CLIMATE VARIABILITY, VULNERABILITY AND ADAPTIVE STRATEGIES FOR SOCIAL WELL-BEING IN MIZORAM

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Submitted

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CERTIFICATE

This is to certify that Gabriel Lalchhandama, registered under MZU/Ph.D./999 of 31.05.2017 is a research scholar working under my supervision on a thesis entitled ‘Climate Variability, Vulnerability and Adaptive Strategies for Social Well-being in Mizoram’.

All through his research pursuance, I found Gabriel Lalchhandama very serious, hardworking and dedicated. He could challenge his tasks with quality of scholarship and was able to carry out his assignment successfully.

I further certified that the thesis in this form is the report of the research scholar’s original work. Certain extracts and quotes are duly referred to in an appropriate manner.

I recommend the thesis for due evaluation and recommendation.

Dated:

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May, 2024

DECLARATION

I, Gabriel Lalchhandama, hereby declare that the subject matter of this thesis entitled '*Climate Variability, Vulnerability and Adaptive Strategies for Social Well-being in Mizoram*' is the record of the work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/Institute.

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(GABRIEL LALCHHANDAMA)

CONTENT

List of Tables

4

List of figures

List of Plates

CHAPTER 1

INTRODUCTION

1.1 Introduction

In recent years climate change and variability has become one of the biggest challenges of the world today, which have been recognized globally as the most critical issue affecting the survival of mankind in the 21^{st} century. The Intergovernmental Panel on Climate Change (IPCC) defined climate change as any alteration in climate over time (IPCC, 1990), It is the unprecedented permanent or long-term continuous atmospheric change of at least 30 years, while climate change refers to the significant deviations from climatic norms, climate variability on the other hand refers to variations from climate means, the variation in climate that typically occurs from month to month, season to season, year to year and decade to decade is referred to as climate variability (WTO-UNEP, 2009; Tam, 2012). Climate variability is also often defined as the variation on the climate statistics from its mean value over a specific time span, the variability in climate might be cause due to two main factors, which are "natural internal process" caused within the climate system or due to deviation in natural or "anthropogenic external factors" (IPCC, 2001)

Due to its serious implications in the sustainability and liveability of the earth, climate change study has become one of the most important topics in recent years. Climate change is a slow and gradual process, significant noticeable changes are in temperature, precipitation or wind pattern, it is rather difficult to detect and perceived without adequate temporal climate data. The most evidently manifestation of climate change is gradually rise and increase of global average temperature, commonly termed as global warming. Global average temperature is estimated to be increased by 0.6°C over the past 100 years, and snow and ice cover has declined by 10% since 1960's (Walther et al., 2002).

In present day climate change or global warming is an important research area, in the absence of proper implementation of adaptation strategies, it can result in an extensive environmental change that could have severe consequences on societies throughout the world in terms of agriculture, disease prevalence, human health, sea level etc. It is therefore crucial to take into account the vulnerabilities of the different regions in any scientific study on climate change and consider its impacts on several sectors.

Vulnerability is a term referring to the total exposure to risk, in this case those risks associated with climate change and variability [Disaster risk = Function (Hazard, Exposure, Vulnerability)] (Kelly & Adger, 2000: Gallopin. 2006). The IPCC defines vulnerability as the degree of susceptibility of individual or system to which they are unable to cope with the adverse effects of climate change, climate variability and extremes (Smit & Pilifosova, 2001). In context of vulnerability assessment, IPCC has defined the contextual vulnerability assessment and the outcome vulnerability assessment, as an important medium for assessing vulnerability (IPCC, 2007). The contextual vulnerability assessment mainly assesses the vulnerability in a constructional approach, with the help of survey instruments and case studies it obtains a qualitative picture of the vulnerability. Whereas the outcome vulnerability assessment is practiced by utilizing reductionist approach, modelling and dose-response functions are performed as part of quantitative techniques. (Fussel, 2009).

Vulnerability to climate change and variability is not universally the same among individual or groups. In order to define the risks posed by climate change and to provide information for identifying measures to adapt to climate change impacts it is important to assess vulnerability. The Intergovernmental Panel on Climate Change (IPCC) identifies three components of climate change vulnerability: Exposure. Sensitivity and Adaptive Capacity.

1. Exposure: Exposure refers to the degree and nature to which a system is exposed to the potential impacts of climate change.
2. Sensitivity: Sensitivity refers ‘to the degree to which a system is affected, either adversely or beneficially by climate related stimuli. The effect may be direct or indirect’.

3. Adaptive capacity: Adaptive capacity refers to 'the ability of system to cope and adapt to climate change, variability and extremes- to take advantage of the opportunity or to adjust with the consequences.

(McCarthy *et al.*, 2001)

The level of vulnerability of a group to a natural hazard depends on the "exposure, sensitivity and response/adaptive capacity" to stressors (Cutter and Finch. 2008).

The effects of climate change and variability on social well-being have been documented throughout the world. Climate change has negative impacts on food production and security, water supply, biodiversity, human health and settlements. Many populations will be at risk to health effects from weather and temperature related events, air pollution and water borne, food borne, vector borne and zoonotic diseases (Patz and Kovats 2002). It is also projected that with increased warming, the intensity and frequency of heat waves will increase (McGeehin and Mirabelli, 2001). Throughout the world, many indigenous communities have been negatively affected by climate change. The negative effects of climate change on communities go beyond immediate threats to food supply (Diffenbaugh et al. 2007) to encompass aspects of health such as susceptibility to diseases as epidemiologies are affected by environmental factors (McCarthy et al. 2001), and a long-lasting cultural disturbances and losses affect well-being (Sakakibara, 2008).

The consequential effects of climate change have reached to a crucial extend that irrevocable change in the functioning of the planet is feared, there are multiple folds in the effects of the global climate change which demands the need to create awareness about its impact on various welfare of mankind (Venkateswarlu and Shanker, 2009). Anthropogenic activities, solar radiation at the earth surface, biotic and abiotic processes might be the cause of climate change. According to (IPCC 2007) the estimated increase in the global average temperature in the last 100 years have increased by 0.3˚C to 0.6˚C and in the year 2100 it is projected to rise by 1.8˚C to 4.0˚C.

One strategy to lessen the harmful effects of climate change is adaptation, as it without a doubt a crucial part of the policy response to climate change. (Adger et al., 2003). The standard definition of adaptation to climate change is a modification to the ecological, social, or economic system to lessen the negative effects of climate change and as a reaction to the actual or anticipated change in climatic stimuli. The IPCC's Fifth Assessment Report (AR5) defines "adaptation" as “the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects’ (IPCC, 2014), as a result, adaptation includes making decisions to adapt and carrying them out by people, groups, or organizations.

Numerous studies have shown that in the absence of adaptation, climate change and variability possess adverse effects on social well-being as well as have an immense environmental impact. Multiple possibilities must be taken advantage of in this respect in order to lessen susceptibility to variability and climate change in the context of adaptation (Easterling et al., 1993). There are several chances and solutions for adaptation, ranging from technological ones like drought management, integrated water resources management, and rainwater collection. It is also possible to increase groundwater availability by combining new infrastructure with supply-oriented initiatives like desalination, reuse, and water marketing, artificial groundwater recharge, and regulations on groundwater usage (Upadhyaya, 2014).

1.2. Study area

Mizoram lies in the southern-most part of Northern Eastern hill ranges of the Himalayas, which is blessed with an evergreen forest, 85 per cent of its geographical area are still under forest cover (FSI, 2019), untouched forest reserved, streams which together makes it a climate sensitive Himalayan eco-system. The state has been divided into three sub-agro climatic zones, viz. Humid Mild Tropical Hill Zone, Humid Subtropical Hill Zone and Humid Temperate Subalpine Zone (Sahoo *et al*., 2018). The Meteorological Department (Aizawl) have categories 4 main seasons viz, Winter (Nov-Jan), Spring (Feb- April), Summer (May-August) Autumn (Sept- Oct).

Monsoon plays an important role in defining the climate characteristic of the state, the climate is characterized with short and dry winter in the month of November to February followed with Monsoon rainfall from the month of May to September. The months of June to August receives the highest Monsoon rainfall in a year. The state's economy is highly dependent on the agricultural sectors. However, the large number of agricultural practices belongs to the shifting cultivation, according to the State Action Plan on Climate Change issued by Government of Mizoram show only 5% of the total land is under cultivation and about 11% of the total cultivated area is under irrigation.

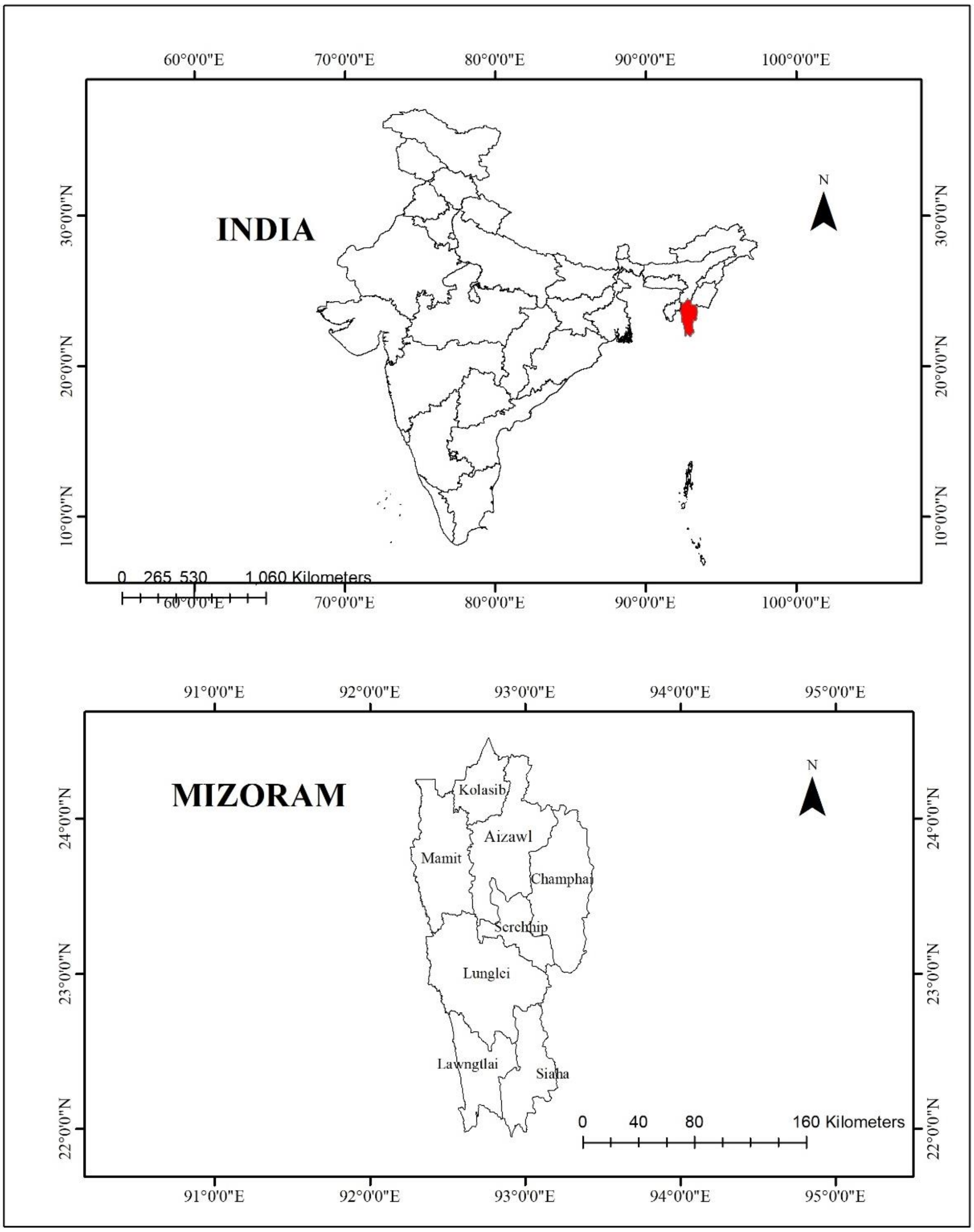

Figure 1.1 The study area, Mizoram, India

1.3 Scope of the study

Variability in regional climate conditions is becoming more evident every day (Stenseth et al., 2002; Patz et al., 2005). It directly influences the suitability of land for agriculture and agricultural productivity, and therefore affects current patterns of agricultural production (Parry and Carter, 1989). Indigenous people various parts of the world are already feeling the impact of climate change and variability. Changes in precipitation patterns have been observed and extreme events are becoming more common (De la Torre, et al., 2009). These changes are affecting indigenous people livelihoods, health and general well-being, and additional impacts are anticipated, such as conflict, migration, greater income inequality, and increasing dependence on food aid and similar forms of assistance (Jones and Thornton, 2003; Ford, et al., 2006; Mcleman and Smit, 2006; Reuveny, 2007; Ford, *et al*., 2010).

Mountains are unique ecosystems covering all latitudinal belts and encompassing within them all the earth's climatic zones. Mountains are widely recognized as containing highly diverse and rich ecosystems, and thus they are key elements of the global geosphere-biosphere system. At the same time mountains contain ecosystems that are unique sensitive and highly vulnerable to natural risks, disasters and ecosystem changes (Messerli and Ives, 1997).

The present study is an attempt to determine the change and variability in temperature and rainfall patterns in Mizoram and its potential effects on the social well-beings of the tribal society. Very limited studies have been carried out in the field of climate change and its vulnerability assessments on social well-being in Mizoram. The scarcity of reliable scientific study on climate change and variability and societal response to the changing climate scenario has enhanced the scope and significance of the present study.

The study will incorporate the traditional method/knowledge of climate studies and correlate it with the existing scientific information. All these will provide a comprehensive, evidence-based and quantitative estimation of climate change and variability and climate vulnerability in Mizoram.

1.4. Research Questions

1. Is Mizoram experiencing climate variability and change in the past 30 years?
2. What are the effects of climate variability and change on the agricultural and health sector?

3. Does Traditional Ecological Knowledge helps in understanding the current change in the climate and environment?

1.5 Objectives

The main objectives of the study are-

1. To examine past climate change and variability in Mizoram through instrumentally recorded climate data.
2. Analysis of climate variability by traditional ecological knowledge.
3. To assess climate vulnerability in Mizoram and develop a district-wise vulnerability index.
4. To analyse the dynamic relationship between climate and social well-being of various communities in Mizoram.

1.6 Chapterization of the study

The chapters in the thesis will be arranged as follows-

Chapter I : Introduction

The Introduction chapter deals with the introductory aspects of the study, which includes the importance of the study, location extend of the study area and its general information, scope and objective of the study.

Chapter II : Review of Literatures

This chapter is concerned with the different studies of literatures, which have been reviewed from numerous international, national and regional journals and books related to the study.

Chapter III : Methodology

This chapter involves the different statistical techniques, methods employed for the analyzing of the meteorological as well as socio-economic data. It also gives a detail account on the different sources of data and materials utilized in the study.

Chapter IV : Analysis of Climate Change and Variability in Mizoram

This chapter involves a detail study on identifying the changing trend and variability of the time-series data on climatic parameter viz, Temperature (maximum and minimum) and rainfall for the period of 1986-2020. The chapter shall also include the non-scientific way of understanding the general change in the pattern of climate by the Traditional Ecological Knowledge technique.

Chapter V : Spatial Pattern of Climate Vulnerability in Mizoram

This chapter is concerned with identifying different spatial pattern which are most vulnerable to the effects of climate variability and change.

Chapter VI : Coping Adaptive Strategies to Climate Variability

This chapter is involved with formulating and construction of different strategies and adaptive steps and measures which would be essential for coping and better management with the changing climatic condition and to limit its effects on the different sectors of social well-being.

Chapter VII : Summary and Conclusion

This chapter involve the brief summary and conclusion of the research work.

CHAPTER 2

REVIEW OF LITERATURES

2.1 Introduction

This chapter examines the body of literature that has been written about various aspects of the current study. The literature review's sources included numerous books, reports, Ph.D. thesis. One of the primary sources for the literature study was online website searches. Every scientific research project must include a thorough review of the literature. The primary purpose of a review of the literature is to familiarise the researcher with both past and present research in the area of study. It offers detail on "what has been done" and instruction on "what is to be done".

2.2 Studies on climate change and variability through recorded climate data

Recent studies have analyzed the variation in temperature and precipitation and their impact on different economic activities (Alexandrov and Hoogenboom 2000). Studies on climate change and variability through recorded climate data a number of studies have been taken out on climate change and variability at international, national and regional levels. Developing countries and their economic progress are likely to suffer tremendously from climate change, given their extremely nature-dependent agrarian economies (Mendelsohn & Dinar, 2009).

Kripalani et al. (2003) examined the inter-annual and decadal variability in summer monsoon rainfall over India by using observed data (1971–2001).They found random fluctuations in annual rainfall and distinct alternate epochs(lasting approximately three decades) of above-and below-normal rainfall for decadal rainfall. They also concluded that this inter-annual and decadal variability appears to have no relationship to global warming.

Goswami et al. (2007) discussed about the variability of rainfall resulting in the increase of extreme rain events such as – landslides, flash floods, crop damage etc. in spite of the fact that no significant long-term trend is identifiable. For the study, the scholars used a daily gauged rainfall data at 1 by 1resolution from IMD based on 1803 stations that have at least 90% data availability for the period 1951-2000. The Central India is selected as the region to examine the trends. The findings suggest that the maximum 1-day rainfall during the summer monsoon of 1951 to 2003 is C1 was 58.2 cm and there is a 10% increase per decade in the level of heavy rainfall since 1950's whereas the number of extreme events have more than doubled indicating a large increase in disaster potential Studies on rainfall and the temperature regimes of Northeast India indicate that there is no significant trend in rainfall for the region as a whole i.e. rainfall is neither increasing nor decreasing appreciably for the reason as a whole although significant change in seasonal rainfall was observed in southern Assam (Das et al., 2013). The summer monsoon rainfall is found to be decreasing over this region significantly during the last century at an approximate rate of 11mm per decade (Mizra, 2003).

In case of Mizoram, it was observed that pattern of rainfall in Mizoram during 1986-2005 show a gradual declining trend but a sudden increase during 1990-1995 (SAPCC, 2012). Temperature data has also been analyzed using 20 years temperature data collected and studied for two decades. The average monthly maximum temperature taken during the decade of 1995-2005 shows an increase over the previous decade of 1986-1995. When analyzed on a whole, there has been an increase in the average maximum temperature during 1996-2005 by +0.28˚C over the decade of 1986-1995, which denotes a trend in increase in temperature during the last decade.

Jain and Kumar (2012) studied the trend analysis of rainfall and temperature data for India, to estimate the magnitude of trend in the variability and change of climate; they have employed the Sen's non parametric estimator of slope. To understand rainfall variability for the country it is necessary to appreciate the impacts of climate change, under the study it has been observed that the variability of rainfall and rainy days during winter, pre monsoon and post monsoon is very high. They also found that the annual rainfall for the period of 1901-1960 had a positive trend over Central India and the adjoining parts of the peninsula, and decreasing trend over some parts of eastern India, A stable northeast monsoon rainfall was found over Tamil Nadu, it is also reported that northeast peninsular, northeast India and northwest peninsula experienced a decreasing trend (ranged between -6% and -8% of the normal per 100 year) in the monsoon rainfall. But the west coast, central peninsula and northwest India experienced increasing trend (about 10-20% of the normal per 100 years) in monsoon rainfall. It has also been found that the trend analysis of rainfall data of 135 years (1871-2005) indicated no significant trend for annual, seasonal and monthly rainfall on an all-India basis. Annual and monsoon rainfall decreased, and pre monsoon, post monsoon and winter rainfall increased over the years, with maximum increase in the pre-monsoon season.

A case of study of Ethiopia on the impacts of weather variability and climate change on the agriculture by Bezabih et al., 2014, data and variables were collected though four waves of rural house hold surveys, conducted in the years 2000, 2002, 2005 and 2007 with same household and collection of climate data from the Ethiopian Meteorological Authority for the years of 1976-2006. They employed an inverse distance weighting interpolation method, in order to impute farm specific information from station level observation. They found that the impact of short summer temperature on revenue from cereal crops shows statistically significant and positive impacts of almost all the categories of temperature. However, for long run term temperature measures, both the lower (>3° C) and upper (>37°C) coefficients show strongly significant and negative impacts on the small cereal revenue. The average of summer precipitation has no effect, while the average of spring rainfall has a significant and positive effect, indicating that spring rainfall has important and positive effects on overall farm level revenue, while the crop-specific effects of rainfall are generally much weaker across or seasons.

Gebrehiwot and Veen, (2013) studied the evidences of climate variability in northern part of Ethiopia, where episodes of droughts of varying severity and duration occur, the occurrence of these droughts is associated mainly with the seasonal rainfall variability. A period of 1954-2008 has been taken for the study of variation in temperature and rainfall. They employed the standardized rainfall anomaly to examine the temporal characteristics of climate variability and determine the prevalence of drought. The analysis revealed that the average annual minimum and maximum temperature over the region has been increasing by about 0.72°C every ten years while average annual maximum temperature has been increasing by about 0.36° C per decade. they also found that northern part of Ethiopia is warming faster than the national average of 0.25° C per decade.

Hossain et al. (2014) examined the spatial and temporal rainfall from the 1940-2007 in the south-west coastal region of Bangladesh. They divided the spatio-temporal trends in three segments (1948-1970), 1971-1990 and 1991-2007) and four seasons (Pre-monsoon, Monsoon, Post-monsoon and winter) during the period of 1948-2007. Time-series statistical test was applied to analyse the variation. In the study of temporal change it is observed that post-monsoon and winter follow significant positive trends at most weather stations during the period 1948-2008, the rate of change was found in exposed zone and interior zone are +12.51 and +4.86 mm/yr, respectively over post monsoon and +0.9 and +1.86 mm/yr, respectively over winter.

Rajeevanand & Nayak, (2017) concluded from their all-India level studies that the Southwest monsoon rainfall does not show any long-term trend, but it exhibits significant multi-decadal variability. Annual mean, maximum and minimum temperatures averaged over the country as a whole showed significant warming trend of 0.60, 1.0 and 0.18 °C per 100 years respectively. The rate of warming trend in the annual mean temperatures since 1980s is much sharper, 0.2°C per decade

Temperature and rainfall are regarded as the essence of climate and therefore, its variability is often considered as synonym of climate variability. Wani et al. (2020) investigated the climate variability over Srinagar and identifying the trends. In their study they have analyze monthly, seasonal and annual rainfall and temperature trends over Srinagar. The study shows that the mean maximum temperature for winter and autumn has shown a sharp increasing trend suggesting a warm trend for the period of the year. Examination of the seasonal mean minimum temperature series indicates that the winter season and spring season show warming trend as the seasons have shown drastic increase in trend especially for winter season.

2.3 Studies on climate change and variability through Indigenous Knowledge

Traditional ecological knowledge refers to knowledge, innovation and practices of indigenous and local communities embodying traditional lifestyle.

Indigenous knowledge was acknowledged in the fourth assessment report of the Intergovernmental Panel on Climate Change as a reliable method of studying climate change and variability. The importance of indigenous knowledge on climate change was acknowledge in the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) as ‘an invaluable basis for developing adaptation and natural resource management strategies in response to environmental and other forms of change’ (IPCC 2007).

Traditional knowledge and its contribution have been appreciated in many fields including biodiversity conservation, environmental assessment, biological information and ecological insights, social development and environmental ethics. However, to explore the value of traditional ecological knowledge related to climate change very little research have been done to understand its potentials. For a very long time the role of traditional knowledge system in mitigation and adaption have been neglected in many developmental policy formulation and implementation (Riedlinger & Berkes, 2001; Macchi, 2008).

Based on traditional knowledge of weather patterns and climatic conditions, indigenous peoples in many parts of the world are increasingly reporting that weather and climate are changing. Such observations have been recorded for indigenous peoples around the world, for example, in the Arctic, Africa, Asia and North America. (Krupnik and Jolly, 2002; Gearheard et al., 2006; Aporta and MacDonald, 2011).

For thousands of years, Early Warning System (EWS) have been existence, in a case study of the tribes in Kenya by Ojwang’ et al. (2010), due to the country’s inadequate data on climate, traditional knowledge of understanding the variability in climate was employed, they highlighted Indicators of traditional knowledge such as,

i) Traditional Indicators: in sub-Saharan Africa, especially the pastoral areas, elders read the intestines of slaughtered small stocks (goats and sheep) to forecast forthcoming drought. The use of such knowledge triggers movement of pastoralists with their livestock to areas of low risks, this may also be an early warning for the people to store food, brace for sickness or perhaps trigger movement.

ii) Nutritional Indicators: Observation arising from malnutrition is an indicator of stress. Children are usually the vulnerable group under this condition and observed to show exhaustion. This method is popular in monitoring the dietary balance in the ASAL and acts as a warning to relief agencies to donate food or simply signify deficiencies in food supply during the prevailing seasons.

iii) Weather and Climate Indicators: The most common method used in traditional forecast is observation of weather and climate indicators. This relies on the change in weather pattern. For e.g. a change in the wind direction or formation of dark clouds is a precursor to the coming rain. In some instances, the elders are capable of predicting the onset of rains from simple astronomical observations, while certain pastoral groups rely on the phonological change taking place on certain vegetation. In the drylands the flowering of certain Acacia species heralds the end of a dry season.

Spink's (1969) work have been identified as first research in the field of traditional knowledge and climate change. In his study, the oral history of indigenous people has been regarded as crucial evidence to support the idea of sea level change. Cruikshank's (1984) studied the indigenous community at Yukon also identified oral history as an important element to understand the past climate (Riedlinger & Berkes, 2001).

Riedlinger and Berkes (2001) mentioned that it is from the Hudson Bay Bioregion project and the Northern River Basin study (McDonald et al., 1997; Bills et al., 1996) that the first attempts to understand the environmental change through traditional knowledge was initiated. It is from these communities-based projects that the environmental change due to large scale developments and incidentally addressed climate related change were documented. From the study it was established that indigenous elders were able to differentiate cycle, changes and pattern in the environment and ecosystem and these knowledge of change in the land and environment became vital indicators to interpret and recognize the change in the season.

Berkes (2009) made a significant statement on conducting research on indigenous knowledge, in which he stated that indigenous knowledge should be examined as process, not as content. Considering the indigenous people of Harbor and Wemindji as an example, the author mentioned that indigenous people regularly observe land, resources, water, birds, animals and based on their behaviour and change the indigenous people have developed the knowledge of climate change. Due to this close interaction with nature and based on their understanding they could identify the abnormal behaviour and change and comprehend what is happening.

The study conducted by Lammel et al. (2011) suggested that indigenous people highlight the persistence of holistic thinking on the perception of climate change, largely based on analytic thinking. Their worldview and their interaction between the different component of climate change have been transmitted from generation to generation.

A case study by Tebtebba Foundation (2011) about the indigenous women of Tuapi consider climate change as a change in the Earth. The indigenous people can no rely on the consistency of natural pattern to guide their activities throughout the year. They expressed that temperature are gradually becoming warmer, seasons are occurring outside their usual time and extreme events of floods and drought are occurring frequently. The change in season has eventually affected the ripening of fruits and has been thrown out of synchronicit.

Nakashima et al. (2012) mentioned in order to solve the issue of climate change the scientific knowledge alone is insufficient hence to deal with climate change it is important to give more importance to all kinds of available knowledge. They further suggested that to understand nature and social interaction it is important to appreciate the contribution of bio-physical and social sciences. The knowledge of local and indigenous peoples often referred as local, indigenous knowledge, which means the long-standing information, wisdom, tradition and practices of certain indigenous is increasing being recognized as an important source of climate change adaptation strategies and climate knowledge (Kothari, 2007).

2.4 Studies on climate vulnerability

The concept of vulnerability is often discussed in relation to natural hazards and the ability of individuals or social groups to cope with these hazards (Adger and Vincent. 2005). On the other hand, although the study of adaptation of humans to environment variability has its roots in anthropology (Janssen, et al., 2006), Recent decades it has principally been applied to issue of global climatic change and its impacts (Adger, et al., 2005; IPCC, 2001). The Intergovernmental Panel on Climate Change (2007) pointed out that those in the weakest economic position are often the most vulnerable to climate change and are frequently the most susceptible to climate related damages, especially when they face multiple stresses.

Mall et al. (2006) pointed out that crop growth, development, water use and yield under normal conditions are largely determined by weather during the growing season and even with minor deviations from the normal weather, the efficiency of extremely applied inputs and food production is seriously impaired. Their study pointed out that climate variability and food production are enormously linked as extreme weather conditions, such as floods, droughts, heat and cold wave, flash floods, cyclones and hailstorm, are direct hazards to crops and subtle fluctuation in weather during critical phases of crop development can also have substantial impact on yields.

Studies on climate change and social well-being Several authors have recognized that that climate change has the potential to profoundly impact human well-being, and that individuals and communities play an important role in responding and adapting to climate change (Fritze, et al., 2008; Berry et al., 2009). This includes the impact of climate change on issues such as health (Costello et al., 2009), security and conflict, and human development (United Nations Development Programme, 2009), as well as on groups such as women and children (Carvajal-Escobar, Quintero-Angel, and Garcıa-Vargas, 2008).

Vulnerability is a dynamic phenomenon however very limited studies have adapted the temporal scale to assess the pattern of climate change vulnerability (Chhotray, 2012; Pranjay, 2012) suggesting that the dimension requires further research. Bosher et al. (2007) argues that with difference in socio-economic groups there is differential vulnerability to climate change. Further on the basis of region and sectors many researchers have highlighted their studies on vulnerabilities to climate change. From the community perspective mapping of vulnerability may yield different results in the same region because socio-economic-cultural dynamics of different communities differs from village to village and community to community in the same region. Therefore, it is crucial to conduct climate change adaptation mapping and perception of climate change in micro scale, i.e. a particular community at a village scale.

Caxton et al. (2013) in his study assessed the impacts of climate stresses and shocks and tries to measure how different types of subsistence livelihoods were affected by the impacts of these climatic stresses and shocks. In order to find out the degree of impact of climatic hazards on natural resources and livelihood and which resources and livelihood were most vulnerable to climatic hazards the author adapted the Livelihood Sensitivity Matrix and the study was undertaken in Lesotho a South African countryside which can be broadly categorized into highlands, foothills and lowlands agro-ecological settings. The study reveals that all the three region experiences change in livelihood system which was due to the direct relationship between climate change and decline of forest resources. By carefully assessing the range of livelihood that are prevailing in the three region it was found that farming and gathering were the worst affected livelihood with related to climate change and the study also shows a decline of cultivable area along side with decline in number of livestock owner and livestock population. However, it was observed that there was no decline of land fertility due to climate variability. Majority of the community are aware of the changing climate trend which have led to shifting of agriculture pattern in the study area, the community shifted to drought resistant sorghum and diversified the existing farming system with horticulture crops.

Eucharia et al. (2015) studied the climate variability on the choices of livelihood In the Anambra state of Nigeria. The Multinomial Logit was employed in the study case, where the livelihood choices were grouped into four categories 1, if he farm household chose crop production; category 2, if fishing was chosen; category 3, if livestock production was chosen and category 4, if the major livelihood choice was from agro forest resources. In their findings, the perception on the effects of climate variability on choices of livelihood shows that the farm household in all the communities sampled perceived the effects of these elements of climate variability which had adverse effects on their choices of livelihood. The finding noted that climate variability through sea level, storm and flood frequency, impact on the physical capital of the households or of entire communities, leading not only to decrease harvesting capacity but also to disrupting of public infrastructure and services that support livelihood.

Ogra and Badola (2015) found that the reason behind poor households to diversify their income source is mainly due to crop failure and declined agricultural yields. The women members of the poor households are compounded to this hardship who do not enough financial support to purchase fodder and fuelwood which they arrange these requirements with their own labour in the absence of alternative assets. In the face of climate induced crop failure animal husbandry becomes an alternative of agriculture.

In a global aspect vulnerability to climate change has been conceptualized through a range of discipline whereas in the Indian context it is largely confined to disciplines like disaster and hazard management (Singh et al., 2016). Their findings also reveals that very limited research emphasized on the concept of vulnerability from the disciplines like political economy, sustainable livelihood, poverty and social protection. Their study also found that only 19% of studies associate to vulnerability to climatic and non-climatic risks.

Deb and Haque (2016) found the increasing climate uncertainties and decline in the natural resource base have resulted food insecurities among the fisher folks of coastal and flood plain region of Bangladesh. By virtue of opportunities and capabilities the fisher folks have learned to adopt multiple livelihoods in the context of changing social relations to cope with the adverse effects of climate change. The ability to cope with different stressors of climate varies greatly and is largely determined by a host of factors: age/experience, gender, altitude, one's physical condition, literacy, social capital and economic endowments.

Barla (2016) revealed through his study that the most adversely effected community due to climate change are the tribals who are primarily dependent on natural resources and rain-fed agriculture. Therefore, it is necessary to intervene and reduce the adverse effects of climate change face by the tribal communities. Some of the key strategies to reduce climate change and GHG emission affects faced by the tribal communities were found to be improved communication on weather related information, practice of improved water management techniques, adoption of climate smart agriculture, utilization of improved rice varieties which requires less water, reduction in the utilization of pesticides and chemical fertilizers.

Asravor (2017) in his study found that the small holder farmers in areas with high rainfall follows diversifying labour supply for total labour and female labour of the region whereas the risky pattern of rainfall compelled the small-holder farmer to go for income diversification. The study also reveals that as compared to the male farmers the women were found to be more diversified due to their larger involvement in many income generating activities. Households with higher farm holdings were found to have diversified their cropland activities whereas households with lower farm holdings were found to have diversified their total labour supply to other economic activities.

Jha et al. (2017) concluded for improving the socio-economic status of the tribal people in developing countries a well-designed government programme and policies plays a vital role and have a wider scope in reducing the vulnerability to climate change. Increase in the availability of water plays a significant role in improving agricultural diversity, helps in increase of crop yield and decreases the vulnerability to climate variability and change. In a tribal dominant areas labour opportunities and daily wage level for unskilled labours plays a better scope than that of non-tribal communities. With increase in the intake of income subsequently lead to increase in the expenditure of nutritious food, health and education thereby reducing both vulnerability aspect of socio-economic and climate change in the marginalized tribal community.

