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Volume 17 **July 2022**

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Articles

ASSESSMENT OF SEASONAL VARIATION IN THE WATER QUALITY CHARACTERISTICS OF TUIKUAL RIVER, AIZAWL, MIZORAM

- Lalnunthari Ngente
B.P. Mishra

Abstract : *Tuikual river is a river that runs through Aizawl city, the river is known as Tuithum Lui just before joining the Tlawng river which is the main source of water supply in Mizoram. The research was conducted for a period of one year from October 2019 to September 2020 where the samples were collected at monthly intervals. The studied area has been divided into four sampling sites along the river from upstream to downstream. The river carries pollutants such as untreated city garbage, sewage discharges and biomedical effluents. The upstream Site 1 sample containing biomedical effluents from Aizawl Civil Hospital (the biggest hospital in Mizoram) and Site 2 sample containing biomedical effluents from Aizawl Civil Hospital and Ebenezer Hospital (a private hospital). The downstream Site 3 (known as Khawhpawp) and Site 4 (known as Tuithum) are tourist attraction that finally joins Tlawng River. Important water quality parameters namely Temperature, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Acidity, Nitrite, Phosphate-P and Sulphate have been estimated for the study of seasonal variation of Tuikual River water quality. The results are computed on a seasonal basis i.e. Pre-monsoon (February-May), Monsoon (June-September) and Post-monsoon (October-January). The monsoon (rainy) season possessed higher values in all the studied parameters except for Dissolved Oxygen which may be due to the flow of heavy rainwater that carries a huge amount of pollutants from the surroundings into the river body of water. The findings were then compared with water quality standards given by USPH, BIS, WHO and ICMR. The correlation coefficient statistical analysis was done using Microsoft Excel. The investigation reveals that there is a significant seasonal variation in all the studied parameters.*

Keywords : *Seasonal Variation, Parameters, Pollutants, Water Quality Standards, Correlation coefficient.*

1. Introduction

Water is an essential element that makes life possible on earth. Even if water quantities may be adequate, deterioration of water quality limits the uses that can be made out of it. The majority of people in Mizoram depend on surface water bodies for their day-to-day life, as underground water is hardly accessible in most parts of the state due to predominance of hilly terrain. A major portion of domestic, agriculture and other wastes are directly or indirectly discharged into the rivers situated in the

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vicinity, as no proper drainage system has been developed in the state so far (Lalparmawii & Mishra, 2012). Unplanned civilization and urbanization have posed a great threat to river water quality. The impact of pollutants on the water body is widely a serious threat to the environment and human health.

Large quantities of wastewater drains, leakage from the sewage system, domestic waste, city garbage and other pollutants flow into the river and banks of the Tuikual River. It is now becoming more polluted and narrower, thereby losing its identity. Tuikual River is being on the verge of disappearing, it will be lost forever if it is not saved in time. It is of utmost importance to study the water quality of the Tuikual River before it leads to dramatic consequences. The aim of the study was to assess the seasonal variation in the water quality characteristics of Tuikual River and compare with standards given by different agencies.

2. Materials and Methods

2.1 Description of the study area and study sites

Tuikual River is a river that runs through Aizawl city. It originates from the center of Aizawl City, Khatla range. The river lies between $23^0$43'49.8" N Latitude and 92^0 42'26.6" E Longitude. The study area is 9.45 kms long-running in the east-west direction. Table 1 shows that rainfall is not distributed evenly throughout the study period. Four sampling sites have been selected to study the water quality characteristics of Tuikual River. The descriptions of selected sampling sites are as follows:

Site 1 : The site is located upstream near the source point. It receives biomedical effluents from Aizawl Civil Hospital, the biggest hospital in Mizoram

Site 2 : The site was selected at a point where the tributary meets. It receives biomedical effluents from both Aizawl Civil Hospital and Ebenezer Hospital

Site 3 : This site is a point where the river receives sandstone quarry effluents at Khawhpawp Lui

Site 4 : This site is located downstream where the river merges with the Tlawng River at Tuithum Lui

Table 1. Rainfall data during the study period (2019-2020), Aizawl District

Month	Rainfall in mm	
	2019	2020
January	0.00	58.60
February	34.40	13.00
March	25.00	0.00
April	147.20	113.40
May	202.40	397.60
June	175.00	376.50
July	568.80	370.40
August	395.20	330.49
September	245.20	328.00
October	201.40	355.60
November	79.80	36.00
December	5.00	0.00

Source : General Economic & Statistical Analysis Branch, Directorate of Economics & Statistics, Mizoram

2.2 Analytical methods

The water samples were collected at monthly intervals for a period of one year from October 2019 to September 2020.

TUIKUAL LUI TO TLAWNG

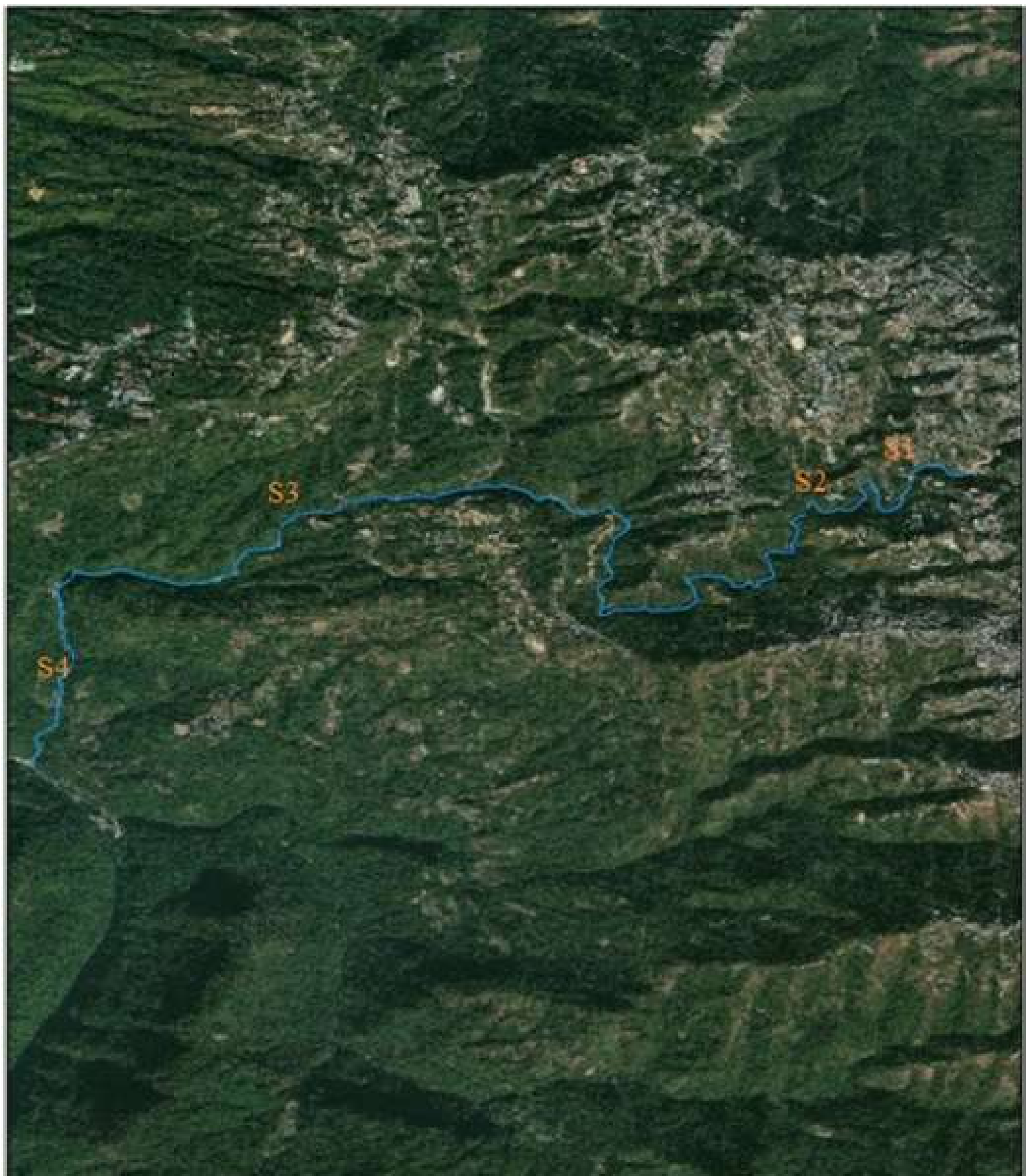

Figure 1. Location map of the study site

The water samples were collected by using wide clean bottles and are transported to the laboratory for analysis. The temperature was determined at the place of collection by using a digital thermometer. The findings were computed on a seasonal basis i.e., Pre-monsoon (February-May), Monsoon (June-September) and Post-monsoon (October-January). The Important physicochemical characteristics namely, Temperature, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Acidity, Nitrite, Phosphate-P and Sulphate have been estimated for the study of seasonal variation of Tuikual river water quality by following the methods outlined in previous studies (APHA, 2005; Maiti, 2001). The findings were then compared with standards given by different agencies like USPH (USPH (1962), BIS (BIS, 1983), WHO (WHO, 2004) and ICMR(ICMR, 1996).

3. Result and Discussion

3.1 Temperature

Water temperature represents the amount of heat in the water that can affect the level of dissolved oxygen and other biochemical processes. It was found that the average water temperature ranged from 20.75^{0}C to 27.45^{0}C at Site 1, 19.8^{0}C to 27.3^{0}C at Site 2, 22.9^{0}C to 28.9^{0}C at Site 3 and 22.9^{0}C to 29.3^{0}C at Site 4. A positive and significant correlation of temperature was found with BOD (0.976**), acidity (0.971**), nitrite (0.864**), phosphate-P (0.938**), sulphate (0.928**) while a negative and significant correlation of temperature was found with DO (0.949**).

The average water temperature was found higher during the monsoon season which may be due to a rise in ambient temperature that transfers the heat to the surface or an increase in the discharge of organic matter through surface run-off. The variation in water temperature depends on the season, geographical location, ambient air temperature and chemical reaction in water body (Ahipathi & Putlaiah, 2006)

3.2 Dissolved Oxygen (DO)

Dissolved oxygen refers to the amount of oxygen that is dissolved in the water body which is essential for aquatic life. The result reveals that the average DO ranged from 4.87 mgL^{-1} to 5.9 mgL^{-1} at Site 1, 4.57 mgL^{-1} to 5.7 mgL^{-1} at Site 2,

Table 2. Water quality standards given by different scientific agencies

Parameters	USPH	WHO	BIS	ICMR
Temperature	-	-	-	-
DO	>4	-	>5	-
BOD	-	-	<3	-
Acidity	-	-	-	-
Nitrite	-	3	-	-
Phosphate	0.1	-	-	-
Sulphate	250	200	150	150

6.47 mgL^{-1} to 7.55 mgL^{-1} at Site 3 and 6.72 mgL^{-1} to 7.9 mgL^{-1} at Site 4. The result indicates that Site 1 and Site 2 DO values were not within the permissible limit laid down by USPH during the pre-monsoon and monsoon season. A negative and significant correlation of DO was found with temperature (0.949**), BOD (0.962**), acidity (0.949**), nitrite (0.929**), phosphate-P (0.965**) and sulphate (0.948**).

DO content was found lower during the monsoon season could be attributed to an increase in the aerobic microbial decomposition of organic matter that results in high consumption of DO.

3.3 Biological Oxygen Demand (BOD)

Biological Oxygen Demand refers to the amount of dissolved oxygen required by the aerobic biological organisms to break down organic material present in the taken water sample at a certain temperature over a specific period of time. The result reveals that the average BOD ranged from 1.9 mgL^{-1} to 2.85 mgL^{-1} at Site 1, 2.12 mgL^{-1} to 3.27 mgL^{-1} at Site 2, 0.72 mgL^{-1} to 1.63 mgL^{-1} at Site 3 and 0.6 mgL^{-1} to 1.5 mgL^{-1} at Site 4. It was found that Site 2 BOD values were not within the permissible limit laid down by BIS during the pre-monsoon and monsoon season. A positive and

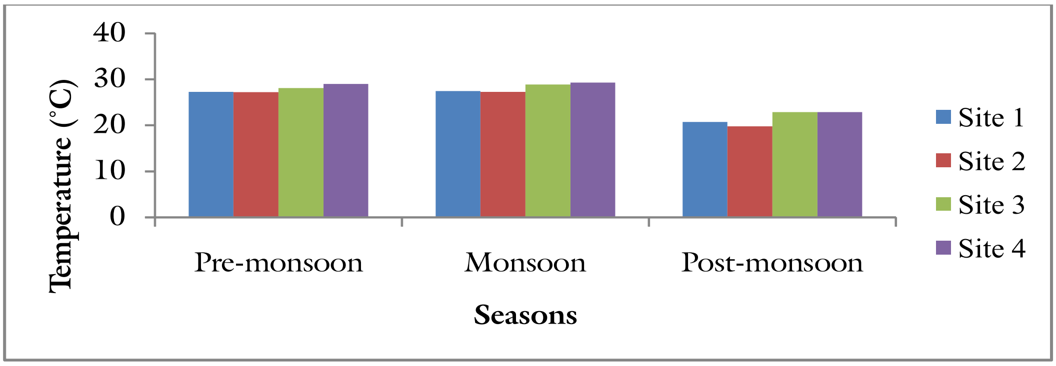

Figure 2. Seasonal variation in Temperature of water at study sites

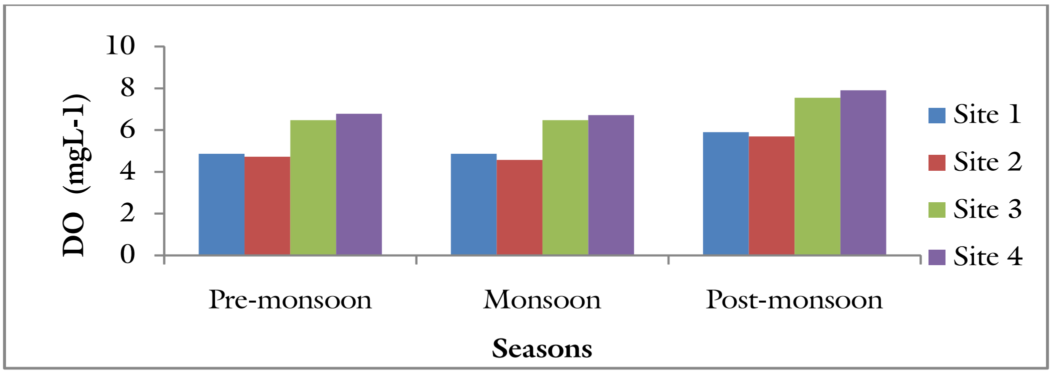

Figure 3. Seasonal variation in Dissolved Oxygen (DO) of water at study sites

significant correlation of BOD was found with temperature (0.976**), acidity (0.992**), nitrite (0.916**), phosphate-P (0.971**), sulphate (0.975**) while a negative and significant correlation of BOD was found with DO (0.962**).

