IMPACT OF RAINFALL ON CROP PRODUCTION IN MIZORAM, INDIA

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IMPACT OF RAINFALL ON CROP PRODUCTION IN MIZORAM, INDIA

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Submitted
in partial fulfillment of the requirement of the Degree of Master of Philosophy in
Department of Environmental Science of Mizoram University, Aizawl

MIZORAM UNIVERSITY
AIZAWL: MIZORAM
(A Central University established by an Act of Parliament No. 8 of 2000)
Prof. Lalnuntluanga **DEPARTMENT OF ENVIRONMENTAL SCIENCE**

CERTIFICATE FROM SUPERVISOR

This is to certify that the Dissertation entitled, "Impact of Rainfall on Crop Production in Mizoram, India", is a bonafied work assigned to Irene LalnipariSellate, Reg No. MZU/M.Phil/ 453 of 27.04.2018 Department of Environmental Science for partial fulfillment of the requirement for the degree of Master of Philosophyunder Mizoram University.

The report submitted by the candidate is her own study and carried out by her and result embodied in the Dissertation have not been submitted for award of degree any other elsewhere. It is recommended that this dissertation be placed before the examiners for the award of the degree of Master of Philosophy.

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June, 2019

DECLARATION

I, Irene LalnipariSellate, hereby declare that the subject matter of this Dissertation is the record ofwork done by me, that the contents of this Dissertation did not form basis of the award of any previous degree to me or to the best of my knowledge to anyone else, and that the Dissertation has not been submitted by me for any research degree in other University/Instituted.

This is being submitted to the Mizoram University for the degree of Master of Philosophy in Department of Environmental Science.

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ACKNWOLEDEMENT

Firstly, I would like to thank the Almighty God whose blessing for good health, kindness and guidance has enable me to complete this dissertation

I am deeply obliged to my Supervisor, Prof. Lalnuntluanga, Department of Environmental Science, Mizoram University for his priceless motivation, understanding and patience. In spite of his busy schedule, he has spared his valuable time and provided me with every bit of an unending support and expertise during the course of my research work. This dissertation would not have been possible without his guidance.

I also extend my thanks, to Prof. B.P. Mishra, Head of the Department of Environmental Science and faculty members of the Department of Environmental Science, Mizoram University for their valuable advice, encouragement, inspiration and motivation. In addition I am grateful to all the Non-Teaching staff of the Department of Environmental Science for their enormous support toward the completion of this dissertation.

I would like to convey my sincere thanks to all the individual farmers with whom I had a lovely and memorable discussions and enhance my understanding of agricultural activities carried out. Another heartfelt gratitude to all the YMA presidents and Village Council members within the agricultural circle of Champhai District. Without their cooperation and sincere support, the research would not be complete.

I am sincerely grateful to my parents for their endless support and encouragement. Also my heartfelt thanks go to my other relatives who had provided me the necessary transportation and contacts for their understanding, support and kindness.

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ABBREVIATIONS

CFC- Chlorofluorocarbon

DAP-Di-ammonium phosphate

FAO- Food and Agriculture Organization

GOI- Government of India

HYV-High Yielding Variety

INCCA-Indian Network on Climate Change Assessment

IPCC- Intergovernmental Panel on Climate Change

MIRSAC-Mizoram Remote Sensing Application Center

NLUP-New Land Use Policy

PRA-Participatory rural appraisal

UN- United Nations

UNDP-United Nations Development Programme

WHO- World Health Organization

WRC- Wetland Rice Cultivation

2,4-D- Dichlorophenoxyacetic acid

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CHAPTER I: INTRODUCTION

INTRODUCTION

Crop production is an important prospect since time memorial for mankind. It had laid the foundation of great civilizations thousands of years ago, and had been responsible for the formation of villages and towns near fertile soils and river banks. Agriculture is the major land use across the globe. Currently 1.2–1.5 billion hectares are under crops, with another 3.5 billion hectares being grazed. Agricultural activities had also been revolutionized numerous times and the revolution that occurred some 10,000 years can be attributed as the start of a new era (Saur, 1952). Growth of agriculture in the fertile soils and river valleys had helped in the rapid increase and over population which exceed the carrying capacity and exploitation of environmental resources which can be said as the cause of demise for old civilization. And its importance is rapidly increasing with the increase in natality especially in the developing countries. Mankind has been improving its agricultural activities and has supplemented its agricultural products with domesticated animals including pig, cow, chicken, turkey, goat, lamb and fishes.

During the last few decades there is an increasing emphasis on food security due to the evidence of change during 20th century (Mall et al., 2006). There is a new problem arising with the increase in population as it is estimated that there is a threefold increase in population since the 19th century to 2002 from 2 billion to over 6 billion individual. The highest decadal increase of population growth from 1950 till date was observed form 1960-1970 at 22%. However, the growth rate has continued to fall every five years and it had declined to 1.18% between 2010 and 2015 and is projected to decline further in the course of the 21st century. Currently the world's population is estimated to be about 7.7 billion. The United Nations stated that the population growth is diminishing due to demographic transition in 2006 and by 2050; the population would reach a plateau at 9.2

billion. However, the United Nations also predicted that by 2050, the population could range between 8-10.5 billion in 2009 (United Nations, 2009). According to the World Health Organization (WHO), the life expectancy is 71.4 years with the women having a life expectancy of 74 years while the male life expectancy is 69 years globally (WHO, 2016).

In India, the population has reached 1.21 billion people in 2011 and is currently the second most populous country in the world. It is estimated that by 2030, India would become the most populous country and it is predicted that the growth rate will continue through at least 2050. With the prediction of increasing life expectancy due to advancement in health care facilities, India's demand of food would continue to rise exponentially together with demand in resources.

Increasing need of resources has led to a change in the space economy and space organization all over the world and the increasing rate of food requirement has influenced the agricultural productivity capacity of different agricultural zones. Though man had numerous advances in various fields and technology had improved and search alternative livelihood of man, agriculture still covers over 35% of the ice free land to meet the need (Foley, 2014). Yet, the demand of agricultural products will continue to rise as the population is expected to rise over 9 billion in the year 2050 and this demand is expected to double of the present demand.

Crop production has been under a great stress not only from population explosion and demand of food but also from the climate. Certain crops such as rice and vegetables have a specific climatic requirement such as precipitation, temperature and humidity. Yet due to anthropogenic and agricultural activities there is an increasing change in the climatic condition all over the world.

There are a number of various factors that influence the crop productivity of a certain agricultural zone. These factors can be categorized as the climatic condition, soil properties and use of chemical substances such as fertilizers, weedicides and pesticides that enhance the yield of crops. However the first two factors can be accounted as one factor with certain properties of soil such as soil moisture and soil air which are influenced by climatic condition.

Among all the climatic conditions, the intensity and pattern of rainfall is the most prominent and rainfall is influenced by urbanization, moisture level in the atmosphere, emission of fine particulates and pollution by human activities but the most influence is by climate. The global averaged annual rainfall over the surface is about 715mm but it is estimated that 990mm is received annually over the whole Earth. The amount, intensity and pattern determine the growth and development of plants and too much or too little can cause devastation in agricultural zones. Excessive rainfall can cause harmful fungus growth and the requirement of rainfall varies. Tropical plants would require hundreds of millimeters of rain annually while certain species of cactus will survive with only a small amount of rainfall.

Based on the origin of rainfall, rainfall can be classified into three specific categories:

1. Convectional Rainfall – occurs for a short period of time and highly localized with minimum cloudiness. This type of rainfall is experienced during the summer around the equator regions such as the Congo basin, Amazon basin and some islands of south-east Asia and predominantly in the northern hemisphere. It is formed when hot air rise caused by extensive heating of the ground which then cools and condenses. Convectional rainfall is associated with towering cumulo-nimbus clouds.

2. Relief Rainfall – also known as orographic rainfall. It is formed when air is blown over the sea and forced to rise over an area of high land which cause the air to cool. Once the air is over the top, it gradually drops which warms the air slowly. This can be the cause for the air to carry greater moisture. This type of rain occurs in certain regions such as Patagonian desert in Argentina, Hawaii, Siera Nevada and Eastern slopes of Western Ghats and are responsible for arid and semi-arid regions.

3. Frontal Rainfall – occurs gradually for a few hours to a few days. It is formed when warm air is forced to rise over cold air and moisture condenses when it cools. Frontal rain produces a variety of clouds and will result in moderate to heavy rainfall. This type of rainfall commonly occurs over Britain and Ireland (Khullar, 2016).

Based on the intensity, Monjo (2016) classified rainfall into light, moderate, heavy and violent rain which corresponds to <2.5 mm, 2.5-10mm, >7.6mm or 10-50 mm and >50mm per hour respectively.

There is a certain way in which climate change can affect agriculture in numerous ways. Firstly, the quality and quality of crop production and then agricultural practices through the change of water use and agricultural inputs such as herbicides, insecticides and fertilizers. In addition to these, there are also the environmental effects in relation to the drainage and erosion of soil and the loss and gain of cultivated land and land use. With the impact of climate change there also arise the urgency to create crops that can withstand the change in pattern of precipitation, flood and salt resistant varieties (Kensa, 2011).

Climate is changing all over the world and this change will continue in an unprecedented rate in the coming years and these changes are real yet highly uncertain at the rate of which it will occur. It can change naturally for a variety of reasons. A number of the driving factors that induce climate change operate over hundreds of millions of years, whereas there are some factors that fluctuate over only a few years. A number of natural processes like variation of solar radiation and Earth's orbital parameters can cause change in the climate (Mishra, 2004). In addition to these there are change in the earth's climate caused by volcanic activities and changes in the concentration of various gases in the atmosphere over the years. These natural processes affect the radiation that is absorbed by the earth's atmosphere. But these changes caused by natural process are now exceeded by human activities (Lerner and Lerner, 2008; Hughes, 2000).

Anthropogenic activities enhance the climate change viz., increasing concentration of aerosol and concentrations of well-mixed greenhouse gases and changes in the O_3 concentration in the stratosphere and in the land surface. However, the main caused is the increased trapping of the heat from solar radiation influenced by the increase concentration of CO_2 and other greenhouse gases produced by anthropogenic activities (Santra, 2014). Farming activities is currently the largest contributor to global warming emitting more greenhouse gases than all other activities. It can be stated that large amount of methane from cattle, sheep and rice fields and nitrous oxide from fertilized fields are emitted by this activity. In addition there is a loss of CO_2 sinks due to rapid deforestation and loss of wetlands.

Change in climatic condition such as precipitation, humidity and temperature is affecting both current and future generations as it will damage the ecological system which in turn will cause a problem in developmental projects and poverty alleviation programs. Additionally, there could be large-scale migration from water or food-scarce regions and increase risk to public health (Khan et al., 2012).

The most important staple food in Mizoram is rice and the production of rice is not limited to shifting/Jhum cultivation, but also to wetland rice cultivation. Rice is the second important crop in the world cultivated within an altitude of 300-2300 meter above sea level with production of about 525 million tons from about 148 million hectares. The importance of rice could be attributed by its tolerance to a wide range of environments and thrive in areas where other crops would fail. Another importance is that rice can provide up to 50% of the dietary caloric supply and provide about 520 million people with protein in Asia Pacific region, parts of Latin America and the Caribbean. Asian countries account for almost 90% of the total rice production while Sub-Saharan African and Latin America produces about 19 and 25 million tons respectively (Chakraborty, 2001). China, India, Indonesia, Bangladesh, Vietnam, Myanmar and Thailand are the major producers of rice with China taking the lead with extensive proper irrigation system unlike the other countries. India and China accounts for about 50% of the rice grown and consumed. In some African countries, rice is slowly replacing other staple crops due to its easier preparation and affordable availability. Egypt, Nigeria and Madagascar are the leading countries that produce rice and along with other countries, Western Africa accounts for 40% of African production in 2006-08. In Latin America and the Caribbean, Brazil, Peru, Columbia and Ecuador are the leading producers with about 11.6 million tons, 2.5 million tons, 2.4 million tons, and 1.6 million tons respectively. Though wheat, maize and beans are important, rice is the main source of calories in Ecuador, Peru, Costa Rica, Panama, Guyana, Suriname, Cuba, Dominic Republic and Haiti. In Europe, Italy, Spain and Russia are the major producers but rice is not the main source of calories. Because of changing taste, ease of storage and preparation and affordability, rice consumption is on the rice in Pacific islands such as Papua New Guinea (Muthayya et al., 2014).

India is one of the largest producers of rice and the increase in rice production is more than 350% from 1950 and the yield per hectare had increased to 262% from the year 1050-1992. In 2009-10 the rice produced reaches 89.13 million (IRRI, 2000). In Mizoram, rice is grown mainly during Kharif season in an area of about 54,250 hectares and produces about 1,03,040 tons. The productivity of rice in lowland/wet rice cultivation is higher than that of jhumming at 2.82 tons/hectares and 1.57 tons/ hectares respectively. However, the total demand of rice is met by the rice produced outside the state. Therefore, there is an urgent need for Mizoram to be self sufficient (Anon, 2007).

Due to demand, the rice production has to be doubled by the year 2020 especially in South Asia (IRRI, 2000). There is a certain requirement of temperature and rainfall for rice and these determines the growth and development of rice and influence the production and productivity. Rice requires 21^{o}-25^{o}C for germination, 15^{o}-20^{o}C for transplanting, 20^{o}-25^{o}C for growth and 25^{o}-34^{o}C for tillering while it requires rainfall for germination and transplanting. However, with rainfall during harvest time, there would be a loss of rice grains (Seetraraman, 1980)

The need to increase the agricultural zone is not only because of growing demand but in order to reduce the environmental stress and degradation caused by jhumming. In Champhai district, 144.46km^2 is estimated to be annually slashed for current jhum. Thong et al. (2018) has reported that the past 17 years had showed a decreasing trend with larger part of shifting area being utilized by 2^{nd} year crop field covering 48.81% of total jhum land.

1.1 Scope of the study

The impacts that are occurring due to climate change may not be felt instantly. But this does not mean that the changes are not occurring. The changes occur slowly over the years, and may take more than decades to be noticed, and these changes are now being slowly felt and can be observed such as the melting of the polar ice caps and rise in temperature. There is now a wide spread awareness of climate change brought about by the government as well as scientist with climate change being a phenomenon with pressing issue that needs an immediate action. Climate change is becoming a global issue which is affecting each and every aspect of the environment. Countries all over the world are now joining hands to combat climate change in the highest level of organization with agreements among which carbon footprint being the most prominent. Various treaty such as the Kyoto Protocol are formulated that aimed at reducing the carbon footprint of developed countries and determination of reducing emission in the developing countries such as India. In the present generation, population explosion and rapid urbanization is demanding agricultural products at an increasing rate and the demand will continue to rise as the mortality rate is decreasing due to advances made in the medical fields while the natality rate is increasing exponentially. So, there is a greater requirement for farmland to yield more to feed the ever increasing population. Importance is now being placed on studying the impact of climatic condition such as temperature, precipitation and humidity on crop productivity. In the present age, there is now a wide spread concern of climate change not only by scientist and governments but also by the general population about its global implications. And the change in the climatic condition is well known all over the world and awareness has been given an utmost importance.

The need to assess the impact of climate change is in demand for long strategic planning so these impacts of climate change can be quantified with a temporal resolution. The need to assess the impact of climate change is of utmost important for long term strategic planning of water resources and for these effects to be quantifies with a high spatial and temporal resolutions.

Currently, there is a lack of documentation and published work on climate change in Mizoram, although research is carried out by the Government of Mizoram to assess the impact of climate change on socio-economic front. Understanding the farmers perception of the impact of climate change and adaption required need to be established. This study analyzes the impact of climate change on precipitation and how it could affect the crop productivity in the study site (Champhai District). It would also help in determining how the increase of precipitation affects the livelihood of those who are dependent on the productivity of the land.

1.2 Objective of the study

1. To study the impact of climate change on rainfall.
2. To determine the impact of precipitation on crop productivity.
3. To study the socio-economic status of the concerned individual.

CHAPTER II: REVIEW OF LITERATURE

REVIEW OF LITERATURE

Variation in the process of development is the innermost functional differences among plant genotypes and species growing in different environment. Environmental stress could have a direct impact on the plants affecting the different organs and tissues within a plant, with response from the molecular, cellular and morphological which varies among the tissues and throughout the developmental lifetime of plants. The difference in developmental processes across genotypes, and the characteristics of the plants to change their developmental processes is the main reason for the success of plants in natural and agricultural settings (Nicotra et al., 2010). The developmental response of plants to the environment may result in the altered initiation of developmental events such as the lateral root initiation (Babe et al., 2012), altered timing of developmental events (Balasubramanian et al., 2006), altered number, shape and size of leaves (Dermody et al., 2006) and change in the individual organs and whole plants such as the presence of additional nodes and larger leaves in soybean due to increase in the CO_2 concentration in the atmosphere. Any change in the function will have a significant impact on the yield of crops. In addition the crop production models are essential for the assessment of climate change on crop disease to understand interactions between crop phenology and pathogen development with impact of disease on crop yield (Newbery et al., 2016).

Crop production and quantity of yield is affected by climate change and technological advancement both directly through the changes in plant growth and production and indirectly by the impacts on plant diseases (Newbery et al., 2016) and is a main determinant of the growth and yield of crops. It has been estimated that there is a reduction of global agricultural production by 1-5% per decade over the last few decades mainly by climate change. And the climate change includes change in temperature, precipitation, and atmospheric composition along with other factors, representing a moving target for plant developmental adaptation (Gray and Brady, 2016). These climatic factors are affecting the molecular function, developmental processes, morphological traits and physiology of plants. Evaluation of the change of climate on crop production ensures the sustainable development of agriculture under climate change. The impact of climate change on the production of a variety of crops has been extensively studied in various parts of the world. It has been established that any change in the precipitation and radiation are the main factors leading to decrease of climatic potential productivity (Guo et al., 2014). Crop distribution in different agricultural zones and climate change are important drivers for crop production and this can affect food security which is required for sustainable development. However the impact of climate change differs and their effect on crop production through the intensity and pattern of rainfall can be profound (Qiao et al., 2018). Climate change is one of the most controversial topics in the field of environment, ecology and politics (Houghton et al., 1990, 1992, 1996; Watson et al., 1996). Global Warming the resultant climate change is predicted to have an increases intensity and occurrence of extreme weather events such as precipitation, cyclone, droughts and floods (IPCC, 2012). It is projected to have monumental effects on ecosystem processes including food web structure, population dynamics, interaction between species and biodiversity (Convey and Smith, 2005; Parmesan, 2006; Grosbois et al., 2008; Keith et al., 2008). The impact of climate change varies and important complex interactions are occurring at distinguishable spacial scales (Kumar et al., 2015). Tropical cereals like maize and rice are worst affected which is projected to continue in the future while there could be an increase in demand by atleast 60% by 2050 (Oerke, 2016) while the global surface temperature may increase up to $4^{o}C$ by 2100 (Kumar et al., 2017). Not only climate change, adaptation towards sustainability such as the plantation of bio-fuel crops and solar farms compete for the existing agricultural zone along with decreasing use of chemicals to decrease the risks in ecosystem services. There is also another factor that determines the crop production –arable crop diseases which cause a loss of atleast 16%.