2.5 Studies on adaptation to climate change and variability

Devenan (1983) stated that in the context of changing circumstances, the cultural practices that allow societies to survive are considered adaptation. Bruton (1997) viewed that depending on the experience, time horizon and the risk tolerance of individual decision-makers, there is a willingness to adapt to climate change and variability. Frequency of extreme events with respect to climate hazards adaptation can be expected to increase as well.

In a study on climate change and variability in California by Wilkinson and Teresa (1998), involves the representatives from abroad cross section of California's major economic, social, government and environmental issues. The analysis of study shows that climate change and variability will potentially affect the state's diverse economic sectors in important and different ways. Some activities and enterprises will be impacted directly through changes in natural resources and ecosystem services. Precipitation falling as rain instead of snow could cost the state's world class winter sports sector to suffer serious losses and will pose major problems for water managers. Agriculture will perhaps be the sector most highly susceptible to climate change, California will hopefully be able to maintain its productivity and contribution to the nation's economy, but farmers may have to alter their practices. As Lowell Lewis, William Rains, and Lynne Kennedy note in "Global climate change and California Agriculture", "A consensus of many scientists is that agriculture is on a collision course with itself; without significant change there may be no agriculture left in some parts of California for climate change to affect."

In climate change studies, the process of social development is increasingly linked in contemporary literature to concepts of vulnerability and adaptation to climate change. Adaptation to changing climate has been documented for agricultural communities in Bangladesh and Vietnam, and indigenous hunting communities in the Canadian Arctic (Cross & Barker, 1992; Lewis & Mortimore, 1998; Berkes and Jolly, 2001).

Bryant et al. (2000) in his study on agricultural adaptation to climate change as a multidimensional and multi-scale and a complex process that may take a number of forms. He identified four main components of adaptation: (1) characteristics of the system (political, economic, cultural and biophysical environment), (2) characteristics of the stress, (3) multiple scales, (4) adaptive responses.

Smit et al. (2000) explained the process through which people reduces the adverse effect of climate on their well-being and health and turning what climatic environment provides as their advantages could be defined as adaptation to climate change. Adaptation involves adjustment to longer term climate change including its current variability and extreme events, to reduce vulnerability to climate and enhance the viability of social and economic activities.

Smit et al. (2000) explains that describing an adaptation necessitates identifying the adapter (or adapters), the stimulus for which the adaptation is made, and the method and shape that the adaptation takes. The phrase, “adaptation to what” refers to whether adaptation is being made in response to climate change fluctuation, climate change, or just the climate itself. Additionally, there are variations in how the issue of adaptation relates to who or what adapts. It can be made up of individuals, social and economic groups and endeavours, as well as regulated or unmanaged ecological and natural systems. A system’s adaptation to climate stimuli can happen in many different ways and take many different forms. Purposefulness and timeliness are the two most frequently mentioned distinctions. Autonomous or spontaneous adaptations are those that naturally occurs in reactive to climate stimuli as a matter of course and without the purposeful intervention of a public agency (after early impacts are obvious).

Tompkins & Adger (2004) proposes the belief that adaptation to climate change requires a broader conceptualization of equitable, legitimate, and sustainable development in effective and resilient response. Some natural systems have inbuilt ability to adapt whereas others have to learn how to become resilient. Here the focus to built resilience in both social and ecological features is on the role of networks and institutions. Managing natural resource systems with the added stresses associated with climate change poses a challenge for socio-ecological systems.

According to UNDP (2005) there has been a significant shift in emphasis on the adaptation to climate change. Adaptation to climate change has changed significantly from being a response mechanism to impact cycle to now being viewed as a process of resilience of communities to the different adverse of climate change and variability and also giving more emphasis on the enhancement of sustainable development. Development programmes are now an ongoing mainstream focus in the field of climate change adaptation research.

Maddison (2006) argued that in order to successfully implement adaptation to climate change it is necessary for farmers to notice that there is a change in the climatic system, and then implement useful adaptation. The author also suggested that there are three ways for farmers to learn the best way of adaptation to climate change: (1) Learning by copying, (2) Learning by doing and (3) Learning by Instruction.

Smit and Wandel (2006) observed that people modify in response to climate stimuli and their impacts in order to lessen the damage or to take advantage of an opportunity. This occurs both automatically and in a planned, anticipatory manner.

Fussel (2007) emphasized that human activities have already affected the climate, from the study of past climate we have learned climate is continuously changing, and the results of emission reductions will take several decades to be notable, in which the author argued emphasis should be focused on formulating adaptation measures to climate change. It is also observed that the action of others highly determines the adaptation measures, the measures can be undertaken at the local or national level.

Nielsen and Reenberg (2010) examined the cultural obstacles in adaptation to climate change in Northern Burkina Faso. The study adapted the method of semi-structured interviews, focus group discussion, questionnaire survey, participant observation and GPS measurement respectively. It was observed that in the development projects and women’s engagement in economic activities the culture practiced by the community served as a major setback for adaptation measures.

Jones and Boyd (2011) conducted a study in the Himalayan region of western Nepal, the study reveals the role of normative, cognitive and institutional dimension of social barriers in formulating adaptation. It was found that in making a successful logical adaptation the social barriers play a significant role in enabling or obstructing it from happening. The study also suggested the importance and requirement of complexity and diversity of social barriers, incorporating the strategic planning in local as well as national level by putting underlying factors behind social exclusion in control and vulnerability.

Dasgupta et al. (2014) investigated "the list of climate change adaptation barriers in small holding agriculture". The study observed that notable barriers in small-scale agriculture in-terms on risk and benefits of climate change adaptation are inadequate information on climate change and its impact, inadequate adoption of adaptive strategies, lack of functioning markets and insurance systems, lack of technical options, inadequate extension services and financial constraints.

Falco et al. (2010) have investigated the factors influencing farmer adaptation and how it affects food production in Ethiopia. The researchers discovered that adaptability boosts food output, access to credit, knowledge of climate change and extension services are among the factors that have been identified to increase the likelihood of adaptation. The likelihood of adaptation is increased by both institutional agricultural extension and farmer-to-farmer extension.

Patra (2014) have suggested that the ongoing climate change adaptation policy and measures practice in India can be improved at a higher level by providing adequate and timely information to decision makers and planners in-order to execute effective planning and action to allocate resources. Such approaches are availability of information and allocation of resources, analysis of adaptation.

Jianjun et al. (2015) have discovered in their research that farmer's risk aversion is positively connected to purchasing weather index crop insurance but negatively related to making climate change adaptation like planting new varieties or implementing new technology. Additionally, education level, farming experience, farm size, household income and perception of the implications of climate change are the primary elements that affect farmer's adaptation decisions.

2.6 Studies on climate change and human health Vulnerability

The changes in the ecological conditions by the change in climate are the indirect effects of climate change on human health, which in-turn favour the problematic issues like infectious diseases. Infectious diseases are highly determined and controlled by environmental conditions for its transmission and therefore highly affected by climate change. An infectious diseases are also called communicable diseases or transmissible diseases and are clinically evident illness resulting from the presence of pathogenic microbial agents, viruses, bacteria, fungi, multi-cellular parasites. The infectious diseases can classify into vector-borne and water-borne diseases, in which vector-borne diseases are mediated through intermediate organisms that act as a carrier in disease transmission to the host. Malaria and dengue are the commonly known and widely spread vector-borne diseases. While, the water-borne diseases are due to the poor quality of potable water that reach human system and cause an effect (Dorland's Medical Dictionary, 1980).

The duration of survival of female *Anopheles* with plasmodium infection determines the malaria transmission which is known as the incubation period, the cycle takes about 9-21 days at 25˚C. Thus, temperature plays a vital role in determining the extrinsic incubation period. (MacDonald, 1957; Boyd, 1949). Temperature with warmer ambient shorten the duration of the extrinsic cycle which leads to the increase of transmission. The various studies conducted on the role of temperature and its effect on mosquito bionomics and malaria risk using ambient temperatures shows the confirmation of the effects of temperature on the incubation period and higher chances of transmission (Guerra et al., 2008; Roger and Randolph 2006; Hay et al., 2000; Martens et al., 1999).

In the central Indian sub-continent, a study was carried to investigate whether climate and malaria incident were related in a highly malaria prone village from 1967-2000. The shows a very weak relation between the two variables (Singh et al., 2002). Similar study examined by (Bhattacharya et al., 2006) to find the relationship between climate change and malaria transmission in India, from the study it has been noted that highest number of reported cases of malaria occurred when the average temperature ranges between 15˚C to 30˚C and shows a positive correlation between relative humidity and malaria transmission when the humidity range is 55% to 80%. In a study at the Ethiopian highlands, the findings show a positive correlation between malaria transmission incidents with increase of temperature from 1968-1993 (Tulu & Nega, 1996).

Highly climate-sensitive diseases such as diarrhoea, cholera, Malaria and dengue have been predicted to be worsen as climate changes and due to the lack of infrastructure facilities and less assistance to prepare and respond to such calamities it is expected that the developing countries will be least able to cope to the adverse effects of climate change situation (McGuigan et al., 2002).

On a regional scale the climatic impacts on health can be broadly classified into:

i) Direct heat-related mortality and morbidity and

ii) ii) Climate-mediated change in the incidence of infectious diseases (Patz *et al.,* 2005).

The major evidences of direct effects on climate change on human health was during the year 2003 in the "Heat wave Episode in Europe", due to the excessive anthropogenic emission resulted in an unusual increase in temperature during the period of 4th August-18th August 2003, which led to an excess of 14,974 deaths in France. Mortality was attributable to dehydration, hyperthermia, heat stroke which are directly link to heat. Seasonal variation, existing respiratory problems and air pollutions were other confounding factors for heat stress (Poumad'ère *et al.,* 2005; McMicheal et al., 2003).

A study in Burkina Faso (Yazoume Ye et al., 2007) investigated the effects of meteorological conditions upon clinical malaria risk among children. The findings confirmed that the malaria rates among children under five years were positively affected by weather and had a significant influence on the transmission of the disease. The mean temperature was the best predictor of clinical malaria incidence, where the risk of the increase in rate of clinical malaria increased with mean temperature up to 27˚C. whereas the increase of clinical malaria cases in-terms of rainfall was observed when it was 100mm. In the highland region due to the high altitude and low temperature its was found as a limiting factor for malaria transmission. For instance, in Bufundi, Kilibwoni, East Africa with an altitude of 2000m, (kristan et al., 2008) studied the association between malaria morbidity and climate. It was found that a peak in rainfall during the months of April – May was followed by a peak in malaria occurrence in June followed by the second peak of rainfall in August followed by low temperature in July, which set the scene for second peak of malaria incident in the month of October.

The World Malaria Report 2011 stated there are about 216 million cases of malaria and 655,000 estimated deaths in 2010 in 106 malaria endemic countries including India, (WHO 2011). The parasites *Plasmodium vivax* and *plasmodium falciparum* are the main causes of malaria transmission and the female *Anopheles* mosquito acts as a vector in transmitting the malaria parasites into human system. Climate parameters affects the disease transmission through the combination of the following ways:

i. affecting the spatial spread of exotic diseases
ii. changing the seasonality and spatial spread
iii. shortening the pathogen incubation period
iv. increasing reproductive and biting rates

All climatic parameters play a direct impact on the transmission of malaria either individually or in a combination. Among the climatic parameters rainfall can create a breeding site where *Anopheles* mosquito can complete its aquatic life stages, from egg to larvae and finally adulthood. Research findings carried on different regions supported a strong relationship between population of *Anopheles* mosquito and nature of rainfall, which shows a significant correlation between malaria case incidents and rainfall in human beings. (de Souza et al., 2010; Zhou et al., 2007; Kelly-Hope et al., 2009; Gosoniu et al., 2012; Huang et al., 2011).

Numerous studies have been conducted to understand complex relationship between climate and malaria. Various quantitative methods were reviewed by Grasso et al. (2012) in the methods used in modelling climate change impacts on human health with special case study on malaria. Such models include cross-section and panel data studies, time-series model, non-statistical and general equilibrium studies. These studies have been carried in different geographical extend, for instance Ahmed *et al.*, (2013) carried the studies in Bangladesh using multivariate regression model; Loha & Lindjon (2012) employed the time-series modelling using Transfer Function (TF) models and univariate auto-regressive integrated moving average (ARIMA) model for South Ethiopia, Kim et al. (2012) in the Kenyan region adopted the generalized linear poisson models and distributed lag non-linear model. Bi et al. (2003) studied the climatic variables and transmission of malaria for the period of 12 years in Shuchen County, China. The effects of climate change on malaria in Burundi was studied by Nkurunziza et al. (2010) by adapting the Bayesian Modelling. Bautista et al. (2006) studied the spatial analysis of malaria and epidemiology in the northern Peruvian Amazon. All these studies show the climatic phenomenon plays an important role in shaping the spatio-temporal distribution of malaria.

2.7 Studies on the vulnerability of the agricultural sector to climate change

Along with other inputs like land, water, chemical fertilizers, etc., climate variables like rainfall and temperature are direct inputs into the agricultural production function. Agricultural productivity is impacted by climate change in two different ways: (1) directly through temperature variation, rainfall and (2) the CO2 fertilization effect (Erda et al. 2005), and also indirectly influenced by the frequency of disease outbreak, pest infestation and changes in the soil moisture and distribution (Rosenzweig et al. 2001). Agarwal (2009) highlights the ways in which climate change has an impact on agricultural productivity. Firstly, changes in rainfall and temperature may affect how agroecological zones are currently distributed spatially as well as the length and timing of crops growing seasons. Secondly, with everything else being equal, higher CO2 level may have some impacts on agricultural yield by increasing photosynthesis and the efficiency with which plants use water. Thirdly, the availability water may have good or negative impact on agricultural output due to climate change. Fourthly, the increased frequency of climate extreme events, such as floods and droughts may have an impact on agricultural productivity.

Kumar and Parikh (2001) have used net revenue as the dependent variable to estimate the impact for India. They discovered that the overall impact due to climate change scenario for a 2˚C rise in temperature and a 7% increase in precipitation are negative and a fall in total farm net revenue for India of about 8.4%. Future reforms are expected to benefits the eastern districts of West Bengal, Orrisa and Bihar.

The Energy and Resource Institute (TERI) (2003) sought to identify Indian agriculture's susceptibility and potential for adaptation in light of both climatic and economic developments. According to the study, "the level of adaptive capacity is high in the districts falling in the Indo-Gangetic plains (except Bihar), whereas it is lower for the districts falling in the interior of the country, such as Bihar, Madhya Pradesh, Rajasthan, Maharashtra, Andhra Pradesh and Karnataka".

O'Brien et al. (2004) attempted to analyse India's district level susceptibility to both globalization and climate change. According to the analysis, which used a method based on indicators and climate change modelling, "the districts concentrated in Rajasthan, Gujarat, Madhya Pradesh, Southern Bihar and Western Maharashtra are highly vulnerable to both climate change and globalization and more likely to pose combined challenges to the agricultural sector". Low vulnerability zones, however, are found in the Indo-Gangetic plains.

Mall et al. (2006) who examined and summarized the potential implications of climate change and variability on the production of food grains in India came to the conclusion that the effects varied both quantitatively and qualitatively by crop, level of agronomic management, region and season. Regarding the effects of the seasons, central and southern India's "rabi" agriculture (winter season) would be more vulnerable. They believed that by the year 2080, when temperature had significantly increased, Indian agriculture would be particularly affected.

Guiteras (2007) in his impressive work on the impact of climate change on Indian agriculture contends that expected temperature change over the period of 2010-2039 will affect key crop yield by 4.5%-9%. His research indicates that the impact over the long term (2070-2099) is more severe, lowering yields by at least 25% in the absence of long-term adaptation. These observations make it abundantly evident that both the food security of India and the Indian economy as a whole will be seriously threatened. He advised rapid adaptation to temperature changes in order to combat such negative conditions.

According to Mariara & Karanja (2007) in their research in Kenya, variations in temperature have a considerably greater impact on agricultural production than changes in precipitation. The anticipated effects of different climate change scenarios on agriculture support their conclusion. They came to the conclusion that farmers in Kenya are aware of short-term climate change and that some had adopted adaptive measures after evaluating farmer's views of climate fluctuations and their response to it.

Wang et al. (2008) discovered that lower temperature and more precipitation increase the likelihood of irrigation when assessing the crop as well as irrigation preferences of Chinese farmers. Future climate scenario will force them to cut irrigation and switch from potatoes, rice, vegetables, soybeans and other crops to oil crops, wheat and cotton.

Seo et al. (2008) has discovered that a rise in temperature encourages farmers to practice mixed farming rather than specializing on one type of farming. Such as raising either corps of livestock while a rise in precipitation prompts farmer to switch from irrigated to rain-fed crops. Additionally, they discovered substantially lower damages than under fixed farm type.

Gbetibouo and Ringler (2009) investigated the climate change resiliency of South African farmers in various coping zones of South Africa provinces. The author utilized principal component analysis (PCA) for weight assignment, observed that the Western Cape, which is characterized by significant exposure to climate change and variability, also has a better capacity to adapt to climate change. Because of this higher affluence advance infrastructure and easy access to resources, it has a strong potential for adaptation.

Ravindranath et al. (2011) developed vulnerability profiles for the agriculture, water, and forest sector at the district level in the North Eastern region of India under the current and anticipated climate change scenario. The study found the agriculture in the districts of Tirap, West Siang, Nalbari, Changlang and Dibrugarh are the most vulnerable to present climate change whereas the district of Kolasib, N.C. Hills, Cachar, Ukhrul and Morigaon are the least vulnerable. The result was determined by using the vulnerability index, principal component analysis (PCA) and PRECIS model.

Latha et al. (2012) who carried out a case study in Dharwad to examine how climate change is affecting rainfed agriculture came to the conclusion that climate variations, such as the occurrence of drought, have a significant impact on the yield of rainfed crops. Farmers are already adapting to the climate change, both positively by adopting technology coping methods and negatively switching to other occupations. They contend that small and medium rainfed farmers were more like to have established coping method methods for climate change than farmers and that these farmers were also extreme vulnerable to climate change.

Sridevi et al. (2014) examine the sensitivity to climate change in various districts in Andhra Pradesh, Karnataka, Tamil Nadu and Kerela. The study's composite vulnerability index was calculated using socio-demographic method, meteorological, agricultural, occupational and common property resource vulnerabilities. Adilabad, Chamrajanagar, Thiruvarur and Kasaragod in Andhra Pradesh, Karnataka, Tamil Nadu and Kerela respectively are most vulnerable districts. Whereas, Hyderabad, Belgaum and Thoothukkudi are the least vulnerable districts, according to the index.

Varadan and Kumar (2015) examined Tamil Nadu, India's agricultural variability to climate change. The three IPCC dimension of vulnerability- "Exposure", "Sensitivity" and "Adaptive Capacity", were used in the study. According to the study the normalized indicators of these dimensions were given weights based on relative acreage of important crops in each district with regard to the state. According to the vulnerable index, the most vulnerable districts are those in Madurai, Coimbatore, Tirunelveli and North Arcot. Whereas the district which are most vulnerable to climate change are Salem, South Arcot, Ramanathapuram, Dharmapuri and Erode, whilst Chengalpattu, Thanjavur and Pudukottai are the least vulnerable districts.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The proposed work will incorporate both quantitative and qualitative study of both primary and secondary data. The following methods will be use for the collection of data on climate variability, vulnerability and social well-being and various statistical methods will be employed to analysed the data.

3.2 Data Collection

Meteorological data have been collected for the different elements of climate: Temperature, Rainfall for the state and different districts of the state from State Meteorological Department (Aizawl), Department of Agriculture (Govt. of Mizoram) and Border Road Organization (GRIEF) Mizoram.

To determine the impacts of climate variability and change on the social well-being such as health, nutrition, water availability and measures of sustainable livelihood, data relating to these climate-sensitive parameters have been collected through questionnaire survey covering all the districts in the state. A sample household size will be determined by using Taro Yamane (Yamane, 1973) formula with 95% confidence level. The formula is given below-

$$n = \frac{N}{1 + N(e)^2}$$

Where: n= sample size required

N = number of population

e = error (0.05)

Selection of households have been preceded by determination of sample size for the entire district which have been proportionately distributed in all the selected villages/towns. To ensure adequate representation of all sections of population, random stratified sampling method was used to select respondents from each selected village/town.

3.3 Coefficient of Variation

To analyze the magnitude of variability in the time series meteorological data the statistical technique of Coefficient of Variation was employed for monthly, seasonal and annual time series data.

The statistical technique of Coefficient of Variation (CV) was assessed in the time series data in order to observed the variation by categorizing the climatic variables of temperature and rainfall in to three different decadal groups, 35year time-series

$$CV = \frac{\sigma}{\mu} \times 100$$

Where, CV – Coefficient of Variation

σ – standard deviation

μ - mean

The change in percentage will be calculate by the following equation,

Percentage change= $\frac{new\ value - old\ value}{old\ value} \times 100$

3.4 Trend analysis

A trend analysis a statistical method of attempting to determine the future behaviors of a variable by analyzing historical data. It can also be explained as the method that aims to predict future movements by investigating past ones. Mann Kendall test (M-K test), has been employed to analyze the changing trend of Temperature (maximum/minimum) 1986-2020. Rainfall 1986-2020. Whereas, the Theil-Sen’s Slope Estimator has been employed to find the degree of magnitude during the trend.

3.4.1 Mann-Kendall Trend Test

The non-parametric Mann-Kendall test have been applied to find out the changing trend of the climate variables by classifying the time series data into three categories of monthly data, seasonal data and annual data sets. The Mann-Kendall test also shows the monotonic trends with statistical significance, which is dependent on the magnitude, sample size and variation of the data series. Non-parametric test is usually much less affected by the presence of outliers and other forms of non-normality (Lanzante, 1996) and represent a measure of monotonic linear dependence (Davis *et al*., 1995).

The Mann-Kendall test is determined by using the following equation.

.
$$s = \Sigma_{k=1}^{n-1} \Sigma_{J=k+1}^{n} sgn(x_J - x_k)$$

Where x_J and x_k are the annual values in years j and k, j>k, respectively, and 'n' is the number of data values. The signum functions; $sgn(x_J - x_k)$ is calculated as follows:

$$sgn(x_J - x_k) = \begin{cases} 1 \; if \; (x_J - x_k) > 0 \\ 0 \; if \; (x_J - x_k) = 0 \\ -1 \; if \; (x_J - x_k) < 0 \end{cases}$$

If 'n' is lower than 10, then MK test statistic 'S' is correlated directly to the theoretical distribution. Increasing trend is identified by the positive result of 'S' and negative value indicated decreasing trend (Salmi *et al*., 2002). If 'n' is greater than or equal to 10, then 'S' is nearly in normal distribution with the mean E(S) = 0 and the variance of 'S' is given by:

$$Var\ (S) = \frac{n(n-1)(2n+5) - \Sigma_{p=1}^{q} t_p\ (t_p - 1)(2t_p + 5)}{18}$$

Here q is the number of tied groups and t_p is the number of data value in the p^{th} group. The results of 'S' and 'Var(S)' are used to calculate the test statistics 'Z' as follows:

$$Z=\begin{cases}\frac{S-1}{\sqrt{var(S)}} & if\ S>0\\ 0 & if\ S=0\\ \frac{S+1}{\sqrt{var(S)}} & if\ S<0\end{cases}$$

The present of statistically significant trend is evaluated using Z value. A positive and negative value of Z indicates an upward or downward trend. The statistic Z has a normal distribution. To test for either an upward or downward monotone trend (a two-tailed test) at α level of significance, H_0 is rejected if the absolute value of Z is greater than $Z_{1-\alpha/2,}$ where $Z_{1-\alpha/2,}$ is obtained from the standard normal cumulative distribution tables. The tested significance levels α are 0.001, 0.01, 0.05 and 0.1 (Salmi *et. al.,* 2002).

3.4.2 Theil-Sen's Slope Estimator

To estimate the degree of trend magnitude Theil-Sen's Slope (β) method is used in the study. In other words, the nonparametric technique of Sen's method is used to estimate the true slope of an existing trend. The Sen's method can be used in cases where the trend can be assumed to be linear. Where, *f(t)= Qt+B, Q* is the trend given by the slope in unite time, 'B' is the intercept and 't' is the time. The slope 'Q' is calculated by using the following equation:

$$Q_i=\frac{x_J-x_k}{j-k}$$

Where $x_J\ and\ x_k$ are the data value at time j and k (j>K) respectively, if there are n values x_J and in the time sequence, there will be as many as N= n(n-1)/2 slope estimate Q_i, the N value of Q_i are ranked from the smallest to the largest and the Sen's estimator is:

$$Q=\begin{cases}Q\ \frac{n+1}{2} & if\ N\ is\ odd\\ \frac{1}{2}\ (Q\frac{n}{2}+Q\ \frac{n+1}{2} & if\ N\ is\ even\end{cases}$$

An assessment of 'B' in equation *f(t)* is made by calculating the 'n' values of different (x_i-Q_i) the median of these values gives an estimation of B (Raja & Reddy, 2018).

3.5 Climate Vulnerability Index (CVI)

The Climate Vulnerability Index (CVI) has been adopted from the Inter-Governmental Panel on Climate Change (IPCC) vulnerability framework and the framework consist the three main components/contributing factors of vulnerability to climate change: Exposure, Sensitivity and Adaptive Capacity (McCarthy *et. al.,* 2001).

The following equation have been used for computing the CVI

Firstly, the raw score of the selected indicators were normalized using the following equation,

$$Index\ K_f = \frac{K_f - K_{min}}{K_{max} - K_{min}}$$

Where K_f is indicators of dimensions and K_{max} and K_{min} are maximum and minimum value of each indicator respectively. For variables which represents frequencies such as percentage of household who have experience climatic change, the minimum value was set at 0 and maximum value at 100.

After each component were standardized, the sub components were averaged using the following equation to calculate the value of each major components.

$$K_h = \frac{\sum_{i=1}^{n} index\ k_f^i}{n}$$

Where, K_h is one of the three components of districts h, Index f_f^i represents the components indexed by i , and n is the sub components of each major components.

After the value for the Exposure, Sensitivity and Adaptive Capacity for each district were calculated, in order to obtain the district vulnerability value (CVI) the three component values were combine using the following equation from Hahn *et. al.,* (2009).

$$CVI_d = (e_d - a_d) \text{ x } s_d$$

Where,

CVI_d is the climate vulnerability index score for the districts d (obtaining using the IPCC vulnerability frame work

e is calculated exposure score for the district ***d***

a is the adaptive capacity score for the district ***d***

s is the sensitivity score for the with district ***d***

3.6 Principal Component Analysis (PCA)

Principal Component Analysis (PCA) was invented in 1901 by Karl Pearson, as an integral part of the principal axis theorem in mechanics, later it was developed and named by Harold Hotelling in the 1930's. PCA is a statistical technique and special case of factor analysis which utilizes an orthogonal transformation to transform the observed correlated variables into linear uncorrelated variables which further can be utilize for summarizing the data. (Jolliffe, 2002; Pearson 190; Hotelling, 1933).

In PCA, the principal component account much of the variance among the sets of original variances, the components are a combination of linear weighted variables of the initial variables. The components are ordered in first, second and third component respectively. In the original variables the first component accounts the largest possible amount of variation whereas the second component is entirely uncorrelated with the first component, on the other hand the third component accounts for the maximum variation compared to the first and second component and so on. (Krishna, 2010).

Principal components are variables of linear combination with weights in terms of their Eigen vectors, which have derived from correlation matrix of the variables. The principal components represent a linear combination of X's obtained as:

$$Y_1= e_{11}x_1+e_{12}x_2+\ldots+e_{1p}x_p$$

$$Y_2=e_{21}x_1+e_{22}x_2+\ldots+e_{2p}x_p$$

$$Y_p=e_{p1}x_1+e_{p2}x_2+\ldots+e_{pp}x_{pm}$$

Where, the variable (Indicators) are represented by $x_1,x_2\ldots.x_q,$ Y_i (i=1….,p) represents the principal components and *p* represent the number of variables and a_{ij} are the component loadings which further selected as weight applied to the variable x_j in the above equation. Where the principal component Y_1 satisfy the followings:

i) they are uncorrelated (orthogonal) and

ii) ii) the maximum possible proportion is accounted by the first principal component and the maximum of the remaining variance is accounted by the second principal components, and therefore,

$$a^2_{ij}+a^2_{i2}+\ldots a^2_{ip} = 1,$$

where i=1,2,...,p,.

Principal Component Analysis implies the finding of the eigen values λ_j, where j = 1,2,…,p, of the sample covariance matrix *CM* as-

$$CM = \begin{bmatrix} cm_{11} & cm_{12} \cdots & cm_{1p} \\ cm_{21} & cm_{22} \ldots & cm_{2p} \\ \ldots & & \\ cm_{p1} & cm_{p2} \ldots & cm_{pp} \end{bmatrix}$$

Where, the diagonal element cm_{ii} is the variance of x_i and cm_{ij} is the covariance of variables x_i and x_{ij}. The eigenvalues of the matrix CM are the variance of the principal components and can be found by solving the characteristics equation where *l* is the identity matrix and λ is the vector of the eigenvalues. An important property of the eigenvalue is that they up to the sum of the diagonal element of CM, that is, the sum of the variance of the principal component is equal to the sum of the variance of the original variables:

$$\lambda_1+ \lambda_2+\ldots.. + \lambda_p= cm_{11}+cm_{22}+\ldots.+cm_{pp}$$

Variables are standardized first to have zero means and unit variances at the start of the analysis so that some of the variables having undue influences on the principal components could be prevented. The correlation matrix is then form by the covariance matrix CM. As stated, in PCA the correlation matrix is used rather than the covariance matrix, informing of principal components all individuals are therefore assigned equal weights. (Chatfield and Collins, 1980).

3.7 Hierarchical Cluster Analysis

The statistical tool of Hierarchical Cluster Analysis has been adopted to assessed the classification of grouping the different variables in regards to similarities to variable characteristics, in which two of the groups which shows significant external heterogeneity, while other groups each had a number of variables with considerable internal homogeneity (Bhuiyan et. al., 2010; Shrestha & Kazama, 2007). While Euclidean distance often reflects the distance between variables and is typically shown by a dendrogram or tree diagram, the most common technique for displaying the relationship between variables or an entire set is the hierarchical agglomerative approach. (Mckenna 2003). The Single Linkage also known as the Nearest Neighbour Clustering was chosen to assessed the classification of groups. The statistical analysis was performed using the statistical package software SPSS (version 20).

The coefficient of the distance equation are:

$$\alpha_i = \alpha_j = 0.5, \beta = 0, \Upsilon = -0.5$$

3.7.1 Goodness-of Fit

Given the ideal technique can be challenging due to the abundance of available methods. Using the outcome with the highest cophenetic correlation coefficient has become a common criterion. This is the relationship between the initial distance and the cluster configuration derived distances. Values over 0.75 are regarded as positive. The statistic appears to have high values when calculated using the group average approach. This might be a factor in its appeal.

CHAPTER 4

ANALYSIS OF CLIMATE CHANGE AND VARIABILITY IN MIZORAM

4.1. Introduction

The Earth's climate system is under increased strain due to climate change, which is also changing the shielding and radiation balance of the globe. Additionally, the effects of climate change varied from area to region and throughout a range of timescales (Gocic et al., 2013). In contrast to developed nations, developing nations like India have more severe effects, especially on the poor and rural communities that rely heavily on natural resources like agriculture and the forest for their survival, rendering them more vulnerable. According to IPCC (2014), the anthropogenic component was the main driver of the change in the global climate, as the temperature climbed by 0.85˚C globally between 1880 and 2012. Additionally, according to projection, India's mean annual temperature has risen by 0.5˚C per 100 years (1901-2007) and 0.2˚C ever ten years (1971-2007), with a greater increase in the minimum temperature than the maximum temperature (Kothawale, et al., 2010). Furthermore, the number of hot days increased during the pre-monsoon season whereas the number of cold days significantly decreased between 1970 and 2007 (INCCA, 2010).

The two main essential variables in climate research that are most commonly utilized to determine the severity and magnitude of climate change and climate variability are precipitation and temperature (IPCC, 2007; Asfaw et al., 2018). In addition, the analysis of climatic trends, its accurate assessment and its accurate forecasting of temperature and precipitation at various temporal and spatial scale aid in understanding the connection between terrestrial ecosystem and climate systems. An in-dept knowledge and information on the wide range of climatic variables regarding climatology, intra-seasonal variability, extreme events and trends plays a key role in understanding the potential effects of climate change and variability and its application on the diverse sector of agriculture, forestry, ecology, hydrology, planning and risk management. Adding into the context, a thorough analysis of precipitation change over a range of time scale may improve comprehension of various calamities such as floods, droughts and water availability for a variety of applications in future climatic scenarios (Wang et al., 2015). Therefore, a thorough examination of current meteorological variables could therefore be a crucial component of comprehending climate change in a region, state or nation as a deciding element for the future.

Appropriate methodology is an essential requirement in-order to draw meaningful inferences from any study. The research methodology adopted for present chapter viz., Co-efficient of Variation, Mann-Kendall Test, Sen's Slope analysis and Traditional Ecological knowledge. The objective of this chapter, therefore, is to examine the trends and pattern of rainfall and temperature in Mizoram. Hence, the present study in this chapter will basically try to Figure out to what extend there has been variability and change in the climate of Mizoram.

4.2. Co-efficient of variation of climatic variables

The meteorological data for the analysis of coefficient of variation for rainfall and temperature (maximum and minimum) covers a time series of 35 years (1986-2020). In order to investigate the variation in the different climate variables, the 35-year time-series data have been divided into seven lustrums (five-year period), furthermore, the time series data have been further divided into yearly and seasonal. The Indian Meteorological Department IMD have categories 4 main seasons viz, Winter (Nov-Jan), Spring (Feb- April), Summer (May-August) Autumn (Sept- Oct).

4.2.1. Annual and seasonal variation of rainfall

The variation of rainfall was analyzed using Coefficient of Variation statistical method. The average rainfall in Mizoram during 1986-2020 was recorded 202.7mm. while the highest rainfall (3081.7mm) was recorded in the year 2007 whereas the year with the lowest rainfall (1518.2mm) was recorded in 2019. In Figure 4.1 the coefficient of variation of last 35 years of rainfall reveals the months of January, February, November and December, shows high magnitude of rainfall variation, the years of 2006-2010 shows highest variation of rainfall as compared to other years (Table 4.1).