Higher BOD values during the monsoon season could be due to an increase in the organic matter through surface runoff that increases the microbial decomposition process at elevated temperatures.

3.4 Acidity

Acidity in water is mainly caused by dissolved carbon dioxide gas. The acidity of the water ranged from 73 mgL^{-1} to 83.2 mgL^{-1} at Site 1, 75.5 mgL^{-1} to 87.2 mgL^{-1} at Site 2, 25.7 mgL^{-1} to 32.5 mgL^{-1} at Site 3 and 15.5 mgL^{-1} to 26.5 mgL^{-1} at Site 4. A positive and significant correlation of acidity was found with temperature (0.971**), BOD (0.992**), nitrite (0.897**), phosphate-P (0.965**), sulphate (0.970**) while a negative and significant correlation of acidity was found with DO (0.949**).

The acidity of water was found higher during the monsoon which might be due to an increase in a load of organic matter that supports microbial decomposition leading to the release of carbon dioxide during the process.

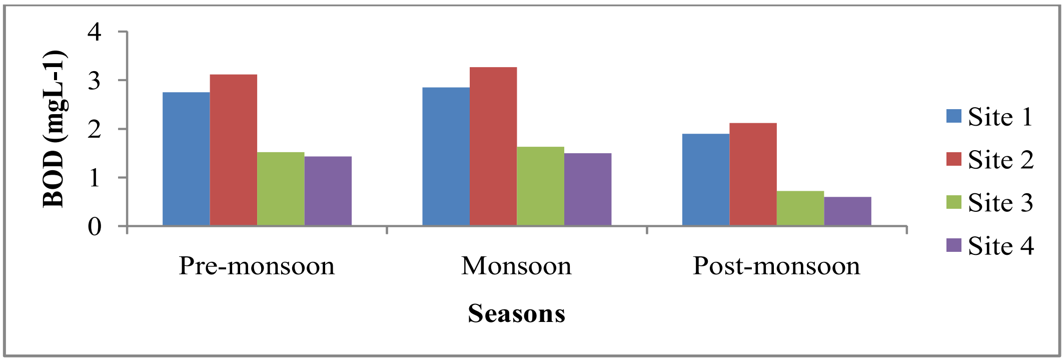

Figure 4. Seasonal variation in Biological Oxygen Demand (BOD) of water at study sites

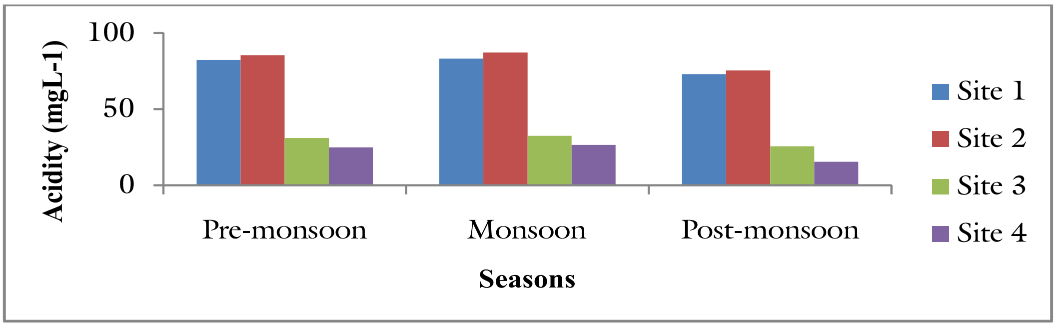

Figure 5.Seasonal variation in Acidity of water at study sites.

3.5 Nitrite

Nitrite enters the water body through surface runoff, leakage from fertilized soil, sewage, septic tanks and drainage system. The investigation reveals that the average nitrite content ranged from 0.039 mgL^{-1} to 0.44 mgL^{-1} at Site 1, 0.041 mgL^{-1} to 0.42 mgL^{-1} at Site 2, 0.037 mgL^{-1} to 0.335 mgL^{-1} at Site 3 and 0.014 mgL^{-1} to 0.17 mgL^{-1} at Site 4. All the nitrite values recorded were within the prescribed limit given by various scientific agencies. A positive and significant correlation of nitrite was found with temperature (0.864**), BOD (0.916**), acidity (0.897**), phosphate-P (0.948**), sulphate (0.937**) while a negative and significant correlation of nitrite was found with DO (0.929**).

Nitrites level was found higher during the monsoon which may be linked to an increase in the nearby agricultural and landscaped areas runoff that have received chemical fertilizer.

3.6 Phosphate-P

During the study period, the average phosphate-P content ranged from 0.128 mgL^{-1} to 0.344 mgL^{-1} at Site 1, 0.16 mgL^{-1} to 0.37 mgL^{-1} at Site 2, 0.052 mgL^{-1} to 0.215 mgL^{-1} at Site 3 and 0.07 mgL^{-1} to 0.16 mgL^{-1} at Site 4. Most of the recorded phosphate-P values were found higher than the prescribed limit laid down by USPH. A positive and significant correlation of phosphate-P was found with temperature (0.938**), BOD (0.971**), acidity (0.965**), nitrite (0.948**), sulphate (0.983**) while a negative and significant correlation of phosphate-P was found with DO (0.965**).

Phosphate-P values found higher during the monsoon may be the result of discharges of waste, soil erosion and agricultural runoff containing phosphate that enters the water body carried by heavy rainfall.

3.7 Sulphate

During the study period, the average sulphate value ranged from 2.16 mgL^{-1} to 3.78 mgL^{-1} at Site 1, 2.49 mgL^{-1} to 4.2 mgL^{-1} at Site 2, 1.44 mgL^{-1} to 2.79 mgL^{-1} at Site 3 and 1.17 mgL^{-1} to 2.6 mgL^{-1} at Site 4. Sulphate recorded values were

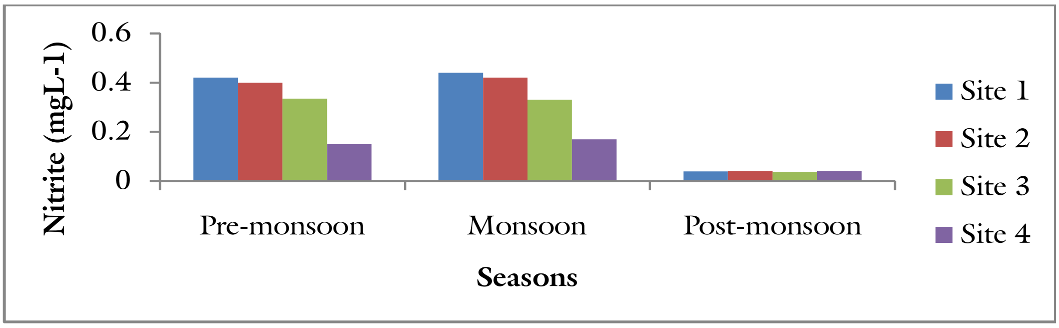

Figure 6. Seasonal variation in Nitrite of water at study sites

within the prescribed limit given by different scientific agencies. A positive and significant correlation of sulphate was found with temperature (0.928**), BOD (0.975**), acidity (0.975**), nitrite (0.937**), phosphate-P (0.983**) while a negative and significant correlation of sulphate was found with DO (0.948**).

Higher values of sulphate content during monsoon might be due to an increase in agricultural and sewage runoff containing sulphate minerals carried by heavy rainwater into the water body.

4. Conclusion

The findings revealed that there was a significant variation in all the studied physicochemical parameters. The upstream site 1 and site 2 showed high values of parameters due to the high pollution load from the catchment area. During the monsoon season, the river was highly been polluted due to heavy rainfall that washes fertilized agricultural fields and other pollutants from the catchment area into the river water body. Precipitation and temperature may be the

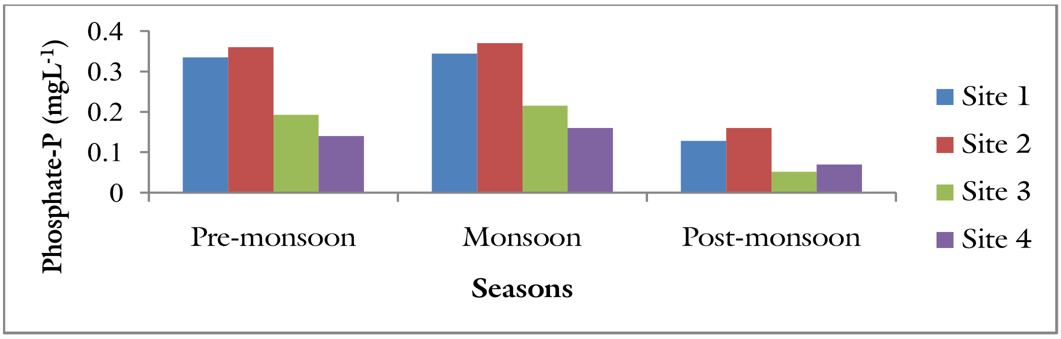

Figure 7. Seasonal variation in Phosphate-P of water at study sites

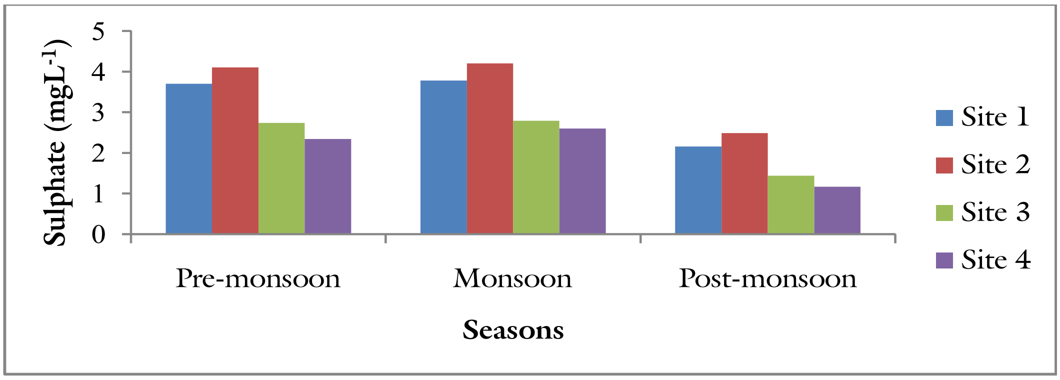

Figure 8. Seasonal variation in Sulphate of water at study sites

main reason for the seasonal changes in the water quality. The DO, BOD and phosphate-P values were not within the prescribed limit given by different agencies. The correlation coefficient analysis showed a strong and significant correlation between all the studied parameters. This research confirmed the need to take serious management strategies and activities for the protection, conservation and management of Tuikual River.

Acknowledgement

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A STUDY ON THE RELATIONSHIP BETWEEN LAND SURFACE TEMPERATURE AND NORMALIZED DIFFERENCE BUILT-UP INDEX: A CASE OF AIZAWL CITY.

- Vanlalchhuanga
Brototi Biswas
Lalrinmawia

Abstract : *Increase in Land Surface Temperature has been seen as the impact of urban development. The current study has performed determination of Land Surface Temperature (LST) and Normalized Difference Build up Index (NDBI) of Aizawl city using Landsat 8 OLI/TIRS satellite data. The NDBI shows the values ranges from -0.3 to 0.2. The higher NDBI values indicate highly concentrated settlements, while the negative values indicate a water body. LST was identified to range from 8.6°C to 23.9°C, and both variables indicated that the higher values were observed within the city's center. Their functional relationship has been determined through simple linear regression, the LST as dependent and NDBI as the independent variables. The correlation coefficient is 489 and the R2 equals 23.9% with the slope of 16.92 and intercept value as 16.96.*

Keywords : *Land Surface Temperature, Landsat, NDBI, Aizawl City*

1. Introduction

The human impacts on the natural environment have been manifested in urbanization, which leads to the rising of temperature in and around the urban area as compared to their surrounding rural areas. This heat concentration around the urban areas is termed as the Urban Heat Island. The heat released from urban houses, transportation and industry is the main causes of urban heat island (Chakraborty et al., 2014). Remote sensing satellite data is the most suitable way to study the spatial and temporal variations of LST (Li et al., 2013). In remote sensing, Thermal infrared (TIR) sensors can obtain quantitative information of surface temperature (Mallick et al., 2008). For understanding the impact of urban infrastructure development in surface air temperature, the current study will enhance the relationship between Normalized Difference Built up Index (NDBI) and Land Surface Temperature (LST) of Aizawl city.

The land surface temperature does not depend upon a single factor (Mathew et al., 2017), land temperature records are much higher in the built up areas as compared to the other land cover of the urban surrounding areas (Grover & Singh, 2015).Likewise, the vegetation covered area has the lower surface temperature(Li et al., 2013; John et al., 2020).

The land surface temperature is proven to have the positive correlation

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with the urban area (Guha et al., 2018). Although other platforms, such as MODIS (or Moderate Resolution Imaging Spectro-radiometer), provided the open source readily available LST data, the Landsat 8 satellite imagery was employed due to its higher spatial resolution to explore the relationship between the LST and NDBI. Landsat 8 satellite has the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) instruments which were both utilized for determining the Land Surface Temperature and Normalized Difference Built up Index.

2. Study Area

The study area Aizawl city is the capital of Mizoram located between 92°40'E - 92°47'E Longitude, 23°39'45"- 23°50'39" N Latitude. As per 2011 census, Aizawl had a population of 293,416. This is 26.89% from the total population of the state. Females constitute 50.61% of the population and males made up the remaining 49.39%. Under the Köppen climate classification, Aizawl features a humid subtropical climate (Cwa). The rapid growth of Aizawl population has put tremendous pressure on the land, economy and physical infrastructure of the city (Saitluanga, 2018). The city has an area of 120.25 sq.km.