Great concern has been caused by the change in climate since the effect in average climatic condition measure over a considerable period of time are far reaching and serious in nature. Humans have now become accustomed to any change in the climatic condition which occurred daily and seasonally. Yet the indirect effects of the climatic change are indeed extremely complex and it is not predictable. Expressed as a global average, temperature between 1906 and 2005 has increased by about 0.74^{o}C. But this increase in temperature is neither steady nor similar in different geographical areas and different seasons (IPCC 2007). This rise in temperature is yet observed in all the continents with the greatest change in temperature observed at middle and high latitudes in the Northern Hemisphere (Chandran and Andimuthu, 2012).

There is a direct impact of climate change and global warming on intensity, frequency and pattern on rainfall. This direct impact could be a result of increase evaporation and surface drying by increased heating which result in increased intensity and duration of drought. Yet, there is an increase of about 7% of the water holding capacity with every 1^{o}C warming which leads to increased water vapour in the atmosphere. Hence, precipitation events could occur to a greater extends with increased tropical cyclones, thunderstorms and snowstorms. These events are occurring at an increasing rate even in regions where total precipitation is decreasing. Because of this, there is evidence that human induced change is changing the hydrological cycle all over the world (Trenberth, 2011).

Any change in rainfall can affect the soil properties and increase the rate of soil erosion and soil moisture which are important for crop yield. With 3-25% increase of precipitation, there would be an increase in soil moisture availability (Mishra, 2004). The IPCC had predicted that precipitation would increase in high latitude and decreasing in most subtropical land regions by as much as 20% while extreme precipitation events is expected to increase with variation in regional precipitation (Kensa, 2011). This may result in longer cropping season in the higher altitudes while deficiency of soil moisture in the middle altitudes affecting the agricultural productivity in the mid latitude granary in the Northern Hemisphere (Mishra, 2004). Change in the intensity, frequency and pattern of rainfall will affect the magnitude of runoff and the intensity of floods and droughts (IPCC 2013).

The agricultural sector has always been vulnerable to variation in climate with incidence of extreme climate events. Climate variability will result in changes in land and water regimes that will have consequence on crop production (Anwar et al., 2013). And the impacts will differ between crops, disease and geographic locations with increasing severity of disease while decreasing in other zones (Newbery et al., 2016). Climate change is likely to have both negative and positive effects with increase in production risks and change in farming and management practices. Agricultural sustainability and crop productivity is impacted by climate change in two interrelated ways: Firstly production of food and fibre could decrease by the diminishing long-term ability of agroecosystems and secondly the shift in agricultural zones by change in climatic condition leading to encroachment of natural habitat for flora and fauna (Kensa, 2011).

Shortage of food grains would be a outcome of negative impact of climate change with people below poverty line being affected. Decreasing crop production as a consequence of climate change is observed in developing countries. This consequence is observed in countries which are extremely vulnerable to climate change with various studies predicting significant decrease in crop production due to future warming and change in rainfall patterns (Ahmed et al., 2015).

Nearly all countries of the world are predicted to face a negative impact of climate change on water resources, freshwater ecosystems and hydrological cycle (IPCC, 2007). The characteristic of the impact differs from one region to another region with huge difference in the intensity and pattern of the impact. In some regions there could be water scarcity affecting large population with the increasing demand and large scale droughts in areas where floods had occurred for decades. On the other hand, there could be a problem of rising sea level in heavily populated coastal regions threatening the lives and livelihood of millions of people. In addition to the impact on water resources, economic cost could increase many fold due to the overall decline of crop production with a risk of poverty and hunger (Abbaspour et al., 2009).

Climate change is identified as one of the leading factor that affects the performance of agricultural activities and it is an interrelated process (Parry et al., 2007) and any change would have a significant impact due to the sensitivity of agricultural activities (Mall et al., 2006). The change hits the farmers the most because any change will have a direct impact on the crops and the need of framers to adapt to climate variation is high (Dhanys and Ramachandran, 2016).

Kharif crops are under the influence of monsoon rainfall. Farmers need to perceive the climate variability, delayed onset, intermittent dry spells, soil moisture and identification of increasing temperature which is the critical factors affecting their cultivation. Plantation of short-duration crops like pulses and vegetables needs to be undertaken and farmers need to adapt these changes. Arid and tropical regions of Asia can be vulnerable to climate change, due to severe water scarcity and drought which will be experienced by the population (IPCC, 2013).

IPCC's Assessment Report also indicates that agricultural productivity in the tropics would decrease with threats on human security due to direct and indirect impact on water resources, agriculture, coastal areas and resource dependent livelihoods (IPCC, 2013). Projects made by the FAO indicates that crop production should have an increase of at least 70% to meet the needs of the population growth all over the world and 11% of arable land could be effected by climate change with decrease production of grain in developing countries (FAO, 2005). Impact of rainfall will be severely felt in the populated countries of Asia such as India as it is the main source of livelihood for at least 60% of the total population. It has been estimated that with an increase of 2.5^{o}-4.9^{o}C in temperature would result in the decrease of the production of rice and wheat by 32-40% and 41-52% respectively (GOI, 2011). Studies show that Indian agriculture would be negatively affected with an expected reduction in the yield of wheat, soybean, mustard and groundnut by at least 3-7% for every increase of 1^{o}C temperature (Aggarwal et al., 2009)

Extreme climatic events such as droughts and heat waves could have disastrous effect and lead to the decline of above-ground, loss nutrients and disappearance of grass species especially in the growing season (Joshi et al., 2013). Research carried out in some African countries by World Bank indicates that there could be a decrease in the duration of rainfall and some areas becoming hotter and dryer (Maddison, 2007) Climate plays as major role in determining the cropping pattern due to climatic condition, irrigation, crop rotation water allocation and soil types. Parikh (2007) states that climate change will bring extra hardship for famers with the poorest people being affected the most with loss of harvest, often their sole sources of food and making them the most vulnerable to climate change.

In order to estimate successful adaptation in the agricultural activities, there is a need to understand the farmer's perceptions of climate variability and change, their impacts, cropping pattern and adaptation along possible response (Bryan et al., 2009).

Indian economy has the agricultural sector in its core and it accounts for 14% of the nation's GDP, about 11% of its exports. And half of the population still depends on agriculture as its principal source of income and this sector contribute 58.4% of the country's work force though the share of agriculture and allied activities to the country's gross domestic product has decreased from 14.5% in 2010-2011 to 13.9% in 2011-2012. Yet there is a steady decline in the growth rate of agriculture from 3.2% in the 1980s to around 2% in the last few years (Census of India, 2011). Impact of climate change on water is becoming a concern in the agricultural sector with farmers in arid and semi-arid areas now depending on monsoon rainfall together with unpredictability and inefficient irrigation developments. Dhanys and Ramachandran (2014) has established that there would be reduction in crop production due to water scarcity such as delayed monsoon onset on certain crops such as rice which are water intensive crop. Due to this increasing water scarcity there is a considerable decline in agricultural area of cereal crops while there is increase of agriculture area for crops which are less water intensive such as pulses like black gram and vegetables with an increase of perennial crops such as fruits, coconut and bananas. Not only crop production, there would also disruption of their livelihood due to the unpredictable nature of summer monsoon onset and high temperature with decreasing soil moisture. Yet after the monsoon onset there could also be monsoonal withdrawal causing dry spell and moisture stress on both plants and soils. This could be disastrous as dry spell during the flowering and formation of fruits and cereals such as rice would decrease the yield considerably. To combat the difficulty the farmers are required to use more fertilizers, pesticides and insecticides due to increasing pest and insect attack brought about by the climate change and would force farmer to focus on the reduction of cultivated areas.

Attention has been given to agricultural effects of climate change (Adams et al., 1998; Adams et al., 1999; Polsky and Easterling, 2001) since the change in climatic condition is one of the main determinants of crop production as it depends on many factors. Hazell (1984) and Anderson and Hazell (1987) established that the use of high-yielding varieties, timing of field operations and planting practices causes the yield of crops to be sensitive to the climatic condition. As climatic condition varies, the production of crop can change due to any alterations in the climatic condition (Adams et al., 1998). Because of this, agricultural activities and patterns need to be changed and adapted to any climatic change which could impact the seeing and other field operations and change in the temperature level. This change can also increase the requirement of water while the water supplies could decrease that is required for urban population, industry and natural ecosystems.

Research studies have estimated that the impact of environmental change on crop productivity levels using either simulation models or regression techniques. Research that uses simulation models to assess the impact on crop production includes Terjung et al., 1984; Eitzinger et al., 2001 while studies that employ regression models for predicting the change in yield by the change in climatic condition includes Mendelsohn et al., 1994; Mendelsohn et al.,1996 and Santer 1985. Using the stimulation model, Mendelsohn (1996) found that the effects of higher temperature ranged from mildly harmful to unequivocally beneficial from studies conducted in the United States about the impact of climatic variables on agricultural returns. Though the impact of climate change had been analyzed on the mean crop yield, the impact on the fluctuation in the crop production is yet to be established (Mearns et al. 1997). With the historical crop yield and climate data, the impact of climatic condition such as precipitation and temperature can be predicted for crop production. Isik and Devadoss (2006) have established that temperature and precipitation have crop-specific impacts in affecting the mean and variation of crop yield using econometric model while the simulation result depicts that although the increase in the mean temperature and rainfall levels in the next 30-90 years would be small, the effects on the variance and covariance of crop yields would reduce the yield significantly. These results are important for determining the future mix of crop production and allocation of agricultural zone among major crops.

The impact of climate change on population dynamics and viability is an imperative topic and at the basic stage it measures the climatic variables like temperature and rainfall on an ecological process like viability and survival. This impact can be predicted if the population growth and the environmental change can be predicted using models (Hunter et al., 2010). It is claimed that climate change has affected different fundamental requirements for health – clean air, safe drinking water, sufficient food and quality shelter (Chandran and Andimuthu, 2012).

Climate change also has a potential threat to biodiversity. Biodiversity is defined by the 1992 Convention on Biological Diversity as 'The variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part. This includes diversity within species (genetic diversity), between species (species diversity) and of ecosystems' (Heywood and Watson, 1995). According to Jenkins (1992), the high habitat modification rate could result in natural habitat and protected areas being an ecological islands surrounded by habitat altered regions. This process of isolation and fragmentation from the biogeography theory (MacArthur and Wilson, 2001) is predicted to proceed with accelerated species extinction at both the local and the global scales directly and indirectly, thus there could be decrease of the biodiversities (Jenkins, 1992; Lawton and May, 1995). Species with a limited niche such as endemic plants that has specific requirements of soil properties and climatic condition may be vulnerable to extinction due to increased difficultly of immigrating to suitable new sites (Damschen et al., 2010). On comparison of threats to biodiversity between climate change and human induced environmental change, direct threats of climate change occur slowly and measurement of impact is difficult but the processes are irreversible and global. While the human induced environmental change includes changes in land use, effect of increased concentrations of greenhouse gases such as carbon dioxide, methane, nitrous oxide and chlorofluorocarbons (CFCs) and pollution by excessive use of chemical substances and indiscriminate disposal of wastes such as radioactive substances (Dale, 1997) and these could result in increase of global temperature (Houghton 1995; Bush 1997). Specifically, atmospheric CO_2 is predicted to reach 730-1000ppm with the end of this century which could result in the increase of global surface temperature by atleast 1.0^{o}-3.7^{o}C (Meehl et al., 2007; IPCC, 2014). Additionally climate change will aggravate the stress on the biodiversity and effects interact with other stress factors (Kappelle et al., 1999).

Additionally there is immense impact on communicable and some non-communicable disease by climatic conditions viz., temperature, precipitation and relative humidity. These climatic conditions are responsible on the occurrence and spread of disease and the change in climate could make any region become favourable while other regions with optimum condition could become hostile to these diseases. Therefore, changes in the optimum levels will determine the emergence, extinction and prevalence of any diseases (Chandran and Andimuthu, 2012).

Increasing trend in annual surface temperature has been predicted by numerous studies (Kumar er al., 1994; Pant el al., 1999; Singh and Sontakke, 2002; Subhash and Sikka, 2014) with a change in the rainfall trend at different regional and local scale in India (Chaudhary and Abhyankar, 1979; Kumar et al., 2005; Kumar et al., 2010; Adarsh and Reddy, 2015). It is projected that India and Southeast Asian countries will face numerous changes as a consequence of climate change and its effect on precipitation. Bhadwal et al. (2003) concludes that there is variability in summer monsoon precipitation, which will affect the water resources and may have negative impact the agricultural sector. Dash et al. (2007) describes the decreasing trend in the monsoon rainfall with an increase in pre- and post-monsoon periods which is based on the rainfall data from 1871 to 2002 while Guhathakurta and Rajeevan, (2008) found significant increase of rainfall in 8 states by performing a monthly rainfall observation across 36 climatological regions for linear trends during the period 1901-2003. However, they also reported a significant decrease in rainfall pattern in the states of Jharkhand, Chhattisgarh and Kerela.

Vulnerability of arid and tropical regions of Asia can increase if there is severe water scarcity and drought with direct and indirect impact on agriculture, resource dependent livelihood, human security and water resources (IPCC, 2013). Sharma (2003) states that there would be an increase of demand of irrigation by 26% with an increase of temperature and decrease in rainfall and increase the demand of water for human activities by 37.9% by 2021. Vinnarasi and Sarma (2011) states that with every 1^{o}C rise in temperature, global runoff will cease by 4% by changes in evapotranspiration and precipitation.

Over 60% of the crop area is under rainfed agriculture and becomes highly vulnerable to climate variability and climate change (Ravindranath et al., 2011). Malla (2008) reported that with an average of 0.06^{o}C/year, there is a rise in temperature from 1975 to 2006 by 1.8^{o}C in Nepal along with the yield of rice and wheat increased by 26.6% and 18.4% due to double CO_2, 17.1% and 8.6% due to increase in temperature respectively through CO_2 enrichment technology.

It can be predicted that increase in temperature will have overall negative effects on agriculture in the world (IPCC, 2001; Ruchita and Rohit, 2017). However, high temperature would increase the growth of certain plants (Aggarwal et al., 2010). Generally agricultural productivity in developing countries is expected to decline by 9-21% because of global warming (Cline, 2008). A small rise in temperature (1-2°C), especially in the seasonally dry tropical regions (IPCC, 2007) would decrease crop yield (Lakshmikumar et al., 2012).

Research shows that a small increase in temperature had larger effect than elevated CO_2 on grain quality (Tester et al., 1995; Williams et al., 1995). Studies shows that every rise of 1°C temperature in the growing period will result in the decline 4-5 million tons of wheat production in India (Aggarwal, et al., 2010) while rice yield will decline by 10% for each 1°C increase in minimum temperature during the growing season (Peng et al., 2004)

In the North-Eastern region, the intensity of rainfall in the region is likely to increase by 1–6mm/day while the number of rainy days is likely to decrease by 1–10 days (INCCA, 2010). In addition, the rainfall is projected to increase in 57 of the 78 districts in Northeast India, with some districts expected to experience almost 25 % more rainfall together with 26% increase of extreme rainfall events per year. Kumar et al, (2017) predicted the increase of temperature by 4^oC by 2100 globally with an annual mean temperature increase of 0.42^oC in India with possible flooding and droughts and significant impact of food, water and biodiversity (Ravindranath et al., 2011).

Ruchita and Rohit (2017) predicted an increase of 0.3-0.7°C for the period 2016-2035 while Khan et al, (2012) predicted that the mean temperature in India will rise by 0.4-2.0°C in Kharif (summer) and 1.1-4.5°C in Rabi (winter). The atmospheric concentration of CO_2 has been predicted to increase from 368 μmol/mol to 540-970 μmol/mol in 2100 while it was around 280 ppm, in 1750 (IPCC, 2001; Kumar, 2011).

India's water requirement for agriculture, industries, domestic purposes, energy sectors and ecosystems depends on the southwest monsoon. Annual rainfall occurs during the monsoon period i.e., between June-September and accounts for more than 80%. Therefore if there is any change in the rainfall pattern particularly during the Indian southwest monsoon would have a significant impact on the agricultural sector with issues related to water management (Mall et al., 2006). Kumar et al. (2017) reports that the amount of rainfall is considerably higher during the monsoon and because of this big change, the magnitude of water balance components can occur with a small change in the monsoon system. In addition, soil runoff will increase with just a small change in the rainfall as the soil moisture is rather high which is responsible for influencing the partition of rainfall into infiltration or surface runoff. However, during the non-monsoon season the soil moisture is quite low so, there will not be a large amount of runoff.

The change in water balance components such as soil moisture depends on the relationship between climate change and land use change. As a result, the impact in a given area depend on the land use pattern and any change in the urbanization and agricultural zonation (Kumar et al., 2017). Further consideration of the land use type, crop rotation and irrigation is the essential for determination of land use management required to counterbalance the impact of climate change in the region.

Understanding and analysis of climate change, crop growth and crop disease models can be used for predicting the impact and planning the adaptation strategies to ensure future food security (Newbery et al., 2016).