After examining the annual rainfall variation, the seasonal rainfall variation shows a high variation in all season during the study period. In Table 4.2 the noTable seasons with high rainfall variation are Spring and Winter showing the highest variation in the year 2016-2020 and 2006-2010 respectively. The Summer and Autumn seasons shows a relatively low variation however in the later lustrum year of 2016-2020 the summer season shows a sudden high variation in rainfall (Figure 4.2).

Table 4.1 Co-efficient of Variation of rainfall in Mizoram, 1986-2020

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1986-1990	119.35	37.46	88.86	35.32	41.76	7.48	9.11	6.61	8.34	33.22	56.27	93.96
1991-1995	83.83	88.25	80.23	58.74	42.27	14.92	16.14	19.61	19.32	30.06	105.73	156.88
1996-2000	109.33	66.31	48.32	58.80	27.92	12.26	38.70	21.90	13.95	35.15	33.11	117.86
2001-2005	171.63	129.66	64.49	59.66	35.84	36.60	29.55	6.92	15.30	32.62	93.95	144.09
2006-2010	185.70	105.93	94.42	48.63	29.52	22.33	15.96	16.53	33.86	23.59	110.05	198.55
2011-2015	98.97	79.22	64.66	69.38	41.33	20.73	14.91	21.29	19.07	18.09	157.21	154.92
2016-2020	160.01	57.97	72.99	41.34	19.66	49.90	16.75	39.23	29.44	46.15	74.59	168.70

Source: Indian Meteorological Department, Aizawl

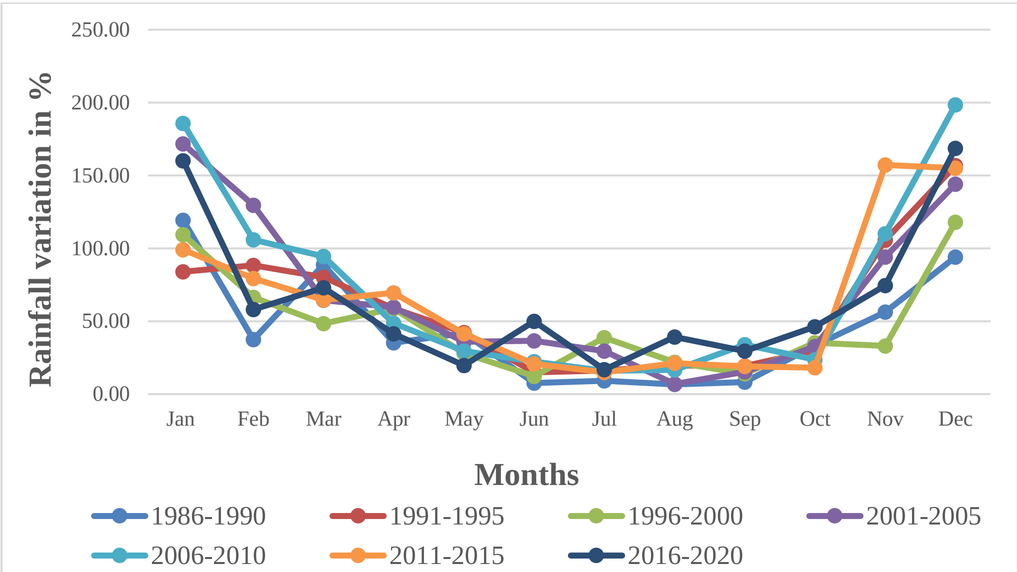

Figure 4.1 Variation in average annual rainfall in Mizoram, 1986-2020

Table 4.2 Co-efficient of Variation of seasonal rainfall in Mizoram, 1986-2020

Year	Spring	Summer	Autumn	Winter
1986-1990	43.09	7.08	13.80	66.15
1991-1995	41.00	13.19	23.47	82.72
1996-2000	40.00	9.25	13.93	51.89
2001-2005	29.65	15.27	18.31	71.89
2006-2010	44.66	14.14	29.20	99.93
2011-2015	57.68	13.69	14.50	89.09
2016-2020	70.01	64.09	39.80	67.76

Source: Indian Meteorological Department, Aizawl

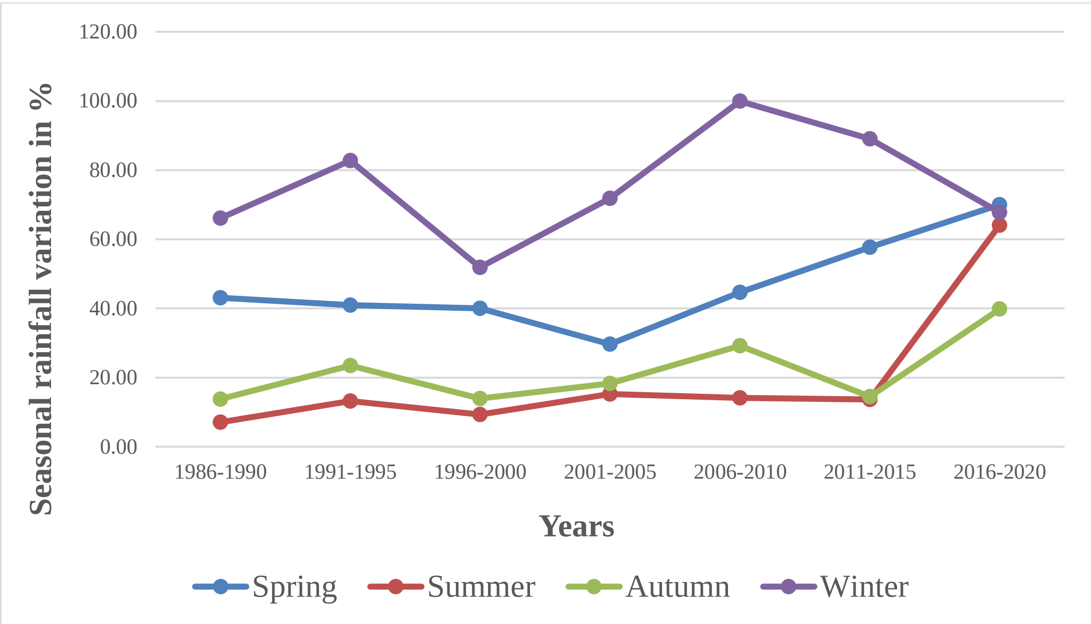

Figure 4.2 Variation in average seasonal rainfall in Mizoram, 1986-2020

4.2.2. Annual and seasonal variation of maximum and minimum temperature

The analysis of both the maximum and minimum temperature reveals a fairly similar pattern of moderate variation in temperature. The timeseries temperature data shows an average temperature of 26.6°C during 35 years of study period. The lowest annual average maximum temperature was recorded in the year 1990 with 24.1°C and the hottest year with the highest annual average maximum temperature was recorded in the year 2018 with 29°C marking a difference of 4.9˚C.

During the entire period, in Figure 4.3 the maximum temperature in the last lustrum years of 2016-2020 the variation results reveal an unusual increase change of high variation in temperature in the months of September, October, November and the month of December shows the highest in particular, whilst the other years shows a symmetrical monotonic variation throughout the years. The seasonal maximum temperature variation on the other hand reveals an intricating nature of high variation in all the seasons (Table 4.4). in Figure 4.4 it can be observed that the Autumn season shows a linear variation in all the years with an abrupt increase of high variation from 2011-2015. Spring and Winter shows a high monotonic variation and similar with the Autumn, Autumn and Winter also shows a sudden increase of variation in the temperature from 2011-2015.

Table 4.3 Co-efficient of Variation of Maximum Temperature in Mizoram, 1986-2020

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1986-1990	4.33	5.28	8.53	8.35	5.27	4.92	2.94	3.17	1.50	4.76	1.97	3.37
1991-1995	9.42	7.62	5.64	4.07	7.00	4.60	1.74	3.61	2.90	2.46	5.72	7.78
1996-2000	5.21	11.31	6.76	7.63	1.97	2.23	2.49	1.50	2.96	1.64	10.42	4.55
2001-2005	2.57	3.39	5.02	5.71	3.65	1.49	3.38	1.98	3.98	1.01	2.8	2.69
2006-2010	5.34	7.48	3.45	3.85	2.86	1.74	2.86	2.98	1.40	2.19	2.07	0.85
2011-2015	3.62	2.11	2.18	6.46	2.91	1.54	2.23	2.04	1.22	3.73	4.80	3.66
2016-2020	7.74	6.52	8.94	5.78	5.29	4.18	7.24	1.57	10.40	14.86	19.15	23.94

Source: Indian Meteorological Department, Aizawl

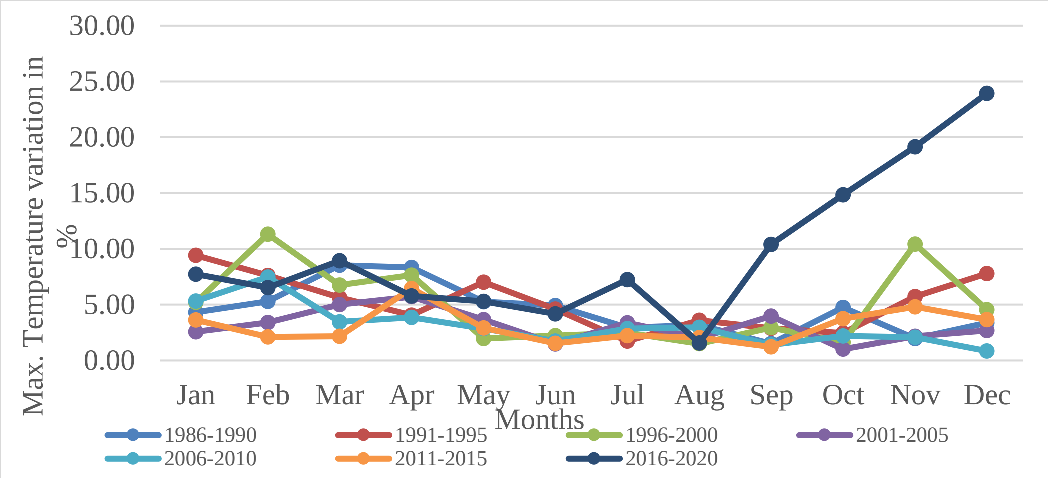

Figure 4.3 Variation in Maximum Temperature in Mizoram 1986-2020

Table 4.4 Coefficient of Variation of Seasonal Maximum Temperature in Mizoram, 1986-2020

Year	Spring	Summer	Autumn	Winter
1986-1990	6.89	3.67	2.86	2.32
1991-1995	4.82	3.53	2.32	6.07
1996-2000	8.13	0.67	2.23	3.66
2001-2005	2.82	1.18	2.22	1.93
2006-2010	3.93	1.62	1.28	2.41
2011-2015	3.07	1.26	2.17	2.62
2016-2020	5.68	2.79	12.55	16.05

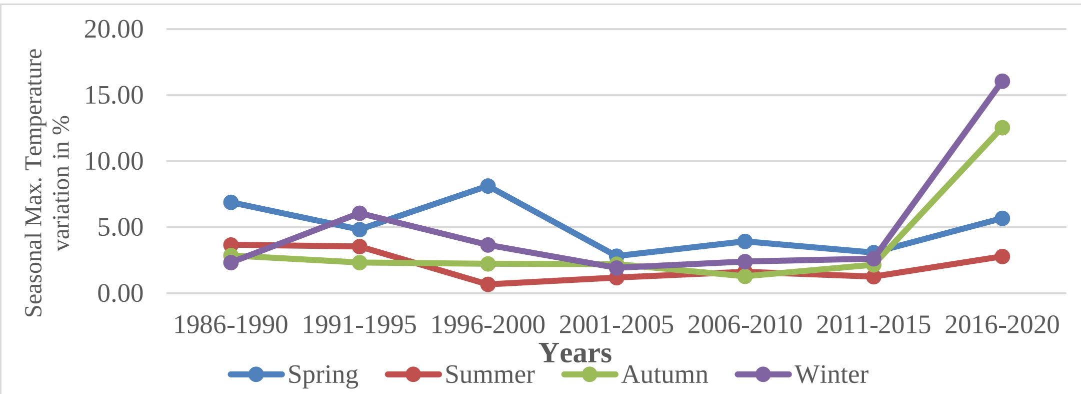

Figure 4.4 Variation in Seasonal Maximum Temperature in Mizoram, 1986-2020

The minimum temperature variation results reveal a similar monotonic variation in all the year groups with moderate and low variation except for the last lustrum year of 2016-2020. In the lustrum year of 2016-2020 it is observed with a very high variation of minimum temperature throughout the year, the month of November showing the highest anomalies followed by the months of January and December (Table 4.5). On the other hand, unlike the seasonal maximum temperature a distinctive similar pattern of monotonic variation is observed in the seasonal minimum temperature variation result (Figure 4.6). The lustrum years of 2001-2005 and 2006-2010 experienced a low variation of seasonal minimum temperature and the following years of 2011-2015 and 2016-2020 shows an abrupt increase of seasonal minimum temperature variation. The season of Spring and Autumn shows a moderate temperature variation whereas the winter records the highest variation of minimum temperature with the year 2016-2020 observed the highest variation in all the seasons.

Table 4.5 Coefficient of Variation of Minimum Temperature in Mizoram, 1986-2020

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1986-1990	7.25	12.62	9.67	9.50	5.86	2.88	2.95	2.00	4.71	4.18	7.91	7.52
1991-1995	14.15	14.58	10.28	7.75	11.22	4.73	4.75	5.22	12.98	7.85	10.19	16.05
1996-2000	3.64	13.90	12.19	11.68	9.02	7.42	8.29	8.74	10.08	9.94	13.80	7.50
2001-2005	9.56	4.72	6.21	3.69	10.35	5.84	5.14	6.12	2.66	3.72	5.40	2.81
2006-2010	8.83	9.52	6.71	5.39	4.46	5.34	2.36	1.99	1.81	2.26	2.47	3.34
2011-2015	13.22	18.60	12.38	12.60	10.85	10.13	9.54	10.49	10.65	10.90	11.08	16.76
2016-2020	32.90	18.74	21.05	21.24	22.63	27.20	29.94	24.33	18.17	30.07	37.61	32.88

Source: Indian Meteorological Department, Aizawl

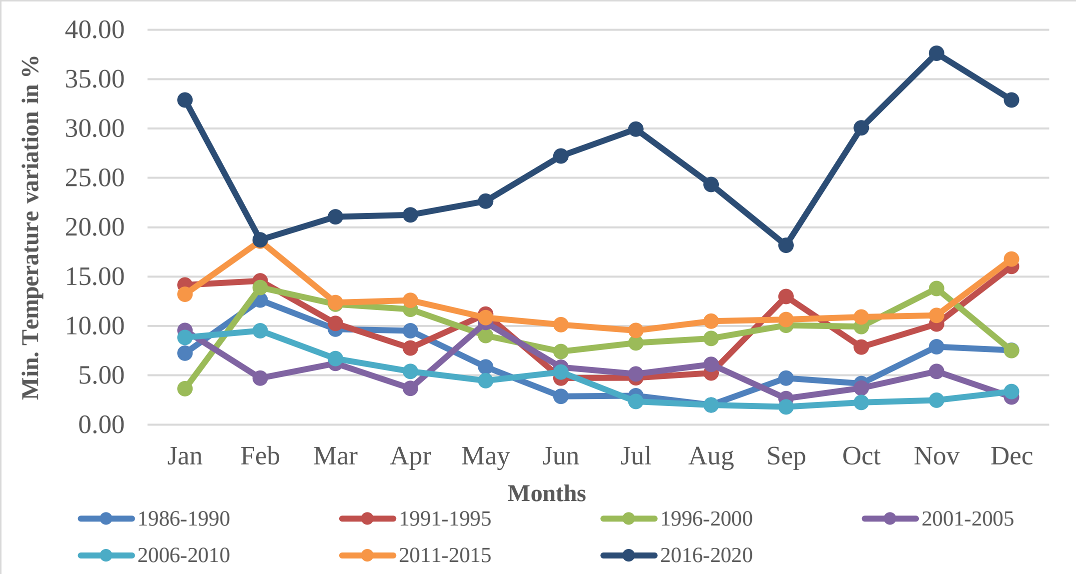

Figure 4.5 Variation in Minimum Temperature in Mizoram, 1986-2020

Table 4.6 Coefficient of Variation of Seasonal Minimum Temperature, 1986-2020, Mizoram

Year	Spring	Summer	Autumn	Winter
1986-1990	6.21	3.16	4.04	6.50
1991-1995	9.89	6.24	8.81	11.05
1996-2000	11.97	8.28	9.93	10.99
2001-2005	2.75	5.98	3.14	4.01
2006-2010	5.90	2.84	1.89	4.30
2011-2015	13.67	10.06	10.74	15.96
2016-2020	19.39	25.44	22.81	31.21

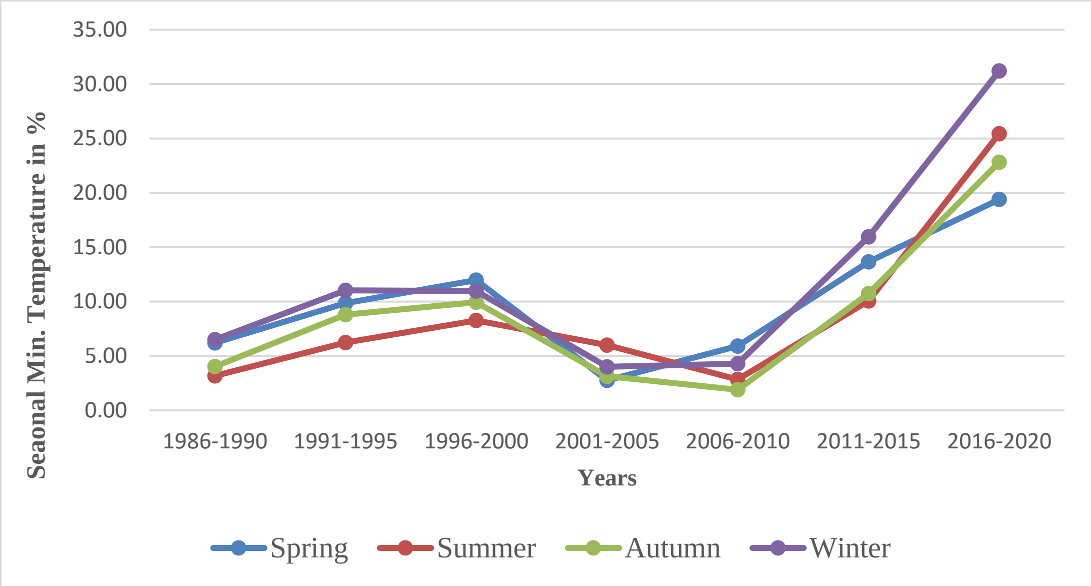

Figure 4.6 Variation in Seasonal Minimum Temperature, 1986-2020, Mizoram

4.3 Trend analysis of annual and seasonal rainfall

The Mann-Kendall and Sen's slope have been estimated to determine the nature of trend of the climate variables. The time-series data was analyzed by categorizing into three groups – monthly, seasonal and annual. In Table 4.7 the rainfall trend results for the period of 35 years shows a continuous negative Z value in monthly, annual and seasonal trend signifying a decline on the rainfall pattern during the study period. The trend analysis reveals the months of July and November with $p<0.05$ denoting a significant negative trend of rainfall (Table 4.7). Whereas, the Sen's slope results for the month of July and November shows a decline of -3.20mm and -1.22mm annual rainfall during the study period respectively (Table 4.7). The total annual rainfall also shows a significant negative trend $p<0.05$ of rainfall with a Sen's slope of -12.53mm of rainfall. In can be observed (Figure 4.7) the Sen's estimator shows a declining monotonic trend and the later year of 2020 shows a sudden drop in the slope. Likewise, the seasonal rainfall trend results also reveal a negative trend of rainfall. The spring, summer and autumn season shows a fairly negative trend out of which the winter season shows significantly highest negative trend ($p<0.05$) among all the seasons.

Table 4.7 Mann-Kendall and Sen's Slope statistics of Rainfall in Mizoram, 1986-2020

Time series	Test Z	Q	B	Signific.
Jan	-0.59	0.00	3.80	
Feb	-1.01	-0.29	22.81	
Mar	-1.53	-1.16	64.97	
Apr	-0.14	-0.17	127.64	
May	-0.01	0.00	290.16	
Jun	-0.97	-2.12	435.26	
Jul	-2.05	-3.20	459.00	*
Aug	-1.14	-1.71	422.92	
Sep	-0.74	-1.29	383.86	
Oct	-1.69	-2.71	249.81	+
Nov	-2.03	-1.23	48.83	*
Dec	-1.60	-0.03	1.63	
Spring	-1.73	-3.70	273.10	+
Summer	-0.94	-5.21	1696.37	
Autumn	-1.96	-3.89	647.77	+
Winter	-2.39	-1.85	75.33	*
Annual average rainfall	-2.16	-12.54	2690.70	*

(Note: + and * indicate significant at 0.1 and 0.5 level of significance respectively)

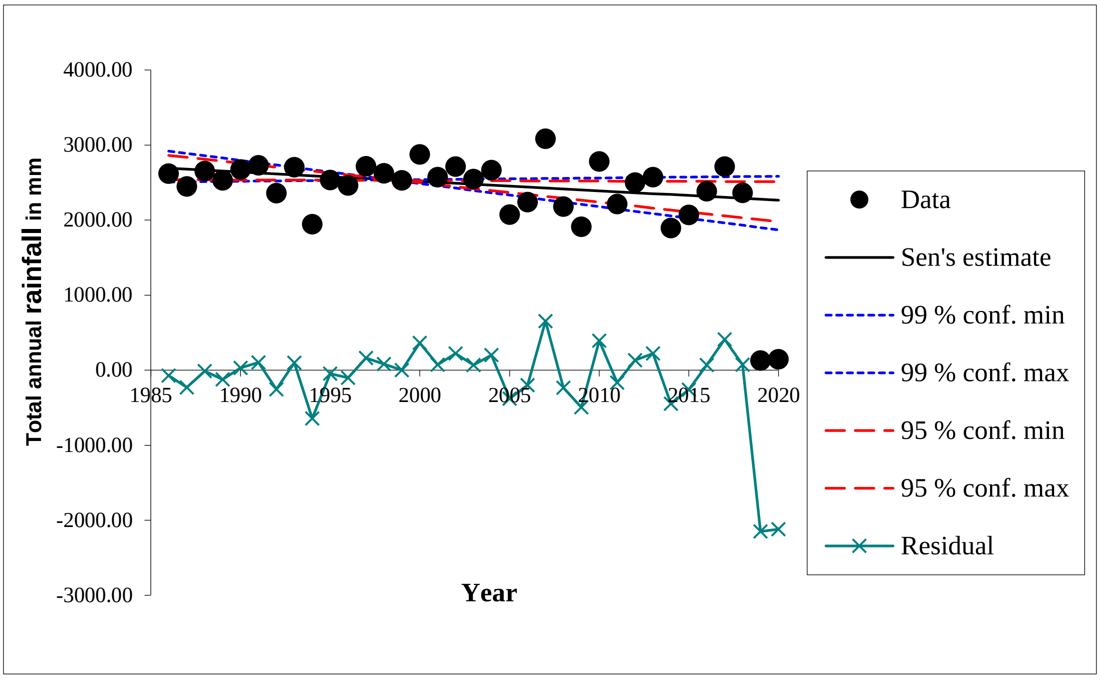

Figure 4.7 trend of total annual rainfall in Mizoram, 1986-2020

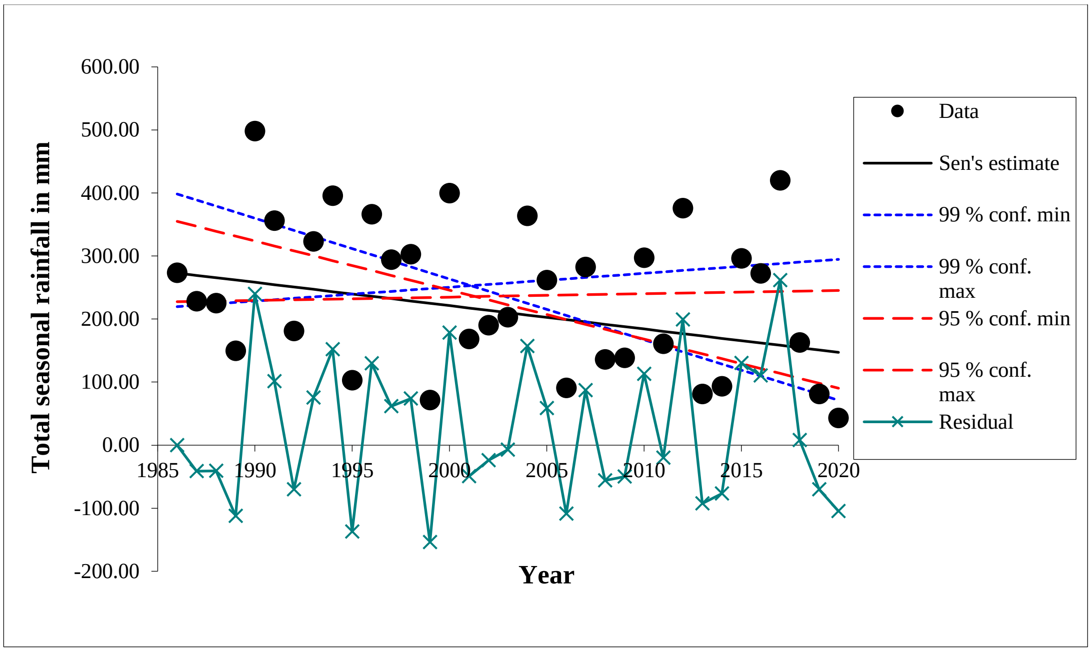

Figure 4.8 Trend of total seasonal rainfall during spring in Mizoram, 1986-2020

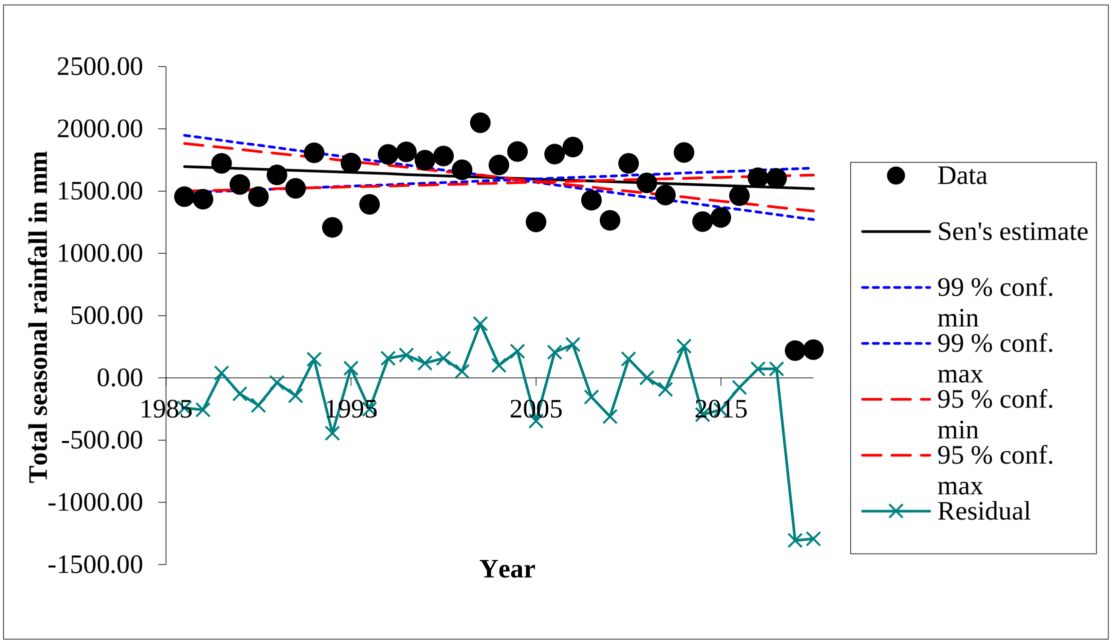

Figure 4.9 Trend of total seasonal rainfall during summer in Mizoram, 1986-2020

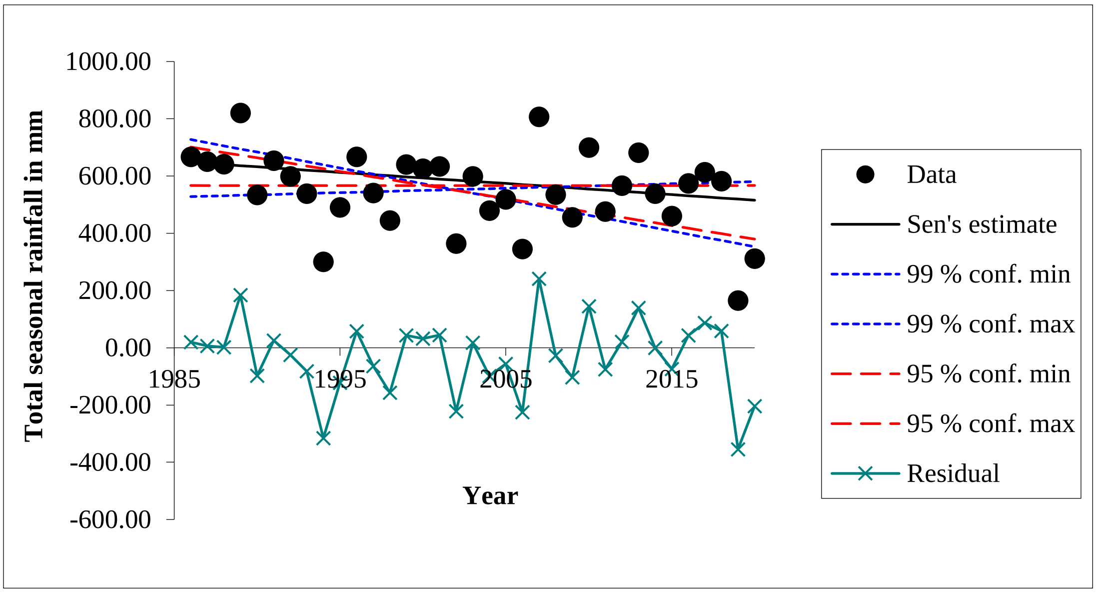

Figure 4.10 Trend of total seasonal rainfall during autumn in Mizoram, 1986-2020

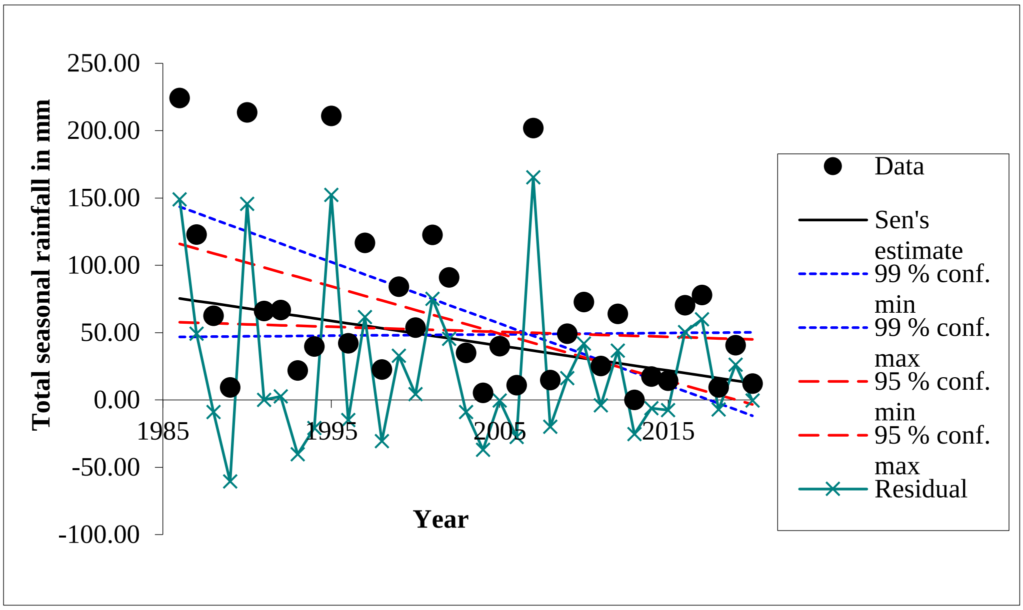

Figure 4.11 Trend of total seasonal rainfall during winter in Mizoram, 1986-2020

4.4 Trend analysis of annual and seasonal maximum and minimum temperature

The analysis of secondary data on temperature with the statistical tool of Mann-Kendall and Sen's slope reveals a substantial variation of monotonic trend in both the minimum and maximum temperature. Similar with the rainfall analysis the temperature trend analysis has also been divided into monthly, seasonal and annual as well. In Table 4.8 the maximum temperature shows a positive trend of Z value with an alarming rate of significantly increase of maximum temperature in all the categories. The month of January shows statistically very strong significance (p<0.001) of positive trend during the entire study period followed by February, November and December with a high statistically significant (p<0.01) of positive trend, the months of March, July and October shows a statistically significant (p<0.05) of positive trend in maximum temperature respectively and the annual average temperature for the past 35 years shows a strong statistical significance (p<0.01) of positive temperature trend (Table 4.8). In Figure 4.12, it can be observed that the trend line depicts a positive incline of slope and a monotonic trend line showing an increasing trend from the year 2015 with an abrupt drop in 2019.

The seasonal maximum temperature trend results reveal a similar outcome of observation with a positive temperature trend in all the seasons in which the month of Winter observes the highest positive trend of Z value and a very strong significant value (p<0.001) followed by the Summer with a significantly (p<0.05) positive trend of maximum temperature during the study period (Table 4.8).