2.1 Data and Methodology

Landsat 8 imagery had been retrieved from USGS (United States Geological survey) earth explorer data portal, which provides 11 bands with different wavelengths. For the current study, Landsat 8OLI/TIRS band 10 (10.6 - 11.19 μm) 100 m which was resampled to 30m spatial resolution, band 6 (1.57 - 1.65 μm), 30 m spatial resolution, band 5 (0.85 - 0.88 μm), 30 m spatial resolution and band 4 (0.64 - 0.67 μm) 30 m spatial resolution were used to determine the LST and NDBI, in Arcmap 10.5 platform. For determining the NDBI, the following equation is used:

NDBI =(SWIR–NIR)/(SWIR+NIR)

In the Landsat 8 data band 6 is the SWIR and band 5 is the NIR, Normalize Difference Build-up Index value lies between -1 to +1. Negative value of NDBI represents water bodies where as higher value represents build-up areas (Yuvaraj, 2020). To calculate the Land Surface Temperature, the thermal infrared sensor band 10 as well as near infrared band 5 and red band 4 were used. The following equations have been undertaken to retrieve the LST from Landsat 8 data.

(i) Conversion of Thermal infrared pixel number to Top Of Atmosphere(TOA) radiance

$$L\lambda = ML * Qcal + AL - O_i$$

Where,

$L\lambda$ = Top of Atmosphere Spectral Radiance

ML = Multiplicative rescaling factor of specific badn

Qcal = quantized and calibrated standard product pixel values (DN)

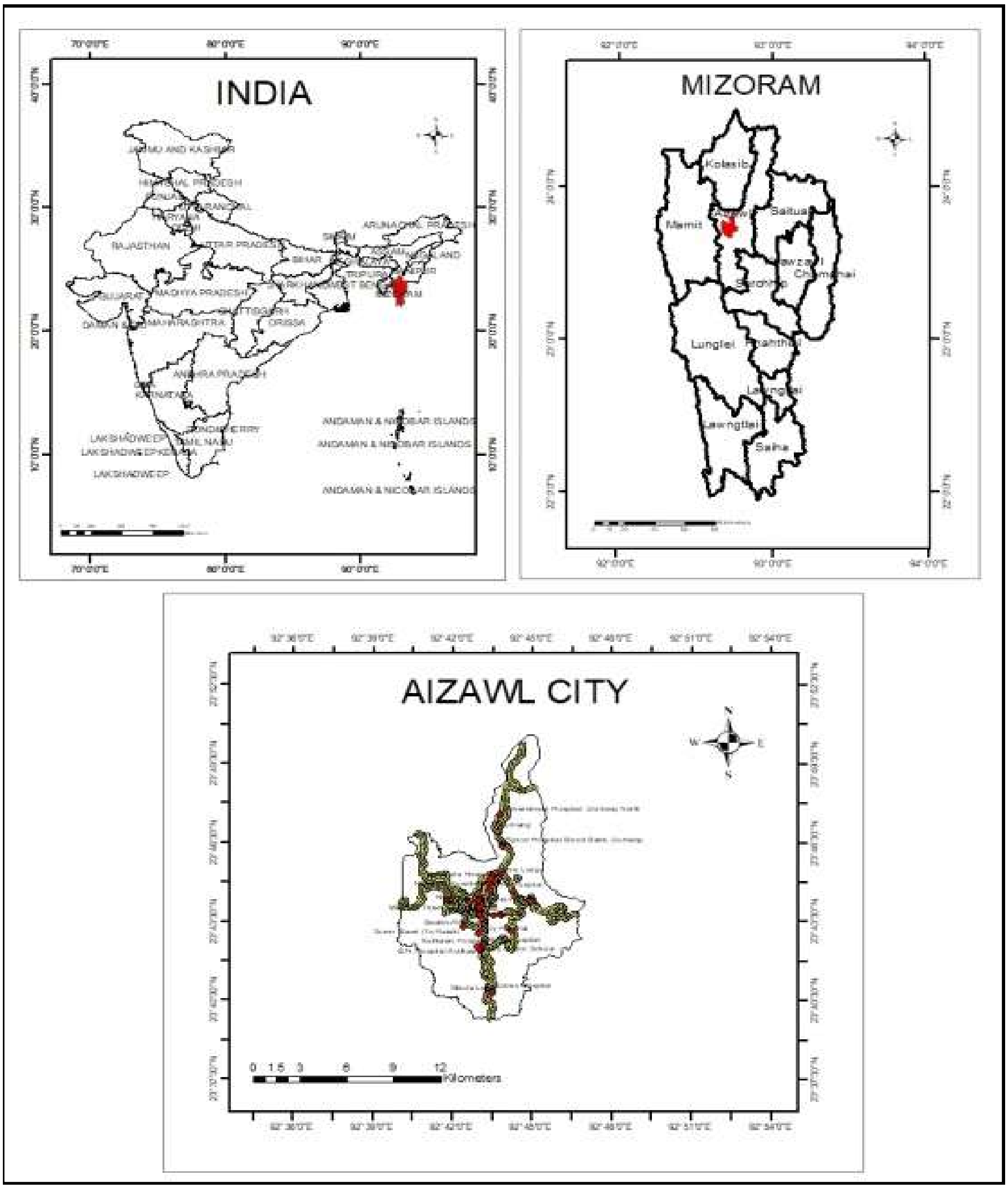

Figure 1. Study area

AL = Additive rescaling factor of specific band

O_i = is the band correction for band 10

(ii) Conversion of TOA to Brightness Temperature (BT)

$$BT = K_2 / l_n(K_1 / L\lambda + 1) - 273.15$$

Where,

BT = TOA brightness temparature

$L\lambda$ = TOA spectral radiance

K_1 = Thermal conversion constants for specific bands

K_2 = Thermal conversion constants for specific bands

(iii) Proportion of Vegetation (P_v)

$$P_V = NDVI - NDVI_{min} / NDVI_{max} - NDVI_{min}$$

Where,

$NDVI_{min}$ = Minimum Dn values from NDVI

$NDVI_{max}$ = Maximum Dn values from NDVI

For determining the NDVI the following equation is used

NDVI = NIR – Red / NIR + Red

(iv) Land Surface Emissivity (LSE)

E = 0.004 * PV + 0.986

Where,

P_v = Proportion of Vegetation

0.986 = correction value of the equation

0.004 = standard deviation of 49 soil spectra

(v) Land surface Temperature

$$LST = BT / (1 + (\lambda * BT / C_2) * l_n E))$$

Where, BT = TOA brightness tempararure

λ = wavelength of emitted radiance

E = Land surface emissivity

C_2 = h* c/s

h = Plank constant = $6.626 * 10^{54}$ JK

c = velocity of light = $2.998 * 10^{8}$ m/s

s = Boltzman constant = $1.38 * 10^{-23}$ JK

3. Data Analysis

After processing and retrieving the data from Landsat 8 OLI/TIRS, the pixel/ digital numbers (Dn) values were extracted through Fishnet in Arcmap. The Dn values were imported to SPSS, and then statistical analysis of correlation coefficient and regression model of LST AND NDBI were determined.

4. Results and discussion

The land surface temperature (LST) of Aizawl city derived from Landsat 8 has the range of 8.6°C to 23.9° C, the land surface higher zones can be easily interpreted with the patterns of settlement concentration, the map clearly indicates the higher LST zones are found over the high populated area, which were in the central portion of the study area map (see Figure 2). The land temperature was recorded decreasing outward from the central portion of the map which is found to be the city business and settlement concentrated area.

The NDBI is a parameter which represents the rates of urbanization in the area, the study area had given the response of NDVI value ranges from -0.3 to 0.2, the negative value indicates the water body the value ranges from 0-0.1 can be termed as the sparse settlement concentration zones, 0.1-0.2 as the dense settlement and above 0.2 as very dense settlement area (Liviona et al.2020). The NDBI map (see Figure 3) shows the dense settlement area and the patterns of settlements along the roads, the linear sprawl of urban development has been observed in the study area.

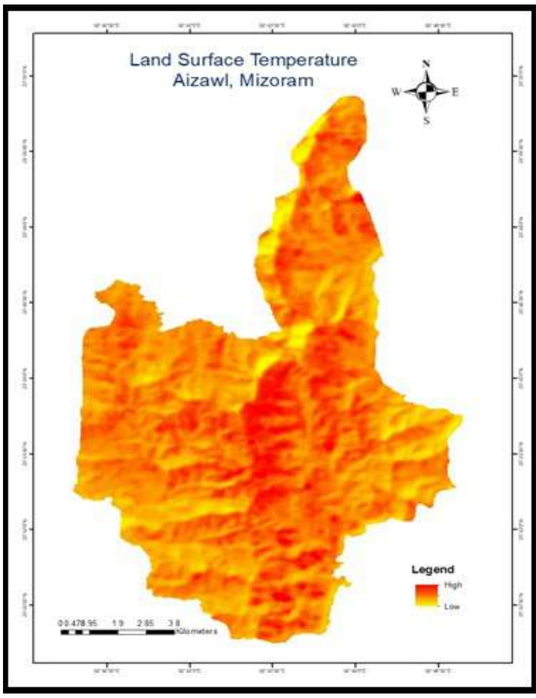

Figure 2. LST of Aizawl City

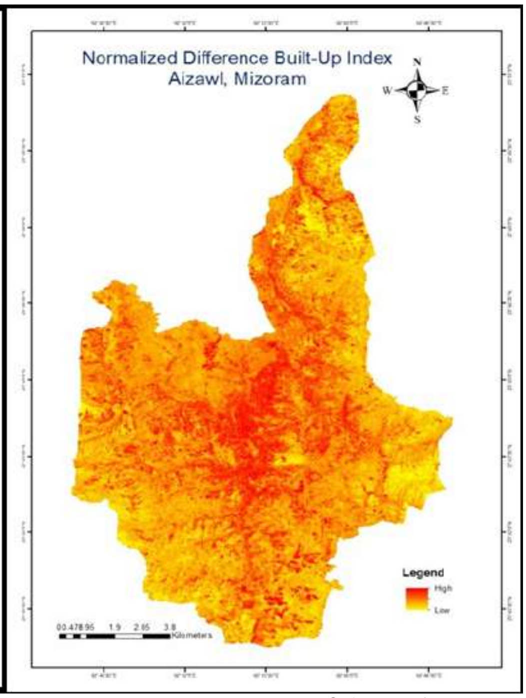

Figure 3. NDBI of Aizawl City

4.1 Effect of NDBI on LST

The functional relationship of NDBI and Land surface temperature was determined using linear regression model. In regression analysis the Land Surface Temperature was taken as dependent variable and NDBI as independent variable. In Table 1, the r value showed the correlation coefficient between NDBI and LST. The coefficient is .489 which shows moderate positive correlation. r^2 explains the percentage contribution of the influence of the independent variable to the dependent variable. r^2 value for the influence of NDBI with LST is 23.9%. Also, Table 2 shows the result of F-test significant value .000which indicates the NDBI has a significant effect on LST, and the scatter plot was created for developing the regression equation, the results shows the slope and intercept variables as 16.92 and 16.96 respectively. Then, the regression equation can be formulated as y=16.96+16.92*x.

Table 1. Percentage of Relations

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.489a	.239	.238	1.71837

Table 2. ANOVA table

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1155.922	1	1155.922	391.467	.000b
	Residual	3685.090	1248	2.953		
	Total	4841.011	1249			

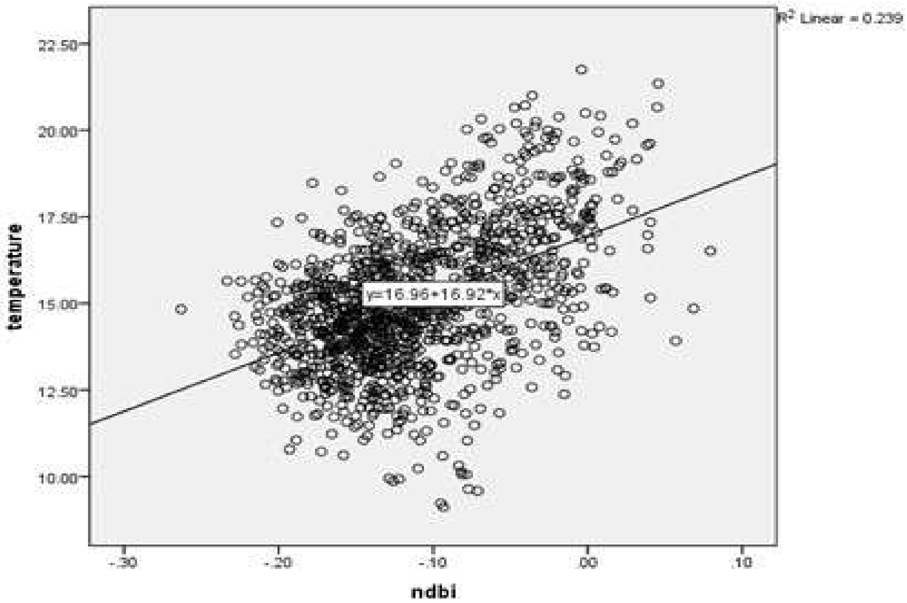

Figure 4. Regression scatter plot

5. Conclusion

The study on Land Surface temperature and NDBI has shown the maximum concentration was found in the central part of the city. The functional relationship between LST and NDBI established through the simple linear regression model had shown little less correlation as compared to other research in different. Which may be due to limited number of parameters, the study concludes that the surface temperature is positively correlated with the built-up area and vegetation plays a significant role on variation in land surface temperature.

