Our latest research suggests that with progressive global warming, malaria will creep up the mountains and spread to new high-altitude areas. And because these populations lack protective immunity, they will be particularly vulnerable to severe morbidity and mortality".

Under such conditions, human populations who have never been exposed to this disease before are now becoming vulnerable — a situation that is made worse because these people have little or no immunity to malaria due to lack of previous exposure.

The resultant data as seen from the simulated results predicts the rise of mosquitoes to new higher elevation areas in Mizoram. However this is a simulated data and without proper validation due to the scarce availability

of field survey data of entomological parameters for the state of Mizoram.

But these scenarios can be overcome or eradicated with proper malaria disease monitoring and control efforts as is being steadily implemented by the STATE VECTOR BORNE DISEASES CONTROL PROGRAMME (SVBDCP) since 2005 under NATIONAL VECTOR BORNE DISEASE CONTROL PROGRAMME (NVBDCP).

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