Table 4.8 Mann-Kendall and Sen's Slope statistics of maximum temperature in Mizoram, 1986-2020

Time series	Test Z	Q	B	Signific.
Jan	3.297	0.096	21.663	***
Feb	3.282	0.120	23.300	**
Mar	2.104	0.071	27.092	*
Apr	1.778	0.047	28.100	+
May	1.039	0.025	27.750	
Jun	0.712	0.011	27.222	
Jul	2.476	0.045	26.282	*
Aug	1.872	0.040	26.860	+
Sep	1.679	0.030	27.050	+
Oct	2.177	0.043	26.671	*
Nov	3.004	0.060	25.240	**
Dec	2.958	0.064	22.564	**
Spring	3.253	0.082	26.433	**
Summer	1.975	0.028	27.060	*
Autumn	1.606	0.031	26.919	
Winter	4.204	0.085	22.782	***
Annual average temperature	3.139	0.051	25.712	**

(Note: + ,*,**,*** indicate significant at 0.1, 0.05, 0.01, 0.001 level of significance respectively)

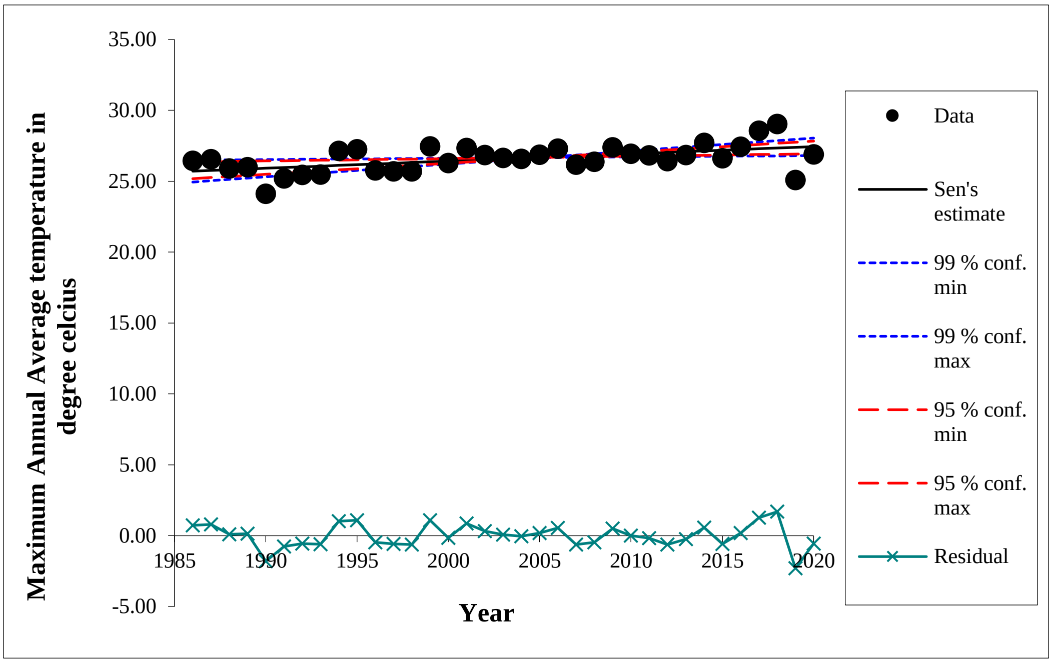

Figure 4.12 Trend of maximum annual average temperature in Mizoram, 1986-2020

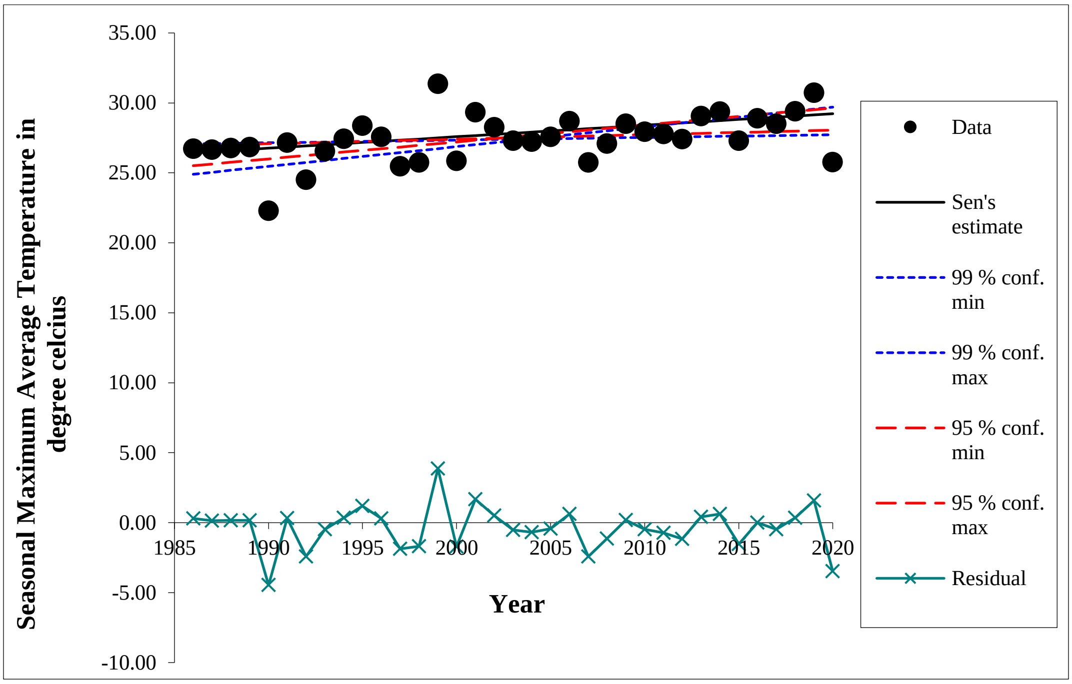

Figure 4.13 Trend of seasonal maximum average temperature during spring in Mizoram, 1986-2020

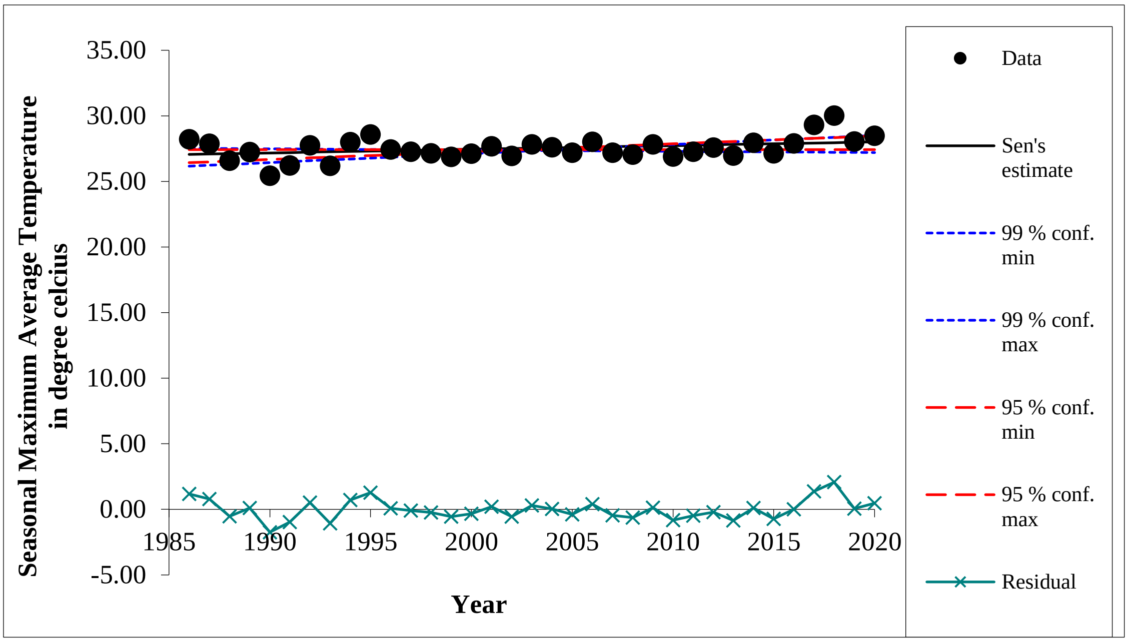

Figure 4.14 Trend of seasonal maximum average temperature during summer in Mizoram, 1986-2020

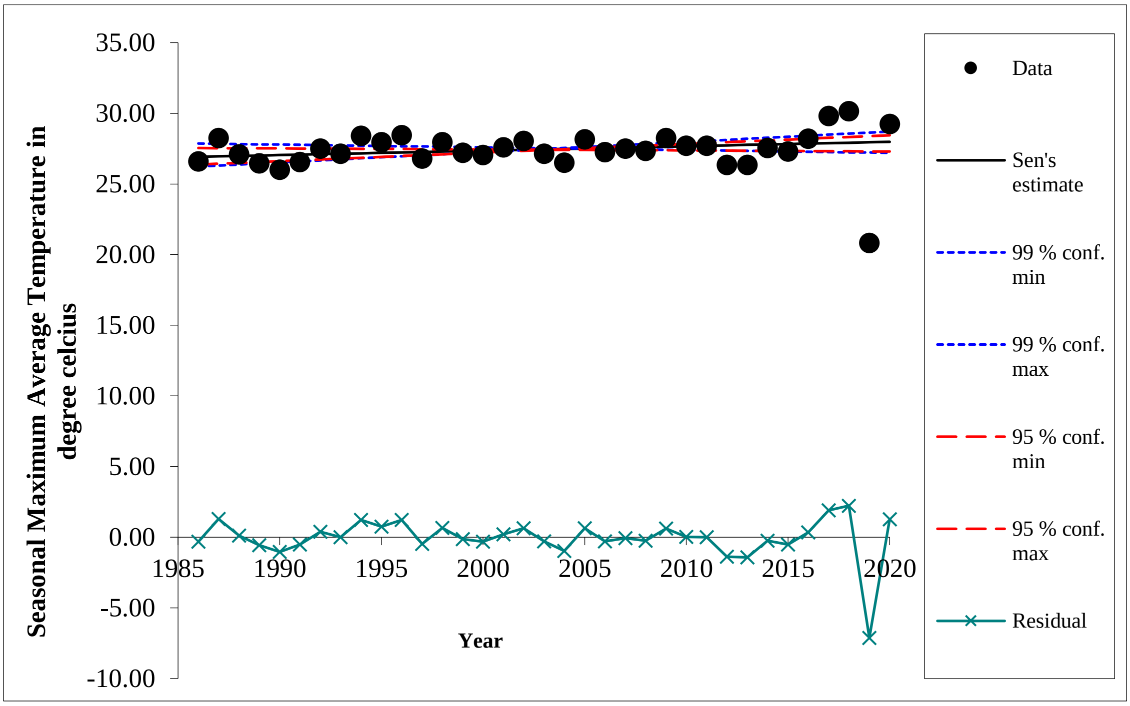

Figure 4.15 Trend of seasonal maximum average temperature during autumn in Mizoram, 1986-2020

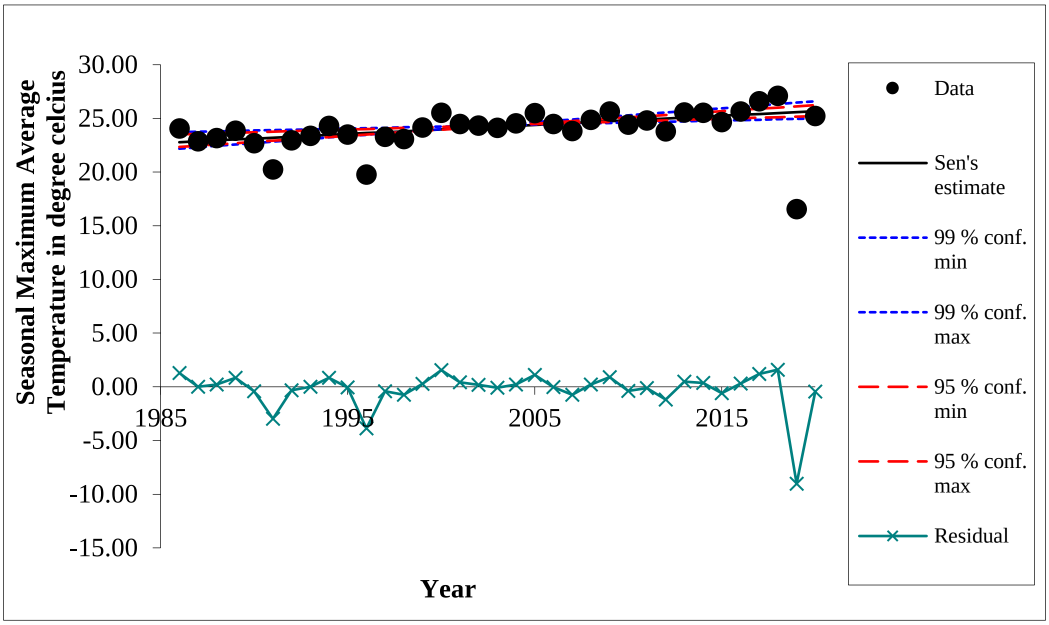

Figure 4.16 Trend of seasonal maximum average temperature during winter in Mizoram, 1986-2020

The minimum temperature trend analysis shows a negative trend results of Z value throughout the study period. From the analysis result in the Table 4.9 it can be observed that the months of November and December records the highest negative trend in all the months during the 35 years span with a significant result of $p<0.05$ and strongly significant result of $p<0.01$ of decline in the minimum temperature in the mentioned months respectively. Figure 4.16 represents the annual average minimum temperature revealing the high variation of monotonic pattern of minimum temperature with a declining Sen's slope estimator line indicating a constant decreased in the minimum temperature during the study period.

The seasonal minimum temperature trend analysis also shows a negative trend of Z values in all the seasons (Table 4.9), indicating the Winter season with a significantly highest negative trend ($p<0.05$) of seasonal average minimum temperature followed by Spring season with a Z value of -1.59.

Table 4.9 Mann-Kendall and Sen's Slope statistics of minimum temperature in Mizoram, 1986-2020

Time series	Test Z	Q	B	Signific.
Jan	-0.505	-0.013	11.450	
Feb	-1.620	-0.061	14.387	
Mar	-1.948	-0.069	17.575	+
Apr	-1.307	-0.044	18.133	
May	-1.905	-0.083	20.067	+
Jun	-1.280	-0.038	20.600	
Jul	-0.967	-0.022	20.309	
Aug	-0.891	-0.031	20.462	
Sep	-1.552	-0.034	20.374	
Oct	-0.726	-0.020	19.020	
Nov	-2.488	-0.090	17.762	*
Dec	-3.001	-0.085	14.390	**
Spring	-1.591	-0.046	16.804	
Summer	-1.165	-0.033	20.241	
Autumn	-0.625	-0.020	19.630	
Winter	-2.443	-0.067	14.567	*
Annual Average Temperature	-1.647	-0.031	17.863	+

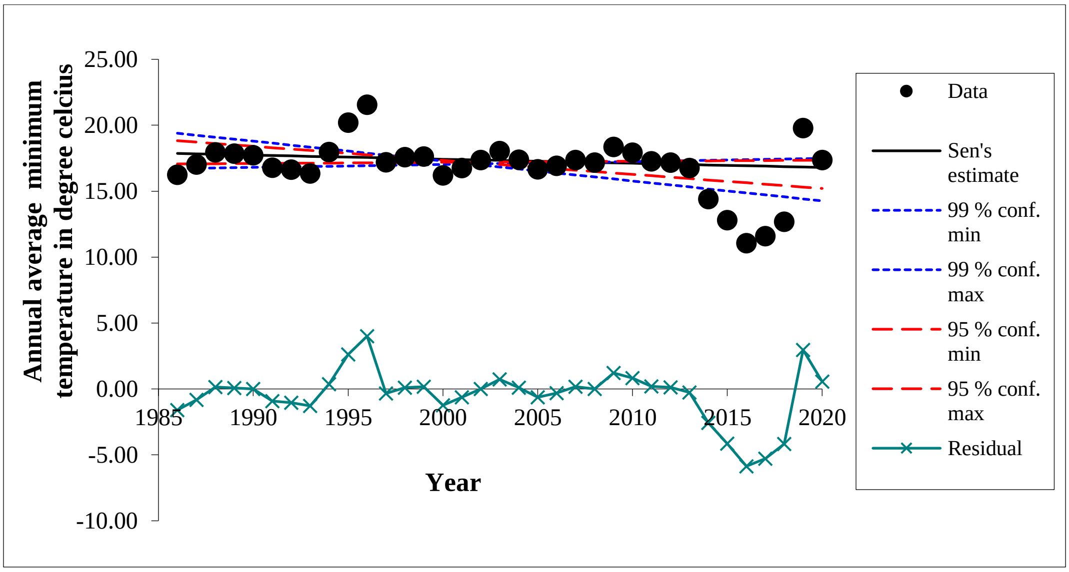

Figure 4.17 Trend of annual average minimum temperature in Mizoram, 1986-2020

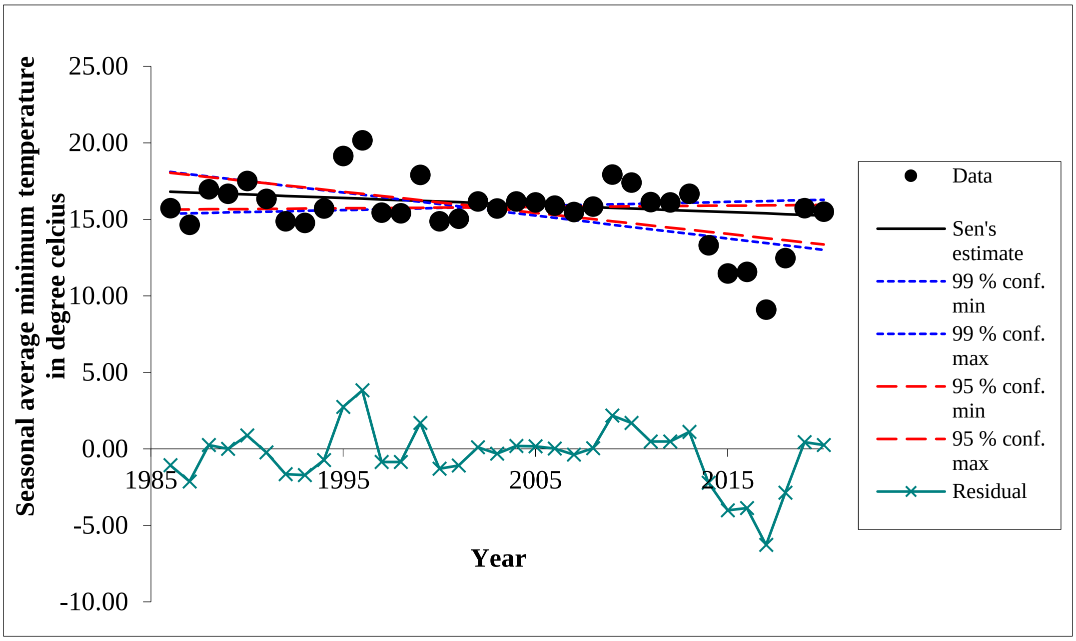

Figure 4.18 Trend of seasonal average minimum temperature in spring in Mizoram, 1986-2020

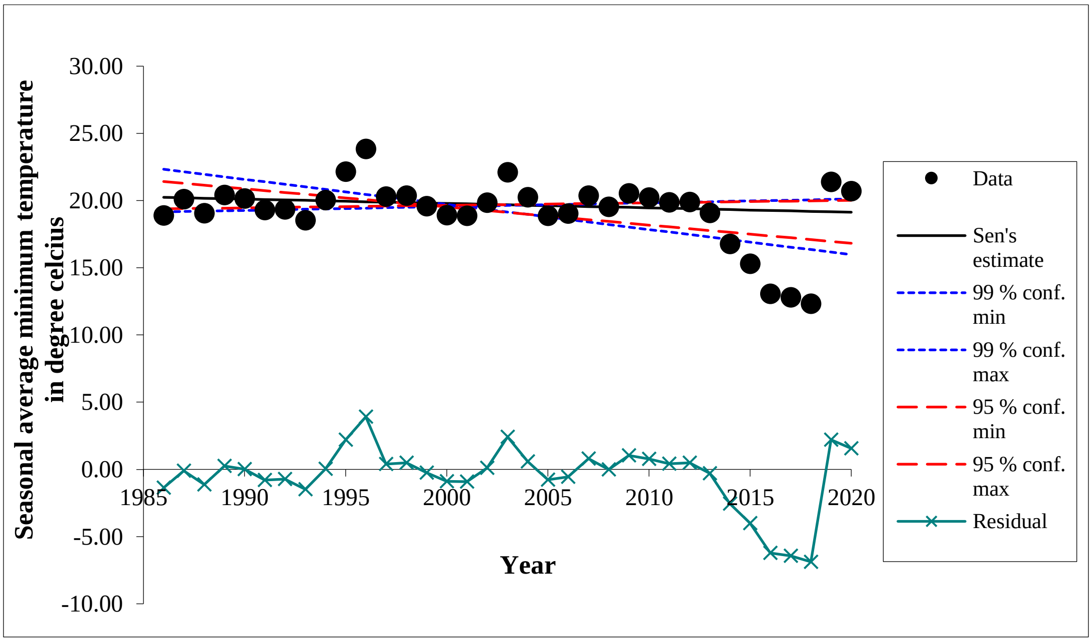

Figure 4.19 Trend of seasonal average minimum temperature in summer in Mizoram, 1986-2020

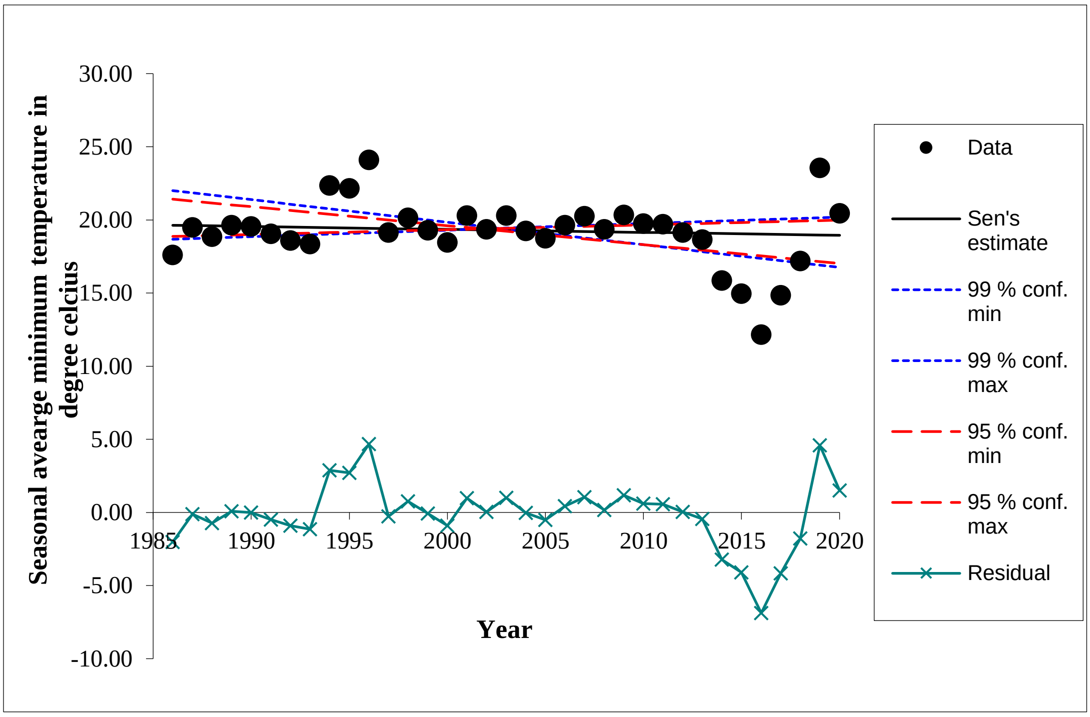

Figure 4.20 Trend of seasonal average minimum temperature in autumn in Mizoram, 1986-2020

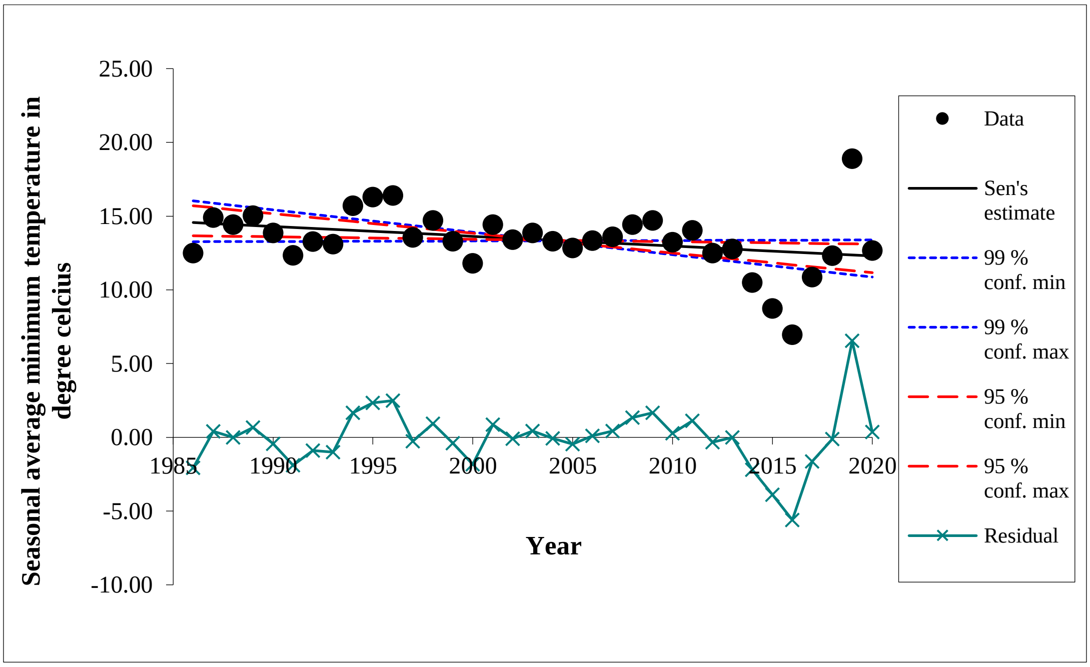

Figure 4.21 Trend of seasonal average minimum temperature in winter in Mizoram, 1986-2020

4.5 Traditional Ecological Knowledge and its relation with Climate Change

Traditional ecological knowledge refers to knowledge, innovation and practices of indigenous and local communities embodying traditional lifestyle. Traditional ecological knowledge an integral part of indigenous knowledge that can be recognized as "a cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings with one another and with their environment" (Berkes, 1999). Indigenous knowledge was acknowledged in the fourth assessment report of the Intergovernmental Panel on Climate Change as a reliable method of studying climate change and variability and as a crucial basis for developing adaptation and natural resource management strategies in response to environmental and other forms of change" (IPCC 2007).

Based on traditional knowledge of weather patterns and climatic conditions, indigenous peoples in many parts of the world are increasingly reporting that weather and climate are changing. Such observations have been recorded for indigenous peoples around the world, for example, in the Arctic, Africa, Asia and North America (Krupnik and Jolly, 2002; Eicken, et. al., 2014; Frankel, 2011).

4.5.1 Traditional Ecological Knowledge practiced by the indigenous tribe of Mizoram

The study is based solely on information collected from the primary source in all districts of Mizoram by conducting schedule interviews and group discussions with village elders who have experienced years of indigenous knowledge and understanding of the general change which have occurred in the natural ecological environment. Even yet, gathering data was laborious since native people were reluctant to share the indigenous wisdom they have been passing down from their predecessors. The interviews with Traditional Knowledge Holders resulted in the identification of 28 bio-indicators (Table 4.10) that are relevant to weather forecasting, which was then documented. It has been discovered that the indicators, which focus on distinguishing characteristics of birds, insects and plants in relation to weather, drought, and natural disasters, are often reliable.

The study also observed that these living things can predict the upcoming weather condition through keen observation and in-depth environmental knowledge, thus the bio-indicators are carefully selected. Weather/climate bio-indicators are mostly based on the identification of particular circumstances as judged by the behaviour of insects, birds, animals and plant species.

Table 4.10 List of Bio-indicators used for forecasting of weather/climate by indigenous people in Mizoram.

Mizo name	**Common Name**	**Scientific name**	**Behaviour**	**Weather Prediction**
Bil thei	Bursera Serrata	*Bursera Serrata*	Blooming of flowers	Monsoon
Buarpui par	Ash Colored Heabane	*Veronica*	Blooming of flowers	Monsoon
Chakai	Common crab	*Brachyura*	Increase in number	Autumn Season
Changkak	Bronzed Drongo	*Dicrurus aeneus*	Migration	Summer Season
Chawn-pui	Thlado tree	*Lagerstroemia Speciosa*	Blooming of flowers	Autumn Season
Chhawhchhi	White durra	*Sorghum Cernium*	Blooming of flowers	Winter season
Chhawlhring	Orange-Bellied leaf bird	*Chrloropsis hardwickii*	Increase in number	Winter season
Fanghmir	Ants	*Formicidae*	Building of nest	Monsoon
Far tuah	Pickly Coral Trees	*Erythrina Stricta*	Blooming of flowers	Summer Season
Herh-ŝe	Indian Rose Chestnut	*Mesua Ferrece*	Blooming of flowers	Summer Season
Kawrthindeng	Elephant apple tree	*Dillenia Indica*	Blooming of flowers	Monsoon
Khiang kung	Chilaune Tree	*Schima Wallichii*	Sprouting of new leaves	Summer Season
Khiangzik	Needle wood	*Schima Wallichii*	Sprouting of new leaves	Summer Season
Mau tuai	Bamboo Shoots	*Phyllostachys Edullis*	Sprouting	Summer Season
Perhpawng	Field Cricket	*Gryllinae*	Singing season	Autumn Season
phivawk	The Indian badder	*Sus scrofa cristastus*	Gathering of Insects and food	Winter season
Phunchawng	Bombacaceae	*Bomban Ceiba*	Blooming of flowers	Summer Season

Sakuh	Porcupine	*Erethizontidae*	Insearch of insects and food	Autumn Season
Sesaw	Jolcham oak	*Quercus Serrata*	Shedding of leave	Autumn Season
Theihai	Mango	*Mamea Suriga*	Blooming of flowers	Monsoon
Thereng	Large tree cricket	*Oecanthus fultoni*	Singing season	Autumn Season
Thingsen	Hallong	*Dipterocarpus*	Blooming of flowers	Winter season
Tlaizawng	Cherry	*Prunus Corasoidas*	Blooming of flowers	Winter season
Tlangsam	Chromolaena (Siam weeds)	*Chromolaena Odorata*	Blooming of flowers	Winter season
Vaiva	Collared Myna	*Streptopelia*	Gathering of Insects and food	Autumn Season
Vamur	House Swift	*Apus nipalensis*	Gathering of Insects and food	Summer Season
Varul	Oriental Darter	*Anhinga melanogaster*	Gathering of Insects and food	Autumn Season
Vathu	Oriental Turtle Dove	*Streptopelia oreintalis*	Increase in number	Summer Season

Source: *Author, field survey*

According to the survey, it has been observed that several of the aforementioned bio-indicators have lately modified their behavioural traits in reaction to the changing natural environment, which suggests a general change in the climatic pattern. Table 4.11 shows the ecological behaviour change on plants and insects.

Table 4.11 Ecological behavioural change

Behavioural change of insects/birds/animals	**Respondent's observation in %**
Respondents who believe cicada (large tree cricket) has changed its season of singing	72.3
Respondents who believe there is an increase in number of Ants	8.5
Respondents who believe there has been a change in the behaviour of birds/blooming of tree flowers like *Herhse*,	19.1

Source: *Field survey*

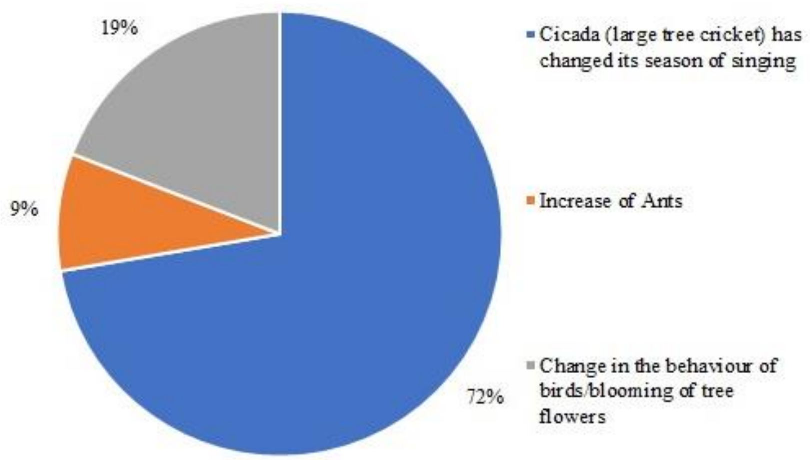

Figure 4.22 Ecological behavioural change

4.5.2 Dependence on Traditional Ecological Knowledge

According to the survey, where majority of the respondents belongs to the rural region of the state it has been observed that a sizable portion of respondents with 61 per cent of the total respondents (Table 4.11) remain heavily dependent on the conventional method of predicting the weather, that is, by observing plant and animal behaviour while only 39% of respondents do not rely on the conventional method.

Table 4.12 Respondent's dependence on plants and animals to predict weather

Category	Reliance on Plants and animals to predicts weather in %
Yes	38.5
No	61.5

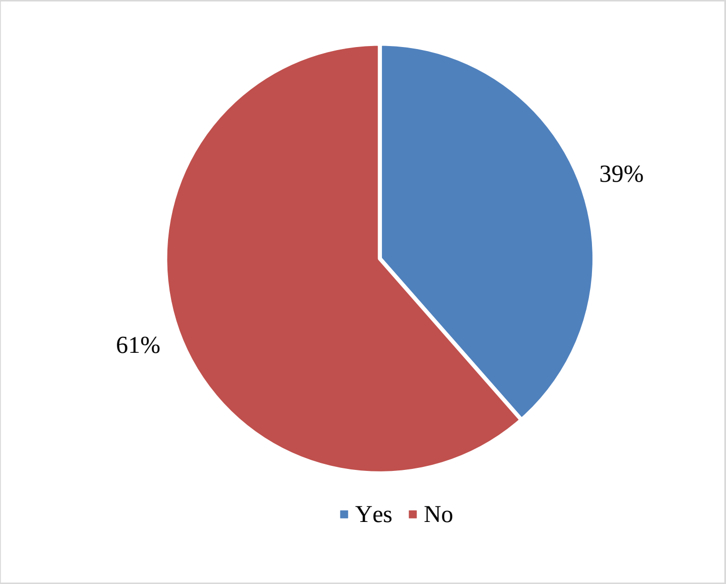

Figure 4.22 No. of respondents relying on plants and animals for predicting weather

4.6 Conclusion

The findings in this chapter can be broadly divided into three parts. The first part deals with the analysis of coefficient of variation of temperature and rainfall (monthly, annual and seasonal), the second part deals with the time series trend analysis of temperature and rainfall (monthly, annual and seasonal) for the period of 35 years (1986-2020) respectively, with the help of Mann-Kendall and Sen's slope method and the third part examines the relation between the Traditional Ecological Knowledge of the indigenous tribes of Mizoram with the changing climate.