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EVALUATING THE SPATIOTEMPORAL DYNAMICS OF RAINFALL EROSIVITY IN AIZAWL DISTRICT, MIZORAM

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P. Rinawma

Abstract : *The present study attempts to determine rainfall erosivity in Aizawl District, Mizoram by applying the Modified Fournier Index using rainfall data for 35 years. The obtained average annual rainfall erosivity is 360.86 (MFI value), which revealed chances of very severe rainwater induced soil erosion. A significant variation was observed among seasonal erosivity where monsoon has the highest mean MFI value of above 250 and contributes 77.59% of the annual rainfall erosivity, while it is only 6.48 (1.98%) in the winter season. The rainfall data and the erosivity values have a strong relationship (r = 90) which was also reflected in the declining trend of both the data during the study period. The northern parts of the study area have the highest rainfall erosivity, which slightly declined towards the south. The research findings may provide a valuable pre-requisite information to policymakers for preparing an effective plan for soil erosion control and management.*

Keywords : *Soil Erosion, Rainfall erosivity, Modified Fournier Index, Aizawl District, Spatiotemporal variation.*

1. Introduction

Soil erosion involves the removal of soil nutrients and topsoil, which is the base for agricultural production, and the deposition of sediments, which can further pollute the riverine ecosystem downstream. As a result, water-induced soil erosion has recently been identified as a severe environmental issue, affecting both the environment and human economic situations (Pandey et al., 2021; Singh & Singh, 2020). Rainfall is a single significant climatic component that has a huge impact on water-induced soil erosion, and, thus, the assessment of rainfall characteristics is necessary (Pradeep et al., 2014). In order to determine the potential capacity of rainfall in triggering soil erosion,the rainfall erosivity index which considers the intensity, magnitude and duration of rainfall can be effectively employed (Nearing et al., 2017; Panagos et al., 2015). Thus, it is a critical task to ascertain the rainfall erosivity conditions in soil erosion assessment, as rainfall directly impacts soil disintegration and surface runoff (Oliveira et al., 2012).

Wischmeier & Smith(1958) presented the basis for R-factor (rainfall erosivity) calculation in the "Universal Soil Loss Equation (USLE)", along with different erosion conditioning factors. The USLE/RUSLE's R-factor index

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(Renard et al. 1997; Wischmeier and Smith, 1978) has been the most widely utilized index in various research worldwide for determining rainfall erosivity (Meusburger et al., 2012; Oliveira et al., 2013; Panagos et al., 2015, 2017; Pradeep et al., 2015; Prasannakumar et al., 2012; Sadeghi et al., 2011). However, calculating the R-factor requires data on the kinetic energy produced by storm occurrences and its maximum 30-minute intensity, which is not available in many regions. With the limits to the availability of such high temporal resolution pluviographic records, monthly and annual records were used to devise multiple indices deployed in various parts of the world to calculate rainfall erosivity (Vantas et al., 2019). Among the various indices, Arnoldus (1980) Modified Fournier Index (MFI) was one of the most widely utilized rainfall erosivity indices in various studies(Abd Elbasit et al., 2013; Andoh et al., 2012; Coman et al., 2019; Costea, 2012; Ferro et al., 1999; Mohtar et al., 2015; Muhire et al., 2015; Tiwari et al., 2015). Furthermore, a strong relationship was observed with the R-factor values generated in the USLE/RUSLE model (Horvath et al., 2016). Therefore, the MFI (Modified Fournier Index) was frequently applied as an alternative for deriving the rainfall erosivity values (Di Lena et al., 2021).

Northeast India is a critical section of the country regarding meteorological factors. The region has about 2068 mm of average annual rainfall, and it belongs to one of the highest zones of rainfall distribution in the world (Jain et al., 2012). Besides, Tiwari et al. (2015) reported that the region has also registered the highest rainfall erosivity all over India. Apart from the potential impact of climatic aggressiveness through heavy rainfall, the study area is also characterized by weak geological and desirable topographical settings for soil erosion. Moreover, a common agricultural practice among tribal inhabitants, namely shifting / jhum cultivation, may increase chances of soil erosion. Considering the combined impact of the geo-environmental and cultural set-up, assessing the rainfall erosivity is necessary to ascertain an area's vulnerability to potential erosion risk. The research findings can beneficially assist the local decision makers for effective soil resources conservation and management. Therefore, the study's main objectives are to evaluate the spatiotemporal characteristics of rainfall erosivity in Aizawl District.

2. Study Area

Aizawl district is located between 23°18'17"N – 24°25'16"N latitudes and 92°37'03"E – 93°11'45"E longitudes, extending to about 3576 sq. km of geographical area in the state of Mizoram (Figure 1). The elevation of the study area ranges from 30 to 1902 metres above msl, and is marked by young landforms with hilly terrain. Due to the rugged topography, the slope is mainly steep, having a maximum slope inclination reaching up to 69.43°. A sub-tropical humid climate governs the study area with a mean annual rainfall of about 2600.25 mm. With 4,00,309 inhabitants, it is the most populous district of Mizoram, having a population density of about 112 persons per sq. km (Govt. of Mizoram, 2018).

3. Database and Methodology

3.1 Data collection

Rainfall data were obtained for the past 35 years (1987 - 2021) from gridded rainfall data sets of the IMD (Indian Meteorological Department) daily records (Pai et al., 2014), and the average seasonal and annual rainfall were determined accordingly. Four seasons were classified based on the IMD classification scheme as, "Winter (December - February), Pre-Monsoon (March-May), Monsoon (June - September), and Post-Monsoon (October and November)".

3.2 Calculation of Rainfall Erosivity

Modified Fournier Index (MFI), devised by Arnoldus' (1980), was applied for calculating the rainfall erosivity, and erosivity classes were derived from the pre-determined values presented in Table 1. The equation calculated MFI as:

$$MFI = \sum_{i=1}^{12} \frac{p_i^2}{P}$$

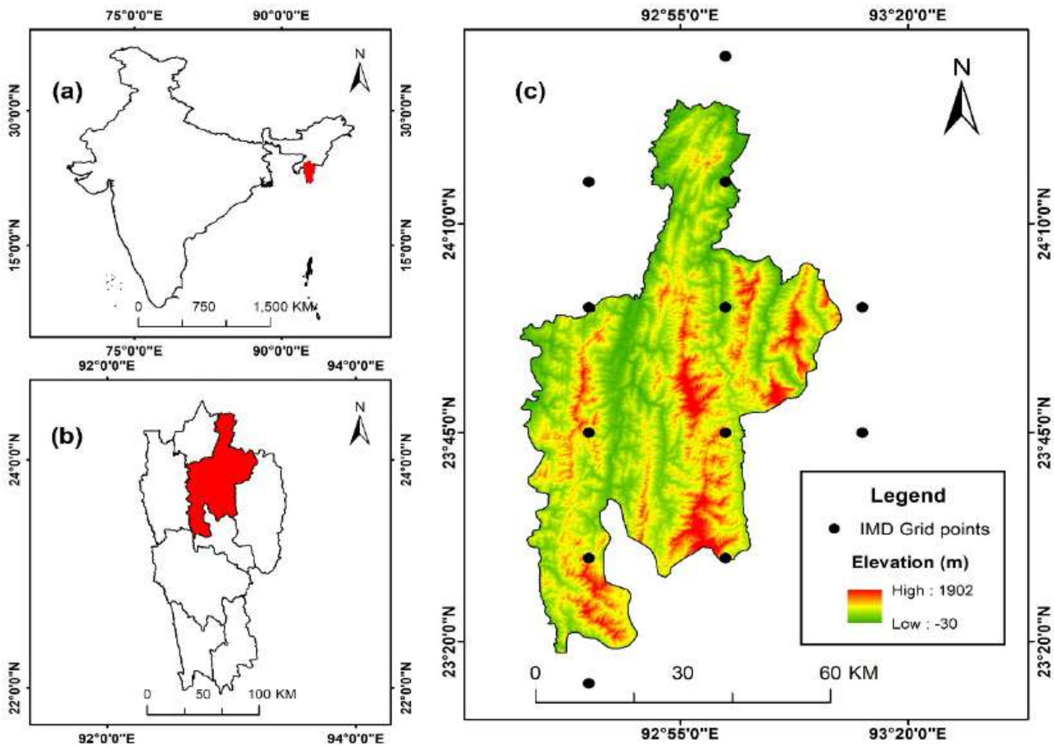

Figure 1. Location map of the study area (a) India, (b) Mizoram, and (c) Aizawl District

Where MFI is the Modified Fournier Index, p_i^2 indicates the average monthly rainfall for the i^{th} month (mm), and P is the annual rainfall average (mm).

Table 1. Erosivity classes for Modified Fournier Index (MFI)

Erosivity Class	F_M values
Very Low	0 – 60
Low	60 – 90
Moderate	90 – 120
High	120 – 160
Very High	> 160

Source : Arnoldus, 1980.

3.3 Station selection and thematic maps preparation

Twelve synoptic rain-gauge stations (Grid points) and their influence area were identified with Thiessen Polygon tools in ArcGIS 10.4.1 software. An interpolation tool in ArcGIS, the IDW (Inverse Distance Weighted), was used to generate thematic maps depicting rainfall erosivity and its trend.

3.4 Trend Analysis

The non-parametric Mann-Kendall (MK) test and Sen's slope estimator were used to identify the rainfall erosivity trend in R software. The trend was analyzed for seasonal and annual erosivity for all the 12 stations considering 35 years (1987 - 2021). Z-statistics in MK-test reveal the trend, whether increasing or decreasing, based on the values obtained for the considered period. On the other hand, Sen's slope estimates the magnitude of the changing trend.

4. Results and Discussion

4.1 Spatiotemporal dimension of Rainfall erosivity

The computed stations erosivity values for seasonal and annual rainfall are shown in Table 2. The mean seasonal erosivity obtained from the study area was 54.53 for pre-monsoon, 254.17 for monsoon, 12.36 and 6.48 for post-monsoon and winter. Monsoon has by far the highest erosivity. Compared with the predetermined erosivity class from Table 1, the MFI values for monsoon season reveal the possible occurrence of very severe erosion. The MFI values for all stations for average annual rainfall erosivity are extraordinarily high, with the lowest and highest values of 286.59 and 352.25, respectively. But, most of the erosive rains of about 77.59 % happened during the monsoon season. The obtained MFI values range between 6.06 to 7.31 during the winter season, and for post-monsoon, they were found between 11.03 and 12.83. Thus, both seasons can be categorized well within the very low erosivity class. Apart from the winter and post-monsoon months, the pre-monsoon period has erosivity values ranging from 46.65 to 64.05. None, other than the monsoonal season exhibitssufficient capacity to affect soil erosion.

Figure 2 illustrates the spatial variability for seasonal rainfall erosivity, which tends to increase slightly towards the north during the monsoon season. This pattern is also quite identical to the pre-monsoon distribution. The spatial erosivity in the winter and post-monsoon seasons is markedly different, with rainfall erosivity increasing in the eastern parts of the study area in winter and decreasing towards the west in the post-monsoon season. However, rainfall's

Table 2. Average Seasonal and Annual MFI values for different stations

Stations	Winter	Pre-Monsoon	Monsoon	Post-Monsoon	Annual
Buangpui	6.56	46.81	253.75	12.39	319.51
Sumsuih	6.46	52.75	251.36	12.51	323.08
Zuangtui	6.40	55.01	253.88	12.58	327.87
North Chaltlang	6.41	56.91	255.52	12.83	331.67
Serlui B	6.32	60.17	263.16	12.56	342.21
Maite	6.51	50.31	261.63	12.03	330.46
Sihfa	6.33	52.95	260.02	12.67	332.09
Lamherh	6.22	57.69	264.52	12.69	341.25
Khawpuar	6.16	60.80	265.47	12.65	345.22
Robipur FV	6.06	64.05	269.43	12.58	352.25
Pamchung	7.04	46.65	233.51	11.75	299.07
Mimbung	7.31	50.30	217.81	11.03	286.59
Mean	6.48	54.53	254.17	12.36	327.60

Source : IMD

aggressiveness for these seasons is exceptionally low, with little or no influence on soil erosion. For annual erosivity, the spatial pattern is similar to that of the monsoon and pre-monsoon season, showing an increasing erosivity potential towards the north with a decreasing trend towards the east and south of the study area. Yearly MFI values were extraordinarily high, but they were further classified into five classes to determine their spatial extent (Figure 3). The very high and high class of annual MFI values, i.e., 335 – 346 and 328 – 334 together, cover about 2619.1 sq. km, which is about 75.91% of the study area. The areal extent for moderate (321 - 327), low (310 - 320) and very low (292 - 309) classes are 677.347 sq.km (19.63%), 108.582 sq.km (3.15%) and 45.361sq.km (1.31%) respectively.

4.2 Seasonal and yearly rainfall erosivity trend analysis

Table 3 shows the results of the trend analysis. The finding suggested that the study area had a downward trend in seasonal rainfall erosivity. The most pivotal season for rainfall aggressiveness, the monsoon period, has demonstrated a significant trend of declining erosivity (P ? 0.05) for majority of the stations. The declining trend ranges from -1.136 to -3.124 with a reducing MFI rate of -7.682 to -15.508, respectively. Another significant trend for rainfall erosivity was also observed for the pre-monsoon season. Seven out of twelve stations have undergone a significant declining trend with a minimum value of -1.676 to a maximum value of -2.783. Furthermore, the magnitude of change (Sen's slope) extended from -7.669 to -12.151 (MFI value), while the remaining stations have shown an insignificant negative trend. On the other hand, a decreasing but insignificant trend was mostly obtained during winter. Throughout the study area, the post-monsoon season has simultaneously experienced an evenly distributed insignificant decreasing and increasing trend (ranging from -0.653 to 0.426).