Rainfall is not the only factor that could affect the crop production. Malla (2008) reported that with an average of 0.06°C/year, there is a rise in temperature from 1975 to 2006 by 1.8°C in Nepal along with the yield of rice and wheat increased by 26.6% and 18.4% due to double CO_2, 17.1% and 8.6% due to increase in temperature respectively through CO_2 enrichment technology. Problem of frequent drought, severe floods, landslides and mixed type of effects in agricultural crops have been experienced in Nepal because of climate change (Malla, 2008).

Greenhouse effect has been enhance by water vapour, carbon dioxide (CO_2), methane (CH_4), Nitrous oxide (N_2O) and chlorofluorocarbons (CFCs) out of which CO_2, CH_4 and N_2O are the three major gases that contribute 88% roles in global warming (IPCC, 1996). The potential of CH_4 release from rice fields had been noted as early as 1913 (Neue, 1993) and it is predicted that the CH_4 level will rise by 3.0-4.0ppm by 2100. In addition, a World Data Center of Greenhouse gases have estimated the abundance of CO_2, CH_4 and N_2O as 377.1ppm, 1.783ppm and 318.6ppb respectively (World Climate News, 2006). Seasonal emission of CH_4 in Thailand, India and Korea has been reported to be 49, 45 and 367 kg/ha respectively while Nepal emitted 28 kg/ha in rain-fed condition (Malla, 2008). Research on the impact of Greenhouse Gases in numerous agricultural zones is required to quantify and verify their contribution more accurately.

Study by Sahoo et al. (2018) has observed that there is an increasing cyclonic storms, cloudburst, hailstorms and landslides, with an increase of 0.01°C in the temperature over a period of

60 years from 1951-2017. However the IPCC (2017) has estimated that there could be a rise of 4.2^{o}C towards the end of the 21st century. Projections of precipitation in Northeast India made by INCCA (2010) for 2030 shows that there would be a reduction in precipitation by atleast 12% while the central portion of the North-eastern region shows an increase of 0% to 25%; evapotranspiration is expected to increase in Mizoram, Tripura, Manipur and Assam. Hence, the water yield for Assam and Manipur is expected to increase by 40% with a decrease of 20% for Arunachal Pradesh.

Meterological changes in Mizoram have been observed by various researchers such as Sati and Lalrinpuia (2017), Das et al. (2006) and Sati and Lalrinpuia (2018). The rainfall has decreased by 1.9% and temperature has increased approximately by 0.4% between 1986 and 2012 and the lowest amount of rainfall over a period of 25 years since 1982 was observed in 2006. Though there are no specific rainfall trends, decreased rainfall and increased temperature had been observed and a decrease of 6-8% in rainfall was also observed over hundred years.

Atmospheric condition i.e., weather at the surface timescale form minutes to months has an important affect on agriculture with a direct impact of temperature and erratic rainfall events. Short-term change in weather affected the production of crops. Insufficient rain and increasing temperature can cause drought while excessive rainfall accelerates rainfall with both causing negative impact on agriculture. However, the rising temperature, increase rainfall and emission of CO_2 will be helpful in production of major crops by enhancing photosynthetic processes, water use efficiency, shorten physiological period. The negative impact includes decrease in grain filling due to increase respiration process, change in agricultural zone leading to change in cropping pattern, increase in insect population, evapo-transpiration, increase in soil erosion, desertification and increase use of fertilizers (Malla, 2008).

Variability in climate and weather changes the soil moisture and the rapid evapo-transpiration will increase the demand of water to reduce drought. Increase in temperature, rainfall and CO_2 levels will bring hidden-hunger problem by decreasing essential nutrients contents in food crops (Malla, 2008).

CHAPTER III: STUDY AREA

STUDY AREA

Mizoram is a mountainous region which became a full-fledged state of the Indian Union on 20th February, 1987. It has a geographical area of 21,081km^2 and is located between 92^o.15'E to 93^o.29'E longitudes and 21^o.58'N to 24^o.35'N latitudes with the Tropic of Cancer passing through the state at 23^{o}30'N longitudes. Its maximum dimensions are 277km from North to South and 121km from East to West (Statistical Handbook, 2016).

The state is sandwiched between Myanmar in the Southwest and Bangladesh in the West with an international boundary of 722kms (404kms with Myanmar and 318kms with Bangladesh). It is also bordered by the states of Assam and Manipur in the north and Tripura in the North-West with Interstate boundary of 123kms, 95kms and 66kms respectively (Statistical Handbook, 2016).

Initially, Mizoram was divided into three districts namely, Aizawl, Lunglei and Chhimtuipui. However, it was later divided into eight states viz., Aizawl, Lunglei, Siaha, Champhai, Serchhip, Lawngtlai, Kolasib and Mamit in 1998. Geographically Lunglei is the largest district with an area of 4,536 sq.km, while Kolasib is the smallest district with an area of 1,382 sq.km. There are three Autonomous District Council in Mizoram with the Chakma Autonomous District Council located in both Lunglei and Lawngtlai District. While Lai Autonomous District Council and Mara Autonomous District Council are located within Lawngtlai and Siaha district respectively. Each district is again divided into 23 Sub-Divisions and 26 R.D. Blocks with a total of 830 villages located all over Mizoram although there are 126 uninhabited villages (Statistical Handbook, 2016).

According to the 2011 census, the total population of Mizoram is 10, 97,206 with a sex ratio of 976 females per 1000 males. The total number of male and female are 5, 55,339 and 5, 41,867 respectively with the majority of people, 5,71,771 living in the urban area. The population density of Mizoram is highest in Aizawl at 112 per sq. Km with a population of 4,00,309 while the sex ratio is 1,009 females per 1000 males and the lowest in Mamit district with a density of 29 per sq.km while the sex ratio is 927 females per 1000 male. However the population density if taken state-wise is 52 per sq.km. The literacy rate is the third highest in India with 91.33% after Kerala and Tripura. The total forest area in Mizoram is 18,353 sq.km with 136 sq.km, 5700sq.km and 12,517 sq.km under Very Dense, Moderately Dense and Open Forest area respectively (Statistical Forest Report, 2017). In Mizoram more than 70% of the population is depending on agriculture for their livelihood with shifting cultivation being practiced by the majority (Statistical Handbook, 2016).

Physiography

The topography of Mizoram is found to be largely immature except in the eastern part. Mizoram is characterized by numerous ranges running generally in North – South direction which is in sharp contrast with the major mountain ranges of the country. As many as 21 major hill ranges or peaks of various heights run through the length and breadth of the state, leaving of course, some plains scattered occasionally here and there. They are separated from each other by narrow synclinal river valleys. The average height of the hill to the west of the state is about 1000 meters which gently rises to 1300 meters to the east. Some areas, however is of higher ranges which go up to a height of over 2000 meters. Phawngpui (Blue Mountain), the highest mountain peak in Mizoram is of 2157 meters. In Mizoram the few patches of flat lands scattered in all parts of the state are generally located in the middle of hills and narrow valleys. These plains are believed to have been found in the beds of silted-up lakes as they are covered with rich alluvial soil. The largest plain is located at Champhai which has a length of 11.27 km and width of 4.83 km.

Climate

Mizoram passes through the tropic of cancer, thereby providing a favorable climate for plant growth throughout the year. As the region falls under direct influence of south-west monsoon, the state receives abundant rainfall. It is humid tropical characterized by a winter with precipitation of less than 30mm during December – January and more than 700mm during the pre-monsoon months of January to February while the distribution of rainfall in February and March is scarce (<110mm). Also long summer without rainfall, except few showers from the first part of March to end of April and monsoon rains from May to September with an annual rainfall ranges from 1,968mm to 3,140.4mm. The annual average rainfall is 2,381mm while the average monthly rainfall is 198.45cms (Statistical Handbook, 2016). Heavy rainfall occurs from June to September accounting nearly 78% to 80%of the total annual rainfall which continued with decreased precipitation received in October and November at about<,200mm and >70mm respectively . The rainfall is not evenly distributed with the southern region receiving relatively higher rainfall than the northern region and the intensity in some period of time is very high that it causes landslides in some places. During monsoon period high rainfall occurs and the humidity is high. The precipitation during monsoon period is also very high, low in summer and medium in winter. Despite such high rainfall, prolonged dry spells and occasional drought conditions are noticed.

Winter is moderately cold. The mean summer and winter temperatures vary from 24^{o}C to 30^{o}C and 10^{o}C to 20^{o}C respectively. The summer months are warm and wet. Although the temperature in the morning is cool, the temperature at noon is quite comfortable (Gopalakrisnan, 1991).

On the basis of temperature and rainfall, the year can be divided into three seasons, namely: spring or mild summer (March to April), rainy or wet summer (May to October) and winter (November to February). The rainiest months were June to August; driest months are November to January.

Soil

The soils of Mizoram are young, immature and sandy and the soils of different physiographic units are homogenous in nature so far as the geological aspects of soil formation is concerned. The formation of soil is influenced by climate, vegetation, relief, parent material and time (Lianzela, 2004).They is characterized by high organic carbon as well as high nitrogen contents. However, they have high acidic content but are low in potash and phosphorus compounds, essential contents for most of the cultivable crops may be the result of heavy leaching experienced generally in areas of extended high rainfall. The soils of Mizoram are mostly red and yellow loam and can be classified as UDIC (MIRSAC, 2006) and further sub-divided into three orders of soil taxonomy viz., Entisols, Inceptisols and Ultisols. Variants of ultisols like Udults, Ochrepts and Orthents are found accordingly at different slope categories with Ulisols found commonly along the foothills of lower slopes. Entisols occur on steep slopes and ridges or in flood plains which receive continually new detritus deposits. In the areas where steep to very steep slopes are found, Hapludults occur to be rich in Iron but are poor in their pH value. In an eroded soil, the content of nitrogen is quite high fostered by accumulation of organic matters and the organic matter content varied from 0.4 to 4.14 per cent with an average value of 2.22. Soil reaction varied from 4.79 to 6.14 in Kolasib district, 4.7 to 6.65 in

Mamit district, 4.99 to 5.76 in Aizawl district, 4.51 to 5.71 in Serchip district, 4.59 to 6.49 in Lunglei district, 4.96 to 6.03 in Lawangtlai district, 5.94 to 7.24 in Siaha district and 4.99 to 5.92 in Champhai district (Brajendra et al., 2016).

Drainage

The state of Mizoram is drained by a number of rivers and streams of different patterns and lengths. Most of the drainage lines of Mizoram originate on the central part of the state and flow either towards north or south directed by the north-south trending ridges. The main drainage patterns of the tributaries are angular, sub parallel to parallel and dendritic. And the system has a straight flow regime. Southern Mizoram has the largest river Chhimtuipui or Koladyne (138.46km in length) in Mizoram which originate in Myanmar and then passes through Lawngtlai and Siaha district before reaching the Bay of Bengal. This river has a number of tributaries and one of these is Khawthlangpui (128.08 km in length) River in the western part of Mizoram which has important cities along its sides (Zoramchhuana, 2000).

There are still some very important rivers in Mizoram that play a role in the drainage syatem. Some of the well known important rivers include Tlawng or Dhaleswari (185.15 km in length), Tuirial or Sonai (11.53 km in length), Tut and Tuivawl (72.45 km in length) on the northern part of Mizoram while Mat (90.16 km in length), Tuichang (120.75 km in length) and Tuipui (86.94 in length) on the southern side. Other rivers include Tiak or Tlau (159.39 km in length), Tuichawng (107.87 km in length), Teirei (70.84 km in length), Tuirini (59.57 km in length) and Serlui (56.33 km in length).

Geology

In Mizoram, the hills consist of sandstone and shale of tertiary age, thrown into long folds. It is covered by quaternary sediments occurring mainly along river valleys. The rocks are a continuation of the rocks forming Patkai ranges and Cachar hills. Bharali et al. (2017) reported that the tertiary sedimentary rocks are thickly deposited in not only Mizoram but also in other parts of northeastern part of India. In general, the geology of Mizoram is represented by repetitive succession of arenaceous and argillaceous sediments which were later thrown into NNW-SSE trending longitudinal plugging anticlines and synclines. Two broad groups-Surma and Barail are prominent, where the formation can be classified under Bokabil, Bhuban and Barail formation (Lalzarzovi, 2014)

Vegetation

Out of the total 21087km2 geographical area, 15,853km2 is covered by vegetation which accounts for 75.17%. The combination and interaction of vegetation reflects the environmental factors that determine the limit of range of plants species to grow. Based on altitude, rainfall and species composition, Singh et al. (2002) described the vegetation type of Mizoram into six different types. They are classified as:

i. Tropical Wet Evergreen Forest
ii. Montane sub-tropical Forest
iii. Temperate Forests
iv. Bamboo Forests
v. Quercus Forest
vi. Jhumland

i. Tropical Wet Evergreen Forest

These forests occur below an altitude of 900m where the rainfall ranges between 2000-2500mm annually with the temperature range between 20^{o}c and 22^{o}C. They are usually located in the southern and western part of Mizoram while the semi-evergreen forests occur in the northern, north-western and central part of Mizoram.

The various zonation or canopies are extremely clear with evergreen trees with tall boles at the top canopy. The lower and middle canopies are dense, evergreen and diverse with few epiphytes and parasites while tree ferns, ferns, orchids, bryophytes, lichens, aroides, palms occurs abundantly. The lower canopy consists of shrubs and small tress with floristic diversity (Singh et al., 2002).

ii. Montane sub-tropical Forests

These forests occur between 900-1500m altitude and in places which are cooler with low precipitation. They are found in the eastern fringes near Chin Hills of Myanmar. *Castanopsis purpurella, Duabanga grandiflora, Pinus kesiya, Prunus cerasoides, Schima wallichii and Quercus acutissima* are some of the most common species of tress (Singh et al., 2002).

iii. Temperate Forests

High altitudes with an evaluation of 1600m is required for these forests and are found in areas like Lengteng, Naunuarzo, Pharpak and Phawngpui forests reserve. Prominent trees include *Oinus keya, Betuia alnoides, Exbucklandia populnea, Michelia doltsopa, Michelia champaca, Litsea salicifolia. Rhododendron arboretum* and *Garcinia anomala* (Singh et al., 2002).

iv. Bamboo Forests

Under the tropical evergreen and sub-tropical mixed-deciduous forests, bamboos are usually grown as an under-storey. However, *Melocanna baccifera* forms dense forests in certain areas in Mizoram. The distribution of bamboo forests occurs mostly between 40m and 1520m in tropical and sub-tropical areas. In shifting cultivation, the forest is cleared and burnt but the bamboos rhizomes are able to survive and remain dormant until the condition becomes favourable (Singh et al., 2002).

v. Quercus Forests

These forests occur in a mix between sub-tropical and temperate areas. It can be found in the Champhai-Baite hill regions and other small patches in the eastern part of Mizoram (Singh et al., 2002).

vi. Jhumland

Jhumlands are predominant in eastern Mizoram and western side of Lunglei district near Bangladesh where jhumming cultivation is practiced. Jhumland is classified as current, old and abandoned jhumland. Jhuming cultivation is termed as one of the factors of deforestation (Singh et al., 2002).

Description of the study site

Champhai District

Champhai District is situated in the eastern side of Mizoram between 24˚ 05’ 03.99” and 23˚ 00’ 03.25” N latitudes and 93˚ 00’ 31.29” and 93˚ 26’ 17.66” E longitudes (MIRSAC, 2006). The total geographic area is 3,185 km2 and accounts for 15.11% of the total geographical area of the state. The forested area can be categorized as Very Dense, Moderately Dense and Open forest having

60km^2, 1,042km^2 and 1570km^2 respectively with a total forested area of 2,673km^2 which accounts for 83.92% of the total geographical area of Champhai district. This district is bounded on the east and south by Myanmar, on the west by Aizawl and Serchhip districts and on the north by Manipur state. Champhai has emerged as the leading place for export and import of goods to and from Myanmar.

The total population according to 2011 census is 1, 25,745 with 63,388 males and 62,357 females having a density of 39 per km^2. And the decadal growth of population in 2001-2011 is 16.31%.The literacy percentage is the third highest in the state with 95.91% just after Aizawl and Serchhip District. Champhai is the district headquarters and it has four sub-divisions viz. Champhai, Khawzawl, Khawbung and Ngopa. This district has 25,520 households in 83 inhabitated village with 7 villages not inhabited (Statistical Handbook, 2016).

Physiography

Champhai District is characterized by rock terrain with hill ranges running from north to south direction and separated by a number of rivers. The hillside slopes are usually steep to very steep and the ridges show serrated tops, which are highly divided and separated by intervening 'V' shaped valleys.

The highest peak in Champhai District is Lengteng with a height of 214m and the biggest plain having 3-10% slopes is adjacent to the Champhai town. The eastern part shows gentler slopes than the western part with an increase in elevation. The five geomorphic units, high structured, medium structured, low structured, valley fill and flood plain accounts for 29.53%, 47.15%, 21.40% 1.36% and 0.56% respectively.

Table 3.1: Physiography of Champhai District

Sl No.	Physiography	Area (in km2)	% to the total area
1	Hill top/hill crest	13.06	0.41
2	Hill side 10-25% slope with current jhum and horticulture	17.20	0.54
3	Hill side 10-25% slope with abandoned jhum	43.01	1.35
4	Hill side 10-25% slope with open forest	23.89	0.75
5	Hill side 10-25% slope with dense forest and forest plantation	175.22	5.50
6	Hill side 25-50% slope with current jhum and horticulture	97.17	3.05
7	Hill side 25-50% slope with abandoned jhum	258.05	8.10
8	Hill side 25-50% slope with open forest	147.19	4.62
9	Hill side 25-50% slope with dense forest and forest plantation	944.92	29.66
10	Hill side >50% slope with current jhum and agriculture	76.15	2.39
11	Hill side >50% slope with abandoned jhum	248.81	7.81
12	Hill side >50% slope with open forest	126.48	3.97
13	Hill side >50% slope with dense forest and forest plantation	894.58	28.08
14	Valley/WRC	98.44	3.09
15	Water body	8.92	0.28
16	Built up land	12.74	0.40
	Total	**3185**	**100**

Climate

Champhai District has a temperature that varies between 4^o-33^oC with a suitable climate, neither too hot nor too cold throughout the year. It is observed that the average mean summer temperature is (April to June) 23.5°C and average mean winter temperature (November to February) is 15.7°C (MIRSAC, 2006). The temperature is modified significantly by usual rains and monsoon rains. This district receives an adequate amount of rainfall during the monsoon season, having heavy rainfall from the second part of May while ending in the first part of October. Usually December and January are the driest month while July and August are the rainiest months. The average annual rainfall is recorded to be about 2346.2 mm (MIRSAC, 2012). Among all of the districts in Mizoram, Champhai district is the highest in elevation and frost is experienced often near Champhai town. These factors influence the evapotranspiration, a critical factor in plant growth and development.