The findings reveals that there has been a significant change on the climatic pattern in Mizoram in the last 35 years (1986-2020). The results of coefficient of variation shows high variation of rainfall in monthly, seasonal and annual categories during the study period. Similarly, the temperature variation analysis also reveals a high fluctuation of maximum temperature in the monthly, seasonal and annual categories while the minimum temperature shows a monotonic moderate and low variation in all year groups.

On the other hand, the trend analysis of climate parameters shows a complex structure of trend results of temperature and rainfall. It is observed that during the study period, the rainfall trend result shows a continuous declining trend of rainfall in monthly, yearly and seasonal terms. Additionally, the total yearly precipitation for 35 years shows a significantly downward trend ($p<0.05$) with a Sen's slope of -12.53. However, the maximum temperature showed a significantly positive trend ($p<0.01$) in monthly, annual and seasonal. While the minimum temperature shows a significantly negative trend on yearly and seasonal terms.

Traditional Ecological Knowledge an indigenous Knowledge based technique was employed to investigate the changing pattern of the climate system and the dependency of indigenous tribals on plants, insects and animals for weather prediction, the information was collected with the help of interview method. In the study it was observed that the indigenous tribal communities in Mizoram rely on 28 bio-indicators for prediction of weather systems and 38% of the total respondents still rely on these bio-indicators. The results also reveals that some of these bio-indicators have changed its natural traits and behaviours due to the changing climate pattern.

CHAPTER 5

SPATIAL PATTERN OF CLIMATE VULNERABILITY IN MIZORAM

5.1 Introduction

This chapter examines how communities in our study area are assessing their susceptibility to climate variability and change, and recognizing the connections to their livelihoods. Our investigation is focused on examining the variables that determine how differently a district will respond to climatic occurrences and how well it will be able to adapt to shifting climatic conditions. We examined the susceptibility of villages and their pattern of livelihood while also using an indicator-based framework to analyse the factors that make communities vulnerable to climate change.

5.2 Vulnerability assessment

The study is focused on examining the variables that determine how differently a district will respond to climatic occurrences and how well it will be able to adapt to shifting climatic conditions. We examined the susceptibility of villages and their pattern of livelihood while also using an indicator-based framework to analyse the factors that make communities vulnerable to climate change.

5.2.1 Climate Vulnerability Index (CVI)

In this study, we used a Climate Vulnerability Index (CVI) to examine the differential vulnerability at district level. The three contributing variables to vulnerability in our CVI are exposure, sensitivity, and adaptive capability (McCarthy et al. 2001). This CVI is based on the IPCC vulnerability framework. Each element in our framework has a number of sub-elements, some of which are based on a review of the literature, while others are indicators particular to locations that are prone to climate change and are based on the district observed adaptive behaviours. The CVI index is built using primary and secondary data from the household survey. Figure 5.1 below displays the index's main constituents.

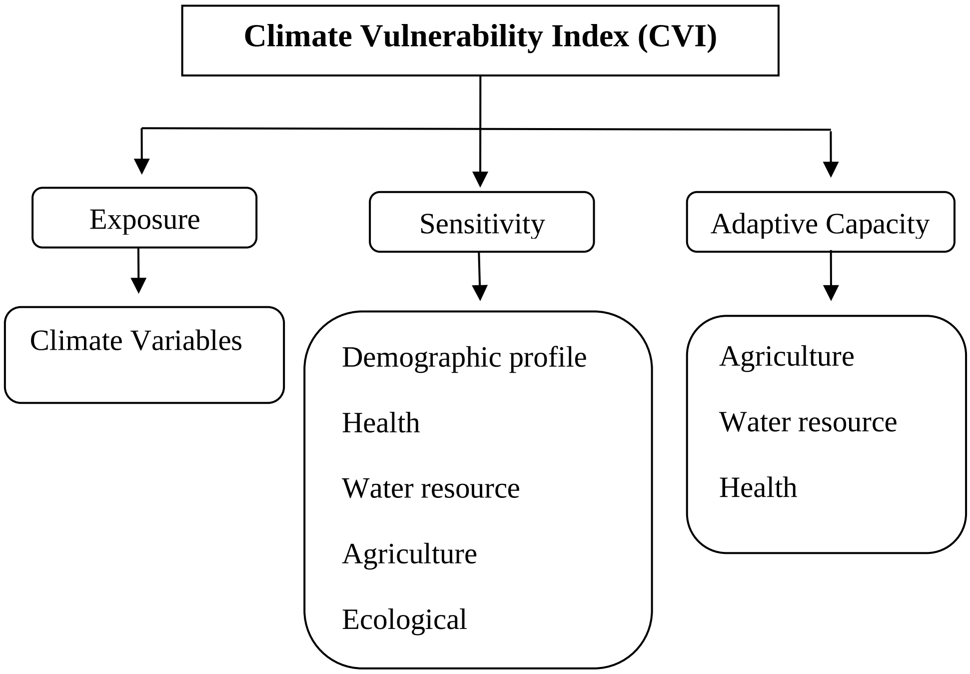

Figure 5.1 Vulnerability Assessment Framework

The quantification of each component using both primary and secondary data is explained in Table 4.1 below. As was already noted, vulnerability is typically assessed by calculating an overall vulnerability index, which is then used to evaluate various communities and districts according to their relative vulnerability. The IPCC vulnerability framework is incorporated into the CVI that we have created; Table 4.1 depicts the arrangement of the three key parts of the CVI framework. The respondents' impressions of temperature changes, rainfall variations, and the frequency of climate-related disaster occurrences they have personally experienced are utilised to gauge the exposure in the study's variables. We used indicators based on people's perceptions to illustrate sensitivity at the household level due to the inadequate data on climate change at the village level.

Table 5.1 Major Indicators for the Climate Vulnerability Index (CVI) Construction Description.

Major Components	Sub components	Indicator Code	Indicators
Exposure	Climate variables	X_1	Percentage of household believing that there is change in the amount and pattern in the rainfall in sometime of the year
		X_2	Percentage of household believing that there is change in the general weather pattern
		X_3	Percentage of household who believe there is new climate event/phenomenon experience
Sensitivity	Demographic profile	X_4	Percentage of female population in the total household
		X_5	Percentage of elderly population in the total household (above 60)
	Health	X_6	Percentage of family's health affected by change in climate/weather
		X_7	Percentage in increase in disease hazards due to climate change
		X_8	Percentage of family vulnerable to disease due to climate change
		X_9	Percentage of satisfaction on health care facilities in the area/village
		X_{10}	Percentage of death to disease and malnutrition due to change in climate and weather
	Water resource	X_{11}	Percentage of increase in difficulty in accessing water comparing to the past
		X_{12}	Percentage of decrease in water quality and disappearing of spring water from its source

		X_{13}	Percentage of groundwater, spring water, streams as an important source of water for domestic purpose
		X_{14}	Percentage of demand of water to be higher in future than present scenario
		X_{15}	Percentage of effect in the availability of water due to change in annual precipitation
		X_{16}	Percentage of adequate supply of water by PHE department for daily sustenance
		X_{17}	Percentage of groundwater deterioration as compared to the past
		X_{18}	Percentage of decreasing of spring water
		X_{19}	Percentage of spring water importance for family's daily need as a source of domestic water
	Agriculture	X_{20}	Percentage of experiencing invasion of pest in agricultural field
		X_{21}	Percentage of increase in the use of pesticides comparing with previous years
		X_{22}	Percentage of receiving adequate amount of rainfall for crops
		X_{23}	Percentage of temperature effects on the growth and productivity of crops
	Ecological	X_{24}	Percentage of invasion of new birds/insects/animals which have never been seen before
		X_{25}	Percentage of decrease in insect population
		X_{26}	Percentage of change in the arrival of monsoon season

		X_{27}	Percentage of effect of late arrival of monsoon on the community and personal
		X_{28}	Percentage of change in the summer temperature and rainfall
		X_{29}	Percentage of experience in any change in the duration of seasons
		X_{30}	Percentage of long periods of dry or hot summer weather affecting the community more the past
		X_{31}	Percentage of climate change effects in personal occupation
Adaptive Capacity	Agriculture	X_{32}	Percentage of preventive measures to stop forest fire due to jhum cultivation
		X_{33}	Percentage of tree plantation
		X_{34}	Percentage of providing better fertilizer to save soil condition
		X_{35}	Percentage of shifting cultivation to areca nut plantation
		X_{36}	Percentage of shifting cultivation to dragon fruit plantation
		X_{37}	Percentage of shifting cultivation to poultry
	Water resource	X_{38}	Percentage of rainwater harvesting
		X_{39}	Percentage of arranging proper storage of water for future purpose
		X_{40}	Percentage of conservation and cleanliness of spring water source
		X_{41}	Percentage of monitoring deforestation. Specially: False Hemp tree (*Tetrameles nudiflora*) and Lampati (*Duabanga grandiflora*)

	Health	X_{42}	Percentage of maintaining cleanliness during rainy season to protect from water borne diseases and insect bites
		X_{43}	Percentage of plantation of trees in house surroundings to regulate temperature
		X_{44}	Percentage of protecting one self from extreme heat

Table 5.2 District-wise Indexed sub-component values

Major Components	Sub-component Indicator Code	Aizawl	Champhai	Kolasib	Lawngtlai	Lunglei	Mamit	Serchhip	Siaha
Exposure	X_1	0.88	0.87	0.93	0.95	0.92	0.81	0.92	0.87
	X_2	0.94	0.89	0.91	0.96	0.97	0.89	0.74	0.91
	X_3	0.58	0.78	0.58	0.77	0.80	0.79	0.78	0.70
Sensitivity	X_4	0.39	0.52	0.40	0.21	0.40	0.44	0.34	0.39
	X_5	0.11	0.19	0.16	0.10	0.16	0.18	0.17	0.12
	X_6	0.70	0.31	0.55	0.97	0.52	0.48	0.51	0.70
	X_7	0.69	0.48	0.52	0.94	0.55	0.47	0.63	0.53
	X_8	0.64	0.31	0.51	0.96	0.48	0.49	0.47	0.64
	X_9	0.42	0.56	0.74	0.18	0.82	0.51	0.63	0.56
	X_{10}	0.56	0.36	0.39	0.95	0.34	0.41	0.41	0.55
	X_{11}	0.89	0.80	0.69	0.99	0.80	0.77	0.78	0.83
	X_{12}	0.85	0.79	0.79	0.97	0.80	0.75	0.82	0.80
	X_{13}	0.82	0.67	0.83	0.95	0.84	0.76	0.84	0.82
	X_{14}	0.95	0.91	0.97	0.97	0.99	0.96	0.95	0.93
	X_{15}	0.89	0.78	0.96	0.95	0.97	0.90	0.95	0.93
	X_{16}	0.83	0.77	0.94	0.83	0.93	0.87	0.88	0.81
	X_{17}	0.78	0.70	0.79	0.97	0.85	0.55	0.78	0.55
	X_{18}	0.83	0.75	0.85	0.97	0.87	0.80	0.84	0.87
	X_{19}	0.79	0.64	0.75	0.97	0.74	0.62	0.80	0.63
	X_{20}	0.44	0.43	0.39	0.57	0.55	0.28	0.42	0.38
	X_{21}	0.63	0.53	0.49	0.65	0.63	0.39	0.55	0.44
	X_{22}	0.50	0.33	0.75	0.44	0.64	0.51	0.59	0.62

	X_{23}	0.76	0.70	0.74	0.82	0.85	0.72	0.80	0.77
	X_{24}	0.42	0.54	0.23	0.70	0.30	0.17	0.76	0.62
	X_{25}	0.71	0.70	0.74	0.92	0.76	0.88	0.92	0.66
	X_{26}	0.87	0.82	0.90	0.95	0.91	0.62	0.92	0.85
	X_{27}	0.78	0.73	0.66	0.94	0.77	0.76	0.75	0.74
	X_{28}	0.78	0.70	0.83	0.98	0.90	0.84	0.79	0.87
		0.84	0.81	0.85	0.97	0.85	0.63	0.86	0.83
	X_{29}	0.77	0.69	0.66	0.97	0.77	0.61	0.75	0.74
	X_{30}	0.70	0.60	0.67	0.98	0.71	0.91	0.68	0.69
Adaptive Capacity	X_{31}	0.15	0.13	0.08	0.38	0.13	0.12	0.08	0.13
	X_{32}	0.08	0.05	0.05	0.06	0.08	0.07	0.02	0.07
	X_{33}	0.04	0.03	0.04	0.03	0.02	0.03	0.01	0.03
	X_{34}	0.02	0.04	0.27	0.04	0.04	0.18	0.01	0.03
	X_{35}	0.01	0.05	0.07	0.03	0.03	0.02	0.03	0.04
	X_{36}	0.19	0.03	0.12	0.07	0.13	0.08	0.06	0.10
	X_{37}	0.15	0.22	0.15	0.15	0.30	0.17	0.09	0.26
	X_{38}	0.08	0.10	0.05	0.06	0.06	0.05	0.03	0.13
	X_{39}	0.09	0.05	0.08	0.15	0.08	0.10	0.03	0.09
	X_{40}	0.05	0.06	0.13	0.21	0.17	0.11	0.04	0.08
	X_{41}	0.15	0.14	0.09	0.19	0.20	0.25	0.08	0.24
	X_{42}	0.09	0.04	0.10	0.06	0.05	0.05	0.05	0.11
	X_{43}	0.15	0.08	0.05	0.07	0.03	0.08	0.02	0.05

Source: Author's calculation

Table 5.3: Major component values and CVI values for all districts

Major Components	Aizawl	Champhai	Kolasib	Lawngtlai	Lunglei	Mamit	Serchhip	Siaha
Exposure	0.799	0.846	0.808	0.892	0.895	0.830	0.813	0.823
Sensitivity	1.333	1.181	1.291	1.569	1.357	1.189	1.352	1.299
Adaptive Capacity	0.097	0.079	0.099	0.116	0.101	0.100	0.042	0.105
CVI	0.20	0.20	0.18	0.22	0.21	0.18	0.19	0.21

Source: Author's calculation

5.2.2 Results

Tables 5.2 and 5.3 present the findings of the four communities' data analysis. Table 5.3 displays the key components and the composite CVI for each village. Table 5.2 lists the sub component values of the CVI separately for each district as well as the lowest and maximum values for each district taken together. The outcomes are broken down into three categories: exposure, sensitivity, and vulnerability. The susceptibility of specific farm units to climate impacts will differ significantly within regions with similar exposure to climate risks, as will agricultural producers' capacity to adjust in relation to a wide range of socioeconomic, institutional, and psychological factors (Easterling, 1996; Brklachich et al., 1997).

5.2.3 Exposure

In the case of exposure, it can be observed from the Table 5.3, the districts of Lawngtlai and Lunglei has the highest overall exposure index with 0.895 and 0.892 each respectively and the districts of Aizawl shows the lowest exposure with index score of 0.799. If we examine the various exposure index sub-components, it can be observed the perception index on change in the general weather pattern and household believing the occurrence of new climate phenomenon is highest in the district of Lunglei with index score of 0.97, followed by Lawngtlai district (0.96). The districts with the lowest index score in the sub-components on change in the general weather and pattern and household believing the occurrence of new climate phenomenon are Serchhip District (0.74) and Siaha (0.70) respectively.

5.2.4 Sensitivity

The degree to which a system is altered or impacted by an internal or external disturbance or combination of disturbances is how Gallopin (2003) defines sensitivity in its broadest definition. The degree to which a group will be impacted by environmental stress is determined by this metric, which represents how sensitive a system is to climatic impacts and is moulded by both socio-economic and ecological factors. However, at the household level, exposure and sensitivity are virtually synonymous ideas (Smit and Wandel, 2006), where sensitivity reflects resource-use patterns, a livelihood's reliance on climate-sensitive activities, as well as the frequency with which households interact with specific sources of stress.

In order to determine the sensitivity to climate variability and change at the district level we selected indicator to reflect climate sensitivity through Demographic profile, Health, Water resource, Agriculture, Ecological change in which these variables are important in influencing their response to climate stress.

The Table 5.3 shows the sensitivity index in which the district of Lawngtlai has the highest sensitivity to climate variability and change, followed by Lunglei and Serchhip districts. Further analysis shows what distinguished the highly sensitive district of Lawngtlai from other districts are high index values on effects of climate change/weather on the family's health, difficulties in accessing water compared to the past, the deterioration in water quality, disappearing of spring water from its source and demand of water to be higher in future than present scenario. As the economy of the state depending on agriculture it can be noted that the household depending on agriculture in Lawngtlai district have shown a high disagreement on the availability of adequate amount of rainfall for crops (0.44 index score) as compared to household to other districts.

It is observed from our field study that the rural and remote population of Lawngtlai district are prominently indulge in the primary sector viz. crop cultivation and animal herding which are directly influence by climate variability and change.

5.2.5 Adaptive Capacity

Every district's household surveyed has positively responded in taking a variety of adaptation measures, including: preventive measures to stop forest fire due to jhum cultivation, changing farming activity from shifting cultivation to areca nut cultivation and other activities, conservation and cleaning of spring water source, harvesting rainwater, maintenance of cleanliness during rainy season to protect from water borne diseases and insect bites and others. Of the total household surveyed, 38.43% of household in Lawngtlai district reported of taking preventive measures to stop forest fire due to jhum cultivation with the value of highest index score of 0.38, Lunglei and

Aizawl districts reports the highest index score of 0.8 each in opting for tree plantation. Whereas, changing of agricultural practice from shifting cultivation to other practices, Kolasib district have reported the highest percentage of 27.4% shift to areca nut plantation (0.27) and with 19.3% of household in Aizawl district reports the highest change into animal husbandry from shifting cultivation with the index score of 0.19.

In the sub-component of water resource, Siaha districts shows the highest index score of 0.26 and 0.13 in the rainwater harvesting and arranging proper storage of water for future purpose respectively, followed by Champhai district with index score of 0.22 in water harvesting and 0.10 index score in arranging proper storage of water for future purpose which are main stored for domestic purpose as well as irrigational purpose in agricultural field during dry seasons. Whereas, in the health sector, the study shows Mamit district the highest percentage of 25.2% (0.25 index score) of household survey reporting maintenance of cleanliness during rainy season to protect from water borne diseases and insects bites. In order to cope with the increase extreme temperature Siaha districts shows the highest index score of 0.11 adaptive strategy by practicing plantation of trees in house surroundings to regulate temperature, while Aizawl district stands the highest in protecting one-self from extreme heat with an index value of 0.15.

Using the average of all the sub-components to calculate our Climate Vulnerability Index (CVI) score, the most vulnerable district to climate variability and change is Lawngtlai with an index score of 0.22 followed by Lunglei and Siaha districts with 0.21 index score respectively. While the districts of Kolasib and Mamit shows the least vulnerable districts to the impact of climate change and variability with the minimum index score of 0.18 each. The scores of various vulnerability components of the CVI are represented by a vulnerability triangle in Figure. 5.2. As per our CVI index, it can be observed in the vulnerability diagram (Figure. 5.2), Lunglei has been highly exposed to the different components of climate change, however, Lawngtlai exhibits the most sensitivity to climate change and, unexpectedly, the strongest adaptation capability as per our CVI score.

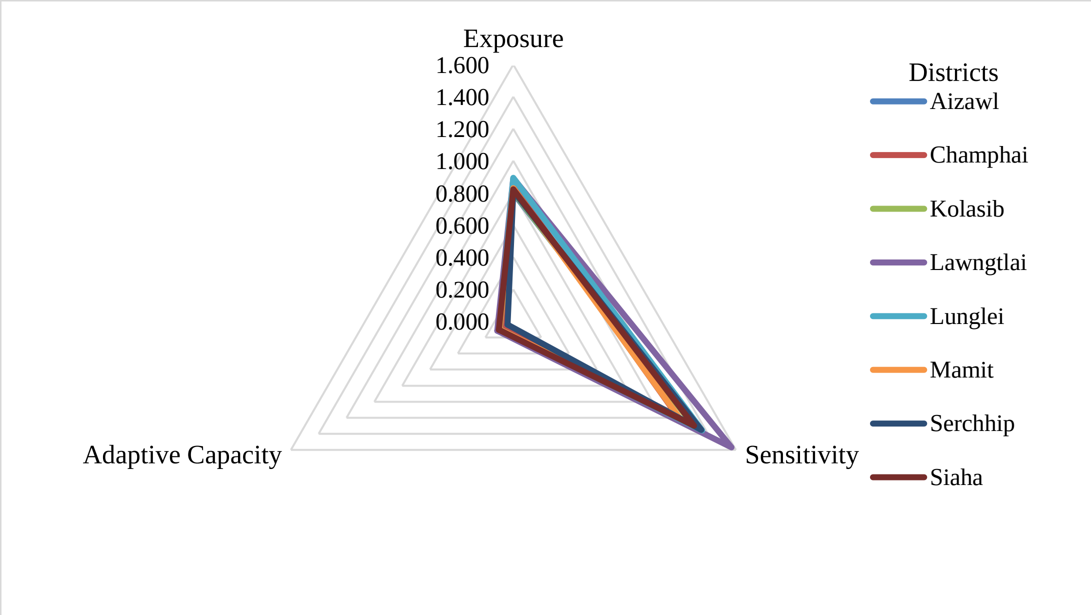

Figure. 5.2 Vulnerability triangle diagram for major components of Climate Vulnerability Index

5.3 Principal Component Analysis

Principal Component Analysis (PCA) has been employed to assess which of the vulnerability indicators accounts for the highest susceptibility to climate change. Five-point Likert scale was designed to enable respondents to choose in order of importance of their perception. To examine the applicability of the methodologies, Principal Component Analysis (PCA) employs correlation analysis, a statistical test known as the Kaiser-Meyer-Olkin (KMO) measure of sample adequacy, and Bartlett's Test of Sphericity. The heat map correlation matrix reveals that the majority of the variables were connected, with no severe multi-collinearity (Table 5.5). The KMO measure of sample adequacy was 0.875, which is acceptable for running PCA. The value of Bartlett's test of Sphericity was also significant at 0.000 level of significance (Table 5.4).

Then, using SPSS software, PCA was ran on the computer to get communalities and components. Using Kaiser's criteria of eigenvalues greater than one, three components were recovered, which explained 59.11% of the overall variance in the data set. The proportion of variance explained is sufficient to proceed with the study. Table 5.5 displays the component loadings.

Table 5.4 Kaiser-Meyer-Olkin (KMO) & Bartlett test of sphericity

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.875
	Approx. Chi-Square	18925.476
Bartlett's Test of Sphericity	Df	406
	Sig.	.000

Computed by: SPSS 20

The heat map correlation matrix of vulnerability has been computed in order to bring light to the strongest correlation and relationships between the different indicators of vulnerability to climate change and variability, the colour coding of the cells makes it easy to identify relationship between variables at a glance. In Table 5.5 the default colour gradients set indicates the different level of correlation between the variables, it can be observed the values with the green shade colour represent relatively high positive correlation, whereas the yellow and red shade of colour represents the weak correlation and high negative correlation between the variables respectively. It can be observed (Table 5.5) the variables of family vulnerable to climate change (*c*) and family's health affected by change in climate/weather (*a*) has the strongest correlation score of .786, followed by effects of climate change in personal occupation (*a3*) and effects of long dry or hot period of summer weather on community (*a2*) with the correlation score of .654. The weakest correlation between the variables is change in summer temperature and rainfall (*z*) and satisfaction on health care facilities in the area/village (*d*) with the correlation score of .002. The matrix correlation also shows majority of the variables are positively correlated with each other. On the other hand, some categories give negative values which indicates a negative correlation. The strongest negative correlation is found between satisfaction on health care facilities in the area/village (d) and family's health affected by change in climate/weather with the values of -.226. The correlation close to 0 (Zero) between several of the categories suggests that there is no linear dependency between the categories and hence no statistical relationship.

Table. 5.5 showing heat map correlation matrix of vulnerability of different indicators

		a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z	a1	a2	a3
Correlation	a	1.000	.547	.786	-.226	.475	.140	.147	.177	-.077	.032	.081	.030	.094	.135	.010	.079	.233	.052	.082	.248	.282	.037	.064	-.002	-.046	.199	-.012	.034	.097
	b		1.000	.642	-.105	.502	.239	.291	.203	-.019	.079	-.011	.239	.257	.246	.104	.157	.126	.097	.123	.210	.324	.153	.179	.109	.058	.200	.045	.145	.224
	c			1.000	-.193	.508	.161	.174	.192	-.086	.048	.045	.088	.155	.189	.027	.068	.231	.075	.095	.233	.302	.017	.062	.008	-.012	.198	-.010	.045	.129
	d				1.000	-.201	-.060	.026	-.014	.218	.261	.042	.153	.135	.041	.077	.068	.042	.105	-.008	-.118	-.058	.146	.136	.056	.091	.002	.182	.084	.095
	e					1.000	.237	.315	.203	-.067	.087	-.074	.204	.238	.171	.128	.166	.015	.089	.084	.298	.274	.130	.160	.225	.117	.215	.093	.286	.294
	f						1.000	.552	.134	.238	.256	-.097	.329	.444	.080	.105	.227	-.158	.225	.209	.124	.198	.303	.325	.286	.189	.123	.210	.313	.252
	g							1.000	.108	.207	.297	-.118	.483	.484	.049	.210	.280	-.088	.247	.212	.155	.243	.317	.312	.347	.196	.164	.222	.355	.387
	h								1.000	.302	.232	.199	.062	.303	.455	.074	.060	.028	.062	-.012	.074	.059	.050	.068	.096	-.008	.120	.035	.125	.093
	i									1.000	.437	.044	.121	.329	.082	.031	.111	-.054	.089	.117	-.129	-.054	.088	.099	.108	.117	.010	.140	.138	.108
	j										1.000	-.026	.237	.415	.159	.159	.217	-.001	.246	.168	-.025	.074	.272	.253	.235	.189	.134	.268	.298	.285
	k											1.000	-.045	-.038	.118	-.054	-.022	.124	-.034	.029	-.065	-.014	.021	.060	-.061	-.105	.039	-.018	-.066	-.090
	l												1.000	.471	.149	.249	.354	-.025	.215	.137	.090	.235	.320	.339	.333	.167	.191	.247	.331	.351
	m													1.000	.268	.167	.209	-.054	.228	.143	.078	.221	.319	.309	.299	.194	.222	.281	.360	.378
	n														1.000	.114	.106	.093	.126	-.045	.109	.129	.098	.113	.140	-.008	.142	.090	.200	.155
	o															1.000	.509	.100	.347	.100	.259	.210	.279	.231	.296	.171	.133	.192	.227	.261
	p																1.000	.014	.427	.135	.175	.209	.338	.322	.324	.196	.119	.228	.272	.303
	q																	1.000	.060	.053	.115	.075	-.098	-.123	-.217	-.173	.148	-.064	-.145	-.072
	r																		1.000	.185	.110	.214	.270	.291	.275	.222	.146	.205	.298	.314
	s																			1.000	.083	.221	.289	.323	.181	.210	.227	.313	.258	.245
	t																				1.000	.288	.127	.085	.124	.093	.231	.104	.151	.180
	u																					1.000	.342	.316	.186	.180	.184	.214	.236	.323
	v																						1.000	.598	.541	.315	.322	.474	.502	.447
	w																							1.000	.559	.385	.346	.527	.490	.420
	x																								1.000	.355	.231	.448	.641	.568
	y																									1.000	.211	.387	.392	.353
	z																										1.000	.379	.351	.303
	a1																											1.000	.508	.519
	a2																												1.000	.654
	a3																													1.000

Note: ***a***=family's health affected by change in climate/weather, ***b***=Increase in disease hazards due to climate change, ***c***=family vulnerable to diseases due to climate change, ***d***=satisfaction on health care facilities in the area/village, ***e***=death to diseases and malnutrition due to change in climate and weather, ***f***=more difficulty in accessing water comparing to the past, ***g***=decrease in water quality and disappearance of spring water from its source, ***h***=importance of groundwater, spring water, stream for domestic purpose, ***i***= demand of water to be higher in future than present scenario, ***j***=effect in the availability of water due change in annual precipitation, ***k***=adequate supply of water by PHE department for daily sustenance, ***l***= deterioration of groundwater as compared to the past, ***m***=decrease of spring water, ***n***=importance of spring water for family's daily need as a source of domestic water,

o=experiencing of invasion of pest in the agricultural field, ***p***=increase in the use of pesticides comparing with previous years, ***q***=receiving of adequate amount of rainfall for crops, ***r***=effects of temperature on the growth and productivity of crop, ***s***=change in general weather pattern, ***t***=invasion of new birds/insects/animals, ***u***=decrease of insect population, ***v***=change in the amount and pattern of rainfall, ***w***=change in the arrival of monsoon season, ***x***=effects of late arrival of monsoon on the community and personal, ***y***=experience of new climate phenomenon**,** ***z***=change in summer temperature and rainfall, ***a1***=experience in change of season duration, ***a2***=effects of long dry or hot period of summer weather on community, ***a3***=effects of climate change in personal occupation.

Table. 5.6 PCA results for indicators accounts for highest vulnerability to climate change

	Component						
Indicators	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Family's health affected by change in climate/weather	-.031	**.836**	-.001	-.026	.041	.097	.111
Increase in disease hazards due to climate change	.068	**.754**	.157	.079	.100	-.014	-.007
Family vulnerable to diseases due to climate change	-.028	**.865**	.049	-.021	.068	.103	.050
Satisfaction on health care facilities in the area/village	.143	**-.366**	.295	.075	.031	.468	-0.65
Death to diseases and malnutrition due to change in climate and weather	.187	**.679**	.042	.064	.175	-.175	-.213
More difficulty in accessing water comparing to the past	.190	.265	**.539**	.165	-.128	-.426	.033
Decrease in water quality and disappearance of spring water from its source	.223	.297	**.559**	.275	-.139	-.295	-.126
Importance of groundwater, spring water, stream for domestic purpose	.007	.181	.287	-.017	**.716**	-.029	.223
Demand of water to be higher in future than present scenario	.034	-.173	**.709**	-.055	.148	.082	.117
Effect in the availability of water due change in annual precipitation	.234	-.030	**.663**	.096	.129	.217	-.032
Adequate supply of water by PHE department for daily sustenance	-.042	-.010	-.072	-.013	.231	.058	**.803**
Deterioration of groundwater as compared to the past	.246	.140	**.427**	.286	-.012	-.121	.094
Decrease of spring water	.268	.190	**.653**	.141	.205	-.086	-.074
Importance of spring water for family's daily need as a source of domestic water	.105	.171	.092	.111	**.749**	.071	.072

Experiencing of invasion of pest in the agricultural field	.154	.013	-.013	**.776**	.103	.097	-.085
Increase in the use of pesticides comparing with previous years	.168	.055	.134	**.772**	.019	-.051	.046
Receiving of adequate amount of rainfall for crops	-.190	.272	-.047	.153	-.027	**.707**	.108
Effects of temperature on the growth and productivity of crop	.208	.035	.178	**.605**	-.018	.84	.050
Change in general weather pattern	**.390**	.175	.194	.046	-.406	.107	.345
Invasion of new birds/insects/animals	.159	.297	-.217	**.314**	.090	.078	-.227
Decrease of insect population	.297	.441	.008	**.300**	-.101	-.006	.105
Change in the amount and pattern of rainfall	**.664**	.043	.143	.291	-.051	-.089	.199
Change in the arrival of monsoon season	**.698**	.073	.155	.225	-.058	-.116	.271
Effects of late arrival of monsoon on the community and personal	**.695**	-.007	.092	.258	.155	-.287	-.052
Experience of new climate phenomenon	**.581**	-.031	.097	.069	-.097	-.046	-.130
Change in summer temperature and rainfall	**.546**	.288	-.004	-.024	.064	.299	.040
Experience in change of season duration	**.767**	-.028	.138	.049	-.029	.143	.032
Effects of long dry or hot period of summer weather on community	**.761**	.073	.164	.140	.170	-.122	-.123
Effects of climate change in personal occupation	**.689**	.168	.172	.202	.103	-.021	-.194
% of Expl. Variance	15.29	12.07	9.21	8.15	5.42	4.83	4.15
Expl. Viarance (eigen value)	4.43	3.50	2.67	2.36	1.57	1.40	1.20
Expl./Total	0.259	0.204	0.156	0.138	0.092	0.082	0.070
Total Variance	17.14						

Extraction method: Principal Component Analysis

Rotation converged in 12 iterations

Note: Expl. Var. is the variance explained by the component and Expl./Total is the explained variance divided by the total variance of the three components.

Following the estimation of component loadings, the individual indicators with the highest component loadings are aggregated into intermediate composite indicators.

There are five intermediate composites since we extracted seven components, as indicated in Table 5.5, including 29 indicators. The factor score for each indication in a component was reduced by the magnitude of its value. Thus, the Table also shows the first component as the most important component and it accounts 15.29% of the total variance. This component mainly describes the experience of climatic change and variation indicators like change in general weather pattern, change in the amount and pattern of rainfall, change in the arrival of monsoon season, effects of late arrival of monsoon on the community and personal, experience of new climate phenomenon, change in summer temperature and rainfall, experience in change of season duration, effects of long dry or hot period of summer weather on community, effects of climate change in personal occupation. Therefore, this component can be labelled as ‘climate change and variability’ component.

The second component accounts for 12.07% of the total variance, and the component signifies the relation between change in climate and its effects on human health indicator like family’s health affected by change in climate/weather, increase in disease hazards due to climate change, family vulnerability to diseases due to climate change, satisfaction on health care facilities in the area/village, death due to disease and malnutrition due to change in climate and weather, further this component can be categorised as ‘climate change and Health’.

The third component accounts for 9.21% of the total variance and the component shows the association between climate change and availability as well as quality of water indicators which includes more difficulty in accessing water quality, decrease in water quality and disappearance of spring water from source, demand of water to be higher in future than present scenario, effect in the availability of water due to change in annual precipitation, deterioration of ground water as compared to the past, decrease in spring water. Hence, this component can be classified as ‘climate change and water resource’.