The identified trend for average annual MFI and its spatial distribution is presented in Figure 4. It has also undergone a negative trend for the study period throughout the study area. About 73.47% (2538.29 sq. km) of the study area has experienced a significant decreasing trend (P≤0.05). These

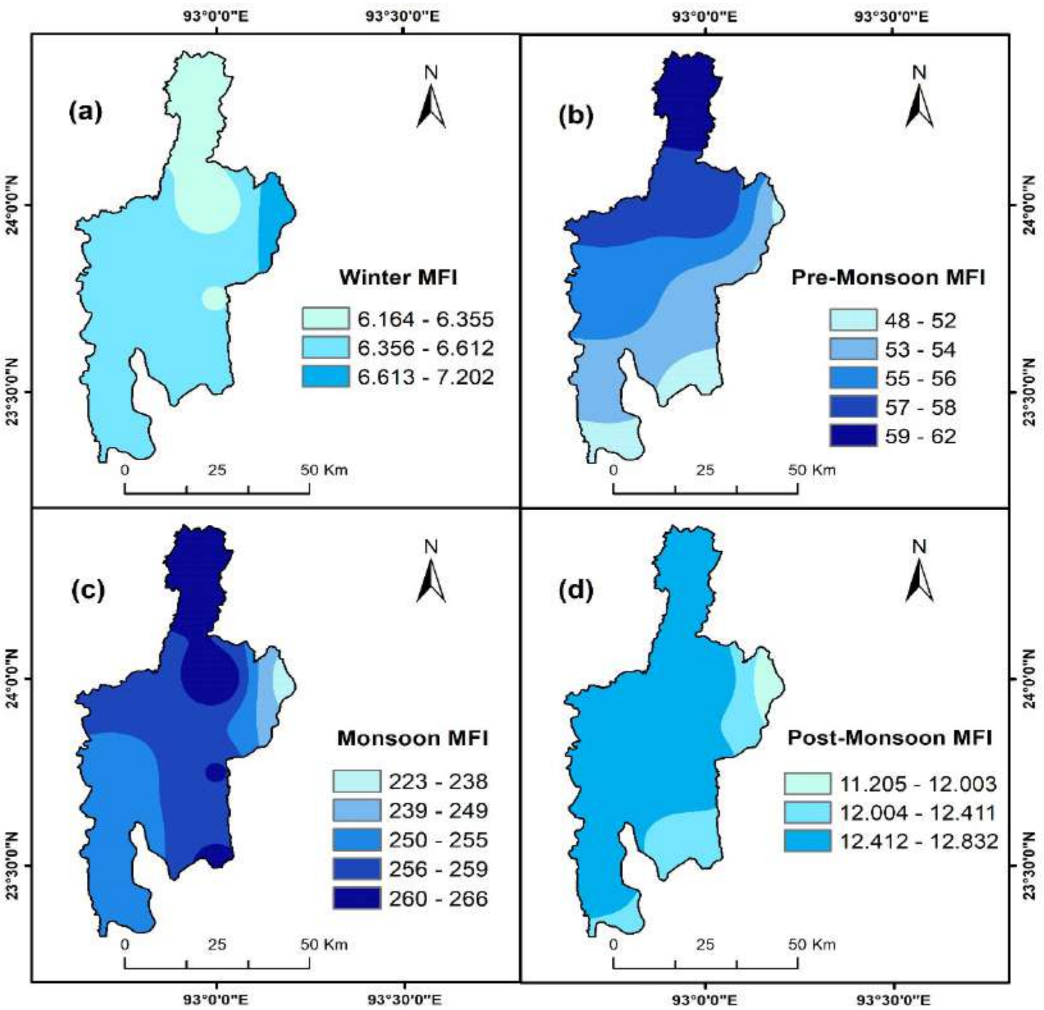

Figure 2. Spatial distribution of Seasonal erosivity (a) Winter, (b) Pre-Monsoon, (c) Monsoon, and (d) Post-Monsoon

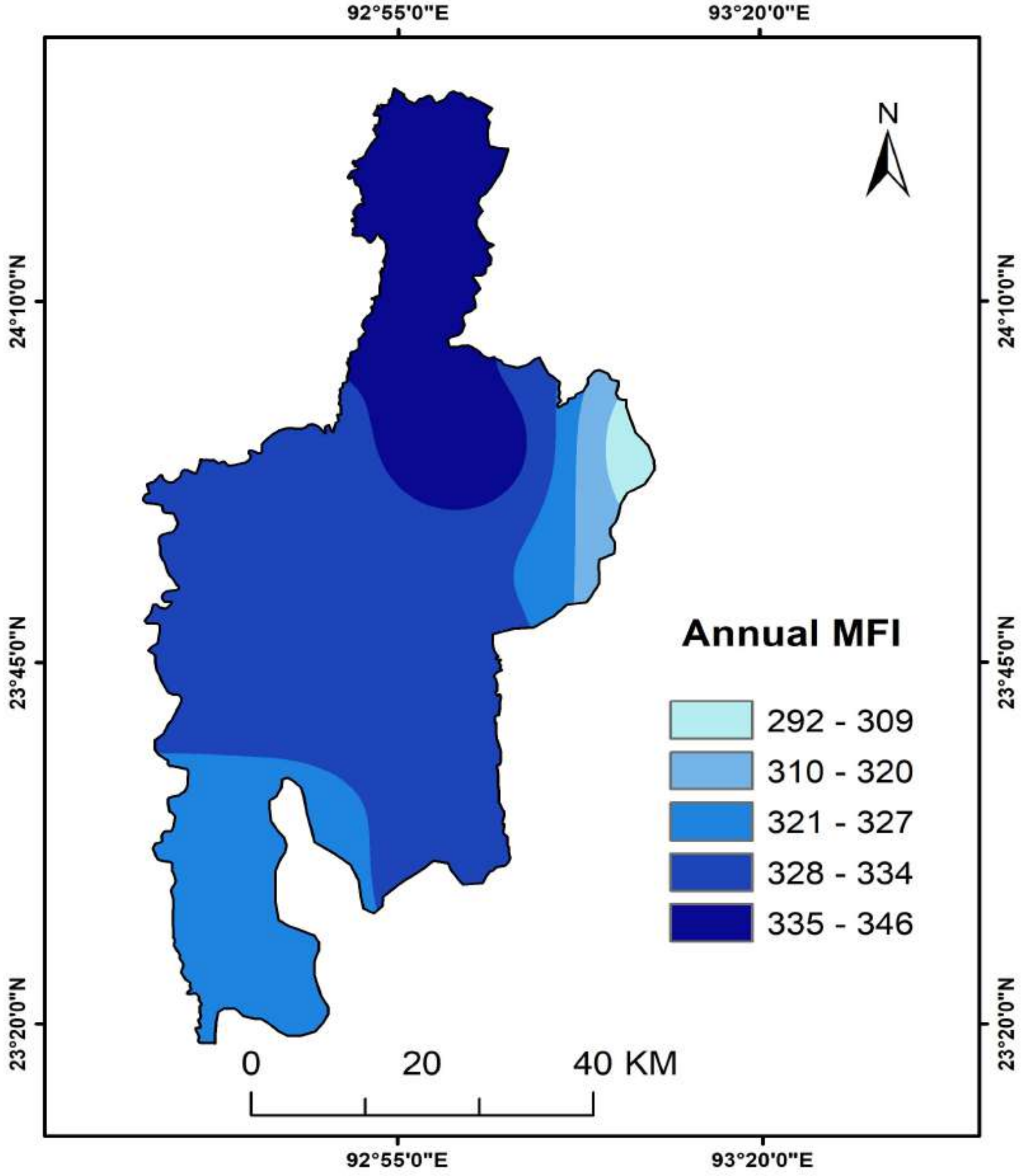

Figure 3. Annual rainfall erosivity of the study area

Table 3. Results for Man-Kendall test and Sen's slope

	Winter		Pre-Monsoon		Monsoon		Post-Monsoon		Annual	
Stations	**Z**	**Sen**	**Z**	**Sen**	**Z**	**Sen**	**Z**	**Sen**	**Z**	**Sen**
Buangpui	**-2.03****	-1.54	**-2.78*****	-12.15	**-1.68***	-8.11	0.43	0.72	**-2.39****	-22.53
Sumsuih	**-1.66***	-1.25	**-2.21****	-9.28	**-2.24****	-11.67	0.14	0.32	**-2.21****	-24.08
Zuangtui	-1.48	-1.08	**-2.19****	-8.54	**-2.53****	-13.62	0.03	-0.01	**-2.19****	-23.79
North Chaltlang	-0.82	-0.79	**-1.68***	-7.67	**-3.12*****	-15.51	0.06	-0.18	**-2.16****	-21.73
Serlui B	-0.62	-0.75	-0.57	-3.27	**-2.16****	-10.86	-0.34	-0.75	-1.45	-16.44
Maite	-1.19	-0.94	**-2.04****	-9.41	**-2.64*****	-15.69	-0.06	-0.22	**-2.50****	-27.99
Sihfa	-0.99	-0.85	**-2.27****	-8.60	**-2.67*****	-16.21	0.03	-0.09	**-2.39****	-26.79
Lamherh	-0.74	-0.64	-1.36	-6.31	**-2.58*****	-14.99	-0.31	-0.69	**-2.04****	-21.57
Khawpuar	-0.51	-0.74	-0.57	-2.20	**-1.93****	-8.96	-0.31	-0.92	-1.25	-12.22
Robipur FV	-0.65	-0.72	-0.94	-4.54	**-2.73*****	-12.07	-0.54	-1.01	-1.82	-18.25
Pamchung	-1.50	-1.09	**-1.87***	-6.39	-1.14	-7.68	-0.20	-0.4	-1.45	-15.37
Mimbung	-1.25	-0.86	-1.31	-3.84	**-1.82***	-9.33	-0.65	-1.33	-1.22	-14.52

Z = Z-statistics of Man-Kendall test; Sen = Sen's Slope. Confidence level: * = 90%, ** = 95% and * = 99%.**

declining erosivity trends have occupied the study area's western, central, and southern parts. Another significant trend for decreasing erosivity was observed in about 13.33% (459.97 sq. km) of the study area covering some parts of the northeast. The remaining 13.1% (452.13 sq. km) have a statistically insignificant diminishing trend and lie in the northernmost and easternmost tips of the study area. Thus, the trend of rainfall erosivity generally decreases towards the south.

4.3 Annual rainfall and rainfall erosivity patterns

The present study obtained rainfall data for 35 years (1987-2021) to determine the rainfall erosivity value (Table 4). As rainfall erosivity is derivative of rainfall characteristics, a strong degree of relationship (r=0.90) was obtained, as shown in Figure 5. The yearly change of the rainfall and rainfall erosivity pattern is also illustrated in Figure 6. For the last 35 years (1987-2021), both annual rainfall records and the derived erosivity have slightly declined. The highest and lowest annual rainfall records of 3540.54 mm and 1107.22 mm occurred in 1991 and 1994. On the other hand, the maximum MFI value (495.95) was observed in 2004, while the minimum MFI value (137.54) was obtained in 1994. Most of the years with high annual rainfall are associated with high erosivity. However, it does not necessarily mean that highest annual rainfall will generate highest rainfall erosivity, as the monthly and annual average rainfall are considered for determining rainfall erosivity. It was also identified that the highest annual rainfall of 1991 has not produced the highest rainfall erosivity.

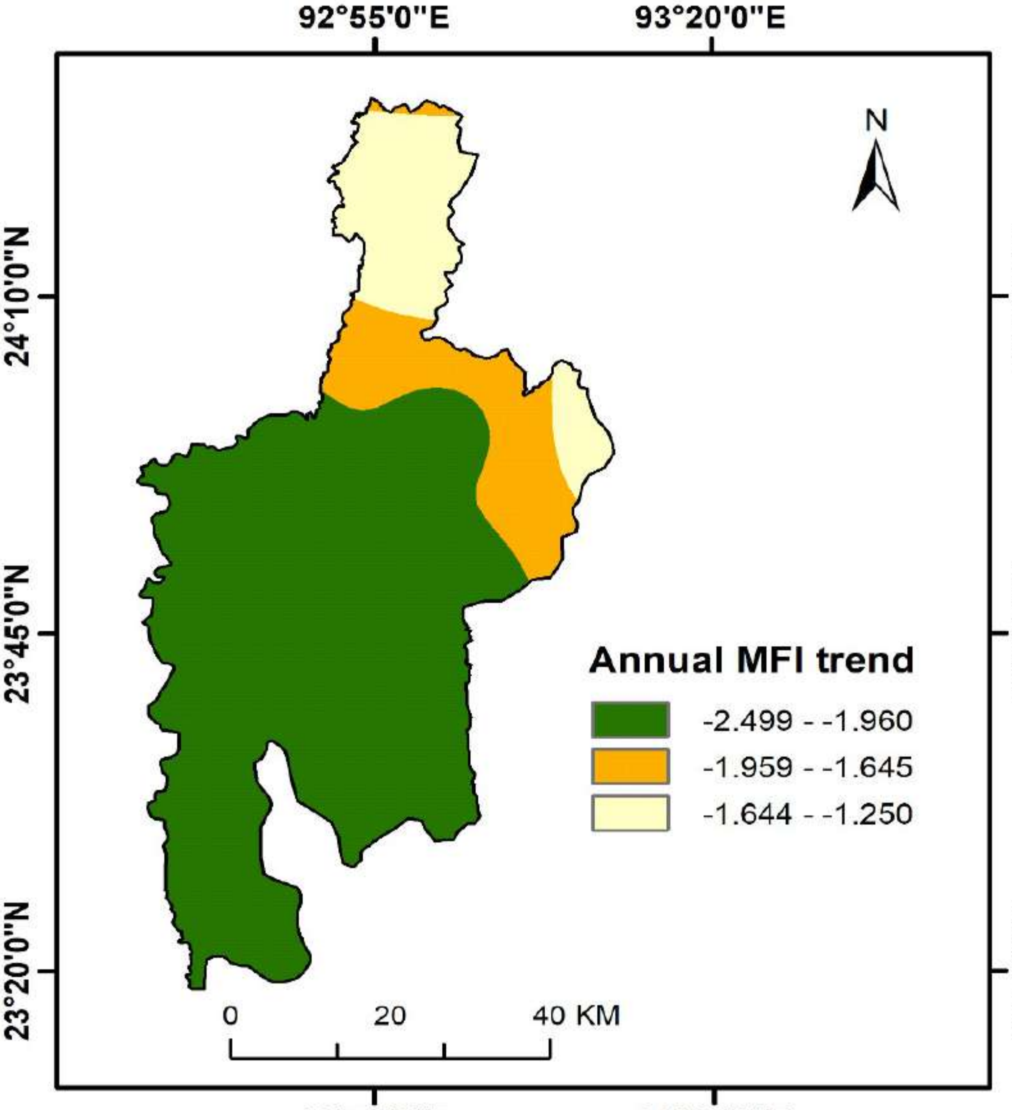

Figure 4. Spatial trend of annual rainfall erosivity, Aizawl District, Mizoram

Table 4. Average annual rainfall and Annual MFI values, 1987-2004

Year	Average annual rainfall (mm)	Long term annual MFI	Year	Average annual rainfall (mm)	Long term annual MFI
1987	2835.22	404.90	2005	2759.83	347.66
1988	2707.88	347.96	2006	2220.91	422.69
1989	3056.45	440.79	2007	2996.96	355.23
1990	3203.08	434.85	2008	3095.16	492.47
1991	3540.54	475.28	2009	2318.98	330.79
1992	2498.93	355.62	2010	3114.67	387.58
1993	3416.00	416.12	2011	2492.68	396.78
1994	1107.22	137.54	2012	2802.28	426.39
1995	2385.98	339.34	2013	1469.94	217.73
1996	2191.99	318.38	2014	1556.41	258.81
1997	2670.49	368.63	2015	2220.22	301.47
1998	2682.30	355.54	2016	2768.93	348.46
1999	2740.66	370.92	2017	3358.42	433.71
2000	3428.65	483.82	2018	2368.47	361.17
2001	2934.93	391.27	2019	1901.41	272.06
2002	2370.92	310.98	2020	1825.64	238.41
2003	2693.79	329.35	2021	1936.37	261.51
2004	3336.44	495.95			