Soil

Soil in the Champhai district are alluvial and colluvial in origin. Based on rainfall and humidity, the soil moisture is high and the crucial elements of soils have been perculated down and became acidic due to heavy rainfall and the soil pH ranges from 4 to 6.5. The soils developed on different slope categories consist of Entisols, Inceptisols and Ultisols order of soil classification. Usually, the hill slopes are covered by soil of medium texture but it is progressively heavier as it reaches the lower slopes.

Drainage

The drainage occurs from the northern and southern part of the district. In the northern side, Tuiphal, Tuisa and Tuila all of which are tributaries of Tuivai river are notable while Tuichang, Tuipui and Tiau rivers are the south flowing rivers. Tiau river forms an international boundary with

Myanmar and flows southwards. Tuipui and Tuiphal flows in opposite directions dividing the district in half and Tuipui forms the largest fluvial plain termed as the 'Rice bowl of Mizoram'.

Geology

The geological features of Champhai has four types of rocks namely sandstone, siltstone-shale, clayey sand and gravel, sand and silt where they account for 48.29%, 48.86%, 2.52& and 0.33% respectively. Champhai district lies over the middle Bhuban formation and in several places, there are evidences of facial changes. The formation of rocks is represented by sandstone, siltstone and soft shale. The hills in Champhai district are approximately North to south trending, steep and mostly anticlines. It is also of structural hills and they are a prominent unit in the entire area. Ngur, Naunuarzo, Ngur and Tan are the highest hill ranges at an altitude of around 6000ft. In addition, the district is transverse by numerous lineaments in different directions and represents monotonous sequence of argillaceous and arenaceous rocks (MIRSAC, 2006)

Vegetation

The forest type is mainly montane sub-tropical forest especially to the eastern side of the district, where the altitude is higher and patches of bamboo on the western side (MIRSAC, 2012). The primary forest in this district is dominated by tropical evergreen forest and includes *Mesua ferrae, Protium serratum, Adina cordifolia, Podocarpus nerifolia, Schima wallichii, Toona ciliate, Duabanga sonneratiodes*, etc. However, there are also semi-evergreen forest and Montane sub-tropical forest which includes species like *Rhododendron sps*, *Schima wallichi* and deciduous species like *Pyrus pashia*. Uniquely, the secondary forest and old jhumland has been dominated by evergreen, semi-evergreen and deciduous tree species instead of bamboo due to the high altitude. Interestingly, there is a natural occurrence of Pinus Kesiya in Ngur, Hnahlan and Farkawn.

Land Use

Utilization of land resources has impact on biodiversity and environment in that particular region. The land use pattern in Champhai district has undergone changes as a result of unproductive and ecologically destructive because of the inherent system of land plans from the last decades. The land use and land cover can be categorized into 11 categories. Man induced land use includes built-up, wet rice cultivation, Agri/horti plantation, current jhum and abandoned jhum. In addition, there are still many categorises of land use such as dense forest, open forest, bamboo, forest plantation, scrubland and waterland (Lallianthanga and Sailo, 2013). Jhum cultivation is less productive than permanent cultivation and is not suitable ecologically in the hill areas of NE. The adverse effects of jhum cultivation can be seen of forests, wild life and land use. There is a great potential in Champhai District for Agri-Horticultural system and plantations (Zoramchhuana, 2000).

Table 3.2: Land use/Land cover of Champhai district

Sl No.	**Land Use/Land Cover Class**	**Area (in km2)**	**% to the total area**
1	Built up -Compact (Continuous)	3.43	0.11
2	Built up -Rural	18.83	0.59
3	Agricultural land -Kharif	46.53	1.46
4	Agricultural land -Agricultural Plantation	15.39	0.48
5	Forest-Evergreen/Semi-evergreen-Dense/Closed	715.88	22.48
6	Forest-Evergreen/Semi-evergreen-Open	660.66	20.74
7	Forest-Forest Plantation	7.48	0.23
8	Forest-Scrub Forest	716.92	22.51

9	Forest-Tree Class Area-Dense/Closed	0.10	0.00
10	Forest-Tree Class Area-Open	518.81	16.29
11	Wastelands- Scrub Land-Dense/Closed	0.03	0.00
12	Wastelands- Scrub Land-Open	9.92	0.31
13	Waterbodies-River-Perennial	11.34	0.36
14	Shifting Cultivation -Current	245.20	7.70
15	Shifting Cultivation -Abandoned	214.47	6.73
	Total	**3185**	**100**

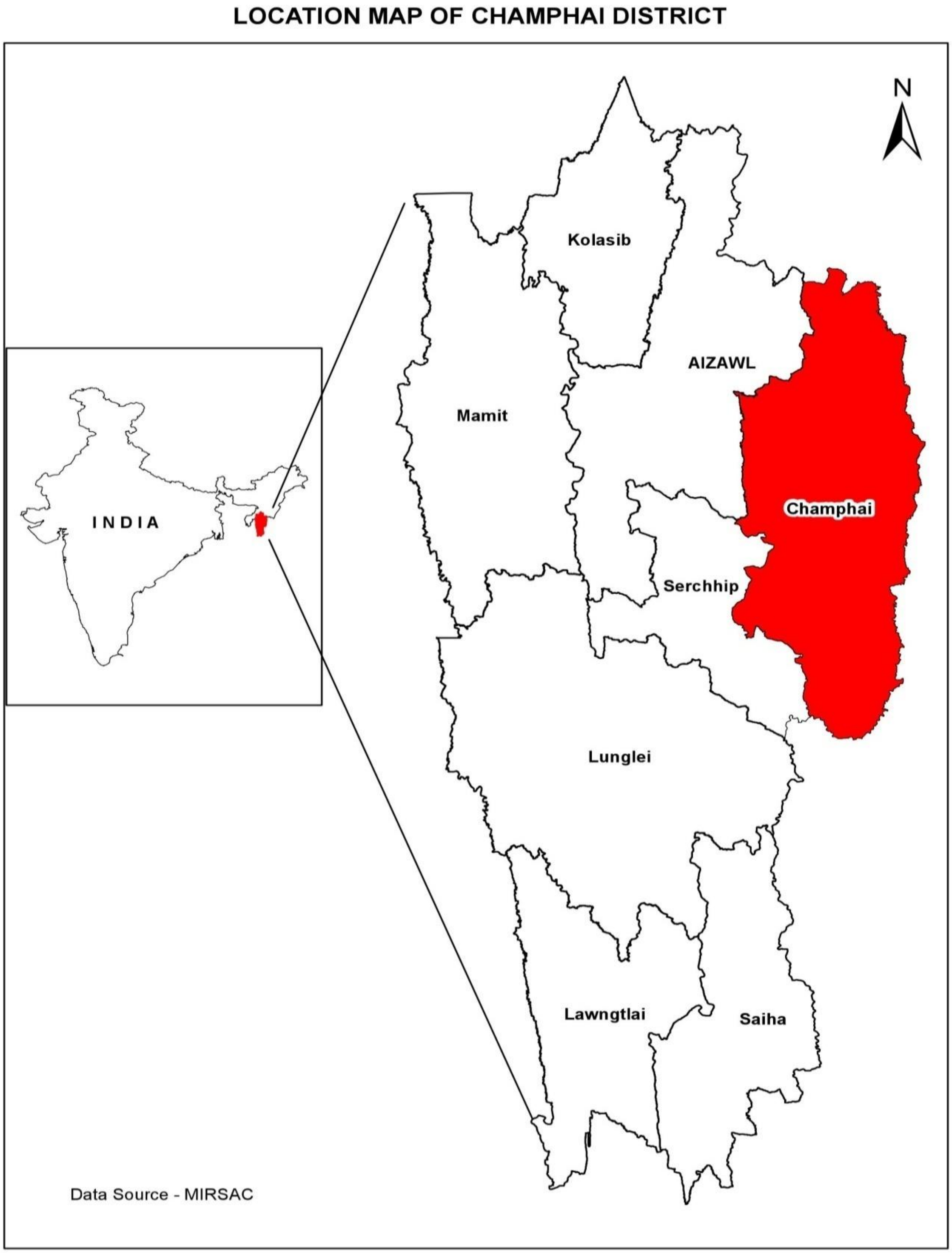

Photo 3.1: Location Map of study site

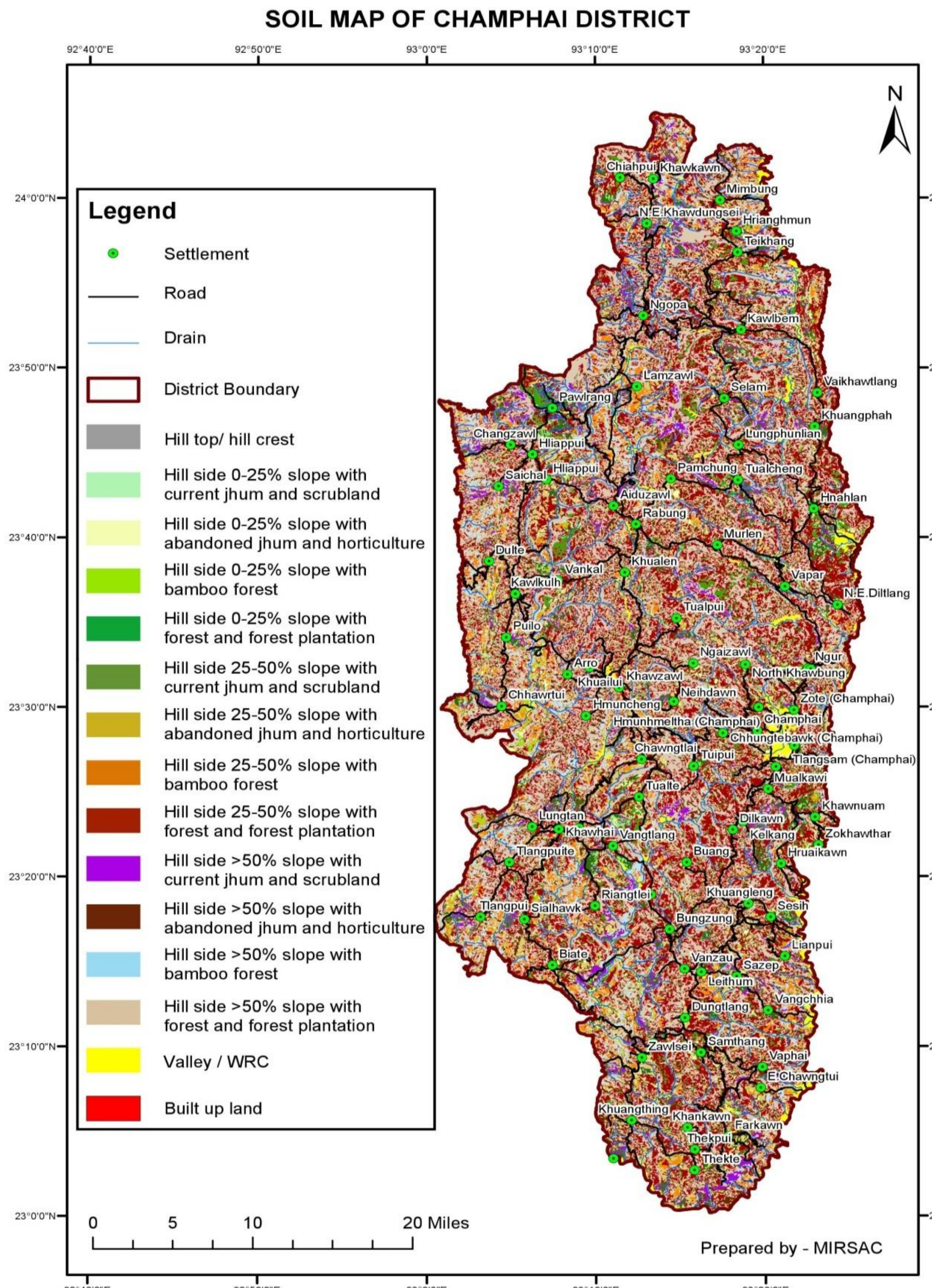

Photo 3.2: Soil Map of Champhai district

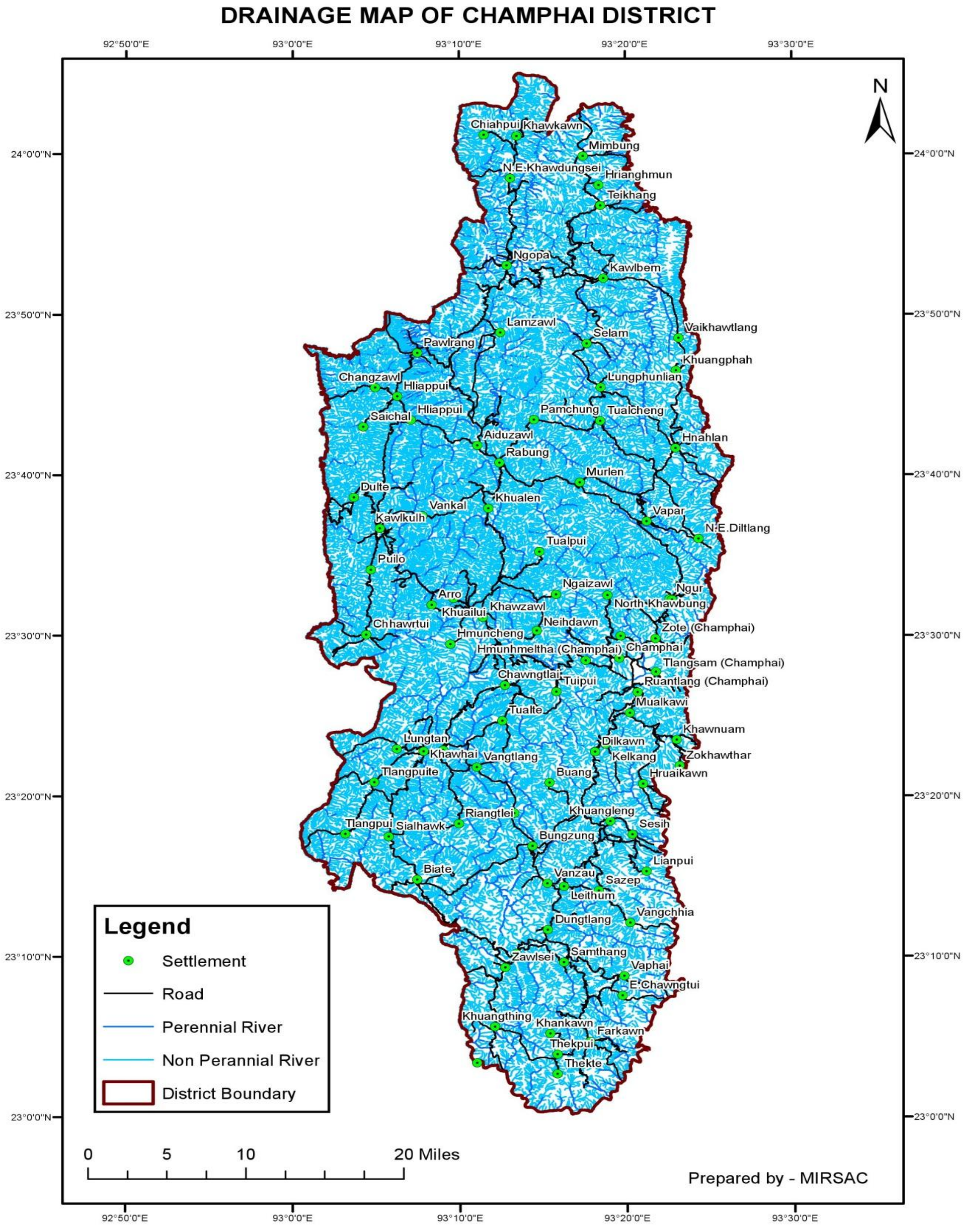

Photo 3.3: Drainage Map of Champhai district

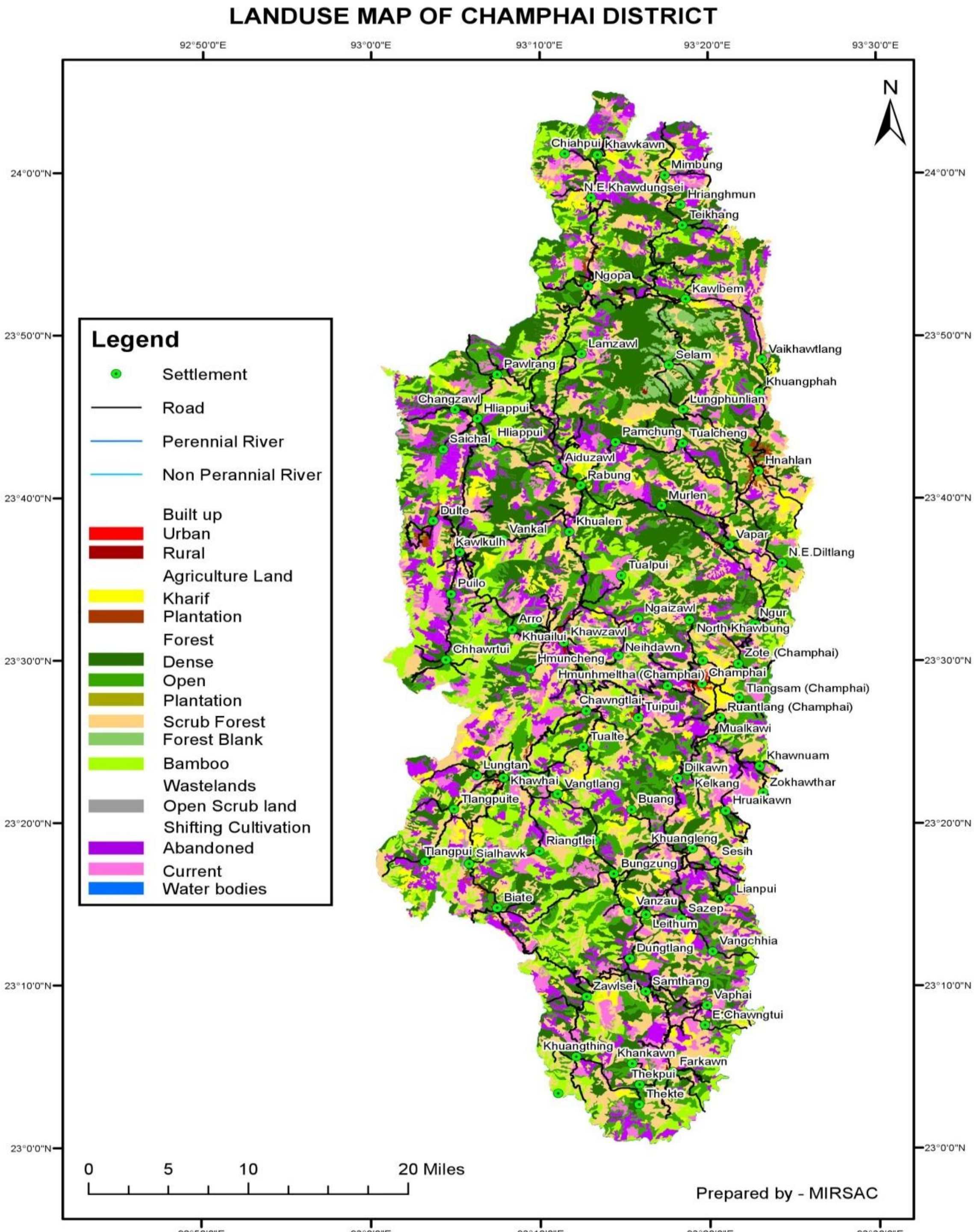

Photo 3.4: Land use/Land cover of Champhai district

CHAPTER IV: METHODOLOGY

METHODOLOGY

This study was conducted using both qualitative and quantitative approaches. For better understanding and evaluation of the problem, individual interviews with the concerned individuals are conducted while analysis of secondary data is carried out. Concerned individuals include farmers of wet rice cultivation within the study site. Overall, this research was based on secondary data as well as on primary data.