The fourth component accounts for 8.15% of the total variance, this component shows the effect of climate change on agriculture productivity and growth of new pest invasion indicators which includes experiencing of invasion of pest in the agricultural field, increase in the use of pesticides comparing with previous years, effects of temperature on the growth and productivity of crop, invasion of new bird/insect/animals, decrease of insect population. Therefore, this component can be assigned as ‘climate change and agriculture’.

The fifth component accounts for 5.42% of the total variation, this component is similar to the third components which is importance on climate change and availability as well as quality of water. Whereas, in this component it advocates the importance of water resource for daily domestic purpose which include the indicator like Importance of groundwater, spring water, stream for domestic purpose and importance of spring water for family’s daily need as a source of domestic water. On that account this component can be called as ‘effect of climate change on domestic-water source’.

The sixth component accounts for 4.83% of the total variance, this component presents the regularity of rainfall and temperature in agriculture aspects where indicators like receiving of adequate amount of rainfall for crops and change in summer temperature and rainfall are included. Therefore, this component can be named as ‘regularity of weather phenomenon’.

The seventh and the last component account for the smallest values of 4.15% of the total variance. This component includes only one indicator that is adequate supply of water by PHE department for daily sustenance. Therefore, this component can be labelled as ‘daily water resource’.

The domain weight of the indicators 9Table 5.6) is calculated by multiplying the first eigen value (4.43) by the first extracted component column (.390, .664, .698, .695, .581, .546, .767, .761, .689), the second eigen value (3.50) by the second component column, the third eigen value (2.67) by the third component column, and so on. Finally, we totalled the values obtained for each variable. For example, 4.43x.689 + 3.50x.162 + 2.67x.172 + 2.36x.202 + 1.57x.103 + 1.40x-0.021 + 1.20x-0.194 = 4.48 for the first variable (impact of climate change on personal occupation).

Table 5.7 Weight of the indicator

Indicators	Weight
Effects of climate change in personal occupation	4.48
Change in the arrival of monsoon season	4.36

Effects of long dry or hot period of summer weather on community	4.34
Change in the amount and pattern of rainfall	4.19
Effects of temperature on the growth and productivity of crop	4.15
Decrease of spring water	4.04
Experience in change of season duration	3.98
Change in summer temperature and rainfall	3.93
Effects of late arrival of monsoon on the community and personal	3.69
Increase in disease hazards due to climate change	3.67
Decrease of insect population	3.55
Effect in the availability of water due change in annual precipitation	3.40
Decrease in water quality and disappearance of spring water from its source	3.39
Deterioration of groundwater as compared to the past	3.32
Family vulnerable to diseases due to climate change	3.30
Death to diseases and malnutrition due to change in climate and weather	3.24
Increase in the use of pesticides comparing with previous years	3.13
Family’s health affected by change in climate/weather	3.06
Importance of spring water for family’s daily need as a source of domestic water	2.93
Change in general weather pattern	2.89
More difficulty in accessing water comparing to the past	2.84
Importance of groundwater, spring water, stream for domestic purpose	2.74
Experiencing of invasion of pest in the agricultural field	2.72
Experience of new climate phenomenon	2.51
Invasion of new birds/insects/animals	1.88
Demand of water to be higher in future than present scenario	1.80

Receiving of adequate amount of rainfall for crops	1.42
Adequate supply of water by PHE department for daily sustenance	0.96
Satisfaction on health care facilities in the area/village	0.24
Total	**90.17**

Source: Field survey

5.4 Hierarchical Cluster Analysis

Cluster analysis (CA) is an effective method for detecting correlations among a wide range of variables (Rakib et. al. 2019), it is typically used to assist in splitting variables into separate groups based on comparable features of a collection of data that may indicate causes, impacts, or the source of any unexplained societal problems. The numerous climate vulnerability indicators were used as parameters in the cluster analysis to categorize the different districts into groups with comparable cohesiveness of vulnerability to the effects of climate change.

The dendrogram (Figure. 5.3) depicts the grouping of districts depending on their vulnerability to the effects of climate change. All of the districts have been categorized into three primary clusters, with one outlier. The districts of Aizawl, Serchhip, and Lunglei have been grouped together as having the greatest coherent vulnerability among themselves with cluster membership value of .079, .074, 0.78 respectively (Table 5.7), the districts of Kolasib (.103), Siaha, (.103), Mamit (.134), Champhai (.134) show the average relation within each other. Whereas the district of Lawngtlai has been represented as an outlier, with a value of 0.00, it has the least resemblance to the other districts in terms of sensitivity to climate change and its consequences.

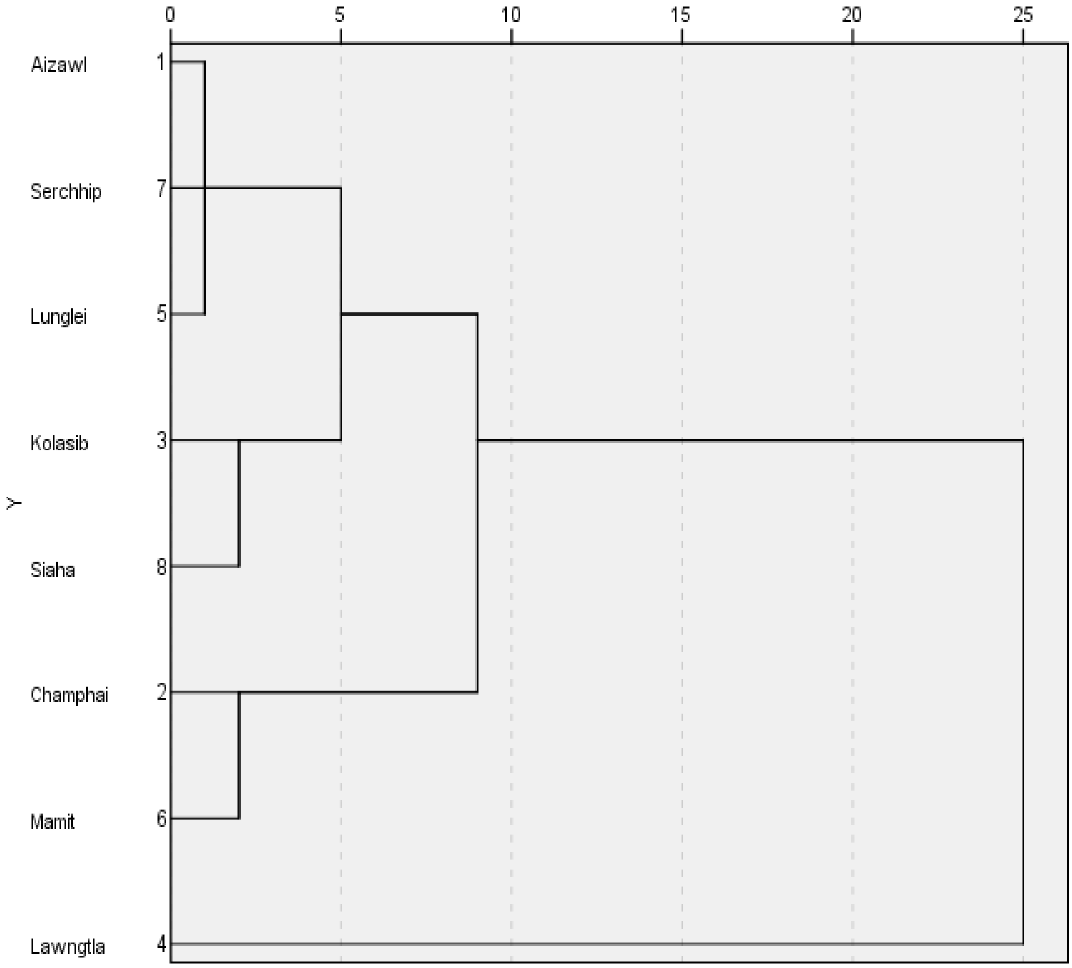

Figure. 5.3 Showing dendrogram using Average Linkage (between groups)

Table 5.8: Cluster membership

Case Number	Cluster	Distance
Aizawl	1	.079
Champhai	2	.134
Kolasib	3	.103
Lawngtlai	4	0.000
Lunglei	1	.078
Mamit	2	.134
Serchhip	1	.074
Siaha	3	.103

5.5 Conclusion

Similar with the findings in Chapter 3, the findings in this study can also be broadly divided into three parts. The first section uses the Climate Vulnerability Index (CVI) technique to measure district-by-district susceptibility to climate change and variability. The second section uses Principal Component Analysis (PCA) to identify the vulnerability indicators that are most susceptible to climate change. The third section evaluates whether to group different districts under the same cluster by establishing correlations between a wide range of variables based on their susceptibility to climate change.

With a Climate Vulnerability Index (CVI) score of 0.22, the district of Lawngtlai was found to be the most vulnerable out of the eight districts to climate change and variability, while the districts of Kolasib and Mamit were listed as the least vulnerable, with CVI scores of 0.18 and 0.18, respectively. The vulnerability indicators were reduced to seven (seven) major components with the use of the Principal Component Analysis, of these seven components, the first one, "climate change and variability," exhibits the highest significance, accounting for 15.29% of the variance. Additionally, the weights assigned to each individual indicator were determined. It was noted that the indication pertaining to the "Effects of climate change in personal occupation" had the highest weight (4.48), indicating the greatest influence. Cluster Analysis reveals the districts of Aizawl, Serchhip, and Lunglei have been combined as having the greatest coherent vulnerability among themselves, according to the CA analysis, with cluster membership values of.079,.074, and 0.78, respectively. In contrast, the district of Lawngtlai was shown to be an outlier with no correlation among the variables with other districts.

CHAPTER 6

COPING ADAPTIVE STRATEGIES TO CLIMATE VARIABILITY

6.1 Introduction

This chapter is a study on developing strategies based on empirical data collected from the study area, problems encountered by respondents, suggestions made by respondents, and an examination of the various techniques and adaptations employed by respondents, as well as the relationship between perception and adaptation to climate change.

The notion of adaptation to climate change and variability is relatively new and challenging for all agencies, despite the fact that it is expected to be one of the most significant issues that civilization will confront at the global, regional, and local levels. There is evidence that climate change will increase the unpredictability and severity of severe events, but there is little knowledge on the exact changes that would be observed at the local and regional levels. Adaptation mechanisms must be adequately designed since changes that will occur over decades or so require long-term planning, but changes connected to catastrophic occurrences will have immediate effects in sensitive places and demand quick treatments.

When it comes to climate change and unpredictability, adaptability is critical for two reasons. For starters, the severity and hazard of climate change can be mitigated by diverse adaptations (Smit 1993; Tol et al., 1997). Most studies currently involve assumptions about the system of interest's projected changes. As a result, the important question concerning adaptation is: what kinds of adaptations are likely? This is mostly a prediction effort that needs knowledge of how and under what conditions adaptation is likely to occur. Secondly, adaptation is seen as a significant policy option or response approach to climate change issues (Frankhauser 1996; Smith, 1996).

6.2 Profile of respondent's socio-demographic characteristics

6.2.1 Gender and age-group

The majority of respondents from all districts were male (88%), with only 12% (percent) being female (Table 6.1 and Figure 6.1). This can be explained by the fact that traditionally, males have been the heads of houses, however, in Figure. 6.3 showing the male-female respondent in different age group, it can be observed that the percentage of female respondents are in higher in 40-49 and 50-59 age group which can be attributed to the traditional role of men being the bread earner and most of them spend time in the farm field or workplace with women assisting them by supervising household-related chores. Majority of the respondents belongs to the mid-age category of 30-39 and 40-49 age-group with 22 per cent and 23 per cent respectively while the older age group of 70-79 and 80-89 show the least number of respondents accounting for 3 per cent and 1 per cent respectively (Table 6.1 and Figure 6.2).

Table 6.1 Distribution of respondents according to their gender

Age Group	Percentage of Respondent age-group wise (%)	Male (%)	Female (%)
20-29	16	23	11
30-39	22	27	20
40-49	23	18	26
50-59	20	12	24
60-69	15	16	15
70-79	3	4	3
80-89	1	0	1

Source: *Field survey*

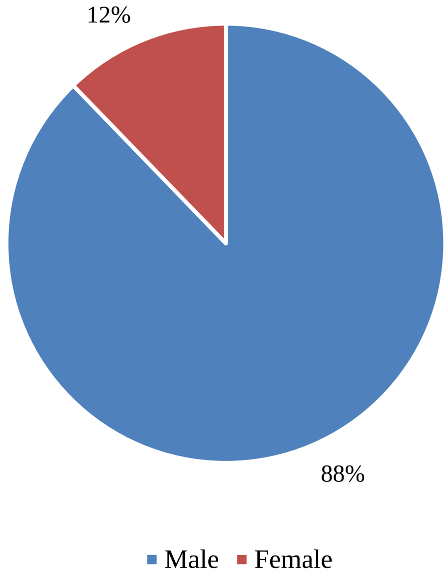

Figure 6.1 Distribution of respondents according to their gender

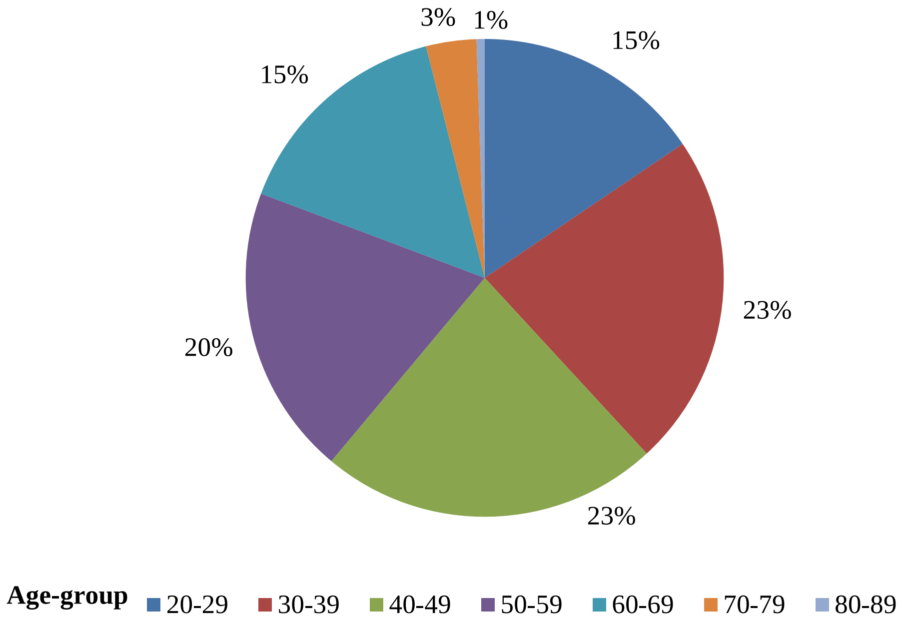

Figure 6.2 Distribution of respondents according to their age-group

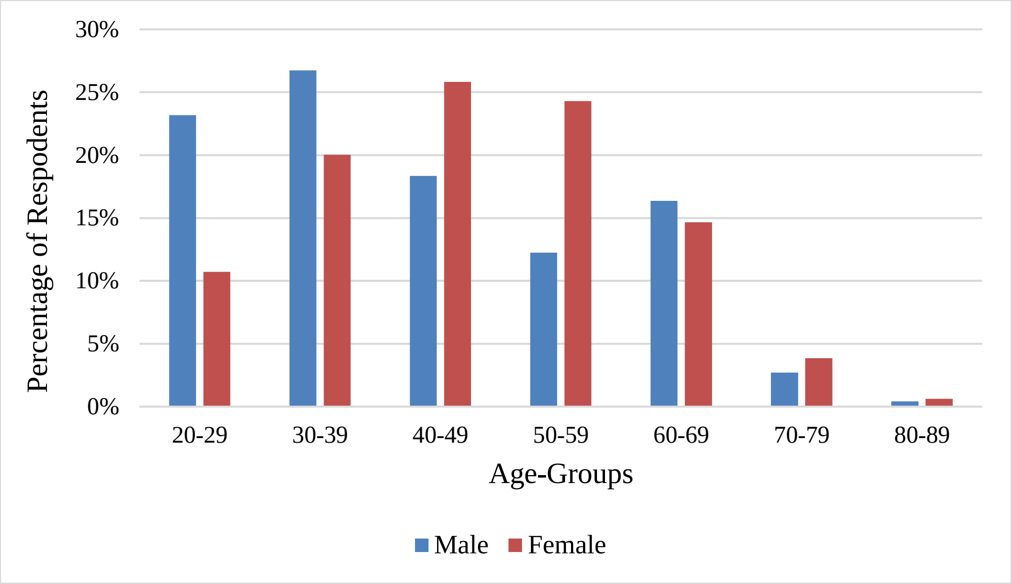

Figure 6.3 Distribution of Male-Female Respondent in different Age-groups

6.2.2 Perception of respondents towards climate change

Table 6.2 shows that the majority of respondents (87.8 per cent) have a positive perspective of climate change, while just 12.2 per cent are oblivious or have no perception of climate change in particular. This high proportion of perspective on climate change may be ascribed to the state's high literacy rate, as well as the growth in simple access to the internet, telecasting, and public awareness programmes provided by the government and non-governmental organizations.

Table 6.2 Respondents perception on climate change

Category	Percentage on the perception on climate change
Yes	87.8
No	12.2

Source: *Field survey*

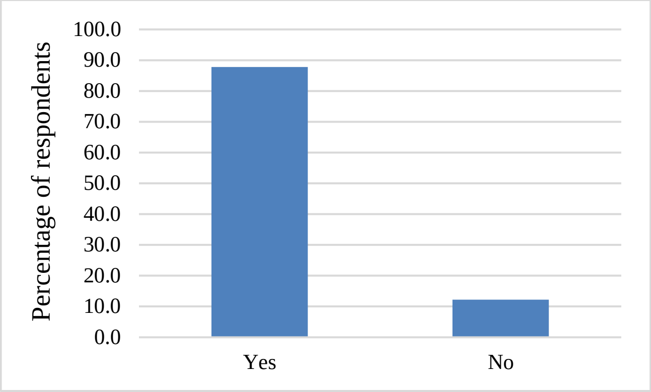

Figure 6.4 Showing respondents perception on climate change

6.2.3 Source of information about climate change

The data in Table 6.3 illustrates the many sources of knowledge the respondents have acquired regarding climate change and variability. Among the many sources of knowledge, the biggest number of respondents (31per cent), came across about climate change from family/friends, followed by television and environmental groups (21.4 per cent and 14.8 per cent, respectively). While government agencies/information supply the least amount of climate change information (1.7 per cent), local councils and radio provide 2.7 and 4.3 percent, respectively.

Table 6.3: Source of information about climate change

Source of Information	**Percentage**
Television	21.4
Family/Friends	31.5
Radio	4.3
Government Agencies/information	1.7
Newspaper	4.8
Local Council	2.7
Internet	12.7
Environmental Groups	14.8
School/College/University	4.9
Others	1.3

Source: *Field survey*

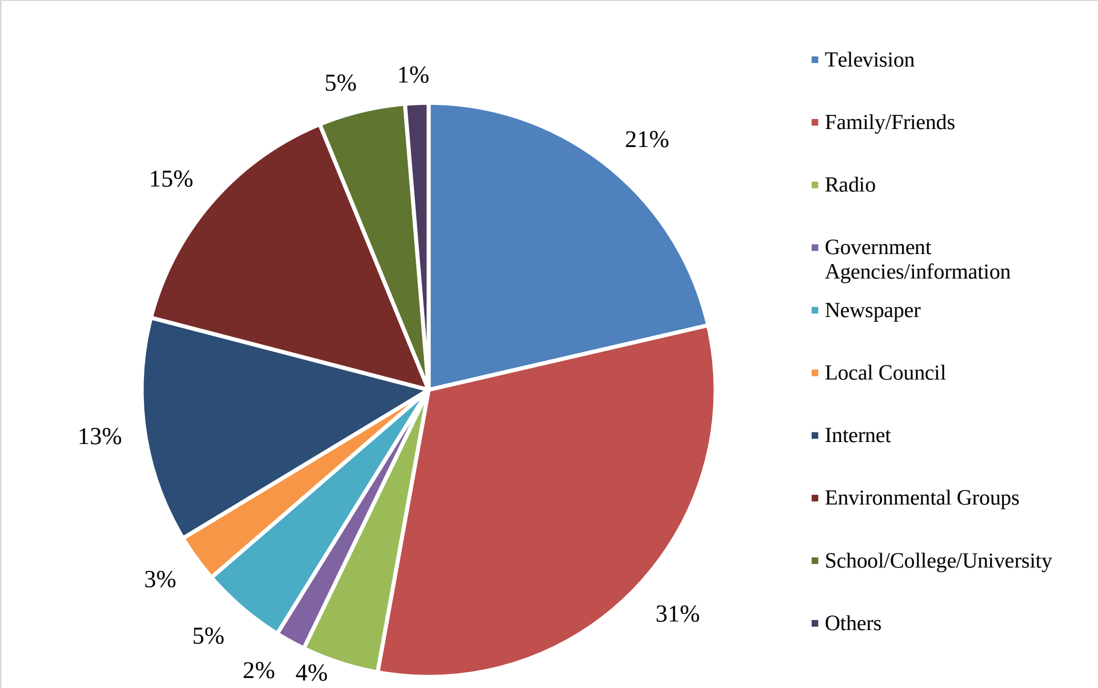

Figure 6.5 Representing the Source of information about Climate Change

6.3 Implementation and adaptive strategies to Climate Change

6.3.1 Agriculture and adaptation to climate change

Mizoram being an agrarian society where agriculture plays a vital role in people's livelihood, the study found that there has been an initiative actions and strategies to deal and adapt to climate change in the context of agriculture. The Table 6.4 illustrates the different measures which have been adopted by the respondents in order to adapt to climate change, it can be observed that preventive measures to stop forest fire due to jhum cultivation has the highest measure with 55.5 per cent which can be supported with the result analysis of rainfall in Mizoram in chapter 4 which shows a declining trend of rainfall in the last 30 years which further makes Mizoram more susceptible to forest wild fire during dry seasons. The other important adaptation include change in farming style from shifting cultivation to areca nut plantation (12.7 per cent), shifting cultivation to crop rotation and mixed farming (10 per cent), shifting cultivation to dragon fruit plantation (5.2 per cent), the study shows there has been a trend of transformation of cultivation practice from an environmental degrading shifting cultivation and oil palm plantation to an eco-friendlier way of farming practice. It has also been observed that there has been a lack of efforts from the government organizations to spread awareness and help farmers to cope and adapt to climate change.

Table 6.4 Distribution of respondents according to their adaptation to climate change and agriculture

Adaptive strategies	No. of respondence in %
Preventive measures to stop forest fire due to Jhum cultivation	55.5
Shifting Cultivation to areca nut plantation	12.7
Crop rotation and mixed farming	10.0
Shifting cultivation to Dragon fruit Plantation	5.2
Planting trees	5.2
From oil palm plantation to areca nut plantation	4.4
From shifting cultivation to poultry	2.2
Govt. have not taken action good	2.2
The Govt. make a good plan but there is no further development from the plan	1.7
Provide better fertilizer to save soil condition	0.9

Source: *Field survey*

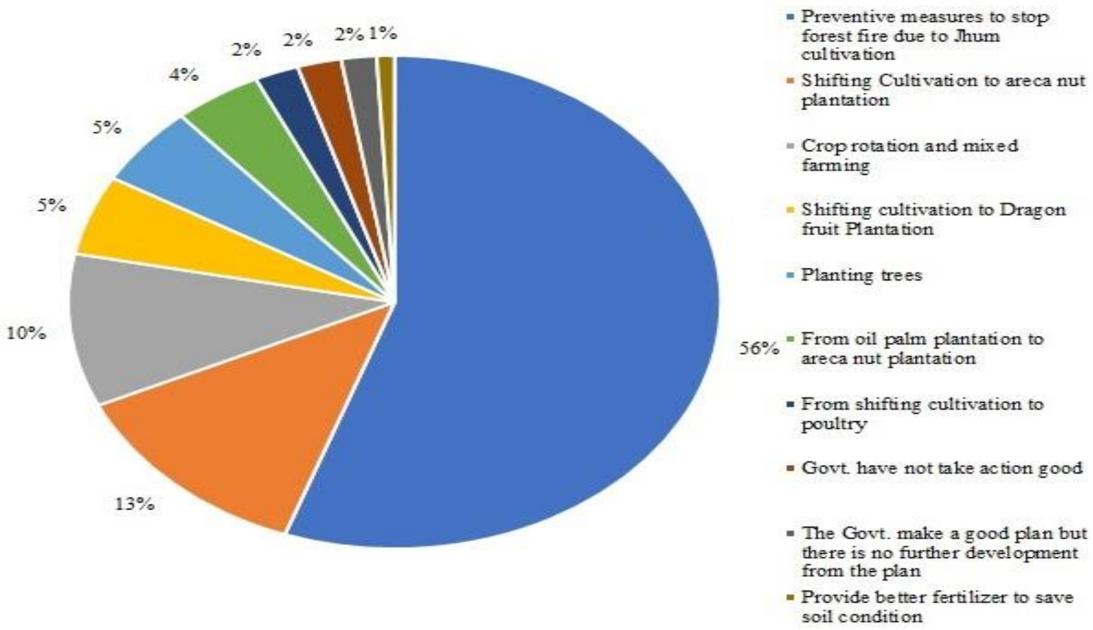

Figure 6.6 Distribution of respondents according to their adaptation to climate change and agriculture

6.3.2 Water Resources and adaptation to climate change

According to the survey, the result in Table 6.5 shows majority of respondents (33.5 per cent) have implemented rainwater harvesting, while 22.6 per cent of respondents were involved in setting up a suitable system for conserving water for future uses, particularly during the dry season. It should be highlighted that springs are the primary supply of water in rural regions, where 21.8 per cent of respondents have made significant efforts to preserve and keep spring water supplies clean. Spring water must be conserved since, as was already noted, it is a significant supply of water. Important actions and procedures, in addition to conservation and cleanliness, include monitoring deforestation in and around the spring as well as tree plantation, specifically, False Hemp Tree (*Tetrameles nudiflora*) and Lampati (*Duabanga grandiflora*) which are reported to help in regenerating water level.

Table 6.5 Distribution of respondents according to their adaptation to climate change and water resources

Adaptive strategies	No. of respondence in %
Rainwater harvesting	33.5
Arranging proper storage of water for future purpose	22.6
Conservation and cleanliness of spring water source	21.8
Monitoring of deforestation. Specially: False Hemp Tree (*Tetrameles nudiflora*) and Lampati (*Duabanga grandiflora*)	16.9
Tree Plantation	5.2

Source: *Field survey*

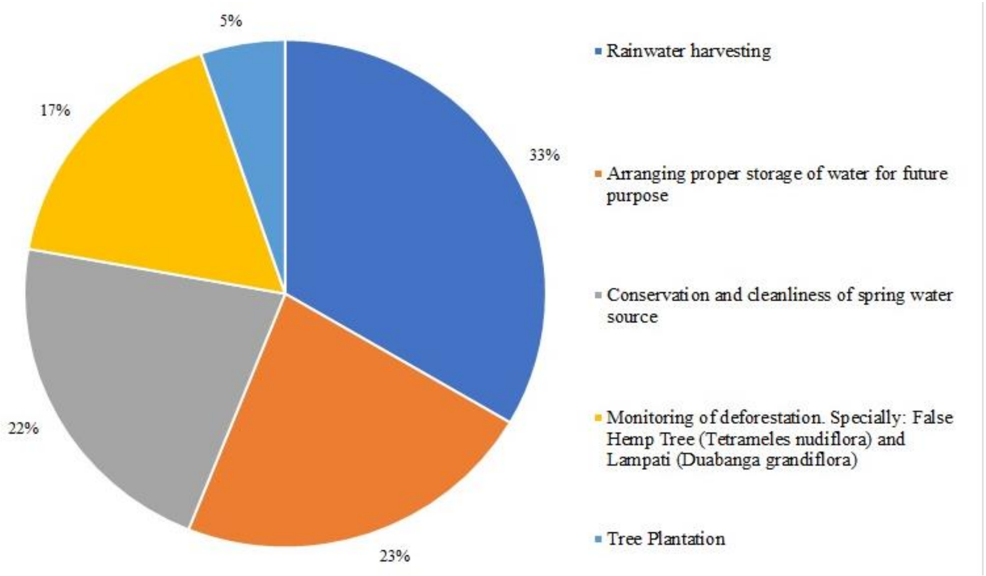

Figure 6.7 Distribution of respondents according to their adaptation to climate change and water resources

6.3.3 Health and adaptation to climate change

Dengue and malaria are endemic diseases in Mizoram that are directly impacted by temperature and precipitation, while deforestation plays a major factor in the state's rising malaria incidence (Karuppusamy *et. al* 2021). Table 6.6 shows that maintaining cleanliness during the rainy season to protect from water-borne diseases and insect bites (67.6 per cent) is the main action taken to deal with adaptation to climate change in terms of health, where the majority respondents agreeing to have taken this initiative both individually and as a community. It has been clearly demonstrated in chapter 4 that the pace of temperature increases during the past 30 years has been dominating. The second-highest adaptation method to deal with the rising temperature is the planting of trees around homes to control temperature (28.5 per cent).

Table 6.6 Distribution of respondents according to their adaptation to climate change and health

Adaptive strategies	Responses in %
Maintaining cleanliness during rainy season to protect from water borne diseases and insect bites	67.6
Plantation of trees in house surroundings to regulate temperature	28.5
Protecting one-self from extreme heat	3.9

Source: *Field survey*

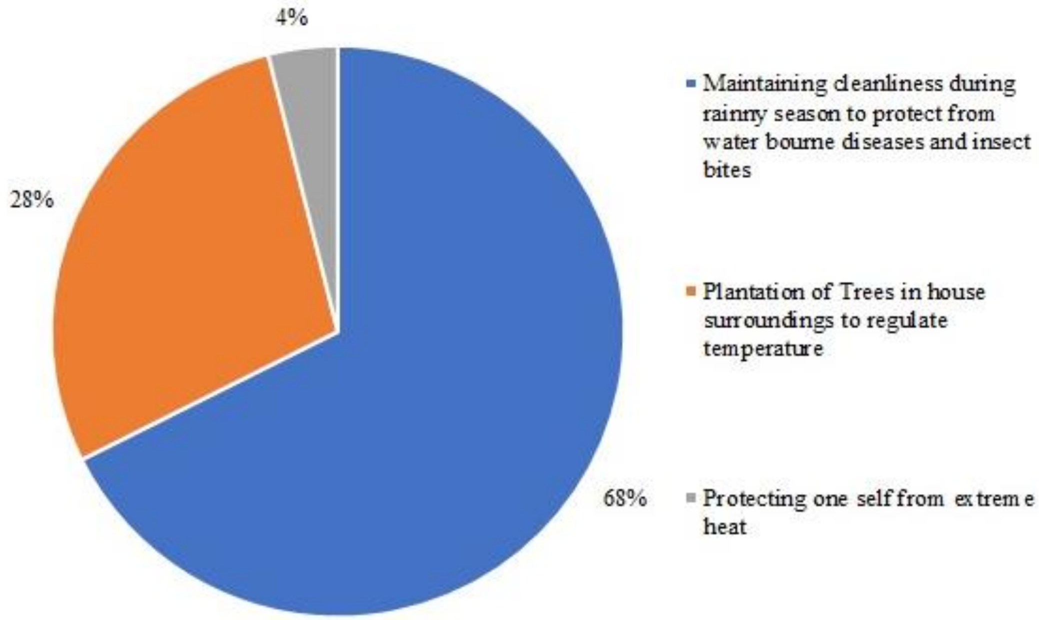

Figure 6.8 Distribution of respondents according to their adaptation to climate change and health

6.3.4 Implementation of adaptive strategies to climate change

The study has formulated a variety of procedures and actions taken by various agencies to deal with and adapt to the changing environment. In Table 6.7 the measures and adaptation are divided into government and non-government organization which may include non-government environmental agencies and local community organization.

Table 6.7 District wise implementation of adaptive strategies

Measures and adaptation strategies	Agencies	Aizawl	Champhai	Kolasib	Lawngtlai	Lunglei	Mamit	Serchhip	Siaha
Flood Protecting (Upgrading drainage system)	Govt.	15	32	29	0	27	11	44	29
	Non-Govt.	7	7	6	10	12	5	5	17
	Planned	34	2	86	2	48	25	11	39
	Unplanned	99	78	75	55	89	148	72	83
Implementation of Pest controls on agriculture and animal husbandry	Govt.	117	156	162	30	183	74	149	90
	Non-Govt.	13	24	30	10	21	26	17	26
	Planned	37	7	18	24	12	65	9	72
	Unplanned	66	43	17	165	11	61	49	35
Conservation of Water Resources	Govt.	44	47	68	6	69	34	61	51
	Non-Govt.	134	124	131	114	134	124	121	115
	Planned	42	26	22	72	11	35	22	34
	Unplanned	13	33	6	37	16	33	20	23
Increase protection of forest area and improve forest fire warning system	Govt.	120	110	94	193	120	77	123	53
	Non-Govt.	80	199	202	19	87	62	81	70
	Planned	15	24	16	11	7	52	6	51
	Unplanned	18	31	25	6	16	38	14	49
Improvement awareness/ preparedness for protecting health in case of extreme weather events	Govt.	12	28	46	0	39	34	36	9
	Non-Govt.	32	70	27	0	48	48	21	20
	Planned	51	113	53	31	51	11	84	19
	Unplanned	138	160	101	198	91	136	83	175
Promoting	Govt.	97	120	131	25	170	56	127	68

sustainable agriculture practice (Conserving moisture, improving irrigation, soil erosion etc.)	Non-Govt.	38	22	29	33	18	22	14	34
	Planned	24	22	25	69	14	29	24	24
	Unplanned	74	66	42	109	27	122	59	97
Appropriate land use planning with regards to climate change	Govt.	65	22	82	0	82	34	31	26
	Non-Govt.	11	142	14	0	9	9	114	8
	Planned	25	66	61	0	52	11	0	8
	Unplanned	130	88	70	229	86	175	0	181

Source: *Field Survey, based on respondents*

A. Flood Protection (Upgrading drainage system):

According to the respondents, the district of Serchhip (44) has the government's highest investment in its drainage system to protect against flooding, whereas Lawngtlai (0) and Mamit (11) which are low elevated districts that are more vulnerable to river floods have little to no investment in their drainage systems from either the government or non-governmental organizations, making them more vulnerable to river floods during periods of intense rainfall. Mamit districts have been found to have the largest number of unplanned measures (148) to deal with the consequences of river floods.