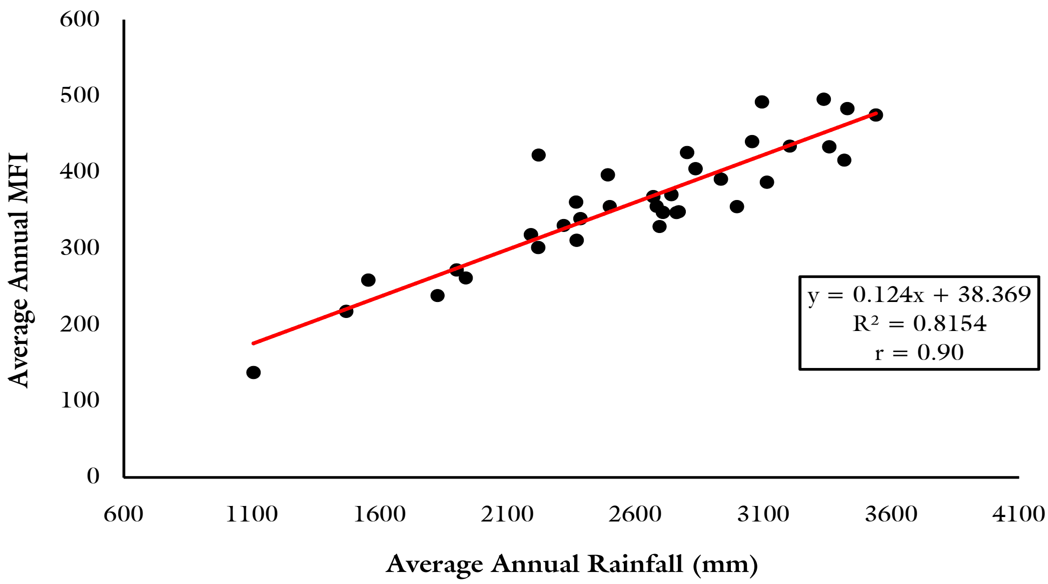

Figure 5. Comparison between Average Annual Rainfall (mm) and Average Annual MFI value

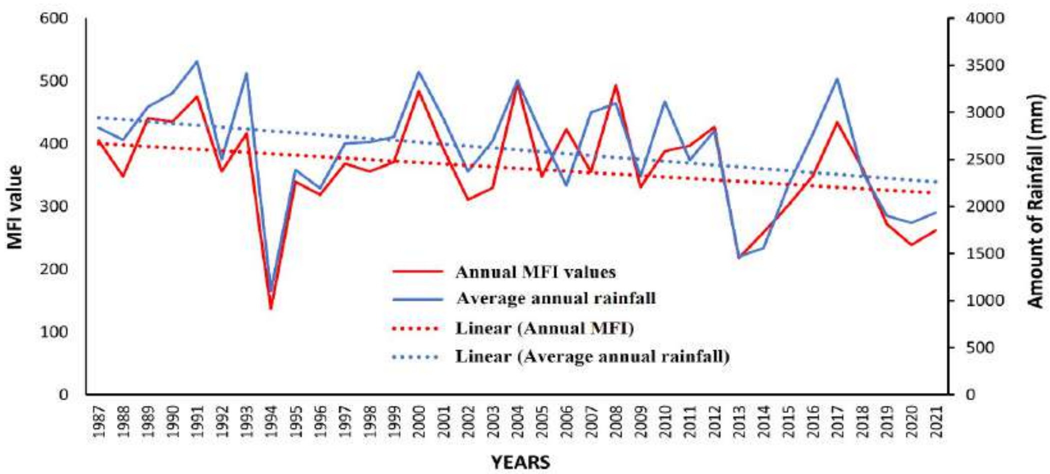

Figure 6. Pattern of inter-annual change in rainfall and rainfall erosivity

5. Conclusion

The observed rainfall erosivity for Aizawl district shows an extremely severe potential for rainfall intensity with an average annual MFI value of about 360.86. The influence of the monsoon is responsible for the intensity of rainfall, as the utmost yearly rainfall is received in the summer monsoon season. The trend analysis of rainfall erosivity shows a slight decrease in the aggressiveness of rainfall during the past 35 years. Because there is a strong relationship (r = 0.90) between the amount of rainfall and the erosivity value, the temporal drop in rainfall intensity can also be attributed to the decline in the annual rainfall. The spatial variability of rainfall erosivity was found quite comparable throughout the study area. The average seasonal and annual rainfall erosivity distributions were higher in the northern half of the study area and gradually dropped towards the south, which is also the case with the average annual rainfall distribution. Thus, the mapping of rainfall erosivity can provide basic information to identify an area's vulnerability to soil erosion, providing remedial direction to policymakers for implementing effective soil erosion control measures in areas of critical erosion risk at the right moment.

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AN ANALYSIS OF PATTERN AND TREND VARIATION IN MINIMUM AND MAXIMUM TEMPERATURE OVER AIZAWL CITY

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Abstract : *A number of studies have been carried out to detect and locate climate changes and trend and pattern in different parts of the world by analyzing climate key factors such as rainfall, temperature and humidity concentration. Some of these studies deal with measurement of temperature time series for specific stations. The study is of great importance as agricultural production is highly influenced by climatic factors. In the present study, an attempt has been done to investigate variation in maximum and minimum of temperature over Aizawl city from 2000-2021. For the purpose, Mann–Kendall's test and Sen's Slope Estimator have been used and concluded that the maximum temperature for the observed period showed a slight warming or increasing trend while the minimum temperature trend showed a cooling trend. A positive trend in monthly maximum temperature is depicted throughout the year and a negative monthly minimum temperature is detected throughout the year both in Mann Kendall and Sen's slope estimator.*

Keywords : *Monthly maximum and minimum temperature, Yearly temperature, Mann Kendall Test and Sen's Slope estimator*

1. Introduction

Temperature trend analysis is one of the major focuses in the recent years due to attention given to global warming by the world scientists. As result, change in temperature has become one of the most significant indicators of climatic parameters. Air temperatures on Earth have been rising since the Industrial Revolution. While natural variability plays some part, there is evidence that human activities particularly emissions of heat-trapping greenhouse gases are mostly responsible for rising the temperature in our planet. According to National Oceanic and Atmospheric Administration (NOAA), the year 2020 tied with 2016 for the hottest year on record since record keeping began in 1880 (NASA/GISS, 2022). According to NASA's Goddard Institute for Space Studies (GISS, 2022), the average global temperature on Earth has increased by at least 1.1° Celsius (1.9° Fahrenheit) since 1880. The majority of the warming has occurred since 1975, at a rate of roughly 0.15 to 0.20°C per decade. According to the Intergovernmental Panel on Climate Change (2001), temperatures are likely to increase by 2°F to 11.5°F, with a best estimate of 3.2°F to 7.2°F, by 2100. Temperature rise to date has already resulted in profound

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alterations to human and natural systems, including increases in droughts, floods, and some other types of extreme weather; sea level rise; and biodiversity loss – these changes are causing unprecedented risks to vulnerable populations (IPCC, 2012a, 2014a; Mysiak et al., 2016). The most affected people live in low and middle income countries, some of which have experienced a decline in food security, which in turn is partly linked to rising migration and poverty (IPCC, 2012a).

Aizawl city recorded a continuous rise in population due to migration from rural areas leading to demand of more land for settlement and agriculture. This has led to more open areas and deforestation, causing an increase in surface temperature. Irregular behaviour of rainfall and the rise in mean maximum and mean minimum temperatures may be due to a sharp decline in the forest cover due to various activities like road construction, lack of proper implementation of the forest acts and absence of the monitoring body (Tiwari, 2006). There is a direct link between environmental land degradation and the rise in temperature leading to the inevitable change in climate. The absence of the trees and plants leads to the atmospheric accumulation of the Greenhouse gasses resulting in the entrapment of heat in those sectors that further increases the temperature of that place (Itagi, 2017).

Increase in temperature is projected to continue causing changes in the hydrological cycle and impact water resource manage in a variety of ways, including a decrease in water supplies due to increased evapotranspiration, decreased runoff, and increase in urban and agricultural demand of water. The range of impacts associated with warmer temperatures will alter seasonal water supplies. Human activities have increased the atmospheric concentration of greenhouse gases, changing the Earth's climate on both global and regional scales. There is evidence that the recent climate is the result of both natural and anthropogenic forcing (Al-Muhyi et al., 2016).

Many studies on India have found that there is an increase in mean and maximum temperatures in space and time scales (Arora et al., 2005). The analysis for the increase in maximum temperature was based on station data. The study conducted by Purnadurga (2017) found that there is increase of temperature over northern India as compared to southern India. A new study by Sharma (2018) has confirmed a rapid rise in surface temperatures in the past 70 years. The study suggested that global warming is manifesting itself over parts of India with the maximum temperatures observed during the warm pre-monsoon period, with an accelerating pace noted, particularly in the last two decades (Sharma, 2018). According to Indian Meteorological Department (2022) average temperatures across seasons in India have seen a sharp upward trend in the country since 1991. There is a rise of 0.26°C in average minimum temperatures over the country 1901 onwards, but a rise of 0.99°C in average maximum temperatures over the same period. India's average temperature has risen by around 0.7°C during 1901–2018. In the recent 30-year period (1986–2015), temperatures of the warmest day and the coldest night of the year have risen by about 0.63°C and 0.4°C, respectively (Krishnan et al., 2020).

2. Materials and Methods

In this study, long-term temperature data were used in the analyses of temperature trends for the period between 2000 and 2021. The long-term temperature data was collected from the Mizoram Science Technology and Innovation Council (MISTIC) which is working under Mizoram Science and Technology Department. The temperature variability for annual and seasonal is examined by using coefficient of variation (CV) to evaluate the degree of variability in the Aizawl city. Mean monthly maximum and mean monthly minimum temperature for each of the months over the 20 years has been considered. Month wise mean maximum and mean minimum temperatures are averaged to get mean monthly temperature year-wise. Finally, the monthly average data-sets were employed for statistical analysis.

The main aim of the study is to find out whether there is a temperature variation and warming over Aizawl city. The city is located in the north eastern part of India. It has a mean temperature of 22.53°C with maximum mean temperature of 30.87°C and minimum of 14.18°C in 2021. Temperature data has been analysed to evaluate the variation of maximum and minimum temperature. The city experienced extreme hot and cold some years back. Due to anthropogenic factors the city is covered by smoke during February and March leading to rise in land temperature. According to the study conducted by Guha et al. (2018), land surface temperature decreases with the increase in green vegetation and land surface temperature increase with the increase in built-up areas.

In this study, the magnitude and the significance of the trend of temperature were determined using a nonparametric statistical technique called Mann–Kendall and Sen's estimator test. A positive value of Sen's slope indicates an upward or increasing trend and a negative value gives a downward or decreasing trend in the time series. The Mann– Kendall test has been extensively used in various studies to detect monthly, seasonal and annual trends in hydrological and climatic data such as wind speed, streamflow, as well as temperature (Suhaila, 2010). The Mann-Kendall (MK) test is to statistically assess if there is a monotonic upward or downward trend of the variable of interest over time. A monotonic upward (downward) trend means that the variable consistently increases (decreases) through time but the trend may or may not be linear. This has carried out with the hypothesis (Ho) that there is no trend in the temperature. Thus, MK statistic is the sum of the number of positive difference minus number of negative difference, which is calculated by using given formula:

$$S = \sum_{I=1}^{N-1} \sum_{J=I+1}^{N} sgn\,(Y_j - Y_j\ )$$

Where Y_j indicates the value of the j^{th} data, n indicates the number of the data and sgn (θ) is the sign function.

$$\text{sgn}(\theta) = \begin{cases} +1\ if\ \theta = Yj - Yi > 0 \\ 0\ if\ \theta = Yj - Yi \quad = 0 \\ -1\ if \theta = Yj - Yi \quad < 0 \end{cases}$$

The positive or negative values show upward trend and downward trend. The variance for the S statistic is defined by: E[S] =0

$$\text{var(S)} = \frac{(N(N-1)(2N+5) - \sum_{i=1}^{n} tii\,(i-1)(2i+5)}{22}$$

where t_i indicates the number of the data in the i^{th} tied group. Finally the standardized test statistics Z can be computed as:

$$Z = \begin{cases} S - 1/\sqrt{Var(s)}\ S > 0 \\ 0 \qquad\qquad S = 0 \\ S + 1/\sqrt{\text{Var(s)}S} < 0 \end{cases}$$

A positive value of Z shows an increasing trend, while the negative value shows a decreasing trend.

$$b_{sen} = \text{Median (Y1-Yj /i-j)}$$

Where Yi and Yj are data at the time *i* and *j* respectively. If the total number of data points in the series is n, then there will be n(1)/2 - slope estimates, and the test statistic b_{sen} is the median of all the slope estimates. The positive and negative sign of the test statistic indicates increasing and decreasing trends respectively.