Rice being the main staple food in Mizoram, the main concern with crop production is placed on rice production from wet rice cultivation (WRC). Though the influence of climatic condition is felt in Jhum lands, the study is based on wet rice cultivation as WRC are considered to have lesser environmental stress and also the possibility of sustaining a greater food demand. In Mizoram, major rice fields are located in Champhai district also known as 'Rice bowl of Mizoram'

4.1 Collection of Meteorological data and Crop Productivity

The climatic condition of Mizoram has been collected by three main departments- Department of Science and Technology, Economics and Statistics and Agriculture, Government of Mizoram for a long period of time. Among the climatic condition, time series data has been well documented for rainfall in the entire 8 district. The changes that occur with respect to the amount of rainfall received within the study site compiled by the Department of Science and Technology, Economics and Statistics, and Agriculture, Government of Mizoram were collected.

In addition, the Department of Agriculture has been collecting the various aspects of agricultural activities such as the type of crops planted and the quantity of crop products together with the area utilized for farming within the state. The Agriculture Statistical Abstract published by the Directorate of Agriculture was collected for compiling the production of rice from WRC. Agricultural data, also published by Department of Economics and Statistics, Government of Mizoram was collected which will be utilized for the statistical analysis together with the meteorological and crop productivity.

4.2 Socio-economic survey

Socio-economic survey of the individual farmers in the study area was randomly selected and face-to-face interview was carried out to understand the challenges they face due to climatic condition. This survey was utilized to establish the methods that would be required to ensure the continuous production of rice even with any change in climatic condition.

Participatory Rural Appraisal (PRA) describes a growing family of approaches and methods to enable local people to share enhance and analyze their knowledge of life and conditions, to plan and to act (Chambers, 1994). McCracken et al. (1988) define PRA as “a semi-structured activity carried out in the field by a multi-disciplinary team and designed to quickly acquire new information on, and new hypothesis about rural life”. It is a means of collecting different kind of data, identifying and mobilizing intended groups and evoking their participation and also opening ways in which untended groups can participate in decision making, project design, execution and monitoring (Mukherjee, 2003). It helps an outsider to quickly understand the village system from the villagers ‘point of view’ (Narayanasamy, 2009). It is a useful methodology to focus attention on people, their livelihoods and inter-relationship and ecological factors (Mukherjee, 2003).

The survey was carried out in all eight circle subdivision of the Champhai district made by the department of Agriculture. These circles include Champhai, Hnahlan, Khuangleng, Vaphai, Khawzawl, Khawhai, Kawlkulh and Ngopa. In these circles, individuals were selected randomly and their responses were noted down in the questionnaire. The data from questionnaire will be programmed and processed.

4.3 Statistical analysis for the study

The secondary data collected from the three departments were compiled and analyzed to establish the correlation between the rainfall and the crop production and the effect of rainfall on crop productivity and climate variability/change was observed.

CHAPTER V: RESULTS AND DISCUSSIONS

RESULTS AND DISCUSSIONS

The secondary data collected from the three Department viz. Department of Science and Technology, Department of Agriculture and Crop Husbandry and Department of Economics and Statistics were studied and analyzed. The intensity and amount of rainfall from the secondary data was observed to change continuously in Champhai district where the highest amount of rainfall occurs in 2012 at 2938.6 mm while the lowest amount rainfall received was observed in the year 2005 at 1642.2mm. On comparison with the entire state of Mizoram, the highest amount of rainfall on 2007 at 3121.9mm while the lowest amount rainfall received was observed in the year 2014 at 1936.8 mm.

While in case of rice production, the highest yield of rice from wet rice cultivation in kg/ha was observed in the year 2004 at 2750kg/ha in an area of 4800 ha and the lowest yield was in the year 2007 at 556 kg/ha in an area of 2374 ha. It was also observed that there was dramatic decrease in the amount of the rice production during the year 2006-2008 (Meteorological data of Mizoram, 1986-2015, Meteorological data of Mizoram 2016 and Agricultural abstract, 2003-2017) as the yield in the year 2006 was 1644 kg/ha in an area of 2619 ha. This decreased could be attributed by a number of factors such as the intensity of rainfall during the harvest season i.e. November/December and the bamboo flowering which occurred during this time period. On comparison to other years, the amount of rainfall in the month of November 2007 at 133mm was considerably higher than other years where the amount of rainfall were usually only 2, 5.7 and 25.2 mm. Excessive rainfall during the harvest period could pose a threat/difficulty in the harvest as almost all the farmers are depended on manual labour for harvesting and could also result in the loss of a large quantity of the rice.

Though rice plant in wet rice cultivation depended on the rainfall for germination and growth; excessive rainfall can cause negative impact on the crop as the amount of rainfall in the months of May and June 2006 were 407 and 674 mm respectively and the rainfall in the months of May-June 2007 at 303.8, 447 and 423.8 mm could have flooding in the rice fields leading to deceased yield. Other factor that could affect the production of rice during the year 2006-2007 is the bamboo flowering which occurs after every 50 years. This phenomenon causes the rapid increase in rat population by providing nutritious seeds to the rats which were not available in other years. Wet rice cultivation was not the only rice cultivation that is affected by the rapid increase of rats; impact of shifting cultivation (Jhum) resulted in the loss of large number of rice plants. Dramatic decrease was however combated with the import of increased rice from other states.

5.1 Impact of climate change on precipitation

Temperature has always played a great role as the farmers stated that the sowing period of rice is delayed in an area where the temperature is high. Areas with low temperature are said to require longer period with delayed harvest time. Production from the wet rice cultivation was however not only dependent on rainfall but also on the temperature and the soil properties. The temperature from the study site shows a relationship with the yield of the rice. Temperature has always played a great role as the farmers stated that the sowing period of rice is delayed in an area where the temperature is high. Areas with low temperature are said to require longer period with delayed harvest time.

Table 5.1: Maximum temperature, Minimum temperature, Average temperature and Annual average rainfall during the year 1988- 2017

Year	Maximum Temperature (°C)	Minimum Temperature (°C)	Average Temperature (°C)	Annual average Rainfall (mm)
1988	31.9	14.7	23.3	235.1
1989	29.5	14.3	21.9	215.5
1990	30.3	13.8	22.1	188.5
1991	28.1	13.7	20.9	182.3
1992	31.3	10.5	20.9	182.5
1993	31.0	13.4	22.2	189.7
1994	31.2	13.3	22.3	134.0
1995	29.5	13.8	21.7	175.9
1996	31.0	11.9	21.5	182.4
1997	30.0	9.6	19.8	168.6
1998	30.4	10.3	20.4	167.9
1999	33.2	12.5	22.9	185.7
2000	32.1	11.4	21.8	169.5
2001	29.7	8.7	19.2	159.5
2002	30.6	9.4	20.0	184.8
2003	30.3	9.4	19.9	157.0

2004	30.8	9.3	20.1	169.0
2005	26.8	12.8	19.8	136.9
2006	28.4	11.0	19.7	174.0
2007	29.5	10.0	19.8	217.5
2008	29.0	9.7	19.4	150.0
2009	28.3	9.5	18.9	143.6
2010	29.4	11.7	20.6	202.0
2011	29.3	11.6	20.5	144.7
2012	25.6	13.8	19.7	244.9
2013	25.2	15.6	20.4	225.7
2014	27.9	18.8	23.4	190.3
2015	26.4	14.2	20.3	155.4
2016	24.6	13.2	18.9	175.2
2017	23.1	12.2	17.7	198.0

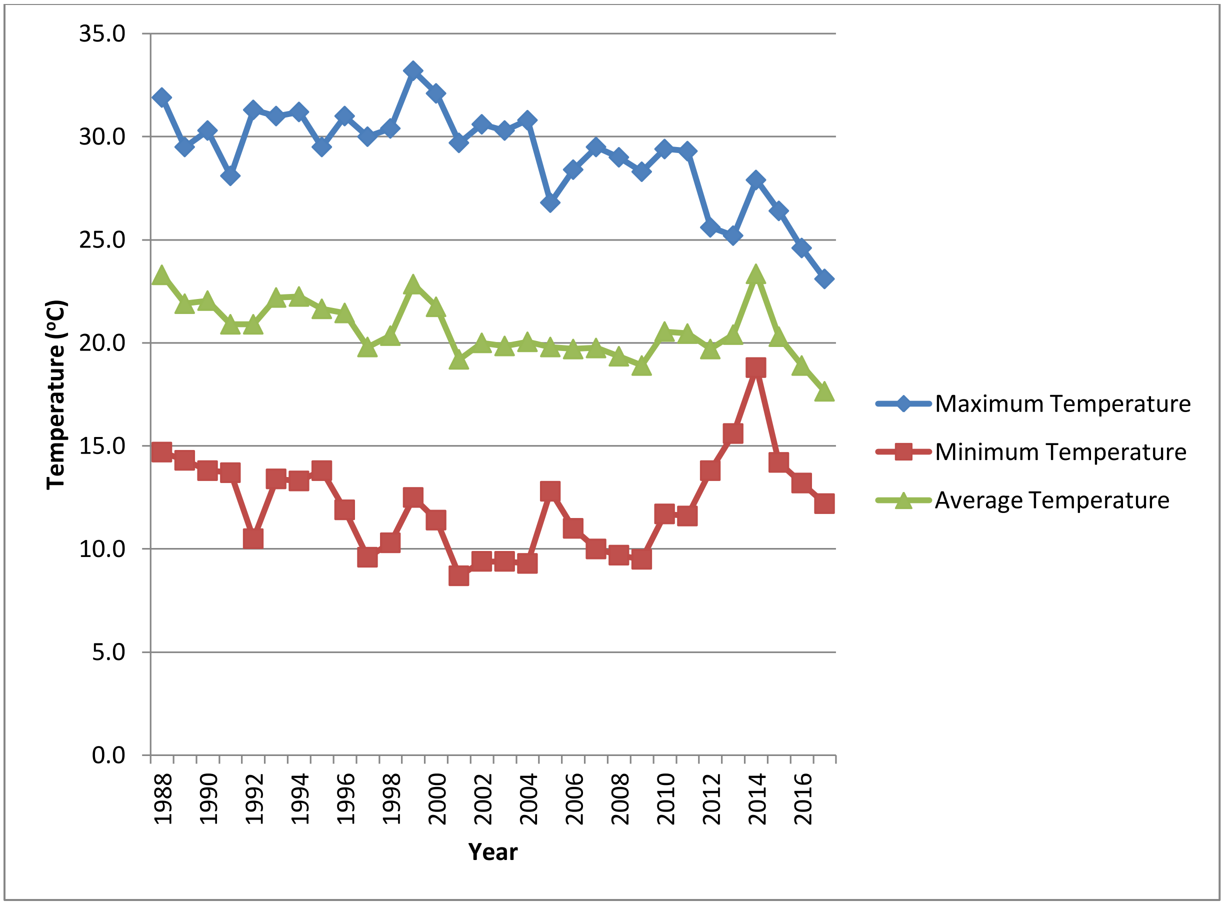

Figure 5.1: Diagrammatic representation of Temperature in Champhai District during the year 1988-2017

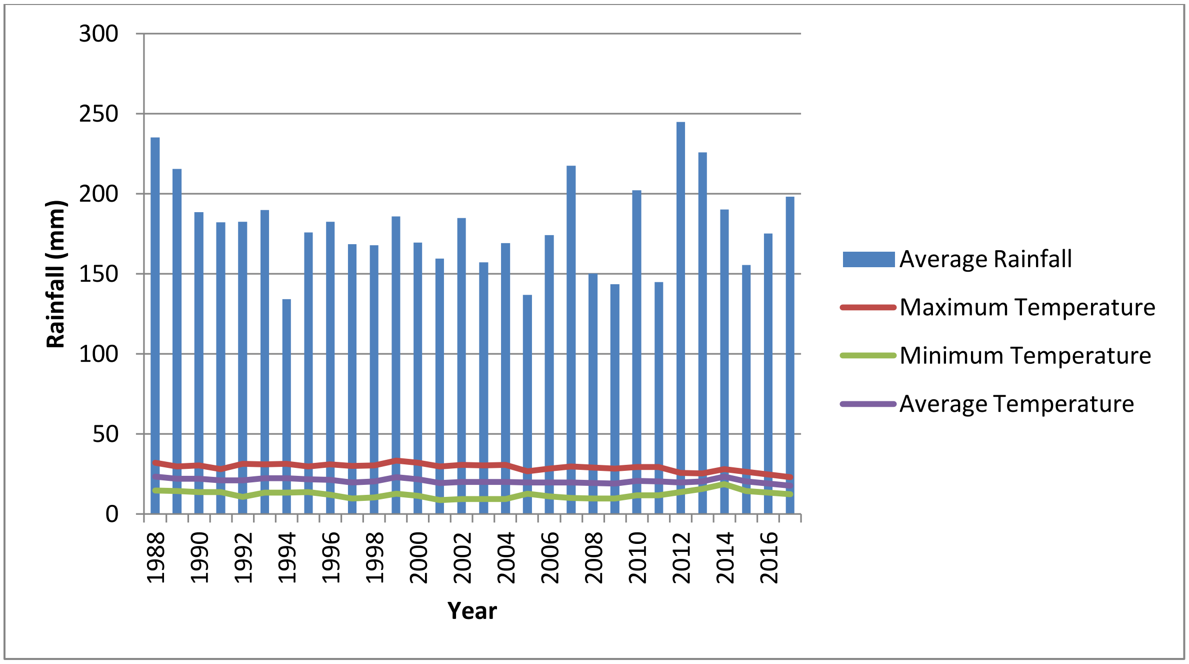

Figure 5.2: Diagrammatic representation of Average temperature, Maximum temperature, Minimum temperature and Average rainfall in Champhai district during the year 1988-2017

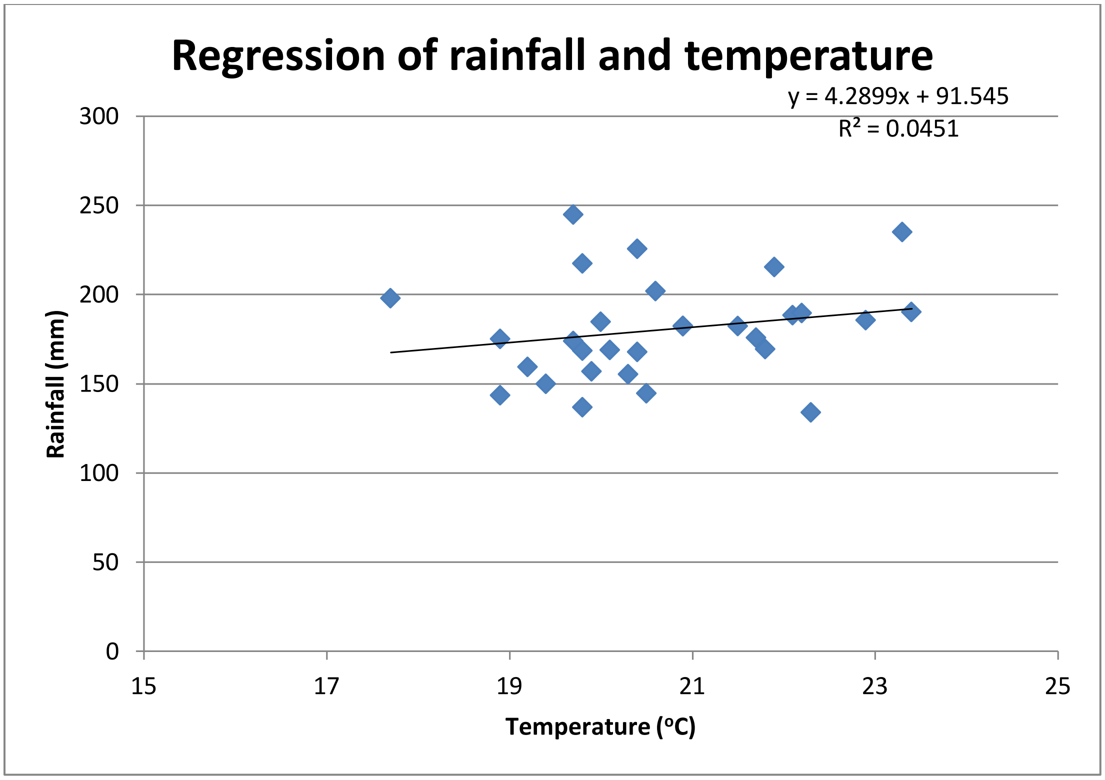

Figure 5.3: Diagrammatic representation of regression between rainfall and temperature

There is no relation between the rainfall and temperature where temperature is independent variable while rainfall is the dependent variable. 4.5% of the dependent variable are explained by the independent variable. The regression equation is Temperature = 4.2899*Rainfall + 91.545.