B. Implementation of Pest Controls on agriculture and animal husbandry:

Agriculture is the industry that is most susceptible to the effects of climatic fluctuation and change. In accordance with the survey, it is evident that respondents in the district of Lunglei (183) reported that the government sector implemented pest controls on agriculture and animal husbandry at the highest rate, followed by Kolasib (162) and Champhai (156), while non-governmental organizations consistently played a small role in putting the measures into action in all the districts. According to the statistics (Table 6.6), there are many respondents in each district who said that there are many unanticipated initiatives and measures being taken in the agriculture sector to adapt to climate change, with Lawngtlai having the highest response of unplanned measures with 165 respondents.

C. Conservation of water resources:

The results show that, in comparison to non-governmental organizations, the government has provided less funding for water resource conservation. In this instance, the village local council is the major non-governmental organization that has taken action to save the water supply. The government recorded the greatest levels of water resource conservation in Lunglei (69) and Serchhip (61). While Lunglei (134) and Aizawl (134) have the greatest levels of non-governmental organization engagement.

D. Increase protection of forest area and improve forest fire warning system

According to the respondents, it is obvious that the government has made significant actions and efforts to safeguard and conserve the forest area and enhance the forest fire warning system. The two districts with the biggest number of such measure implementations by the government are Lawngtlai (193) and Serchhip (123). Prior to the start of shifting agriculture, which entails slashing and burning of forest areas, local council (non-governmental organization) would frequently conduct awareness programmes, according to the respondents, regarding the forest fire warning system.

E. Improvement awareness/preparedness for protecting health in case of extreme weather events

According to the study, there has been a lack of effort on the part of both governmental and non-governmental organization to raise public awareness of the need for health protection in the event of extreme weather occurrences. Kolasib (46) has the largest percentage of responders who are aware of climatic extremes, whereas Lawngtlai (0) and Siaha (9) have little to no understanding of this issue. It has also been noted that the majority of respondents across all districts concur that there has been no planning for raising awareness or preparing for health protection in the event of extreme weather occurrences.

F. Promoting sustainable agriculture practice

Sustainable agriculture aids in the preservation and maintenance of soil fertility, soil erosion etc. is a crucial step in combatting against climate change. Table 6.4 has already shown that the majority of farmers have chosen crop rotation strategy over the traditional shifting agriculture. According to the respondents, the government may have made strong efforts to raise awareness of sustainable agriculture practices and provide hands-on training in virtually all of the districts, with Lunglei (170) ranking highest followed by Kolasib (131) and Serchhip (127).

G. Appropriate land-use planning with regards to climate change

The replies in Table 6.6 show that little effort has been made by the government and non-governmental organizations to raise awareness about the proper land-use planning in light of climate change. Lawngtlai districts have shown 0 (Zero) respondents who support any land-use planning efforts. The biggest number of responders who have experience with land-use planning are in Kolasib (82) and Lunglei (82). Additionally, a significant percentage of respondents indicated that there were no unanticipated methods in this area.

6.4 Conclusion

The findings in this chapter shows the different levels of adaptive strategies adopted by the respondents to cope with climate change and the relationship between social well-being and climate change. It was found that 87 per cent of respondents were well acquainted to the perception of climate change and their main source of knowledge about climate change were from family/friends (31.5 per cent) followed by television (21.4 per cent) and internet (12.7 per cent), suggesting the substantial role of telecommunication and internet as a significant medium of spreading awareness on climate change and its potential impacts on social well-being.

The results also showed that many adaptive strategy programmes were initiated at the village level by the local non-government organization as well as the government sector. Such strategies are implementation on awareness of forest fire which are mainly due to shifting cultivation practiced by tribal communities in the agriculture sector. In the water resource sector, it was found that planting specific types of trees in and around the source of spring water helps in conserving the source and regenerating the level of water. While in the heath sector, the prominent strategies were maintaining cleanliness specially during the rainy season to regulate the case of vector borne diseases. It was also found that the implementation of adaptive strategies and spreading of awareness on climate change by government and non-governmental organization has played an equal roll in all sector of adaptive measures.

Plate 6.1 Face to Face interview with the respondent

Source: Author's photograph, field survey

Plate 6.2 Practice of shifting cultivation (prior to burning)

Source: Author's photograph, field survey

Plate 6.3 Shifting cultivation (after burning of field)

Source: Author's photograph, field survey

Plate 6.4 Change in agricultural practice from oil palm plantation to areca nut plantation

Source: Author's photograph, field survey

Plate 6.5 Oil palm plantation at study area

Source: Author’s photograph, field survey

Plate 6.6 PHE supplied water station point

Source: Author’s photograph, field survey

Plate 6.7 Community based water station point 1

Source: Author's photograph, field survey

Plate 6.8 Community based water station point 2

Source: Author's photograph, field survey

Plate 6.9 Natural spring water station

Source: Author’s photograph, field survey

Plate 6.10 Poultry farming as a substitute to shifting cultivation

Source: Author’s photograph, field survey

CHAPTER 7

SUMMARY AND CONCLUSION

7.1 Introduction

All across the world, people are aware that the effects of climate change are major concerns. This calls for further focused research to evaluate the past and forecast future effects on a given industry at the regional, state, and national levels in order to create sector-specific suitable adaptation and mitigation plans. The biotic and abiotic elements of the ecosystem are still vulnerable to dangerous climatic phenomena as a result of climatic change. according to the shifting conditions from the perspectives of society, the economy, agriculture, and human health, climate susceptibility takes many different forms (Cutter et al., 2003; Warren et at., 2011). According to their physiological, behavioural, socio-demographic, and developmental features, humans exposed to various climatic exposures in outdoor settings appear to be sensitive. The relative sensitivity and capacity of a local community to adjust to the climatic circumstances are clearly used to determine the degree of vulnerability of a population in a particular environment (McCarthy et al., 2001, Adger et al., 2003).

Due to their fragile nature, dependency on traditional economies, and relatively low degree of development, it is often believed that residents of tropical regions, highlands and mountainous areas are more vulnerable and susceptible to environmental change (Ives and Messerli, 1989; Koenig and Abegg, 1997; Beniston 2003; Kohler et al., 2014; Nag et al., 2007; Kjellstrom et al., 2009). Hilly regions may easily experience frequent occurrences of natural hazards, disturbance of the ecological system, decline in agricultural production, decrease in water availability, and, ultimately, harm to the environment's overall health and that of humans. Since many researchers have evidently proved there has been a significant change in the environment of the north-eastern Himalayan area of India over the past three decades, it is also extremely sensitive to climate-related calamities (Das 2009, Jain et al., 2013).

7.2 Summary

During the study, the following finding have been drawn

7.2.1 Analysis of trends and patterns in temperature and rainfall

The first objective of the study deals with the assessment of variation and trend analysis of climate parameters (temperature and rainfall) in Mizoram for the time period of 35 years (1986-2020) using statistical method of coefficient of variation and Mann Kendall & Sen's slope test. The meteorological data were obtained from Indian Meteorological Department (IMD) and it was further categorized into Annual and seasonal (Summer, Autumn, Winter and Spring). By utilizing the coefficient of variation, we found a high magnitude of rainfall variation in the months of January, February, November and December during the study period while the years of 2006-2010 shows highest rainfall variation. Whereas, the highest seasonal variation of rainfall was observed in the season of Spring and Winter in the year 2016-2020 and 2006-2010 respectively. In contrast, the examination of temperature coefficient of variation reveals a pattern of modest change in both maximum and minimum temperature. The research period revealed an uncommon increasing shift of high fluctuation in maximum temperature in the months of September, October, November, and December during the lustrum years of 2016-2020. On the other hand, the seasonal maximum temperature variation demonstrates the intricate structure of high variance in each season. Except for the final year of the lustrum of 2016-2020, the findings of the minimum temperature variation show a similar monotonic variation in all the year groups with moderate and low variance.

The trend analysis of temperature and rainfall was performed with the aid of Mann-Kendall & Sen's Slope analysis. The results on rainfall trend analysis demonstrate a continuous falling trend of rainfall in monthly, yearly, and seasonal terms. The total yearly precipitation has a significant downward trend ($p < 0.05$) with a Sen's slope magnitude of -12.53, additionally the year 2019 received the lowest rainfall during the study period. Unlike the rainfall, the yearly maximum temperature showed a significantly positive trend ($p < 0.01$) indicating an increase in maximum temperature annually and seasonally. Likewise, the seasonal maximum temperature also observed a positive trend, where the winter recorded the highest positive trend (p <0.001). On the other hand, the minimum temperature shows a significantly negative trend both on yearly and seasonal minimum temperature (p <0.005).

7.2.2 Analysis on Traditional Ecological Knowledge

The second objective of the study involves The Traditional Ecological Knowledge (TEK), an indigenous technique used for weather prediction. The analysis shows a total of 28 bio-indicators were identified which the respondents use to practice weather prediction based on the activity of various insect, bird, animal, and plant species. Additionally, it has been noted that a number of bioindicators have recently altered their behavioural patterns in response to the changing natural environment, which suggests a slow shift in the climate system. A high number of respondents (72.3 per cent) responded to have noticed cicada (large tree cricket) to have change its singing period indicating the late arrival of rainy season. While 19 per cent of respondents believed in the shift of blooming of tree flowers indicating change in the pattern of seasons.

7.2.3 Assessment of district wise climate vulnerability

The third objective deals with the vulnerability assessment to climate change at the community level and ranking district wise vulnerability and sensitivity of the communities. Our investigation was focused on identifying the variables that distinguish households based on both their susceptibility to climatic occurrences and their ability to adapt to changing climatic conditions. In order to rate the districts according to how vulnerable they are to climate change, we performed vulnerability assessments at the village level using an indicator-based approach. Indicators of exposure, sensitivity, and adaptability at the household and district levels were combined to define vulnerability. The study reveals the district of Lawngtlai as the most vulnerable districts under the Climate Vulnerability Index with the CVI Score of 0.22 followed by Lunglei and Siaha score CVI of 0.21 each. It was also observed that the district of Kolasib (0.18) and Mamit (0.18) were the least vulnerable to the climate variability and change. Our study's key finding is that the districts with the greatest ability for adaptative capacity are also the ones that are most exposed to and sensitive to the effects of climate change. This implies that families with low sensitivity to climate hazards are unlikely to invest in risk reduction techniques, whereas households with relatively high sensitivity are more inclined to address these sensitivities by whatever measures they can take and whatever resources are available to them.

The Principal Component Analysis (PCA) was employed to determine which of the vulnerability indicators has the highest susceptibility to climate change. The analysis helped reduced the vulnerability indicators into 7 (seven) major components which are subsequently labelled as 'climate change and variability', 'climate change and health', 'climate change and water resource', 'climate change and agriculture', 'effect of climate change on domestic water source', 'regularity of weather phenomenon' and lastly, 'daily water resources', among these components the 1st component 'climate change and variability' shows the most important components as it accounts 15.29% of the total variance. Further, weightage for each individual indicators were calculated, in which it was observed that the 'Effects of climate change in personal occupation' shows the highest weight of 4.48 signifying the highest impact of climate change.

Cluster analysis (CA) was employed to group districts under same clusters by determining the correlation among the wide range of variables. Therefore, in order to organise the various districts into groups with equal cohesion of sensitivity to the effects of climate change, a number of climate vulnerability indicators were utilised as parameters in the cluster analysis. With cluster membership values of .079,.074, and 0.78, respectively, the CA analysis revealed that the districts of Aizawl, Serchhip, and Lunglei have been combined as having the greatest coherent vulnerability among themselves, whereas the district of Lawngtlai was shown to be outlier with no correlation among the variables with other districts.

7.2.4 Assessment on identifying coping strategies and adaptation to climate variability

By examining the adaptation strategies in light of climatic variability, the fourth objectives aim to determine the relation between climate and social well-being. We looked at the various coping mechanisms used by the community with support from governmental and non-governmental organisations in order to understand the communities' ability for adaptation. It was found that 87 per cent of respondents were well acquainted to the perception of climate change and their main source of knowledge about climate change were from family/friends (31.5 per cent) followed by television (21.4 per cent). The adaptive strategies which were adopted in the agricultural sector were implementation on awareness of forest fires due to Jhum cultivations (55 per cent), it was also observed that many farmers shifted from shifting cultivation to other farming practice such as crop rotation (10 per cent), dragon fruit plantation (5.2 per cent) and poultry (2.2 per cent). While, in water resource sector it was found rainwater harvesting (33.5 per cent) was highly practiced in order to cope with the declining trend of rainfall and dry season to meet the water necessity. Conservation of spring water source and plantation of trees especially False Hemp Tree (*Tetrameles nudiflora*) and Lampati (*Duabanga grandiflora*) in the spring surrounding were important strategies followed in almost every part of the state. In the health sector it was found that maintaining cleanliness (67.6 per cent) specially during rainy season was judged to be an important strategy in order to safe-guard from water borne diseases and insect, followed by plantation of trees surrounding houses (28.5 per cent) to help regulate temperature as it has been evidently proven the increase rate of maximum temperature in recent years.

The implementation of adaptive strategies and spreading of awareness on climate change by government and non-governmental organization has played an equal roll in all sector of adaptive measures. According to the study, while non-governmental organisations have made significant contributions to the conservation of water resources across the state, on the other hand, the government has focused most of its efforts on adopting adaptation measures in the agricultural sectors. It must be noted, nonetheless, that neither the government nor non-governmental organisations have succeeded in raising vital understanding about how to prepare for defending oneself against the consequences of catastrophic weather occurrences.

7.2 Conclusion

The present research is a modest and maiden attempt to quantitatively assessed how societies in Mizoram are vulnerable and sensitive to climate change as well as identifying the different adaptive strategies that have been initiated to cope with the changing climate. It is important to point out the main limitation faced during the course of study was lack of proper data from the secondary sources, data of various climatic variables, including data on different socio-economic sectors should be made more available in order to carry a wider range of in-depth research on the effects of climate change on human well-being. However, it is evident from the study that Mizoram has been experiencing significant climatic change, and it possesses a potentially high risk of vulnerability to every sector of social well-being. Hence, the study's main goal is to provide the government, policymakers, researchers an evidence-based study that would highlight the current and potential burden of climate change's adverse effects, some of which require immediate attention in order to take preventive measures to lessen the burden of the change.

APPENDIX

The Questionnaire is for Climate variability and vulnerability on social well-being and Traditional Ecological Knowledge. The responses will be kept confidential.

Date:

Ward No.: _____________ District: _________________

Village: _____________ House No. : ________________

Family occupation and status:

Sl. No.	Name	Sex (1. Male, 2. Female, 3. others)	Age	Relationship with head	Occupation	Edu. Qlfn.	Avg. Monthly Income (Rs)
1							
2.							
3.							
4.							
5.							
6.							
7.							

1. Have you ever heard about Climate Change?

☐ Yes ☐ No

If Yes, *Tick as many as you feel apply:*

☐ Television

☐ Radio

☐ Newspaper

☐ Internet

☐ Environmental groups

☐ School/College/University

☐ Friends/Family

☐ Government agencies/Information

☐ Local Council

☐ Other

2. Scale of vulnerability: 1= very low, 2= low, 3= medium, 4= high, 5= very high

Health Vulnerability	**Level of vulnerability to climate Variability**				
	1	2	3	4	5
Has change in the weather/climate has affected you and your family's health?					
Do you think climate change is responsible in increase of disease hazard? e.g Malaria					
Do you think you and your family are vulnerable to diseases due to climate change?					
Are you satisfied with the health care facilities in your village/area?					
Do you think change in weather and climate is responsible for death from diseases and malnutrition?					

3. Is there any family member having chronic disease? if yes, how many?
____

4. Is there any family member who had died before attaining 5 years of age? If yes, how many? _______________

5.

Water resources	**Level of vulnerability to climate variability**				
	1	2	3	4	5
Do you think there is more difficulty in accessing drinking water comparing to the past?					
Has there been decrease in water quality, and disappearance of spring water from its sources?					
Are groundwater, spring water, streams still an important source of water for domestic purpose?					
Could demand of water be higher in future than present scenario?					
Do you think changes in annual precipitation affects the availability of water?					
Is the water supplied by the PHE department inadequate for daily sustenance?					
Is the groundwater quality deteriorating compared to past					
Do you think the amount (Volume) of spring water is decreasing?					

How important is spring water for your family's daily need as a source of domestic water?					

6.

Socio-Economic	Tick which ever is applicable	
House Type	Tatch	
	Assam Type	
	Concrete RCC Building	
Is Electric (Power) connection available?	Yes	
	No	
House owner	Owner	
	Rented	
Do you own a vehicle?	Yes	
	No	
Do you own agricultural field	YES	
	No	
	If yes how many hector (ha) or local measurement of field size	
Do you practice animal husbandry? (If yes, tick the following)	Poultry	
	Cattle	
	Fishery	
	Mixed farming	

7.

Agriculture/crop Vulnerability		**Level of vulnerability to climate variability**				
		1	2	3	4	5
Is the there any change in yearly agricultural product due to climate/weather change?	Increasing change					
	Decreasing change					
Do you experience any invasion of new pest in the agricultural field?						
Is there any increase in the use of pesticides comparing with previous years?						
Do you receive adequate amount of rainfall for your crops?						
Does increase in temperature affects the crops growth and productivity?						

8.

Ecological vulnerability		**Level of vulnerability to climate variability**				
		1	2	3	4	5
Do you feel the pattern of weather is generally changing?						
Do you experience/observed change in the surrounding natural environment due change in climate pattern? Have you noticed any changes in the plants or the trees in the bush such as:	New Species					
	Anything that has disappeared or appeared?					
	Change in the season of blooming and shedding leaves in trees?					
Have you notice any kind of birds or insects or animals you haven't seen before?						
Has there been any decrease of insects?						
Have the amount and pattern of rainfall changed in sometime of the year?						
Do you experience any change in the arrival of the monsoon season?						
Does the early or late arrival of monsoon affect you or the community?						
Have you experience new climatic event/phenomenon?						
Have you noticed changes in summer temperature and rainfall? Compared with when?						
Do you experience any change in the duration of seasons?						
Are long periods of dry or hot summer weather affecting your community more than in the past?						
Do you think climate change is something that is affecting or is going to affect you personally or in your occupation?						

Have the amount and pattern of rainfall changed in sometime of the year?					

9. Have you notice any kind of birds or insects or animals you haven't seen before?

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____
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____
___

10. Have you noticed greater number of some kinds of birds or insects or animals? Have any of them begun to behave differently?

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____
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____
____
____
____
___

11. Does your area experiences migration of birds?

☐ Yes ☐ No

if yes, is there any delay or change in their arrival of migration.

____
____
____
____
____
____

12. Do you rely on plants and animal behavior to practice traditional method of weather prediction? If yes, mention the name of the animal or plants and its behavior prior to the weather even:

☐ Yes ☐ No

Animal/Plant	Behavior/Reaction	Weather Prediction

13. Mark the option to classify the current status of adaptive strategies in the study area

Adaptive Measures	Implemented		Planned	Not yet planned	Not relevant
	Govt.	NGO's			
Flood Protection (upgrading drainage system)					
Implementation of pest control on agriculture and animal husbandry					
Conservation of water resources					
Increase protection of forest area and improve forest fire warming system					
Implementation plans for conservation of biodiversity					
Improve awareness/preparedness for protecting health in case of extreme weather events					
Promoting sustainable agriculture practice (conserving moisture, improve irrigation, soil erosion prevention measures, selection of appropriate varieties for cultivation)					
Appropriate land use planning with regard to climate change					

14. What is/are the step(s) taken by you to cope with the affect of climate change?

Agriculture	Animal husbandry	Water resource	Health	Land use planning

Signature of the Respondent/Thumb Impression

REFERENCES

Adger, W. N., Huq, S., Brown, K., Conway, D., & Hulme, M. (2003): Adaptation to climate change in the developing world, *Progress in development studies*, 3, pp.179-195.

Adger, W.N., Arnell, N., Tompkins, E. (2005): Successful Adaptation to Climate Change Across Scales, *Global Environmental Changes*, 15(2), pp. 77-86, DOI: 10.1016/j.gloenvcha.2004.12.005

Adger, W.N., Vincent, K. (2005): Uncertainly in adaptive capacity Incertitudes dans la capacite d'adaptation, External Geophysics, *Climate and Environment*, 337(4), pp. 399-410. DOI: https://doi.org/10.1016/j.crte.2004.11.004

Agarwal, P.K. (2009): Global Climate Change and Indian Agriculture, *Indian Council of Agricultural Research, New Delhi.*

Ager, W.N., Huq, S., Brown, K., Conway, D. Hulme, M. (2003): Adaptation to change in the developing world, *Progress in Development Studies*, 3, pp. 179-195.

Ahmed, S., Galagan, S., Scobie, H., Khyang, J., Prue, C.S., Khan, W.A., Ram, M. (2013): Malaria hotspots drive hypoendemic transmission in the Chittagong Hill Districts of Bangladesh, *PloS One*, Vol.. 8(8), pp. 69-75

Alexandrov. V. & Hoogenboom (2000): The impact of climate variability and change on crop yield in Bulgaria, *Agriculture and Forest Meteorology*, 104(4), pp. 315-327

Aporta, C. and MacDonald, J. (2011): *An elder on sea ice: an interview with Aipilik Inuksuk of Igloolik, Nunavut*, Canadian Geographer, 55, pp. 32-35.

Asfaw, A., Simane, B., Hassen, A., Bantider. A. (2018): *Variability and time series trend analysis of rainfall and temperature in northcentral Ethiopia: A case study in Woleka subbasin*, Weather and Climate Extremes, Vol.19, pp. 29-41.

Asravor, R. K. (2018): Livelihood diversification strategies to climate change among smallholder farmers in Northern Ghana, *Journal of International Development*, Vol. 30(8), pp. 1318–1338.

Barla, M. (2016): Impact on climate change on tribal economy: A study of Jharkhand State of India, *Proceedings of the International Conference on Poverty and Sustainable Development*, Vol. 3(1), pp. 25–36

Bautista, C.T., Chan, A.S.T., Ryan, J.R., Calampa, C., Roper, M.H., Hightower, A.W., Magill, A.J., (2006): Epidemiology and spatial analysis of malaria in the Northern Peruvian Amazon, *The American Journal of Tropical Medicine and Hygiene*, Vol.. 75, (6), pp. 1216– 1222.

Beniston M. (2003): Climate Change in Mountain Regions: A review of Possible Impacts, *Climate Change*, 59, pp-5-31. DOI: https://doi.org/10.1023/A:1024458411589

Berkes, F. (1999): Sacred Ecology: *Traditional ecological knowledge and resource management*, Taylor and Francis.

Berkes, F. (2009): Indigenous ways of knowing and the study of environmental change, *Journal of the Royal Society of New Zealand*, *39*(4), pp. 151–156. DOI: https://doi.org/10.1080/03014220909510568

Berkes, F. and D. Jolly. (2001): Adapting to climate change: social-ecological resilience in a Canadian western Arctic community, *Conservation Ecology*, 5(2), pp. 18, [online] URL: http://www.consecol.org/Vol.5/iss2/art18/

Berry, H.L., Bowen, K.J., Kjellstrom, T. (2010): Climate Change and mental health: A casual pathways framework, *International Journal of Public Health*, 55(2), pp. 123-32. DOI: http://dx.doi.org/10.1007/s00038-009-0112-0

Bezabih, M., Di Falco, S., & Mekonnen, A. (2014): *On the Impact of Weather Variability and Climate Change on Agriculture: Evidence from Ethiopia*, Environment for Development Initiative, http://www.jstor.org/stable/resrep15002

Bhattacharya, Sumana, C., Sharma, R. C., Dhiman A., P., Mitra. (2006): Climate change and malaria in India, *Current Science*, Vol. 90, No 3.

Bhuiyan, M.A.H., Parvez, L., Islam, M.A., Dampare, S.B., Suzuki, S. (2010): Heavy metal pollution of coal mine-affected agricultural soils in the northern part of Bangladesh, *J. Hazard Mater*, 179, pp. 384-392

Bi, P., Tong, S., Donald, K., Parton, K., Ni, J. (2003): Climatic variables and transmission of malaria: a 12-year data analysis in Shuchen County, China, *Public Health Reports*, Vol.. 118(1), pp. 65–71.

Bosher, L., Penning-Rowsell, E., Tapsell, S. (2007): Resource accessibility and vulnerability in Andhra Pradesh: caste and non-caste influences, *Dev. Change*, Vol. 38, pp. 615–640

Boyd, M.F. (1949): Malariology: *A Comprehensive Survey of All Aspects of This Group of Diseases from a Global Standpoint*, Saunders, Philadelphia.

Brklachich, M., D. McNabb, C. Bryant, J. Dumanski. (1997): Adaptability of agriculture systems to global climate change: a Renfrew County, Ontario, Canada Pilot study. Agricultural Restructuring and Sustainability: A Geographical Perspective. B. Ilbery, Q.Chiotti, T. Rickard (eds.). CAB International: New York

Bryant, R.C., Smit, B., Brklacich, M., Johnston, R.T., Smithers, J., Chiotti, Q., Singh, B. (2000): Adaptation in Canadian agriculture to climatic variability and change, *Climatic Change*, Vol. 45, pp. 181–201.

Carvajal-Escobar, Y., Angel, M.Q., Vargas, M.G. (2008): Women's role in adapting to climate change and variability. Advances in Geosciences, 14, pp. 277-280, DOI: 10.5194/adgeo-14-277-2008

Caxton H. (2013): Matarira Deepa, Pullanikkatil ,Tawanda ,Keseke, Everness, S. D. M. Socio-economic impacts of climate change on subsistence communities, *Int. J. Clim. Chang. Strateg. Manag.,* Vol. 5, pp. 404–417

Chatfield, C., & Collins, A.J. (1980): *Introduction of multivariate analysis*, London and New York: Chapman and Hall.

Chhotray, V., Few, R. (2012): Post-disaster recovery and ongoing vulnerability: ten years after the super-cyclone of 1999 in Orissa, India, *Glob Environ Change*, Vol. 22(3), pp. 695–702. DOI: 10.1016/j.gloenvcha.2012.05.001

Costello, A.M., Abbas, M., Allen, A.E. (2009), Managing the health effects of climate change: Lancet and University College London Institute for Global Health Commission, *The Lancet*, 379(9676), pp. 1639-733.

Cross, N. and Barker, R. (1992): *At the desert's edge: oral histories from the Sahel*. London: SOS Sahel.

Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003): Social Vulnerability to Environmental Hazards, *Social Science Quarterly*, 84(2), pp. 242-261.

Cutter, S.L., Finch, C. (2008): Temperal and Spatial Changes in Social Vulnerability to Natural Hazzard, Proceedings of the National Academy of Sciences, 105(7), 2301-6. DOI: 10.1073/pnas.0710375105

Das P.J. (2009): *Water and climate induce vulnerability in northeast India: concerns for environmental security and sustainability,* WATCH Research Report 1, AARANYAK, Guwahati.

Das, S., Tomar, C.S., Saha, D., Shaw, S.O., C. Singh. (2015): Trend in Rainfall Pattern over North-East India during 1961-2010, *International Journal of Earth and Atmosphere Science*, 2(2), pp. 37-48.

Dasgupta, P., Morton, J.F., Dodman,D., Karapinar, B., Meza, F., Rivera-Ferre, M.G. (2014): *Impacts, Adaptation and Vulnerability. Part A: Global and Sectoral Aspects*, WG II 5AR to IPCC, Cambridge University Press, Cambridge and New Work, NY, pp. 613-657.

Davis R.A., Huang, D, Yao, Y. (1995): Testing for a change in the parameter values and order of an autoregressive model, *The Annals of Statistics*, 23(1), pp. 282-304.

de la Torre, A., Fajnzylber, P., Nash, J. (2009): *Low Carbon, High Growth: Latin American Responses to Climate Change*, The International Bank for Reconstruction and Development, The World Bank, ISBN: 978-0-8213-7619-5, DOI: 10.1596/978-0-8213-7619-5

de Souza, D., Kelly-Hope, L., Lawson, B., Wilson, M. Boakye, D. (2010): Environmental factors associated with the distribution of *Anopheles gambiae* s.s in Ghana; an important vector of lymphatic filariasis and malaria, *PloS One*, 5(3), e9927.

Deb, A. K., Haque, C. E. (2016): Livelihood diversification as a climate change coping strategy adopted by small-scale fishers of Bangladesh. In Climate Change Adaptation, *Resilience and Hazards.* pp. 345–368

Denevan, W.M., (1983): Adaptation, variation, and cultural geography, *Professional Geographer*, Vol. 35, pp.399–407.

Diffenbaugh, N.S., Giorgi, F., Pal, J.S. (2008): Climate Change hotspots in the United States, *Geophysical Research Letters*, 35(16), DOI: 10.1029/2008GL035075

Dorland, Wan. (1980): *Dorland's medical dictionary*, Saunders Press.

Easterling, W. III. (1996). Adapting North American agriculture to climate change in review. *Agriculture and Forest and Meteorology*, 80:1-54.

Easterling, W.E., Crosson, P.R., Rosenberg, N.J., Mckenney, M.S., Katz, L.A., Lemon, K.M. (1993): Paper 2. Agricultural impacts of an responses to climate change in the Missouri-Iowa-Nebraska-Kansas (MINK) region, *Climate Change*, 24(1-2), pp. 23-61.

Eicken, H., Kaufman, M., Krupnik, I., Pulsifer, P., Apangalook, L., Apangalook, P., Weyapuk JR, W., Leavitt, J. (2014): A framework and database for community sea ice obeservations in a changing Arctic: an Alaskan prototype for multiple users, *Polar Geography*, 37(1), pp. 5-27.

Erda, L., Wei, X., Hui, J., Yinlong, X., Yue, L., Liping, B., Liyong, X. (2005): Climate change impacts on crop yield and quality with CO2 fertilization in China. *Philosophical Translations of the Royal Society*, Vol. 360, pp. 2149–2154. DOI: 10.1098/rstb.2005.1743.

Eucharia, A.O., Arua, R., Festus, U.A. (2015): Effects of climate variability on the choice of livelihood among farm households in Anambra State, Nigeria, *African Journal of Agricultural Research,* 10(44), 4134-4141. DOI: http://dx.doi.org/10.5897/AJAR2015.9663

Falco, S., Veronesi, M., Yesuf, M. (2010); *Does Adaptation to Climate Change Provides Food Security? A Micro Perspective from Ethiopia*, Working Paper No. 22, Centre for Climate Change Economics and Policy

Ford, J.D., Smit, B. and Wandel, J. (2006): Vulnerability to Climate Change in the Arctic: A Case Study from Arctic Bay, Canada, *Global Environmental Change*, 16, pp. 145-160. https://doi.org/10.1016/j.gloenvcha.2005.11.007

Ford, J.L., Berrang-Ford, L., king, M., Furgal, C. (2010): Vulnerability of Aboriginal health systems in Canada to climate change, Global Environmental Change, 20(4), pp. 668-680, DOI: https://doi.org/10.1016/j.gloenvcha.2010.05.003

Forest Survey of India (FSI) (2019): State of Forest Report 2019, Ministry of Environment Forest and Climate Change, Dehradun, India

Frankel, S (2011): Trademarks and traditional knowledge and cultural intellectual property rights, *Victoria University of Wellington Legal Research papers*, 1 (6), pp. 36

Frankhauser, S., (1996): The Potential Cost of Climate Change Adaptation, *Adaptation to Climate Change: An international Perspective*, Springer, New York, pp. 80-96

Fritze. J.G., Blashki, G.A., Burke, S., Wiseman, J. (2008): Hope, despair and transformation: Climate Change and the promotion of mental health and wellbeing, *International Journal of Mental Health System*, 2(1), pp.1-10. DOI: http://dx.doi.org/10.1186/1752-4458-2-13

Fussel, H. (2007): Vulnerability: A general applicable conceptual framework for climate change research, *Global Environmental Change*, Vol. 17 (2), pp. 155-167

Fussel, H. (2009): Review and quantitative analysis of indices of climate change exposure, adaptive capacity, sensitivity and impacts. In Background Note to the World Development Report, 2010, World Bank, Washington DC.

Gabrehiwot, T., & Veen, A.V.D. (2013): Farm Level Adaptation to Climate Change: The Case of Farmer’s in the Ethiopian Highlands, *Environmental Management*, 52 (1), pp. 29-44. DOI: 10.1007/s00267-013-0039-3

Gallopin, G.C. (2003): What kind of system of science (and technology) is needed to support the quest for sustainable development? In: Schellnhuber, H.J., Crutzen, P.J., Clark, W.C., Claussen, M., Held, H. (eds.) Earth system analysis for sustainability. The MIT Press, Cambridge, MA, pp. 367-386.

Gallopin, G.C. (2006): Linkages between vulnerability, resilience, and adaptive capacity, *Global Environmental Change*, (16), pp.293-303.

Gbetibouo, G. A., & Ringler, C. (2009:. *Mapping South African farming sector vulnerability to climate change and variability: A subnational assessment*. International Food Policy Research Institute (IFPRI) and Center for Environmental Economics and Policy in Africa (CEEPA), pp. 2-4

Gearheard, S., Matumeak, W., Angutikjauaq, I., Maslanik, J., Huntington, H.P., Leavitt, J., Kagak, D.M., Tigullaraq, G., Barry, R.G. (2006): *"It's Not that Simple": A collaborative comparision of sea ice environments, their uses, observed changes, and adaptation in Barrow, Alaska, USA and Clyde River, Nunavut, Canada*. Abio, 35(4), pp. 203-211.

Gocic, M., Trajkovic, S. (2013): Analysis of changes in meteorological variables using Mann-Kendall and Sen's slope estimator statistical tests in Serbia, *Global and Planetary Change*, Vol. 100, pp. 172-182.

Gosoniu & Laura (2012): Spatially Explicit Burden Estimates of Malaria in Tanzania: Bayesian Geostatistical Modeling of the Malaria Indicator Survey Data, *PloS One*, Vol..7(5), pp. e23966.