3. Results and Discussion

In the Mann-Kendall test, parameters like Kendall's tau, S statistic and the Z statistic were considered to identify the increasing or decreasing trend in the time series of climatic parameters. A variability analysis of temperature is of great importance for researchers in decision making as temperature plays dominant role in agricultural production. During the study period, the mean maximum temperature varies from 26.53°C in December to 33.62°C in April and minimum temperature varies from 17.07°C in August to 7.47°C in January. Following Pandu and Sahu (2019), Coefficient of variation (CV) is used to classify the degree of variability as less (CV<20%), moderate (20<CV<30%), high (CV>30%), very high (CV>40%) and CV>70% indicate extremely high inter-annual variability of rainfall. The highest coefficient of variation for maximum temperature was observed in December while the lowest variation was found in September (Table 1). The highest minimum temperature of coefficient of variation was observed on January with 31.58 percent and the lowest on June with 16.71 percent (Table 1). The Mann-Kendall test shows that there was a monotonic relationship between maximum temperature and minimum temperature. The calculated p-value of maximum temperature is lower than 0.05. The Kendall's tau, S (Statistics) and Var(S) are all positive showing increasing trend of maximum temperature from 2000- 2021. The minimum temperature shows a slight decreasing trend with calculated value of Kendall's tau -0.226 (Figure 1 & Figure 2 and Table 2). The variation in temperature around the average value during the study period is explained by the equation Y=-0.1427X+300.2. Using this linear regression model, the rate of change is defined by the slope of regression line which in this case is 0.171°C during the study period. The coefficient of determination R squared is a statistical measure of how close the data are to the fitted regression line. Similarly, the variation in the trend of maximum temperature has been shown by the regression equation Y= 0.0508X – 71.477. With this linear regression model, the rate of change is defined by the slope of regression line which is 0.330°C. A 0 percent (%) indicates that the model explains none of the variability of the response data around its mean.

Table 1. Coefficient of Variation of Maximum and Minimum Temperature

Variable	Mean	Std. deviation	Coefficient of variation
January MAX	27.527	1.153	4.19
January MIN	7.491	2.366	31.58
February MAX	29.664	1.359	4.58
February MIN	9.295	2.388	25.69
March MAX	32.045	1.203	3.75
March MIN	11.682	2.276	19.48
April MAX	33.618	1.774	5.28
April MIN	12.286	2.625	21.36
May MAX	32.427	1.534	4.78
May MIN	13.455	2.767	20.56
June MAX	31.173	1.033	3.31
June MIN	16.350	2.732	16.71
July MAX	30.955	1.220	3.94
July MIN	16.905	3.450	20.41
August MAX	31.286	1.116	3.57
August MIN	17.073	3.079	18.04
September MAX	31.364	0.943	3.01
September MIN	16.791	2.934	17.47
October MAX	31.550	1.444	4.58
October MIN	15.905	3.474	21.84
November MAX	29.359	2.744	9.35
November MIN	12.314	2.827	22.96
December MAX	26.527	2.957	11.15
December MIN	9.282	2.007	21.62

Table 2.Test Statistics for Maximum and Minimum Temperature

Test	Maximum	Minimum
Kendall's tau	0.408	-0.226
S	94.000	-52.000
Var(S)	1256.667	1256.667
p-value (Two-tailed)	0.009	0.150

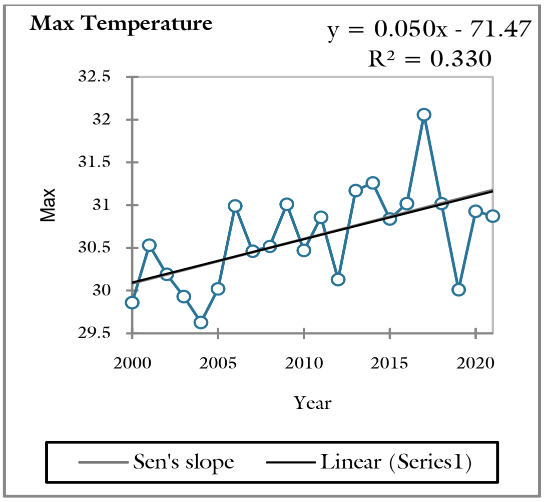

Figure 1. Sen's Slope for Maximum temperature

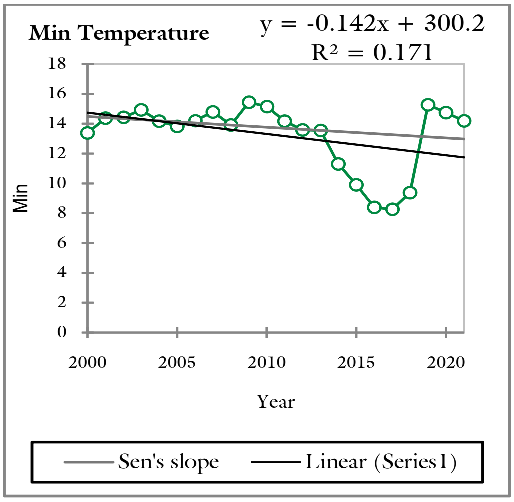

Figure 2. Sen's Slope for Minimum temperature

Table 4. Summary of Maximum and Minimum Temperature

Series	Maximum Temperature			Minimum Temperature		
	Kendall's tau	p-value	Sen's slope	Kendall's tau	p-value	Sen's slope
January	0.205	0.194	0.056	-0.209	0.185	-0.138
February	0.244	0.120	0.094	-0.196	0.214	-0.142
March	0.088	0.591	0.029	-0.039	0.821	-0.027
April	0.355	0.024	0.117	-0.095	0.554	-0.086
May	0.197	0.214	0.056	-0.217	0.167	-0.136
June	0.219	0.166	0.060	-0.222	0.158	-0.100
July	0.358	0.023	0.100	-0.166	0.296	-0.080
August	0.333	0.034	0.086	-0.413	0.009	-0.214
September	0.348	0.027	0.075	-0.433	0.006	-0.227
October	0.450	0.004	0.111	-0.235	0.135	-0.163
November	0.149	0.351	0.059	-0.114	0.479	-0.064
December	0.031	0.865	0.007	-0.166	0.296	-0.079

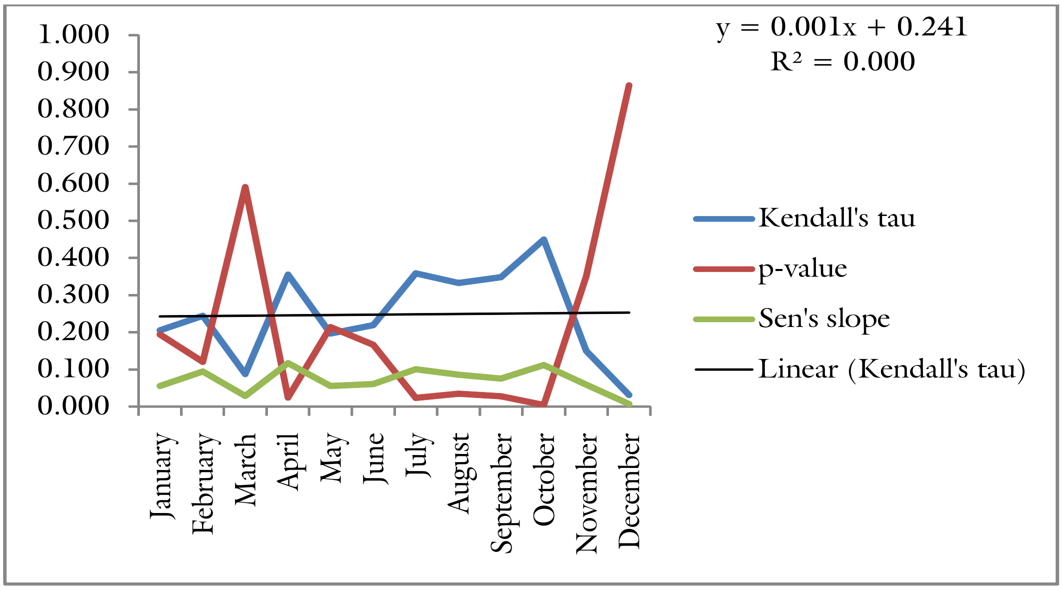

Figure 3. Summary of Maximum Temperature

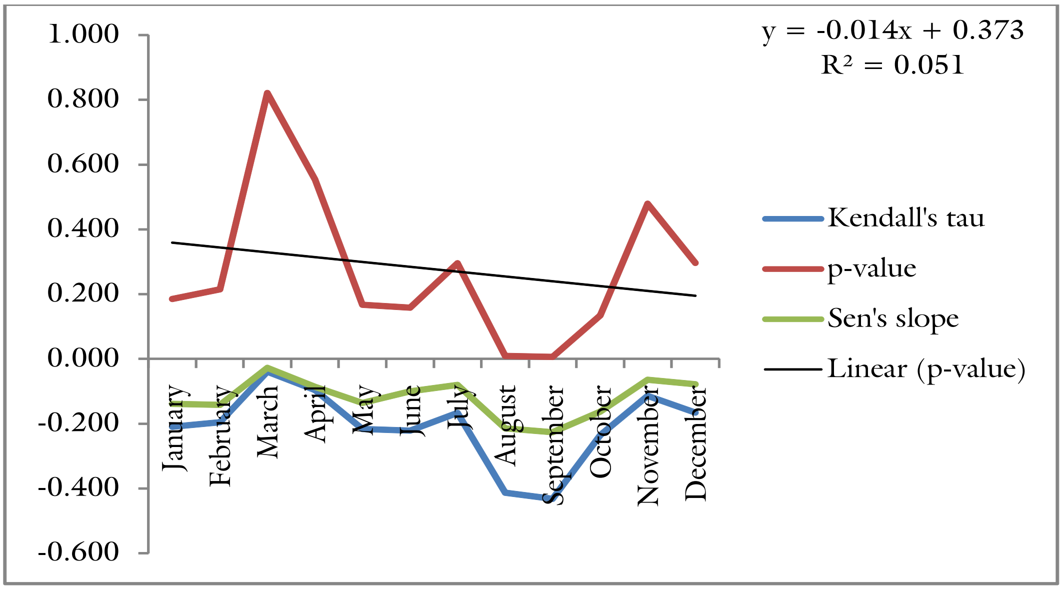

Figure 4. Summary of Minimum Temperature

It can be observed from the Table 4 that the MK test and Sen's slope have very similar value. The regression equation for Maximum temperature is Y=0.001X +0.2418 with R- squared of 0.0008. Similarly the regression equation for minimum temperature is Y= -0.0149 X + 0.3737 with R- squared of 0.0515. The lower R-Squared shows that the data contain an inherently higher amount of unexplainable variability because temperature are fairly unpredictable. The Kendall and Sen's slope of minimum temperature show negative value from January to December while the Maximum temperature shows a positive value throughout the seasons for 21 years. The P value in Maximum temperature is lower at a given alpha level (0.05) in April, July, August, September and October which indicates that there is no trend in the time series. Similarly, The P value in the minimum temperature is lower in the month of August and September also showing non-significant and no trend in the time series.

4. Conclusion

From the analysis, it has been observed that the temperatures show slight warming or increasing trend and decreasing trend of minimum temperature during the study period. The monthly calculated values of both Mann Kendall Test and Sen's slope are found be very low. A great variation in S value can be seen for both minimum temperature (-52.00) and Maximum temperature (94.00). This study was done to find the monotonic trend for temperature time series, which was found to be increasing (positive) in Maximum temperature with non-significance trend.

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CLIMATE CHANGE : IMPACT AND ADAPTATION STRATEGIES IN HILL AGRICULTURE OF NORTH EAST STATE OF MIZORAM

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Abstract : *Climate change is intensifying the challenges faced by the agriculture sector, adversely affecting crop production. Slash and burn agriculture (Jhum) is still practiced in almost all the hill states as well as Mizoram state which produced large amount of greenhouse gasses. In this context, ICAR Research Complex for NEH Region, Mizoram Centre under National Initiative Climate Resilient Agriculture (NICRA) project has identified some suitable upland and lowland rice varieties/germplasms for early maturation and higher productivity. Moreover, pulses and oil seed crops is also planned immediately after rice harvest and harvested rice plant biomass use as mulch to conserve soil moisture. Among all upland variety, Bhalum 3 recorded significantly higher grain (26.8 q/ha) and straw yield (73.8 q/ha) and MZR-19 produced higher grain yield of 28.3 q/ha among all locally collected upland rice germplasm. Gomati Dhan shows higher potential among all lowland rice varieties in case of early maturity, higher yield and pest and disease resistance. NPJ 113 (mustard), DPL 62 (lentil), VL 42 (pea) and JG 14 (chick pea) performed very well in upland and lowland rice ecosystem. Resource conserving practices like zero tillage can help farmers to grow crops soon after rice harvest so that the grain matures before the onset of pre-monsoon shower and also reduced the emission of greenhouse gases by avoid biomass burning.*

Key word : *Climate change, Slash and burn agriculture (Jhum), greenhouse gasses, resource conservation technologies*

1. Introduction

Agriculture in North Eastern Hill (NEH) region of India is mainly rainfed and subsistence in nature. Generally, the region is fragile, inaccessible, and marginal. As a result of the region's undulating topography, geo-physical surroundings, and flawed land use regimes. They have modest land holdings, minimal investment and risk carrying capabilities. Over 75% of the region's population is directly dependent on agriculture for food and nutrition. Thus, improving agriculture directly impacts the region's economy. Climate change is currently a hotly discussed issue internationally. Climate change impacts agriculture in many nations, including India (Samraet *et al*., 2004; Prasad & Rana, 2006). The NEH Region is also experiencing rising temperatures, harsh occurrences

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including heavy rainfall, frequent droughts and floods, and changes in rainfall patterns. Climate change will disproportionately harm the poorest people who rely on climate-sensitive industries like rainfed agriculture and fisheries. Climate change is anticipated to reduce agriculture, animal, and fisheries output, yet opinions of the intensity and impacts of climate change vary. The issues in North Eastern hill agriculture are exacerbated by climatic unpredictability and a lack of resources and mitigating techniques (Rajkhowa *et al.*, 2017).