Table 5.2: Correlation between different variables during the year 1988-2017

	Average temperature	**Maximum temperature**	**Minimum temperature**	**Annual average rainfall**
Average temperature	1			
Maximum temperature	0.604	1		
Minimum temperature	0.58	0.299	1	
Annual average rainfall	0.216	-0.139	0.401	1

Analysis of the different variables viz. Maximum temperature, Minimum temperature, Average temperature and Annual average temperature shows that there is a significant relationship between the average temperature and the maximum temperature while there is no significant relationship between all the others variables.

5.2 Impact of precipitation on crop production

The growing period of rice were taken into consideration where the annual average rainfall is calculated with the amount of rainfall during the months of May to November of the study period. Though there is difference in the sowing and harvest period of the rice due to the temperature of that particular area, the sowing period is taken to occur in the month of May and the harvest occurs in November.

Table 5.3: Annual rainfall (mm), Average rainfall (mm)and yield from WRC (kg/ha) of Champhai district during the year 2003-2017

Year	Annual rainfall (mm)	Annual average rainfall (mm)	Area (ha)	Production (MT)	Yield (kg/ha)
2003	1884.1	421.2	4750	13060	2749
2004	2027.7	431.8	4800	13200	2750
2005	1642.2	345.1	4809	10685	2222
2006	1914.5	471.8	2619	4306	1644
2007	2609.9	587.9	2374	1319	556
2008	1799.3	417	3562	9421	2645

2009	1723.3	399.2	3345	7049	2107
2010	2424.2	503.6	3750	8148	2173
2011	1736.3	391.6	3775	7639	2024
2012	2938.6	609.1	3993	8135	2037
2013	2708.2	652.1	4384	9338	2130
2014	2283.6	534	4479	8915	1990
2015	1864.9	392	4554	10018	2200
2016	2129	482	4529	9747	2152
2017	2376.8	479.6	3700.2	8502.1	2298

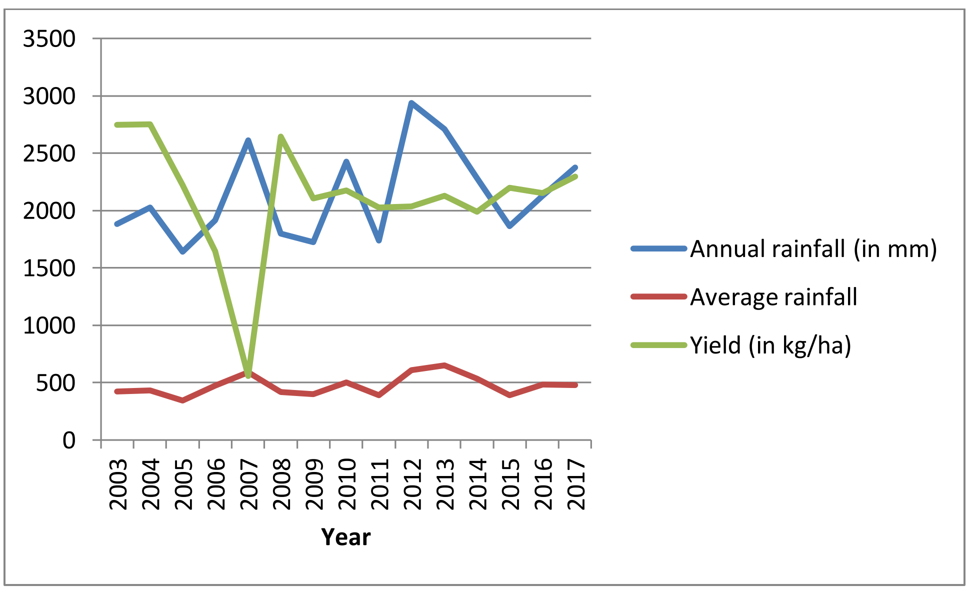

Figure 5.4: Diagrammatic representation of Annual rainfall, Annual average rainfall and yield from WRC (kg/ha) of Champhai district during the year 2003-2017

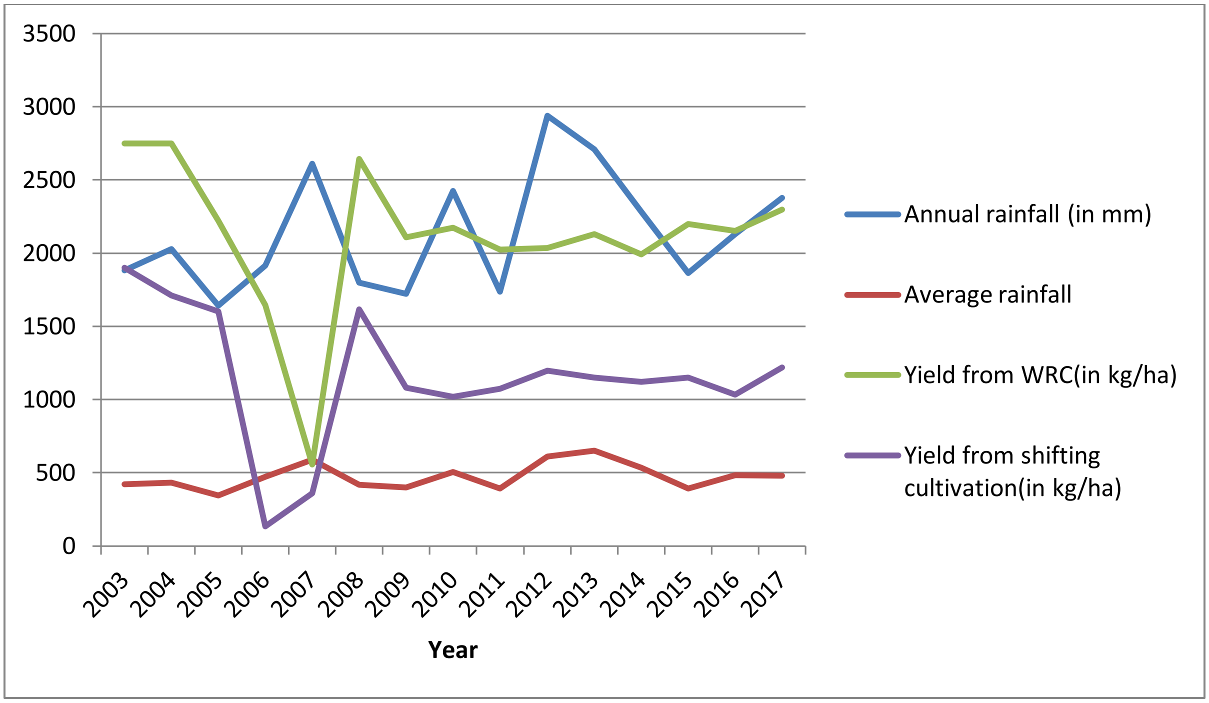

Figure 5.5: Diagrammatic representation of the annual rainfall (mm), average rainfall (mm), yield from Jhum and WRC (kg/ha) in Champhai district during the years 2003-2017

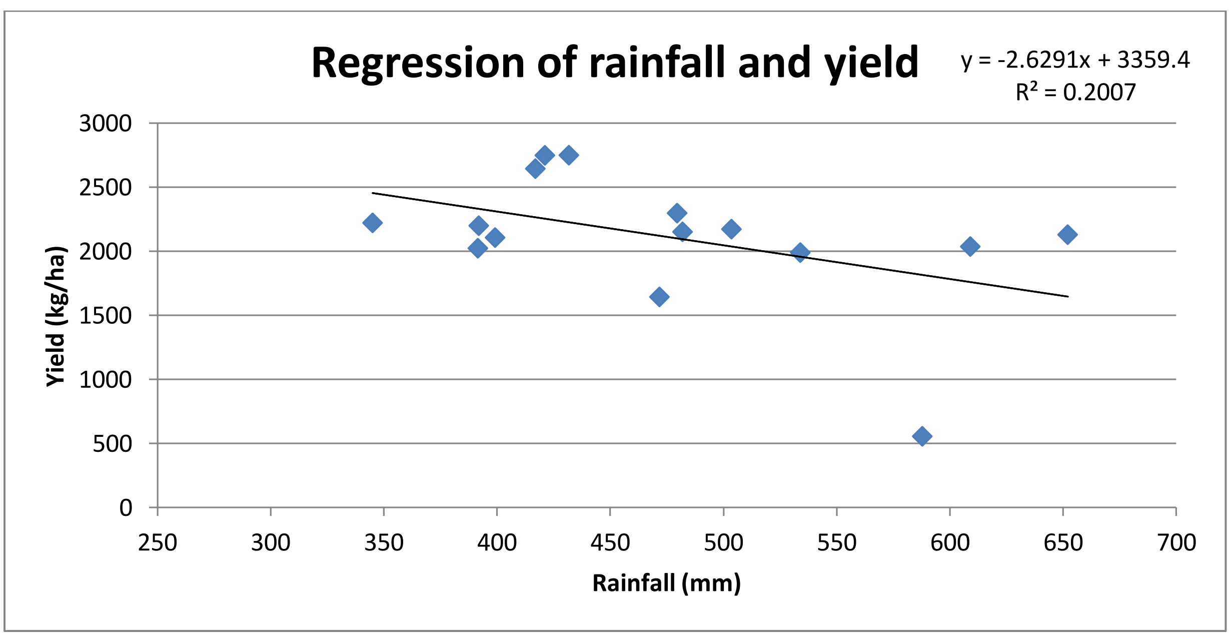

Figure 5.6: Diagrammatic representation of regression between rainfall and yield

There is no relation between the rainfall and yield where rainfall is the independent variable while yield is the dependent variable. 20.07% of the dependent variables are explained by the independent variable. The regression equation is Yield (kg/ha) = -2.6291*Rainfall +3359.4.

Table 5.4: Correlation between different variables during the year 2003-2017

	Average temperature	**Maximum temperature**	**Minimum temperature**	**Annual average rainfall**	**Yield from WRC**	**Yield from Jhum**
Average temperature	1					
Maximum temperature	0.352	1				
Minimum temperature	0.61	-0.527	1			
Annual average rainfall	0.19	-0.287	0.416	1		
Yield from WRC	-0.832	-0.0032	-0.078	-0.448	1	
Yield from Jhum	-0.018	-0.09	0.092	-0.388	0.84	1

Analysis of the different variables for any significant correlation shows there is a negative relation between the average temperature and yield from wetland rice cultivation which can be stated that production of rice would decrease with an increase in the average temperature. However, analysis of the annual average rainfall (in mm) and crop production (in kg/ha) shows that there was insufficient correlation between them during the years 2003-2017.

In addition, analysis of the shifting cultivation, annual rainfall and annual rainfall shows that there was insufficient correlation while the yield (in kg/ha) is significantly higher in WRC than in Jhum. From the total area 142913.4 ha utilized for rice cultivation, Shifting and WRC accounts for 58.42% and 41.58% respectively while the yield from Shifting and WRC accounts for 35.41% and 64.59%. Statistically with the optimum climatic condition, increase development of the potential area 1585.1 ha for WRC would increase the production of rice and other winter crops.

5.3 Socio-economic survey

Farmers from the eight agricultural circles were selected randomly and 186 households were interviewed about the species of rice planted, farming practices, crop productivity, their views on the change in climatic condition and difficulties associated with farming. The dependence of farming for their livelihood, production of rice from WRC and the use of inorganic fertilizers were also discussed.

5.3.1 Demographic profile

Demography can be used to indicate the different age group from different sectors which includes age, gender, marital and educational status. The farmers are categorized into Youth (18-34), Middle Aged (35-59) and Elderly (60 and above). From this classification the Middle Aged group accounts for 79.57% followed by the Youth with 9.68% while the Elderly farmers' accounts for

10.76% of the farmers. There is a wide difference in the gender of the farmers. Even if the owners of the rice fields were female, the actual manual labour is carried out by the male individuals of that household. Usually their sons would be responsible for the actual manual labour or in some cases individual would be hired to carry out the labour.

Marital and education status determines the number of workers that would perform the manual labour. Separated and divorced account less than 10% of the total farmers while married individual accounts for the majority of the farmers. Youths with higher educational status prefer to work in offices or in schools rather than work in the field. It is because of this that there is a significant difference in the age group and the educational status of the interviewed farmers.

5.3.2 Socio-Economic status

The farmers divided into ethnic group belong to different sub-tribes like Thado, Hmar, Lushai, Paite, and Pawi. Lushai accounts for the majority of the interviewed farmers specifically in Champhai, Khawzawl and Hnahhlan at 70.97% while the remaining 29% belongs to other sub tribes that include Hmar, Paite and Pawi. Economically the primary source of income is from the cultivation of rice for 69% of the interviewed farmers while the remaining farmers use the harvest to supplement their other source of income. This dependence of harvest is observed more in villages such as Vaphai, Khawhai, Bungzawl, Khuangleng and Ngopa.

5.3.3 Farming Practices

Due to the educational status of the farmer’s children and other members of the household, 85% of the farmers are required to hire labourers for the sowing, planting and harvesting of the rice. Because of these some farmers employ zamindary system as it is more productive. In this case, the harvest would be divided between the owners and the workers where the owners would take half of the harvest. If the owners provide facilities for the tilling, then the harvest would be divided in such a way that the owners would receive more than 70% of the total harvest.

Almost all the farms visited were rain fed and were solely dependent on the rainfall and irrigated rice field accounts for only 9% of the rice fields. Usage of fertilizer is significantly high in the rice fields of Champhai where cultivation had been carried out for more than 100 years. Cultivation had been carried out since 1898 in the farms within the Champhai circle area; the need for nutrients is higher compared to other location therefore continuous fertilization is required to supplement the loss of nutrients over the years as plantation with nitrogenous plants is not carried out in all the farms. Enhancement of soil is carried out in the rice fields older than 50 years but these are inorganic which could have a negative implant in the water drained from these rice fields. The common fertilizers and weedicides used include Urea, 2,4-D, Machete, DAP and Glycel.

Clearly there is a significant relation between the amounts of rainfall received to the rice production. However there can be various factors that play a role such as the amount of fertilizers used and the species of rice plant. The other factor determines the yield of rice, such that the tolerance level and ability of withstanding wind during the monsoon period.

The common rice species planted includes Vanzema buh, Buhsakei, Liankhuma, Manipur buh, Sanghleia buh, UNDP, Thangzauva buh, Remliana buh, Fanai buh, Vuak khat, Buhtawisang, Buh ban, Thluma buh, Buh tawi, Muankima buh, Sanghleia buh, Tuibuh, Burma buh and Dawktawra. There is no record of the scientific name for the above mentioned rice species. This could be due to the collection of rice seeds from different places where there is no proper documentation of rice cultivated and because of the rice being named to the individual who first planted the seeds for e.g. Thangzauva buh, Remliana buh, and from the area from where they were collected for e.g. Burma buh and Manipur buh. Though the Department of Agriculture had introduced High Yielding Varieties (H.Y.V.) to the farmers for their high yield, farmers prefer other rice because of their taste and fragrance.

Additional cultivation of winter crops such as mustard, cabbage, pumpkin, peas and onions introduced by the Department of Agriculture had increased the income of the farmers uplifting their livelihood to a certain degree. However, some farmers from Vaphai are unable to plant winter crops as they depend on animals for ploughing and farmers would need to spend the winter season in their farms to prevent the animals from consuming their crops. Carrying out aquaculture also increases the income of farmers; though not all the farmers can continue during the winter season due to the inadequate irrigational facilities. Common carps are the most common fishes as they are easily available, easy cultivation and their high monetary value.

Observations made from the survey states that approximately 90% of the farmers will not be able to plant rice if there is any shortage of rainfall. In the events of droughts, there would be difficulty in farming as there is lack of proper irrigational system/facilities in more than half of the rice fields. Even though there are rivers and streams flowing near the rice fields and water is available for irrigation, farmers are unable to purchase equipment to utilize the water and there is no system in place for helping the farmers in utilizing the water available in more than half of the farms.

It was also claimed that rainfall received during the crucial period of harvesting significantly decrease the rice production. The entire individual interviewed also shared their opinion in regards to the amount and intensity of rainfall received. They stated that rainfall is the most important climatic condition for wet rice cultivation.

In any case, if the amount of rainfall increases significantly there will be a chain of events that could lead to decrease in the rice production. There could be an occurrence of flooding of farms located near the river and difficulty in harvesting if there is an occurrence of rainfall during or few weeks before harvest time which is usually during the month of November and first week of December. However, decrease amount of rainfall in the months of May and June will cause delay in the sowing period or even make cultivation impossible. Any small change in the temperature would result in the change of the sowing and harvest period; increase temperature would require delay in the sowing with early harvest while a slight decrease in temperature would prolong the cultivation period.