Goswami, B.N., Venugopal, V., Sengupta, D., Xavier, P. (2007): Increasing Trend of Extreme Rain Events Over India in a Warming Environment, *Science*, 314(5804). pp. 1442-5. DOI: http://dx.doi.org/10.1126/science.1132027

Government of Mizoram (GoM) (2012): State Action Plan on Climate Change: Mizoram 2012- 2017, Department of Science & Technology, Government of Mizoram, Accessed from https://forest.mizoram.gov.in/uploads/attachments/eaca54828e34ef7b4472fd5c985fd31b/pages-202-sapc-mizoram-2012-17.pdf

Grasso, M., Manera, M., Chiabai, A., Markandya, A. (2012): The health effects of climate change: a survey of recent quantitative research, *International Journal of Environmental Research and Public Health*, Vol.. 9(5), pp. 1523-1547.

Guerra, C.A., Gikandi, P.W., Tatem, A.J., Noor, A.M., Smith, D.L., Hay, S.I., Snow, R.W. (2008): The limits and intensity of *Plasmodium falciparum* transmission: implications for malaria control and elimination worldwide, *PLoS Medicine*, Vol.. 5, pp. e38.

Guiteras, R. (2007): *The Impact of Climate Change on Indian Agriculture*, Job market paper- Draft. December, 2007.

Hahn, M.B., Riederer, A.M., Foster, S.O. (2009): The Livelihood Vulnerability Index: a pragmatic approach to assessing risks from climate variability and change– a case study in Mozambique, *Global Environmental Change* , 19, pp. 74–8

Hay, S.I., Myers, M.F., Burke, D.S., Vaughn, D.W., Endy, T., Ananda, N., Shanks, G.D., Snow, R.W., Rogers, D.J. (2000): Etiology of interepidemic periods of mosquito-borne disease, *Proceedings of the National Academy of Sciences of the United States of America USA*, Vol.. 97(16), pp. 9335–9339.

Hossain Md. S., Roy K., Datta D. K. (2014): Spatial and Temporal Variability of Rainfall over the South-West Coast of Bangladesh, *MDPI Journal, Basel, Switzerland*.

Hotelling, H. (1933), Analysis of a complex of statistical variables into principal components, *Journal of Educational Psychology*, 24, pp. 417–441, and pp. 498–520

Huang, F., Zhou, S., Zhang, S., Wang, H., Tang, L. (2011): Temporal correlation analysis between malaria and meteorological factors in Motuo County, Tibet, *Malaria Journal,* 10(1), 54.

INCCA (2010): *Indian Network for Climate Change Assessment. Report 2. Climate Change and India: A 4x4 Assessment - A sectoral and Regional Analysis for 2030s, Ministry of Environment and Forest, Government of India*. http://www.indiaenvironmentportal.org.in/files/fin-rpt-incca.pdf (accessed on 28th May, 2018)

Intergovernmental Panel on Climate Change (IPCC) (1990): C*limate Change: The IPCC Scientific Assessment* [J. T. Houghton, G. J. Jenkins and J. J. Ephraums (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Intergovernmental Panel on Climate Change (IPCC) (2007): *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)* [Solomon, S., D. Qin, M. Manning,

Intergovernmental Panel on Climate Change (IPCC) (2007): Climate Change 2007: *The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (IPCC) [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H. L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Intergovernmental Panel on Climate Change IPCC (2014): Summary for policymakers. In: Climate Change 2014: *Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of* *the Intergovernmental Panel on Climate Change* [Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R. and White, L.L. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1-32. https://www.ipcc.ch/site/assets/uploads/2018/03/ar5_wgII_spm_en-1.pdf (accessed on 20th May, 2018)

Intergovernmental Panel on Climate Change IPCC, 2001b: *Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [McCarthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken, and K.S. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1031.

Ives J.D., Messerli. B. (1989): The Himalayan Dilemma: Reconciling Development and conservation. Routledge: New York

Jain S. k., & kumar V. (2012): Trend Analysis of Rainfall and Temperature Data for India. *Current Science. Vol.. 102. No. 1.* pp. 41-46.

Jain S.K., Kumar V., Saharia M. (2013): Analysis of rainfall and temperature trends in Northeast India, *International Journal of Climatology*, 33, pp. 968-978.

Janssen, M., Schoon, M., Kee, W., & Borner, K. (2006): Scholarly networks on resilience, vulnerability and adaptation within the human dimensions of global environmental change. *Global Environmental Change*, 16, pp. 240-252. doi: https://doi.org/10.1016/j.gloenvcha.2006.04.001

Jha, S. K., Mishra, S., Sinha, B., Alatalo, J. M., Pandey, R. (2017): Rural development program in tribal region: A protocol for adaptation and addressing climate change vulnerability, *Journal of Rural Studies*, Vol. 51, pp.151–157.

Jianjun, J., Yiwei, G., Xiaomin, W., Nam, P.K. (2015): Farmers' risk preferences and their climate change adaptation strategies in the Yongqiao District, China, *Land Use Policy*, Vol. 47 (2015), pp. 365–372

Jolliffe I.T. (2002): *Principal Component Analysis*, Series: Springer Series in Statistics, 2^{nd} ed., Springer, NY, 2002, XXIX, 487 p. 28 illus.

Jones, L., Boyd, E. (2011): Exploring social barriers to adaptation: insights from Western Nepal, *Global Environmental Change*, Vol. 21(4), pp.1262-1274.

Jones, P.G. and Thornton, P.K. (2003): The Potential Impacts of Climate Change on Maize Production in Africa and Latin America in 2055, *Global Environmental Change*, 13, pp. 51-59. https://doi.org/10.1016/S0959-3780(02)00090-0

Karuppusamy, B., Sarma, D.K., Lalmalsawma, P., Pautu, L., Karmodiya, K., Nina, P.B. (2021): Effect of climate change and deforestation on vector borne diseases in the North-Eastern Indian State of Mizoram bordering Myanmar, *The Journal of Climate Change and Health*, 2 (2021), pp. 1-8

Kelly, P.M., Adger, W.N. (2000): Theory and Practice in Assessing Vulnerability to Climate Change and Facilitating Adaptation, *Climate Change*, (47), pp. 325-352. DOI: http://dx.doi.org/10.1023/A:1005627828199

Kelly-Hope, L., Hemingway, J., McKenzie, F.E. (2009): Environmental factors associated with the malaria vectors *Anopheles gambiae* and *Anopheles funestus* in Kenya, *Malaria Journal*, 8, pp. 268.

Kim, Y-M., Park, J-W., Cheong, H-K., (2012): Estimated effect of climatic variables on the transmission of *Plasmodium vivax* malaria in the Republic of Korea, *Environmental Health Perspectives*, Vol.. 120(9), pp. 1314 – 1319

Kjellstrom, T., Holmer, I., & Lemke, B. (2009): Workplace heat stress, health and productivity–an increasing challenge for low and middle income countries during climate change, *Global Health Action*, *2*(1), pp. 20-47.

Koening U., Abegg B. (1997): Impact of Climate Change on Winter Tourism in the Swiss Alps. Journal of Sustainable Tourism, 5(1), pp. 46-58. DOI: 10.1080/09669589708667275

Kohler T., Wehrli A., Jurek M. (eds) (2014): *Mountains and climate change: A global concern*. Sustainable Mountain Development Series. Bern, Switzerland, Centre for Development and Environment (CDE), Swiss Agency for Development and Cooperation (SDC) and Geographica Bernensia.

Kothari, A. (2007): Traditional Knowledge and Sustainable Development, *International Institute for Sustainable Development, Draft for Discussion, September, Canada*. Retrieved from http://search.iisd.org/pdf/2007/igsd_traditional_knowledge.pdf

Kothawale, D.R., Munot, A.A., Kumar, K.K. (2010): *Surface air temperature variability over India during 1901-2007, and its association with ENSO*, Climate Research, pp. 89-104.

Kripalani, R., & Kumar, P. (2004): Northeast Monsoon Rainfall Variability over South Peninsular India vis-à-vis Indian Ocean Dipole Mode, *International Journal of Climatology*. 24(10), pp. 1267-1282.

Krishnan, Vijaya (2010): *Constructing an Area-based Socio economic Index: A Principal Components Analysis Approach*, An earlier version of this paper was presented at the

Early Childhood Intervention Australia (ECIA) 2010 Conference, “Every day in every way: Creating learning experiences for every child”, National Convention Centre, Canberra, Australia, 20-22 May 2010

Kristan, M., Abeku, T.A., Beard, J., Okia, M., Rapuoda, B., Sang, J., Cox, J. (2008): Variations in entomological indices in relation to weather patterns and malaria incidence in East African highlands: implications for epidemic prevention and control, *Malaria Journal*, Vol.- 7(231).

Krupnik & Jolly, D. (2002): The Earth is Faster Now: Indigenous Obervation of Artic Environmental Change, Fairbanks: Arctic Research Consortium of the United States (ARCUS), *Etudes Inuits*, *Inuits Studies*, 26(2), pp. 196, DOI: http://dx.doi.org/10.7202/007655ar

Krupnik, I., Jolly, D. (2002): *The Earth is faster now: Indigenous observations of Arctic environmental change*, Fairbanks: Arctic Research Consortium of the United States (ARCUS)

Kumar, K.S., Parikh, J. (2001): Indian Agriculture and Climate Sensitivity, *Global Environmental Change*, Vol. 11, pp.147–154

Lammel, A., Dugas, E., & Guillen, C. (2011): Traditional Way of Thinking and Prediction of Climate Change in New Caledonia (France), *Indian Journal of Traditional Knowledge*, Vol. *10*(1), pp. 13–20.

Lanzante, J.R. (1996): Resistant, Robust and Non-Parametric Techniques for the Analysis of Climate Data: Theory and Examples, Including Applications to Historical Radiosonde Station Data, *International Journal of Climatology*, 16, pp.1197-1226, DOI: https://doi.org/10.1002/(SICI)1097-0088(199611)16:11%3C1197::AID-JOC89%3E3.0.CO;2-L

Latha, K.V.A., Gopinath, M., Bhat, A.R.S. (2012): Impact of Climate Change on Rainfed Agriculture in India: A Case Study of Dharwad, *International Journal of Environmental Science and Development*, Vol. 3(4), pp. 368-371, DOI: http://dx.doi.org/10.7763/IJESD.2012.V3.249

Lewis, L.A., Mortimore, M. (2000): Roots in the African Dust: Sustaining the Sub-Saharan Drylands, *African Studies Review*, 76(4), DOI: http://dx.doi.org/10.2307/144394

Loha, E., Lindtjorn, B. (2012): Model variations in predicting incidence of Plasmodium falciparum malaria using 1998-2007 morbidity and meteorological data from south Ethiopia, *Malaria Journal*, Vol.. 9, pp. 166.

Macchi, M. (2008): *Indigenous and Traditional Peoples and Climate Change* (Issue Paper), International Union for Conservation of Nature, Retrieved from https://cmsdata.iucn.org/downloads/indigenous_peoples_climate_change.pdf

Macdonald, G. (1957): *The Epidemiology and Control of Malaria*, Oxford University Press, 201.

Maddison, D. (2006): The perception of and adaptation to climate change in Africa, CEEPA Discussion Paper No. 10, *Centre for Environmental Economics and Policy in Africa*, University of Pretoria, South Africa

Mall, R.K., Singh, R., Gupta, A., Srinivasan, G., Rathore, L.S. (2006): Impact of Climate Change on Indian Agriculture: A Review, *Climatic Change*, 78. pp. 445-478, DOI: https://doi.org/10.1007/s10584-005-9042-x

Mariara, J.K., Karanja F. K., (2007): The Economic Impact of Climate Change on Kenyan Agriculture, *World Bank Policy Research Working Paper 4334*, August 2007

Martens, P., Kovats, R.S., Nijhof, S., Vries, P De., Livermore, M.T.J., Bradley, D.J., Cox, J. McMichael, A.J. (1999): Climate change and future populations at risk of malaria, *Global Environmental Change*, Vol.. 9, pp. 89–107.

McCarthy, J.J. (2001): Impacts, Adaptation, and Vulnerability- Contribution of working group II to Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK.

McCarthy, J.J., Canziani, O.F., Leary, N., Dokken, D.J., White, K.S. (2001): Climate change 2001: Impacts, adaptation, and vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), *Global Ecology and Biogeography*. 12:87-88.

McGeehin, M.A., Mirabelli, M. (2001): The Potential Impacts of Climate Variability and Change on temperature-related morbidity and mortality in the United States. *Environ Health Prospectives*, 109 (2), pp. 185-189, doi: 10.1289/ehp.109-1240665

McGuigan, C., Reynolds, R., & Wiedmer, D. (2002): *Poverty and Climate Change: Assessing Impacts in Developing Countries and the Initiatives of the International Community*, London School of Economics Consultancy Project for the Overseas Development Institute.

Mckenna Jr., J.E. (2003): An enchanced cluster analysis program with bootstrap significance testing for ecological community analysis, *Environ. Model. Softw*., 18 (3), pp- 205-220.

McLeman, R., Smit, B. (2006): Migration as an Adaptation to Climate Change, *Climatic Change*, 76, pp.31–53, DOI: https://doi.org/10.1007/s10584-005-9000-7

McMichael, A.J., Campbell-Lendrum, D.H., Corvalán, C.F., Ebi, K.L., Githeko, A.K., Scheraga, J.D., Woodward, A. (2003): *Climate Change and Human Health: Risks and Responses*, World Health Organization, Geneva.

Mendelsohn, R. & Dinar, A. (2009): *Climate change and agriculture; An economic analysis of global impacts, adaptation and distributional effects*, Edward Elgar, UK, ISBN: 978-1-84720-670-1. 45-51.

Messerli, B., Ives, J.D. (1997): Mountains of the world: A Global Priority, *Land Degradation and Development*. 11 (2): pp. 197-198. DOI: 10.1002/(SICI)1099-145X(200003/04)11:2<197::AID-LDR390>3.0.CO;2-U

Mirza, M. (2003): Climate change and extreme weather events: Can developing countries adapt?, *Climate Policy*, 3(3), pp. 233-248, DOI: http://dx.doi.org/10.1016/S1469-3062(03)00052-4

Nag, P. K., Nag, A., & Ashtekar, S. P. (2007): Thermal limits of men in moderate to heavy work in tropical farming, *Industrial Health*, *45*(1), pp.107-117.

Nakashima, D. J., McLean, K. G., Thulstrup, H. D., Castillo, A. R., & Rubis, J. T. (2012): *Weathering Uncertainty: Traditional Knowledge for Climate Change Assessment and Adaptation*, Paris and Darwin: UNESCO and UNU.

Nielsen, J. Ø., Reenberg, A. (2010): Cultural barriers to climate change adaptation: A case study from Northern Burkina Faso, *Global Environmental Change*, Vol. 20 (1), pp. 142-152.

Nkurunziza, H., Gebhardt, A., Pilz, J. (2010): Bayesian modelling of the effect of climate on malaria in Burundi, *Malaria Journal*, Vol.. 9, pp. 114.

O'Brien, K., Leichenko, R., Kelkar, U., Venema, H., Aandahl, G., Tompkins, H., West, J. (2004): Mapping vulnerability to multiple stressors: climate change and globalization in India, *Global environmental change*, Vol. 14(4), pp. 303-313.

Ogra, M. V., Badola, R. (2015): Gender and climate change in the Indian Himalayas: Global threats, local vulnerabilities, and livelihood diversification at the Nanda Devi Biosphere Reserve, *Earth System Dynamics*, Vol. 6(2).

Ojwang, G. O., Agatsiva, J., Situma, C. (2010): *Analysis of Climate Change and Variability Risks in the Smallholder Sector. Case Studies of the Laikipia and Narok Districts representing major agro-ecological zones in Kenya*. Department of Resource Surveys and Remote Sensing (DRSRS) in collaboration with the Food and Agriculture Organization of the United Nation. Rome.

Parry, L., Carter, T.R. (1989): An assessment of the effects of climate change on agriculture, *Climatic Change*, 15, pp. 95-116, DOI: doi.org/10.1007/BF00138848

Parry, M. L., Canziani, O. F., Palutikof, J. P., Van der Linden, P. J. and Hanson, C. E. (eds). (2007): *Contribution of Working Group II tothe Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, UK, pp. 976.

Patra, J. (2014): Linking Assessments with Actions Climate Change Adaptations, *Economic and Political Weekly*, Vol. 49 (47)

Patz, J., Lendrum, D.C., Holloway, T., Foley., J.A. (2005): Impact of Regional Climate Change on Human Health, *Nature*, 438 (7066), pp. 310-317, DOI: 10.1038/nature04188

Patz, J.A., Kovats, R.S. (2002): Hotspots in Climate Change and human health, *BMJ Clinical Research*, 325 (7372:1094-8), DOI: 10.1136/bmj.325.7372.1094

Pearson, K. (1901): On Lines and Planes of Closest Fit to Systems of Points in Space, *Philosophical Magazine*, 2 (6), pp. 559–572

Poumad'ère, M., Mays, C., Le Mer, S., Blong, R. (2005): The 2003 heat wave in France: dangerous climate change here and now, *Risk Analysis*, 25(6), pp. 1483–1494.

Pranjay, R. (2012): Urbanization, climate change and water security: a study of vulnerability and adaptation in Sultanpur and JhanjhrolaKhera in peri-urban Gurgaon, *Peri-Urban Water Security Discussion* Paper Series, Paper 3

Raja, P.R., Reddy, S.R., (2018): Rainfall Trend Analysis of a Mini Watershed: A Case Study on Degrading Lakes/Tanks. *International Journal of Research GRANTHAALAYAH*, 6(7), pp. 24-44, DOI: 10.5281/zenodo.1322995

Rajeevan, M.N., & Nayak, S. (2017): *Observed Climate Variability and Change over the Indian Region,* Springer Geology, DOI: 10.1007/978-981-10-2531-0

Rakib, M.A., Sasaki, J., Pal, S., Newaz, Md. A., Bodrud-Doza, Md. (2019): An investigation of coastal vulnerability and internal consistency of local perceptions under climate change risk in the southwest part of Bangladesh, *Journal of Environmental Management*, 231 (2019), pp. 419-428.

Ravindranath, N. H., Rao, S., Sharma, N., Nair, M., Gopalakrishnan, R., Rao, A. S., Krishna, N. (2011): Climate change vulnerability profiles for North East India, *Current Science*, pp. 384-394.

Reuveny, R. (2007): Climate Change-Induced Migration and Violent Conflict, *Political Geography*, 26(6), pp. 656-673, DOI: 10.1016/j.polgeo.2007.05.001

Riedlinger, D., & Berkes, F. (2001): Contributions of Traditional Knowledge to Understanding Climate Change in the Canadian Arctic, *Polar Record*, *37*(203), pp. 315–328.

Rogers, D.J., Randolph, S.E. (2000): The global spread of malaria in a future, *warmer world*, Vol.. 289, pp. 1763-1765.

Rosenzweig, C., Iglesias, A., Yang, X.B., Epstein, P.R., Chivian, E. (2001): Climate change and extreme weather events; implications for food production, plant diseases, and pests, *Global change and human health*, Vol. 2(2), pp. 90-104.

Sahoo, U.K., Singh S.L., Lalnundanga., Lalnuntluanga., Devi A.S., Zothanzama, J. (2018): Climate Change Impacts on Forest and its Adaptation study in Mizoram, Mizoram University, Aizawl.

Sakakibara, C. (2008): Our home is drowning, Iñupiat storytelling and climate change in Point Hope, Alaska, *Geographical Review*, Vol.. 98, pp. 456–475.

Salmi T., Maatta A., Anttila P., Airola T.R., Amnell T. (2002): Dectecting Trends of Annual Values of Atmospheric Pollutants by the Mann-Kendall Test and Sen's Slope Estimates- The Excel Template Apllication Makesens, Finnish Meteorological Institude.

Seo, N. Mendelsohn, R. (2008): A Structural Ricardian Analysis of Climate Change Impacts and Adaptations in African Agriculture, *World Bank Policy Research Working paper 4603*, April 2008

Shrestha, S., Kazama, F. (2007): Assessment of surface water quality using multivariate statistical techniques: a case study of the Fuji river basin, Japan, *Environ. Model. Softw*., 22. pp. 464-475.

Singh, N., Sharma, V.P. (2002): Patterns of rainfall and malaria in Madhya Pradesh, central India, *Annal Tropical Medicine and Parasitology*, 96(4), pp. 349–59.

Smit, B & Pilifosova, O. (2001): 'Adaptation to climate change in the context of sustainable development and equity'. Climate change: Impacts, adaptation and vulnerability.

Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, Cambridge University Press, pp. 877–912.

Smit, B. (1993): *Adaptation to climate variability and change*, Environment Canada, Guelph

Smit, B. and Wandel, J. (2006): Adaptation, adaptive capacity and vulnerability, *Global Environmental Change*, Vol. 16, pp. 282-292

Smit, B., Burton, I., Klein, R. J. T., Wandel, J. (2000): An anatomy of adaptation to climate change and variability, *Climatic Change*, Vol. 45, pp 223–251.

Smit, B., Wandel, J., (2006): Adaptation, adaptive capacity and vulnerability, *Global Environmental Change*, 16 (3), pp. 282–292

Smith, J.B. (1996): Using a decision matrix to Assess Climate Change Adaptation, Adaptation to Climate Change: An international Perspective, *Springer*, New York, pp. 68-79

Sridevi, Jyotishi, G., Amalendu, Mahapatra, Kumar, S., Jagadeesh, G., Bedamatta, Satyasiba, (2014): Climate Change Vulnerability in Agriculture Sector: Indexing and Mapping of Four Southern Indian States Quaderni WorkingPaperDSEN°966. Available at SSRN: https://ssrn.com/abstract=2503834 or http://dx.doi.org/10.2139/ssrn.2503834.

Stenseth, N. C., Mysterud, A., Ottersen, G., Hurrel, J.W., Chan, K., Lima, M. (2002): Ecological Effects of Climate Fluctiations, *Science*, 289, pp. 1292-1295.

Tam, B. (2012): *The Effects of Weather and Climate Variability on the Well Being of a Rural and Urban Aboriginal Group in Ontario, Canada*, Department of Geography, University of Toronto, Canada.

Tebtebba Foundation. (2011): *Indigenous Women, Climate Change and Forests*, Philippines: Tebtebba Foundation.

TERI (The Energy and Resources Institute) (2003): *Coping with global change: vulnerability and adaptation in Indian agriculture*, Delhi, India.

Tol, R.S.J., Frankhauser, S., Smith, J.B., (1997): *The scope of Adaptation to Climate Change: What Can We Learn from the Literature?*, Institute for Environmental Studies, Vrijc Universiteit, Amsterdam.

Tompkins, E., Adger, W.N. (2004): Does Adaptive Management of Natural Resources Enhance Resilience to Climate Change?, *Ecology and Society*, 9(2), DOI: http://dx.doi.org/10.5751/ES-00667-090210

Tulu, Nega, A. (1996): Determinants of malaria transmission in the highlands of Ethiopia: the impact of global warming on morbidity and mortality ascribed to malaria, *London School of Hygiene & Tropical Medicine*, pp. 13-34

UNDP (2005): In: Lim B, Spanger-Siegfred E (eds). *Adaptation policy framework for climate change: developing policies strategies and measures*, Cambridge University Press, Cambridge.

Upadhyaya, H. (2014): *Vulnerability and adaptation to climate change in the context of water resource with reference to Rajasthan*, Department of Geography, The IIS University, Jaipur.

Varadan, R. J., Kumar, P. (2015): Mapping agricultural vulnerability of Tamil Nadu, India to climate change: a dynamic approach to take forward the vulnerability assessment methodology, *Climatic change*, Vol. 129(1-2), pp. 159-181.

Venkateswarlu, B., Shanker, A.K. (2009): Climate change and agriculture: Adaptation and mitigation strategies, *Indian Journal of Agronomy*, 54(2), pp. 226-230

Walther, GR., Post, E., Convey, P., Menzel A., Parmesan C., Beebee T.J.C., Fromentin. J.M., Guldberg, O.H., Bairlein F. (2002): Ecological responses to recent climate change, *Nature*, **416,** pp. 389–395 https://doi.org/10.1038/416389a

Wang, C.L., Zhao, N., Yue, T.X., Zhao, M.W., and Chen, C. (2015): Change trend of monthly precipitation in China with an improved surface modelling method, *Environmental Earth Sciences*, Vol. 74(8), pp. 6459-69.

Wang, J., Mendelsohn, R., Dinar, A., Huang, J. (2008): How China's farmers adapt to climate change, *World Bank Policy Research Working paper 4758; October 2008. https://openknowledge.worldbank.org/handle/10986/6915*

Wani, S.A., Mahdi, S.S., Samoon, S.A., Hassan, G.I., Dar, S.A. (2020): Climate change-its impact on Argriculture, *Phytol*, 2(10), pp. 82-86.

Warren, R., Price, J., Fischlin, A., de la Nava Santos, S., & Midgley, G. (2011): Increasing impacts of climate change upon ecosystems with increasing global mean temperature rise, *Climatic Change*, *106*(2), pp.141-177.

WHO (2011): *World Health Statistics 2011*, World Health Organisation (WHO), (ISBN 9789241564199).

Wilkinson, R. and Teresa, R. (1998): *Climate Change and Variability in California; White paper for the California Regional Assessment. National Center for Ecological Analysis and Synthesis, Santa Barbara, California Research Paper No. 4*. Online: http://www.nceas.ucsb.edu/papers/climate.pdf

World Trade Organization-United Nations Environment Programme ((WTO-UNEP) (2009): Trade and climate change WTO-UNEP report. Accessed from https://www.wto. org/english/res_e/booksp_e/trade_climate_change_e.pdf.

Yazoume Ye., Kyobutungi, C., Louis, V.R., Born, R.S. (2007): Micro epidemiology of Plasmodium falciparum malaria: Is there any difference in transmission risk between neighbouring villages, *Malaria Journal*, Vol. 6(46).

Zhou, G., Munga, S., Minakawa, N., Githeko., A.K., Yan, G. (2007): Spatial relationship between adult malaria vector abundance and environmental factors in western Kenya highlands, *The American Journal of Tropical Medicine and Hygiene*, Vol.. 77(1), pp. 29–35.

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2.	An Estimation of Annual and Seasonal Rainfall Anomaly Index for Aizawl District, Mizoram	Geographic	0975-4121	2021	Peer reviewed journal
3.	Long Term Annual and Seasonal Temperature and Rainfall Trend Analysis in Aizawl District, Mizoram	Contemporary Issues, Problems and Challenges in India	978-81-953777-1-8	2021	Book chapter

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Sl.No	Title of the Paper presented	Title of Conference / Seminar	Organised by	Whether international /national/ state /regional /college
1.	Trend Analysis of Annual and Seasonal Relative Humidity in Mizoram	Mizoram Science Congress 2020	Directorate of Science and Technology, Govt. of Mizoram	State level
2.	Analysis of Rainfall Trend by Mann Kendall and Sen's Slope Estimator for the state of Mizoram	International Seminar on Recent Advances in Science and Technology (ISRAST)	Mizoram University	International Level
3.	Climate Change: Long Term Analysis of Temperature and Rainfall in Aizawl District, Mizoram.	National Seminar on Climate and Development Interface	Govt. Aizawl North College, Department of Geography and State Institution of Rural Development & Panchayati Raj (SIRD), Govt of Mizoram	National Level

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ABSTRACT

CLIMATE VARIABILITY, VULNERABILITY AND ADAPTIVE STRATEGIES FOR SOCIAL WELL-BEING IN MIZORAM

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CLIMATE VARIABILITY, VULNERABILITY AND ADAPTIVE STRATEGIES FOR SOCIAL WELL-BEING IN MIZORAM

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ABSTRACT

Climate Variability, Vulnerability and Adaptive Strategies for Social Well-being in Mizoram

The focus on the impacts of climate variability and change on social well-being with reference to the vulnerability and adaptive capacity is important as the different sector of wellbeing is considered to be highly sensitive to the impacts of climate change. Today, research on climate change and global warming is crucial because, if adaptation measures are not implemented properly, there could be significant environmental changes that have a negative impact on human health, agriculture, disease prevalence, and other aspects of society worldwide. Thus, it is imperative that any scientific study on climate change include the vulnerabilities of various locations and its effects on several sectors. The study of climate change has gained significant importance in recent times due to its grave consequences for the sustainability and livability of the planet. Without sufficient historical climatic data, climate change is a long and gradual process that is difficult to identify and sense.

Global documentation of the impact of climatic variability and change on social well-being is available. The availability of water, biodiversity, human health, human settlements, and food production and security are all negatively impacted by climate change. Numerous communities will be vulnerable to the negative health consequences of extreme weather and temperature, air pollution, waterborne infections, foodborne infections, vector-borne infections, and zoonotic illnesses (Patz and Kovats 2002). Several studies have demonstrated that climate change and variability have a significant negative influence on the environment and negatively affect societal well-being when adaptation is not implemented. In the context of adaptation, it is imperative to leverage several opportunities to reduce sensitivity to unpredictability and climate change (Easterling et al., 1993).

The present research work has been carried out in the state of Mizoram, it lies in the southernmost region of the Northern Eastern Himalayan hill ranges. Three sub-agroclimatic zones have been identified for the state: the Humid Temperate Subalpine Zone, the Humid Subtropical Hill Zone, and the Humid Mild Tropical Hill Zone. The state's monsoon season is crucial in determining its climate, which is

marked by a brief, dry winter from November to February and monsoon rains from May to September. The greatest Monsoon rainfall occurs between the months of June through August each year. The agricultural industries have a significant impact on the state's economy.

The main objectives of the study are-

1. To examine past climate change and variability in Mizoram through instrumentally recorded climate data.
2. Analysis of climate variability by traditional ecological knowledge.
3. To assess climate vulnerability in Mizoram and develop a district-wise vulnerability index.
4. To analyze the dynamic relationship between climate and social well-being of various communities in Mizoram.

1. Analysis of trends and patterns in temperature and rainfall

The first objective of the study deals with the assessment of variation and trend analysis of climate parameters (temperature and rainfall) in Mizoram for the time period of 35 years (1986-2020) using statistical method of coefficient of variation and Mann Kendall & Sen’s slope test. Using the coefficient of variation, we discovered that the research period's months of January, February, November, and December had the biggest magnitude variations in rainfall, while the years 2006–2010 had the highest variations in rainfall. On the other hand, the seasons of Spring and Winter in the years 2016–2020 and 2006–2010, respectively, had the greatest seasonal fluctuation in rainfall. On the other hand, a pattern of little variance in both the maximum and minimum temperature is shown by looking at the temperature coefficient of variation. During the lustrum years of 2016–2020, the research period showed an unusual growing shift of high variability in maximum temperature in the months of September, October, November, and December. However, the seasonal change in maximum temperature shows the complex structure with significant variance.

The Mann-Kendall and Sen’s slope results of the rainfall trend study show that the monthly, annual, and seasonal rainfall trends are all continuously declining. With a Sen's slope magnitude of -12.53, the total annual precipitation shows a significant negative trend ($p < 0.05$). 2019 also saw the least amount of rainfall across the studied period. In contrast to rainfall, the annual maximum temperature exhibited a statistically significant upward trend ($p < 0.01$), signifying a rise in both the annual and seasonal maximum temperature. Similarly, there was a positive tendency detected in the seasonal maximum temperature, with the winter recording the strongest positive trend ($p < 0.001$). Conversely, the seasonal and annual minimum temperatures exhibit a markedly negative trend ($p < 0.005$) for the minimum temperature.

2. Analysis on Traditional Ecological Knowledge

The study's second goal focuses on Traditional Ecological Knowledge (TEK), an indigenous method for predicting the weather. According to the research, the respondents employ a total of 28 bio-indicators, which are determined based on the behaviour of different insect, bird, animal, and plant species, to predict the weather. Furthermore, a subtle shift in the climate system is suggested by the fact that some bioindicators have lately changed their behavioural patterns in reaction to the changing natural environment. A significant proportion of participants (72.3%) reported observing a shift in the singing time of cicadas, which are huge tree crickets, signifying the delayed onset of the rainy season. However, 19% of respondents thought that tree flower blossoming will change.

3. Assessment of district wise climate vulnerability

The third objective deals with the vulnerability assessment to climate change at the community level and ranking district wise vulnerability and sensitivity of the communities. According to the report, the district of Lawngtlai has the highest level of vulnerability, scoring 0.22 on the Climate Vulnerability Index. Lunglei and Siaha come in second and third, respectively, with scores of 0.21. Additionally, it was found that Mamit (0.18) and Kolasib (0.18) districts were the least susceptible to changes in the climate. The main conclusion of our study is that the districts most exposed to and sensitive to the consequences of climate change are also the ones with the highest capability for adaptation. This suggests that whereas households with relatively high sensitivity are more likely to address these sensitivities by taking whatever action they can, families with low sensitivity to climate threats are reluctant to invest in risk mitigation approaches.

To ascertain which vulnerability indicator is most vulnerable to climate change, Principal Component Analysis (PCA) was utilized. The susceptibility indicators were whittled down into seven primary components with the aid of the study. The weights assigned to each individual indication were also determined. It was found that the indicator with the highest weight, "Effects of climate change in personal occupation," (4.48), indicates the greatest impact of climate change.

Cluster analysis (CA) was employed to group districts under same clusters by determining the correlation among the wide range of variables. The districts of Aizawl, Serchhip, and Lunglei were found to have the most coherent vulnerability when analyzed using the CA method, whereas the district of Lawngtlai was found to be an outlier with no association between any of the variables and any other district.

4. Assessment on identifying coping strategies and adaptation to climate variability

The study reveals that 87 percent of respondents were found to be well-versed in the concept of climate change, and the majority of them (31.5%) got their information about it from family and friends, with television coming in second (21.4%). The agricultural sector implemented several adaptive strategies, including raising awareness of the risk of forest fires caused by Jhum cultivations, which accounted for 55% of the adoptions. It was also noted that many farmers switched from shifting cultivation to other farming practices, such as crop rotation (10%), dragon fruit plantations (5.2%), and poultry (2.2%). However, it was discovered that the water resource sector heavily relied on rainwater collecting (33.5%) to deal with the trend of decreasing rainfall and the dry season. In the health sector, it was discovered that keeping houses clean (67.6%), particularly during the rainy season, was deemed to be a crucial strategy to protect against water-borne illnesses and insects. This was followed by planting trees around houses (28.5%) to help regulate temperature, as it has been demonstrably demonstrated that the maximum temperature has been rising in recent years.