Table 5.5: Production of rice from WRC, average area and number of farmers as per the farmer's response

Sl. No.	**Production (kg)**	**No. of individuals**	**Percentage**
1	600-899	5	2.69
2	900-1199	6	3.23
3	1200-1499	10	5.38
4	1500-1799	17	9.14
5	1800-2090	28	15.05
6	2100-2399	18	9.68
7	2400-2699	15	8.06

8	2700-2999	30	16.13
9	3000-3299	29	15.59
10	3300-3599	16	8.6
11	3600-3899	2	1.07
12	3900-4199	7	3.76
13	4200-4499	3	1.61

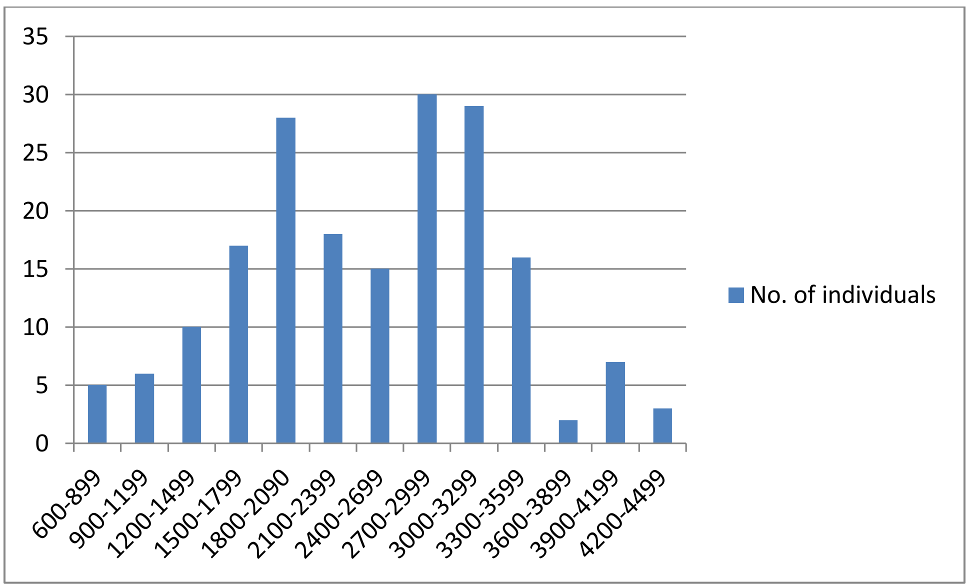

Figure 5.7: Diagrammatic representation of the rice production and the number of individual

CHAPTER VI: CONCLUSION

CONCLUSION

Northeastern regions and Mizoram in particular are experiencing the change in the climatic condition as there is clear evidence in change of the frequency and pattern of the rainfall and the period/occurrence of monsoon season. Being a hilly area it is difficult in Mizoram to get a large yield from any type of cultivation due to difficult terrain, soil erosion, frequent natural disasters and lack of irrigation. Dependence on farming is the way of life in rural areas; with WRC carried out in areas where there are potential areas. However, this is not possible in all the areas. Farmers have also observed the change in the rainfall patterns over the past years with more erratic and strong winds, occurrence of the monsoon season and the amount of rainfall. There is therefore, a need to have a strategy to combat the possible change in the production of rice not only by the local and the state government but also by the farmers.

Measurements and determination of climate change is difficult in any locations especially in regions where there is lack of monitoring equipments (Eckman et al, 2015; Eckman and Laltanpuii, 2016). In Mizoram, there is a lack of scientific research and observations which is attributed by the remoteness, extremely difficult terrain as well as direct field observations. Actual forecasting and reporting is still lacking in this region though weather forecasting is carried out for the whole country. In addition there is no systematic distribution of meteorological stations, and in some cases these stations are unmonitored or partly functional which this contributes to the absence of rainfall data in the study area.

There is sufficient relation between the rainfall and the crop production in some period though there is insufficient relation during all the study period. However, rainfall is not the only condition that determines the yield; other climatic condition, usage of nutrient enhancing substances and the species of the rice cultivation contribute significantly to the yield. It can be concluded that rainfall cause a havoc during the sowing and harvest period.

From the survey it has been observed that there is a dramatic demographic change within the study site. Due to urbanization and increased job opportunities, the youth left the rural areas to pursue other careers which results in the farmers and producers to be elder individual being responsible for cultivating rice. In some cases the fields are rented out to others who are required to give a certain amount of their yield to the owners. Episodes of droughts and flooding have also been observed on a large scales, which have caused a change in the agricultural system to start a more sustainable cultivation of cash crops and plantations aided by the previous Government's flagship programme – New Land Use Policy (NLUP).

Farms near the river banks are flooded early in almost all the study site; embankments had been made although these embankments are not available in all the required areas. The main problems faced by the farmers are flooding and droughts. Provision of irrigational facilities would encourage the farming to be extended in all the potential areas. In addition, possible way to supplement the income of the farmers also needs to be undertaken where water is available during the winter season such as the plantation of winter crops such as chick peas, mustard, cabbage and onions. Provision of irrigational facilities could enable the farmers to earn a better livelihood.

On comparison with the shifting cultivation, WRC could be the type of cultivation where Mizoram would be able to be independent in rice. Destroying the precious forest area is another setback brought about by Shifting cultivation, fallow lands are increasing yearly and these lands would required more than 5-6 years to replenished the nutrients loss by soil erosion, run off etc and more than 10 years for the lands to be claimed as forested areas.

It is estimated that by 2030, India would become the most populous country and it is predicted that the growth rate will continue through at least 2050. Northeast region has high population in rural areas and any change in the climatic condition will have a negative impact on who are depended on agricultural individuals. Demand for food and other resources will drive towards environmental degradation and sustainable development will not be possible in the current trend. Adaptation to possible changes affecting the water resources, agriculture, human health and biodiversity has to be established in the need future together with the need to develop crops that can withstand even the most extreme climatic condition.

Mitigation process for climate change is rising as 50% of the population of Mizoram is dependent on agriculture which it contributes less than 5% of the total state's GDP. Newer technology and equipments are required to increase their yield while prediction of the possible variation of climatic condition such as temperature and rainfall will enable the farmers to make a plan to utilize the climatic condition at maximum degree. Modeling of possible climatic change will solve the farmer's problem for irrigation which is difficult for more than 90% of the interviewed individuals within the study site (Champhai). Increased development of the areas potential for WRC would be in the general interest as shifting cultivation does not yield a large production though the area under cultivation of shifting cultivation is higher.

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PHOTOPLATES

Photo 1: Land preparation of farmland for sowing and water management for germination

Photo 2: Germination of seeds in WRC field

Photo 3: WRC at New Champhai after transplantation of rice plants

Photo 4: WRC at Zote village after transplantation of rice plants

Photo 5: WRC at Zotlang, Champhai after harvest season

Photo 6WRC area left barren before the monsoon period


Photo 7: Interview of farmers for socio-economic survey in Champhai

Photo 8: Interview of farmer for socio-economic survey in Khawzawl

APPENDICES

Table 1: Monthly rainfall of Champhai District during the year 1988-2017

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
1988	0	27	53	158	355	500	433.5	432	408.5	394	53	7	2821
1989	0	25	33	123	193	428	493	476	353	430.5	33	0	2587
1990	0	44	208	229.5	138.5	414.5	265	317.5	336.5	122	112.5	74.5	2263
1991	21	7.5	43	169	331	368	309	379	275.5	242	28	15.5	2188
1992	0	38	25	106	183.5	369.5	511.5	446.5	242.5	225.5	36.5	5.5	2190
1993	22.5	129	29	53	309	401.5	450	420	240.5	208.5	14	0	2276
1994	2	17	164	139	169	307	214	308	172	80	36	0	1608
1995	10	3	52	63	297	430	227	402	289	189	149	0	2111
1996	0	15	326	70.5	172.5	157	339.5	544.5	383	141.5	40.5	0	2189
1997	14.5	4.5	102	83.5	188.5	267	607.5	241.5	338	90	35.5	51.5	2024
1998	43	28	131	136	314	278	280.5	442.5	230.5	128.5	3.5	0	2015
1999	0	0	20	51.7	328.3	286.7	428	297	459.3	267	48.3	42	2228
2000	18.7	15	90	163.3	415.7	189.3	222	382	351	136.3	51	0	2035
2001	0	28	21	58	317	315	230.3	260	204	370	111	0	1915
2002	51.3	8	NA	137.3	317.7	268.7	407	303.7	303.7	100.3	134.7	0	2032
2003	1.3	10	55	103.3	195.3	499.3	212.7	340.3	277	160.3	0	29.3	1884
2004	0.7	0	16	284	138	380	439	276	406	86	2	0	2028
2005	1	0.7	127	82.7	213.5	169.3	259.3	281.7	204.3	282.7	5.7	14.3	1642
2006	0	3.3	NA	24.3	407	674.3	263	175.8	244.8	122	0	0	1915
2007	0	58	8	192.8	303.8	447	423.8	400.3	467.7	175.7	133	0	2610
2008	51.3	27	25	28	196.7	249.4	278.6	430.5	392.3	106.8	13.7	0	1799
2009	0	0	14	112.5	136.8	344.3	250.8	396.3	297.8	145.6	25.2	0	1723
2010	0	0	148	203.6	239	294.8	423.6	339.7	480.1	219.7	17.5	58.1	2424
2011	18	0.1	55	96.78	250.5	352.3	319.9	307.6	187	146.3	2.9	0	1736
2012	22	15	27	438	258	536	391	496.3	465	186	104	0	2939
2013	0	4.1	4.5	91.1	634.2	399.6	445.4	586.6	383.4	159.3	0	0	2708
2014	0	22	37	86.4	466.4	320.7	447.3	313.3	481.6	106	2.8	0	2284
2015	8.4	4.2	29	253	103.2	177.5	449.7	426	238.9	168.1	4.6	2.3	1865
2016	3.4	7.6	61	102.2	323	369	361.8	345.8	308.7	151.6	68	0	2129
2017	0	8.8	116	273.3	186.1	419.9	389.7	305.2	330.5	249	37.8	60.3	2377

Table: Annual rainfall and average rainfall of Champhai District and Yield of Rice during the year 2003-2017

Year	Annual rainfall (in mm)	Average rainfall	Area (in ha)	Production (in MT)	Yield (in kg/ha)
2003	1884.1	421.2	4750	13060	2749
2004	2027.7	431.8	4800	13200	2750
2005	1642.2	345.1	4809	10685	2222
2006	1914.5	471.8	2619	4306	1644
2007	2609.9	587.9	2374	1319	556
2008	1799.3	417	3562	9421	2645
2009	1723.3	399.2	3345	7049	2107
2010	2424.2	503.6	3750	8148	2173
2011	1736.3	391.6	3775	7639	2024
2012	2938.6	609.1	3993	8135	2037
2013	2708.2	652.1	4384	9338	2130
2014	2283.6	534	4479	8915	1990
2015	1864.9	392	4554	10018	2200
2016	2129	482	4529	9747	2152
2017	2376.8	479.6	3700.2	8502.1	2298

Table: Production and yield of WRC and Jhum in Champhai during the years 2003-2017

Year	Type of Cultivation	Area in Ha	Production in MT	Yield in kg/ha
2003-2004	Jhum	4614	8766	1900
	WRC	4750	13060	2749
2004-2005	Jhum	5999	10272	1712
	WRC	4800	13200	2750
2005-2006	Jhum	5610	8975	1600
	WRC	4809	10685	2222
2006-2007	Jhum	7685	1020	133
	WRC	2619	4306	1644
2007-2008	Jhum	11238	4051	360
	WRC	2374	1319	556
2008-2009	Jhum	5900	9534	1616
	WRC	3562	9421	2645
2009-2010	Jhum	4628	7155	1082
	WRC	3345	7049	2107
2010-2011	Jhum	4350	4431	1019
	WRC	3750	8148	2173
2011-2012	Jhum	3730	4004	1073
	WRC	3775	7639	2024
2012-2013	Jhum	5900	7060	1197
	WRC	3993	8135	2037
2013-2014	Jhum	5602	6442	1150
	WRC	4384	9338	2130
2014-2015	Jhum	4302	4822	1121
	WRC	4479	8915	1990
2015-2016	Jhum	4254	4892	1150
	WRC	4554	10018	2200
2016-2017	Jhum	4488	4636	1032
	WRC	4529	9747	2152
2017-2018	Jhum	5190.2	6330	1220
	WRC	3700.2	8502.1	2298

Table: Demographic and Socio-Economic Status

Sl.No	Characteristics	No. of individuals	Percentage
I	**Age Group**		
	Youth	18	
	Middle Age	148	
	Elderly	20	
II	**Gender**		
	Male	171	91.95%
	Female	15	8.06%
III	**Marital Status**		
	Unmarried	0	0
	Married	139	74.73%
	Divorced/Separated	18	9.68%
	Remarried	21	11.29%
	Widowed	8	4.30%
IV	**Educational Status**		
	Illiterate	0	0.00%
	Higher Secondhary and below	158	84.95%
	Graduate and above	28	15.05%
V	**Type of Family**		
	Nuclear	112	60.22%
	Joint	74	39.78%
VI	**Ethnic Group**		
	Chin	186	100%
VII	**Sub Tribe**		
	Hmar	28	15.05%
	Lushai	132	70.97%
	Paihte	14	7.53%
	Pawi	12	6.45%
VIII	**Religion**		
	Christianty	100	100%
IX	**Source of Income**		
	Farming	128	68.82%
	Others	58	31.18%

Table: Temperature of Champhai during the year 1988-2011

Year	Jan		Feb		Mar		Apr		May		Jun	
	Max	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**
1988	29.0	11.0	30.0	11.0	32.0	15.0	40.0	15.0	32.0	15.0	35.0	18.0
1989	22.0	4.0	22.0	8.0	31.0	12.0	36.5	14.0	35.0	19.0	35.0	19.0
1990	25.0	8.0	26.0	11.0	31.0	11.0	31.0	12.0	34.0	16.0	33.0	18.0
1991	24.0	7.0	30.0	10.0	32.0	12.0	32.0	13.0	29.0	15.0	29.0	16.0
1992	27.0	6.0	27.0	7.0	35.0	12.0	35.0	10.0	31.0	12.0	34.0	11.0
1993	33.0	6.0	32.0	8.0	33.0	12.0	33.0	15.0	32.0	14.0	30.0	14.0
1994	27.0	7.0	30.0	9.5	32.0	11.0	35.0	13.0	34.0	15.0	32.0	16.0
1995	28.0	6.0	26.0	9.0	33.0	12.0	34.0	13.0	34.0	17.0	32.0	18.0
1996	22.0	8.0	25.5	10.5	30.0	12.0	32.0	13.0	29.0	13.0	40.0	16.0
1997	24.0	0.0	24.0	0.0	28.0	7.5	30.5	8.0	34.0	13.5	34.0	15.0
1998	21.0	0.0	24.0	3.0	30.0	3.0	32.0	9.0	36.0	11.0	35.0	16.0
1999	27.0	5.0	29.5	6.0	26.0	4.5	36.0	11.0	36.0	16.0	38.0	18.0
2000	26.0	4.0	28.0	5.0	34.5	6.0	36.5	15.0	35.0	16.0	34.0	18.0
2001	22.0	0.5	26.5	2.0	30.0	6.0	34.0	9.5	34.0	12.0	35.0	16.0
2002	23.0	0.0	26.0	1.0	30.0	4.0	32.0	10.0	35.0	12.0	36.0	17.0
2003	21.0	0.0	26.0	2.0	29.0	3.0	33.0	4.0	33.0	15.0	36.0	14.0
2004	24.0	0.0	27.0	0.0	35.0	6.0	31.0	9.0	35.0	11.0	33.0	11.0
2005	22.0	4.2	24.5	6.6	29.7	10.4	29.9	12.7	13.9	15.9	32.0	18.2
2006	22.0	4.0	25.0	7.0	29.0	10.0	30.0	11.0	32.0	13.0	32.0	13.0
2007	21.0	1.0	22.0	4.0	27.0	6.0	28.0	6.0	31.0	8.0	36.0	17.0
2008	23.0	1.0	25.0	0.0	29.0	8.0	32.0	10.0	34.0	14.0	32.0	16.0
2009	22.0	2.0	26.0	1.0	30.0	13.0	30.0	13.0	32.0	16.0	31.0	14.0
2010	27.0	4.0	28.0	8.0	30.0	14.0	32.0	16.0	31.0	17.0	29.0	15.0
2011	24.0	3.0	27.0	4.0	30.0	13.0	31.0	14.0	31.0	16.0	30.0	14.0
2012	22.6	10.2	24.3	10.3	23.9	14.3	23.4	16.7	24.1	13.4	31.2	12.2
2013	17.0	2.7	24.3	10.0	25.5	15.3	25.2	17.2	23.2	16.5	27.5	16.8
2014	20.7	8.0	20.0	9.9	22.3	14.1	27.7	16.7	28.4	21.3	34.2	26.6
2015	23.5	10.5	25.2	10.0	30.2	11.5	30.2	11.9	29.2	18.1	26.6	18.4
2016	18.3	4.1	20.8	6.0	26.4	14.1	26.9	13.1	30.5	18.2	29.0	17.8
2017	16.7	5.6	21.8	5.4	22.7	11.8	25.0	15.2	26.8	16.4	24.5	15.7
Average	23.5	4.4	25.8	6.2	29.6	10.1	31.5	12.2	31.2	14.9	32.5	16.2
Average mean	9.0		16.0		19.8		21.85		23.05		24.35	

Table: Temperature of Champhai during the year 1988-2011

Year	Jul		Aug		Sep		Oct		Nov		Dec		Total	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1988	30.0	18.0	30.0	18.0	31.0	18.0	36.0	14.0	35.0	13.0	23.0	10.0	31.9	14.7
1989	31.0	19.0	29.0	20.0	30.5	21.0	30.5	18.0	27.0	12.0	25.0	5.0	29.5	14.3
1990	35.0	19.0	32.0	19.0	32.0	18.0	31.0	13.0	29.0	12.0	25.0	9.0	30.3	13.8
1991	30.0	19.0	30.0	19.0	29.0	17.0	28.0	15.0	24.0	14.0	20.0	7.0	28.1	13.7
1992	30.0	12.0	31.0	12.0	32.0	14.0	31.0	14.0	29.0	8.0	33.0	7.5	31.3	10.5
1993	31.0	18.0	32.0	19.0	31.0	19.0	33.0	15.0	26.0	12.0	26.0	9.0	31.0	13.4
1994	32.0	18.0	31.0	18.0	31.0	18.0	30.0	16.0	28.0	9.0	32.0	9.0	31.2	13.3
1995	30.0	18.0	30.0	18.0	29.0	18.0	29.0	17.0	27.0	11.0	22.0	9.0	29.5	13.8
1996	35.0	17.5	34.0	18.0	34.0	17.0	34.0	11.5	30.0	4.5	26.0	1.5	31.0	11.9
1997	33.0	18.0	33.0	17.5	32.0	16.0	31.0	11.0	29.5	7.0	26.5	1.5	30.0	9.6
1998	35.0	18.0	34.0	19.0	33.0	19.0	32.0	13.0	29.0	8.0	24.0	4.0	30.4	10.3
1999	34.5	17.0	36.0	20.0	37.0	20.0	35.0	19.0	33.0	9.0	30.0	5.0	33.2	12.5
2000	34.0	18.0	35.0	16.0	33.0	18.0	34.0	14.0	34.0	5.0	21.0	2.0	32.1	11.4
2001	34.0	19.0	36.0	18.0	33.0	15.0	28.0	3.0	22.0	1.5	22.0	1.5	29.7	8.7
2002	33.0	18.0	34.0	18.0	34.0	16.0	32.0	11.0	29.0	6.0	23.0	0.0	30.6	9.4
2003	35.0	19.0	34.0	19.0	33.0	18.0	31.0	11.0	26.0	5.0	26.0	3.0	30.3	9.4
2004	34.0	18.0	36.0	19.0	34.0	18.0	34.0	11.0	25.0	5.0	22.0	3.0	30.8	9.3
2005	30.4	19.0	32.4	19.1	30.4	18.5	29.4	14.2	25.2	8.5	22.0	6.0	26.8	12.8
2006	33.0	18.0	30.0	18.0	30.0	15.0	29.0	16.0	27.0	5.0	22.0	2.0	28.4	11.0
2007	35.0	18.0	36.0	19.0	34.0	19.0	33.0	13.0	29.0	9.0	22.0	0.0	29.5	10.0
2008	32.0	14.0	32.0	17.0	32.0	18.0	32.0	14.0	23.0	2.0	22.0	2.0	29.0	9.7
2009	29.0	13.0	28.0	14.0	26.0	13.0	30.0	7.0	29.0	5.0	26.0	3.0	28.3	9.5
2010	32.0	16.0	31.0	16.0	30.0	16.0	30.0	14.0	29.0	1.0	24.0	3.0	29.4	11.7
2011	29.0	14.0	30.0	15.0	30.0	14.0	30.0	10.0	29.0	7.0	30.0	15.0	29.3	11.6
2012	28.2	18.1	29.0	19.6	30.2	18.6	27.2	16.1	25.7	12.4	17.3	4.1	25.6	13.8
2013	26.5	22.3	31.9	28.6	29.8	21.8	25.3	13.9	23.9	12.9	22.7	9.7	25.2	15.6
2014	33.3	26.5	32.9	27.6	33.2	27.8	32.4	22.1	25.5	15.5	23.8	9.4	27.9	18.8
2015	26.1	16.6	27.1	16.7	27.4	16.9	26.4	16.2	24.2	14.0	20.7	9.4	26.4	14.2
2016	28.6	17.9	25.4	16.8	23.5	14.5	24.4	14.0	22.6	11.9	19.1	10.5	24.6	13.2
2017	24.1	15.6											23.1	12.2
Average	31.5	17.8	31.8	18.4	31.2	17.7	30.6	13.7	27.4	8.5	24.1	5.6	29.1	12.1
Average mean	24.65		25.1		24.45		22.15		17.95		14.85		20.6	

QUESTIONNAIRE FOR ASSESSING CROP PRODUCTIVITY

Name of the respondent: ____

Village: _________________________ District: _________________________

No. of family members: _______________ Male:______; Female:_______

FARMING PRACTICES

No. of family members involved in farming: _____________________________

Total no. of person involved in the farming process incase helpers/labourers are employed:_______

If not involved, is Zamindari system employed? ____________________________

How many individuals are involved in the system? __________________________

What is the rent per season or percentage of sharing of crop produced?______________

Time period of farming: ____

Area of land cultivated:____

How is the farmed area irrigated? Is it dependent on rainfall or irrigated using tanks or ponds?_______

Which irrigation will be best suited to the field if the irrigation practice currently utilized is inefficient? ____

Is any organic or inorganic fertilizer used? Yes/No _____

If Yes, name of fertilizer used and amount used in relation with the area of the field: _________

VARIETY OF CULTIVATED SPECIES

How many varieties of rice are being cultivated? _____

If 1, name the cultivated species: ____________________________________

If more than 1, list the variety of rice species cultivated: ____________________________

____

Plantation of the crop according to the variety:

____

CROP PRODUCTIVITY

Amount of crop produced in the last 10 years (if possible):

Year	Crop produced in terms of Kg	Crop produced in terms of Rupees
2008		
2009		
2010		
2011		
2012		
2013		
2014		
2015		
2016		
2017		
2018		
Total		

Income obtained by the landowners when Zamindari system is followed:

Year	Crop produced in terms of Kg	Crop produced in terms of Rupees
2008		
2009		
2010		
2011		
2012		
2013		
2014		
2015		
2016		
2017		
2018		
Total		

Income obtained by the labourer:

Year	Crop produced in terms of Kg	Crop produced in terms of Rupees
2008		
2009		
2010		
2011		
2012		

2013		
2014		
2015		
2016		
2017		
2018		
Total		

Investment (money per crops):

Year	Investment in terms of Rupees
2008	
2009	
2010	
2011	
2012	
2013	
2014	
2015	
2016	
2017	
2018	
Total	

REMARKS/SUGGESTION

Is there any problem related with the present farming practices? Yes/No

___

Suggestion for handling the present problems mentioned above:

___

Any remarks with regards to the amount of precipitation received in relation to crop productivity:

___

Date: ____________________________

(IRENE LALNIPARI SELLATE)
MPhil Scholar,
Department of Environmental Science, MZU

PARTICULARS OF THE CANDIDATE

NAME OF CANDIDATE : Irene Lalnipari Sellate

DEGREE : Master of Philosophy

DEPARTMENT : Environmental Science

TITLE OF DISSERTATION : Impact of Rainfall on Crop Production in Mizoram, India

DATE OF PAYMENT OF ADMISSION : 24/08/2017
(Commencement of First Sem)

COMMENCEMENT OF SECOND SEM/
DISSERTATION : 6/02/2018
(From conclusion of end semester exams)

APPROVAL OF RESEARCH PROPOSAL

1. BOS : 19/04/2018
2. SCHOOL BOARD : 27/04/2018

REGISTRATION NO. & DATE : MZU/M..Phil/453 of 27.04.2018

DUE DATE OF SUBMISSION : 31/07/2019

EXTENSION (IF ANY) : One semester (Till 31/07/2019)

Head

Department of Environmental Science

BIO-DATA

NAME : Irene Lalnipari Sellate

FATHER'S NAME : Thilthakunga Sellate

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CATEGORY : Schedule Tribe

PERMANENT ADDRESS : House No. A- 24, Venglai, Lunglei, Mizoram. 796701

PHONE NUMBER : 9856941927

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EDUCATIONAL QUALIFICATIONS

Sl. No	Name of Examination	Year of Passing	Name of the Board/ University	Percentage/Grade
1	HSLC	2009	Mizoram Board of School Education	74.40%
2	HSSLC	2011	Meghalaya Boars of School Education	69%
3	B.Sc	2015	Northeastern Hill University	51%
4	M.Sc	2017	Mizoram University	80.50%

ABSTRACT

IMPACT OF RAINFALL ON CROP PRODUCTION IN MIZORAM, INDIA

IRENE LALNIPARI SELLATE

DEPARTMENT OF ENVIRONMENTAL SCIENCE,
MIZORAM UNIVERSITY

ABSTRACT

IMPACT OF RAINFALL ON CROP PRODUCTION IN MIZORAM, INDIA

BY

Irene Lalnipari Sellate
Department of Environment Science

Submitted
in partial fulfillment of the requirement of the Degree of Master of Philosophy in
Department of Environmental Science of Mizoram University, Aizawl

ABSTRACT

Agriculture had played an important role in the growth of civilization around fertile soils, river banks and deltas and exceeding the carrying capacity and overexploitation of the available resources had caused demise of civilization thousands of years ago. Agricultural activities had also been revolutionized numerous times and the revolution that occurred some 10,000 years can be attributed as the start of a new era (Saur, 1952). Improvement of these activities includes domestication of animals such as cows, goats, sheep, chicken and fishes to supplement the agricultural products.

Increased requirement of agricultural products has influenced the agricultural productivity capacity of different agricultural zones. Though man had numerous advances in various fields and technology had improved and search alternative livelihood of man, agriculture still covers over 35% of the ice free land to meet the need (Foley, 2014). In the present age, 1.2-1.5 billion hectares are used for crop cultivation while another 3.5 billion hectares are used for grazing animals. However, there is still shortage of food and famine in a lot of developing and third world countries and malnutrition of children is a problem faced even in the 21st century. Projects made by the FAO indicates that crop production should have an increase of at least 70% to meet the needs of the population growth all over the world and 11% of arable land could be effected by climate change with decrease production of grain in developing countries (FAO, 2005).

The global population is estimated to be about 7.7 billion and the population could range from 8-10.5 billion by 2050 although the population growth is diminished due to demographic

transition (United Nations, 2009). And the current global life expectancy is 71.4 years with male and female life expectancy being 69 and 74 years respectively (WHO, 2016). India is the second most populous country in the world with 1.21 billion people in 2011 and is expected to surpass China to be the most populous country by 2050. In addition, the demand of resources will increase in India due to increased life expectancy as a result of improvement of health care facilities and rise in the living standard.

Increasing population and rising demand of food are not the only factors that cause stress on the crop production; climatic conditions plays a tremendous role and significant impact in the quantity of crop production and it is an interrelated process (Mall et al., 2006; Parry et al., 2007). This is due to the specific climatic requirement such as rainfall, atmospheric composition, temperature and humidity by certain crops such as maize, rice, wheat and other vegetables. If there is a slight change in the climatic condition, there could be an occurrence of famine in countries where the main source of income is agriculture and farmers will be the most affected section of the society (Dhanys and Ramachandran, 2016). And this change in climatic condition is occurring due to emission of greenhouse gases from anthropogenic and agricultural activities.

Effect of climate change on agriculture is given attention as change in climatic condition is one of the main determinants of crop production (Adams et al., 1998; Adams et al., 1999; Polsky and Easterling, 2001). Increasing sensitivity of plants to climate change can be due to use of high-yielding varieties, timing of field operations and planting practices (Hazell, 1984; Anderson and Hazell, 1987). Because of this, the agricultural activities and practices needs to be changed and prepare for the possible change that will have a tremendous impact on human society as a whole.

In addition to climatic condition, various factors that influence the crop productivity of a certain agricultural zone. These factors can be categorized as the soil properties, types of crops planted, technological advancement (Newbery et al., 2016) and use of chemical substances such as fertilizers, weedicides and pesticides that enhance the yield of crops. However the first two factors can be accounted as one factor with certain properties of soil such as soil moisture and soil air which are influenced by the amount of precipitation even if the change is 2-3% (Mishra, 2004).

Decreasing crop production of due to climate change had been observed in vulnerable countries and is predicted to increase further with future warming and change in rainfall patterns (Ahmed et al., 2015). Asian countries are also vulnerable to climate change due to severe water scarcity and droughts and tropical countries will face a threat to human security due to direct and indirect impact on water resources (IPCC, 2013). It is estimated that there would be an increase in demand of irrigation by 26% with an increase in temperature and decrease in rainfall while there will be 4% cease of global runoff with every $1^{o}C$ rise in temperature due to evapotranspiration and precipitation (Sharma, 2003; Vinnarasi and Sarma 2011).

The intensity and pattern of rainfall which can be influenced by moisture level in the atmosphere, emission of fine particulates, pollution and urbanization is the most prominent climatic condition and it determines the yield of crop production. In the North-Eastern region, the intensity of rainfall in the region is likely to increase by 1–6mm/day while the number of rainy days is likely to decrease by 1–10 days (INCCA, 2010) while some areas of this region is expected to experience almost 25 % more rainfall together with 26% increase of extreme rainfall events per year.

India is one of the largest producers of rice and the increase in rice production is more than 350% from 1950 and the yield per hectare had increased to 262% from the year 1050-1992, in 2009-10 the rice produced reaches 89.13 million (IRRI, 2000). In Mizoram, rice is grown mainly during Kharif season in an area of about 54,250 hectares and produces about 1,03,040 tons. The productivity of rice in lowland/wet rice cultivation is higher than that of jhumming at 2.82 tons/hectares and 1.57 tons/ hectares respectively. However, the total demand of rice is met by the rice produced outside the state. Therefore, there is an urgent need for Mizoram to be self sufficient (Anon, 2007).

There is a certain requirement of temperature and rainfall for rice and these determines the growth and development of rice and influence the production and productivity. Rice requires 21^o-25^oC for germination, 15^o-20^oC for transplanting, 20^o-25^oC for growth and 25^o-34^oC for tillering while it requires rainfall for germination and transplanting. However, with rainfall during harvest time, there would be a loss of rice grains (Seetraraman, 1980)

The need to assess the impact of climate change is in demand for long strategic planning so these impacts of climate change can be quantified with a temporal resolution. Understanding the farmers perception of the impact of climate change and adaption required need to be established. This study analyzes the impact of climate change on precipitation and how it could affect the crop productivity in the study site (Champhai District). It would also help in determining how the increase of precipitation affects the livelihood of those who are dependent on the productivity of the land.

The main objective of the study is to study the impact of climate change on rainfall, impact of precipitation on crop productivity and study of socio-economic status of concerned individuals.

Mizoram, the selected study area is located in the north-eastern region of India, sharing an international border by Bangladesh in the west and Myanmar in the southwest and bordered by the states of Assam and Manipur in the north and Tripura in the North-West. The selected study site, Champhai is one of the eight (8) districts with temperature and rainfall providing the requirement for agricultural activities and has a potential for Agri-Horticultural system and plantations.

The main food staple in Mizoram is rice; therefore the main concern with crop production is placed on rice production from wet rice cultivation (WRC). Though the influence of climatic condition is felt in Jhum lands, the study is based on wet rice cultivation as WRC are considered to have lesser environmental stress and also the possibility of sustaining a greater food demand. The effects of jhum cultivation can be observed on forests, wildlife and land use. In Mizoram, major rice fields are located in Champhai district also known as 'Rice bowl of Mizoram' and had carried out WRC for more than 100 years.

For this study, individual interviews with the concerned individuals were conducted while analysis of secondary data was carried out to understand and evaluate farming practices and socio-economic status of concerned individuals. To understand the socio-economic status of farmers, questionnaire and interviews were carried out in the eight (8) agricultural circles of Champhai District. These circles are Champhai, Hnahlan, Khuangleng, Vaphai, Khawzawl, Khawhai, Kawlkulh and Ngopa where 186 individuals were selected at random and their responses were noted down. The secondary data regarding the climatic condition such as temperature and rainfall were collected from three main departments- Department of Science and Technology, Department of

Economics and Statistics and Department of Agriculture and Crop Husbandry, Government of Mizoram. To determine the impact of rainfall on crop production, the Agriculture Statistical Abstracts published by the Directorate of Agriculture which included the area utilized of cultivation and yield of crops were collected for compiling the production of rice from WRC. The collected secondary data were analyzed to establish the correlation between the temperature and rainfall and crop production to establish the impact of rainfall on crop production.

Climatic condition of Champhai district was observed to change continuously where the highest amount of rainfall occurs in 2012 at 2938.6 mm while the lowest amount rainfall received was observed in the year 2005 at 1642.2mm. On comparison with the entire state of Mizoram, the highest amount of rainfall on 2007 at 3121.9mm while the lowest amount rainfall received was observed in the year 2014 at 1936.8 mm.

Analysis of the secondary data reveals that there is no significant relationship between the temperature and the annual average rainfall although there is a significant relation between the average temperature and the maximum temperature.

For studying the impact of rainfall on crop production, the study period was changed to include only the months during which cultivation of rice occurs. Analysis of the annual average rainfall (in mm) and crop production (in kg/ha) shows that there was insufficient correlation between them during the years 2003-2017. However, there is a negative relationship between the average temperature and the yield from the wetland rice cultivation where there would be decrease in the yield with an increased in temperature. Although there is no significant relationship between the rainfall and the yield, there could be a number of other factors that involved such as the amount of fertilizers utilized and the rice species planted.

Farmers interviewed for this study stated that there would a loss of income for 69% of the concerned individual while the remaining individuals have other sources of income to supplement their total income. Farming is becoming difficult for more than 80% of the individuals due to shortage of help from the household and there was an increase in the need of helpers as the younger members of the household turn to other sectors to earn their livelihood. Because of this there are farmers that employed the zamindary system as it is more productive.

Most of the farms visited were rainfed and only 9% of the total farms account for irrigated rice fields and there was an increasing use of fertilizers in the rice fields where cultivation had been carried out for more than 100 years. The common chemical substances used to enhance the yield included Urea, DAP, 2,4-D and Glycel which is now posing a threat to the environment.

From the interviews, it is understood that there is a need to provide irrigational facilities for the rainfed rice fields and embankments for the farms hat are located on the river banks. There had been many instances where a number of farmers were unable to cultivate rice due to the rise in the river level and also due to flooding. In these cases, the farmers were required to find others means of income to provide for their family. The Department of Agriculture and Crop husbandry and Department of Horticulture had introduced the cultivation of certain rabi crops and aquaculture to increase their income by providing the saplings and seeds although it cannot be carried out in all the eight circle due to unavailability of water for the plants and fishes.

The conclusion and observation made from the survey showed that 90% of the farmers will not be able to have any type of cultivation if there is no rainfall thereby establishing the fact that intensity and amount of rainfall impacted the crop production for them although statistical analysis show no significant relationship. In addition rainfall during the harvest will decrease the production and excessive rainfall will have profound negative impact.

The development of wetland rice cultivation in the potential area within Mizoram would be an answer for providing the local demand as the yield from wetland rice cultivation will be higher than from shifting cultivation and decrease the environmental degradation. From the total area 142913.4 ha utilized for rice cultivation, Shifting and WRC accounts for 58.42% and 41.58% respectively while the yield from Shifting and WRC accounts for 35.41% and 64.59%. Statistically with the optimum climatic condition, increase development of the potential area 1585.1 ha for WRC would increase the production of rice and other winter crops.