Slash and burn agriculture (*Jhum*) is still practiced in almost all the hill states of Northeast India, with reduced cycle of 2-3 years as against 10-15 years in the past. About 0.88 m ha area is still under shifting cultivation in the NE region. Huge amount of biomass (about 10 t/ha) burnt annually in *Jhuming* that leads to release of considerable amount of CO_2. The region, once endowed with rich genetic diversity of flora and fauna, has been denuded due to human activities and adoption of unscientific and unsustainable land use system. With rapid increase in human and livestock population and the rising demand of food, feed, fuel, fodder, fibre, timber and the other developmental activities, the farmers have been forced to exploit forestland and water resources in complete defiance of the inherent potential. This has resulted in progressive decrease in forest cover, loss of biodiversity, serious soil erosion leading to depletion of plant nutrients, water, gradual degradation and decline in land productivity and drying up of perennial steams as well as causing serious ecological imbalances. Gradual degradation of these resources is of prime concern and calls for location-specific measure to conserve, utilise and manage these resources for optimizing production on sustained basis without adversely affecting its quality. The annual mean maximum temperature in the region is rising at the rate of + 1.11^{0}C per decade (Singh and Ngachan, 2012). The annual mean temperature is also increasing at a rate of 0.04^{0}C per decade in the region (Das, 2009). The decreasing trend of rainfall and number of rainy days has also been reported (Saikia *et al.*, 2012).

Climate variability and change are now real. Understanding the consequences and vulnerabilities of hill agriculture, as well as adaptation strategies, is critical. A multi-pronged strategy of leveraging indigenous coping mechanisms, expanding current climate counteracting technology, and coordinating research and development activities to produce new place specific solutions is required. Increased usage of organic manure and biomass recycling will enhance the SOC pool (Mahanta *et al.*, 2014). Conserving natural resources including water, air, fossil fuels and soil may be achieved by adopting resource conservation practises like no or minimal tillage, residue management, crop rotation, large-scale production of organic manures and effective use of water. Biomass recycling has a significant potential for improving soil health in the region. Earthworms and cellulose degrading microorganisms were also used to efficiently convert various plant biomasses (Rajkhowa & Kumar, 2013). These technologies can increase agricultural sustainability by saving resources and reducing GHG emissions. Micro irrigation integrated pest management, crop insurance, increasing nutrient usage efficiency and agroforestry intervention. Climate change adaptation strategies for agriculture include improved weather-based agro-advisory, protected cultivation, intercropping/mixed cropping, use of renewable energy, seed banks, custom hiring centres and indigenous technical knowledge. Skill and capacity development among

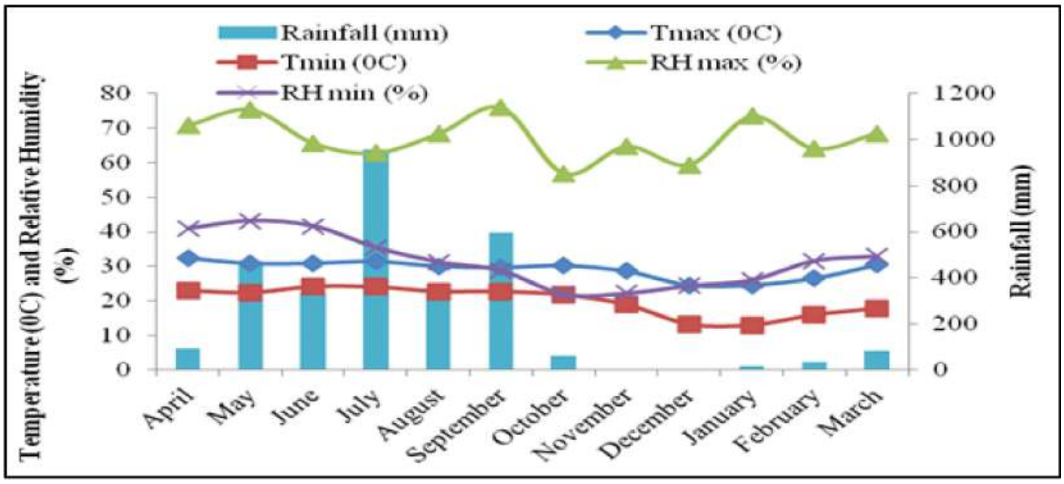

Figure 1: Average monthly meteorological variables at Kolasib Mizoram

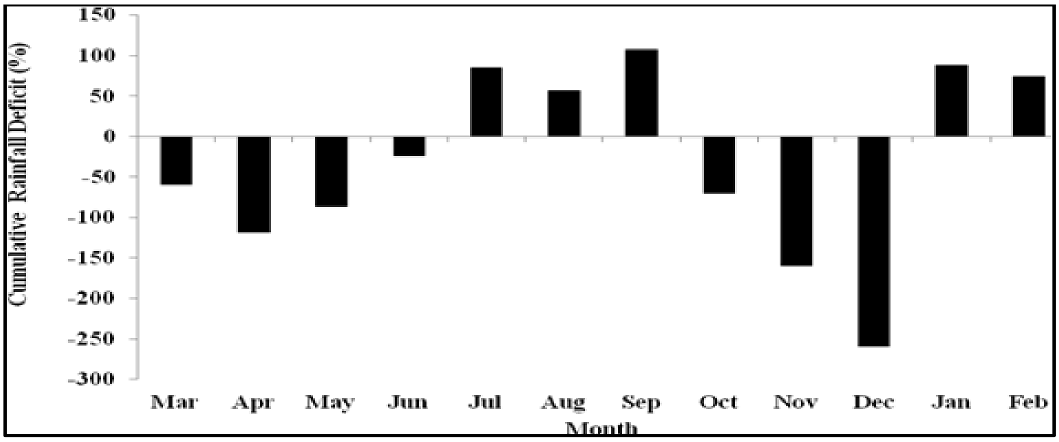

Figure 2: Temporal pattern of the cumulative rainfall deficit at Mizoram

farmers is vital not just for job efficiency but also for economic activity and climate adaption.

2. Methodology

2.1 Weather Data

Weather data is recorded at meteorological station of ICAR RC for NEH Region, Mizoram Centre. Ten-year average (2010-20) annual rainfall was 2643.7mm. According to rainfall distribution, season has been divided in to pre monsoon (March to May), monsoon (June to September), post monsoon (October to December) and winter (January to February) at Mizoram. In pre monsoon season 619.7 mm, monsoon 2235.6 mm, 66.8 mm and 132.6mm rainfall were received. Rainfall was deficit in the in pre monsoon season (-85.68%) but in the month of July and August excess rainfall has been precipitated 2.09 and 1.50 times more than normal. So, rainfall was compensated in monsoon season and surplus around (106.74%). In Post monsoon season, no change has been observed. In Rabi season, some excess rainfall has been observed.

Five varieties viz. Bhalum 1, Bhalum 2, Bhalum 3, Bhalum 4 and IURON-514 and Seventy-two upland indigenous rice varieties were collected from eight districts of the Mizoram and evaluated for their yield potential were tested under upland condition with all agronomic practices under National Initiative Climate Resilient Agriculture (NICRA) project at research farm of ICAR Research Complex for NEH Region, Mizoram Centre during 2016-2020. Similarly, RCPL 1-111, RCPL 1-126, RCPL 1-131, RCPL 1-132, RCPL 1-140, RCPL 1-149, RCPL 1-160, RCPL 1-300, RCPL 1-303, RCPL 1-307, RCPL 1-308, RCPL 1-400, RCPL 1-401, RCPL 1-408, RCPL 1-410, RCPL 1-475, Gomati Dhan, IR 64, RCM 9, RCM 10 and RCM 11 were collected from different centres of ICAR RC for NEH Region and evaluate at research farm of ICAR Research Complex for NEH Region, Mizoram Centre.

Harvesting of rice at ground level is common practice in low laying area of North East region and rice straw is mostly used for fodder. Those farmers who do not keep any livestock usually burn residue after its harvest. Similarly, in traditional rice cultivation farmers plough the field several times before sowing, particularly during puddling which leads to destruction of soil structure and loss of organic carbon from the soil. As soil carbon is designated as black gold of soil, an optimum level of soil organic carbon (SOC) is needed to conserve soil, water and nutrient; favour biological activity and high productivity in any system. Many a times, sowing of rabi crops is not possible after harvest of puddled rice because of poor soil structure and soil fertility. Tillage affects soil physical, chemical and biological properties and can play an important role in enhancing the yield potential of crops. Resource conserving practices like zero tillage can help farmers to grow crops soon after

Figure 3. Performance of different HYV upland rice varieties in Field trail at ICAR, Mizoram Centre

Table 1. Evaluation of rice varieties under upland conditions

Varieties	Harvest from DAS	Panicle height (cm)	No of grain/ panicle	Grain yield (q/ha)	Straw yield (q/ha)	Test weight (g)
Bhalum 1	113.84	19.06	156.91	17.9	49.4	23.36
Bhalum 2	118.95	20.41	149.60	16.5	42.8	21.60
Bhalum 3	128.94	22.44	205.34	26.8	73.8	27.91
Bhalum 4	122.57	23.86	187.62	20.3	48.4	22.84
IURON 514	131.54	25.91	198.62	24.6	70.6	23.84
SEm (±)	2.57	0.84	3.81	1.60	0.60	0.51
CD (P = 0.05)	5.81	2.61	6.51	4.40	5.60	2.47

rice harvest so that the grain matures before the onset of pre-monsoon shower.

3. Result and Discussion

3.1 Evaluation of different rice varieties under upland conditions

Bhalum 3 recorded significantly higher grain (26.8 q/ha) and straw yield (73.8 q/ha) followed by IURON-514 which was recorded 24.6 q/ha grain yield and 70.6 q/ha straw yield while lowest grain yield was recorded in 16.5 q/ha and 42.8 q/ha straw yield in Bhalum 2 (Table 1, Figure 3). Bhalum 3 shows higher resistance against disease like rice blast and sheath blight and insect like rice leaf folder.

3.1.1 Evaluation of local germplasm of rice under upland conditions of Mizoram

Yield data depicted in Figure 4 revealed that MZR-19 produced higher grain yield of 28.3 q/ha followed by MZR-53 (26.2 q/ha) and MZR-27 (25.5 q/ha), whereas lesser grain yield recorded from MZR-58 (3.2 q/ha). Rice neck blast (Magnaporthe grisea) and rice sheath blight (Rhizoctonia solani) were observed in majority of the selections.

3.1.2 Evaluation of different rice varieties under lowland conditions

Among twenty-one rice varieties tested under lowland conditions,

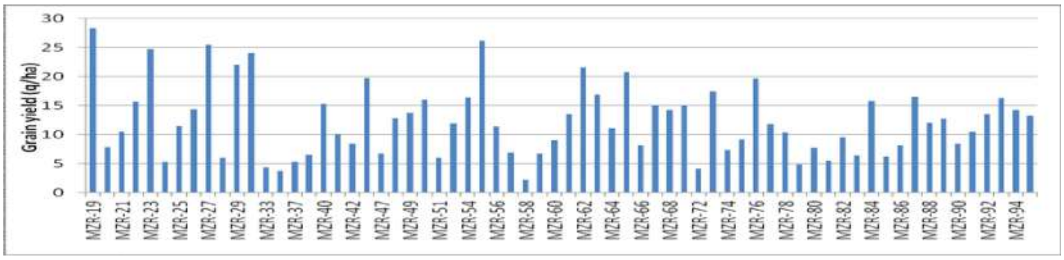

Figure 4. Grain yield (q/ha) of different local germplasms of rice

Figure 5. Phenotypic difference of local germplasms of rice collected form Mizoram

Gomati Dhan showed higher grain yield (43.6 q/ha) followed by RCPL 1-408 (39.8 q/ ha), whereas RCPL 1-111 recorded lesser grain yield (20.0 q/ha) (Table 2). Rice neck blast (Magnaporthe grisea) and rice sheath blight (Rhizoctonia solani) diseases were prevalent for majority of the landraces. Rice stem borer (Scirpophaga incertulus) and rice leaf folder (Cnaphalocrocis medinalis) were the major insect infestation recorded during the trial.

3.1.3 Identification of temperature (drought or high temperature) tolerant rice varieties

Leaf folder infestation was very high in RCM-9 and RCM-11, whereas Gomati Dhan was free from leaf folder infestation. Three lowland rice varieties such as RCM-9, Gomati Dhan and RCM-11 (Figure 6) along with one local check were evaluated under different agro-climatic conditions of Mizoram viz., Kawnpui (Kolasib district), Khawzawl and Champhai

Table 2. Yield attributes different rice cultivars at ICAR, Mizoram centre in 2014-2015

Varieties	Panicle length (cm)	No of panicle	Panicle weight (gm)	No of grains/ panicle	Test weight	Grain yield (q/ha)
RCPL 1-111	26.51	4.81	40.52	148.51	27.56	12
RCPL 1-126	27.86	6.41	25.22	106.51	26.06	19.4
RCPL 1-131	27.91	7.51	31.52	157.51	26.76	16.9
RCPL 1-132	26.09	8.61	31.52	101.21	31.76	15.3
RCPL 1-140	28.31	11.31	21.52	110.51	24.36	23.6
RCPL 1-149	27.64	10.11	34.82	116.81	29.76	20.6
RCPL 1-160	28.91	6.81	44.22	111.81	34.36	22.7
RCPL 1-300	26.73	10.11	50.52	178.51	33.46	24.1
RCPL 1-303	25.81	9.61	39.82	114.81	26.76	25
RCPL 1-307	26.75	6.11	31.52	140.21	26.06	21.2
RCPL 1-308	25.44	10.91	35.82	103.21	26.86	29.2
RCPL 1-400	28.24	7.11	56.52	154.21	24.06	22.9
RCPL 1-401	26.24	8.61	41.82	128.21	22.06	33.1
RCPL 1-408	26.24	5.01	53.02	133.51	30.56	39.8
RCPL 1-410	25.54	7.61	30.22	102.51	26.36	14.3
RCPL 1-475	26.24	3.81	31.52	92.21	25.76	19.9
Gomati Dhan	27.94	8.41	39.82	167.81	26.86	43.6
IR 64	26.94	8.11	38.82	125.41	27.76	19.2
RCM 9	27.44	8.31	39.32	146.61	27.36	24.2
RCM 10	26.34	6.21	22.62	120.41	25.16	24.1
RCM 11	27.94	7.71	39.82	167.81	26.86	31.1
SEm±	**0.70**	**0.30**	**0.90**	**3.10**	**0.50**	**0.7**
CD (P = 0.05)	**1.90**	**0.80**	**2.50**	**9.30**	**1.30**	**2.0**

Figure 6. Performance of different rice varieties viz., Gomati Dhan, RCM-9 and RCM-11

Table 3. Performance of rice varieties under different climatic conditions of Mizoram

Varieties	Height of Plant (cm)*	Nos. of Tiller*	Length of Panicle (cm)*	Yield (Q/ha)	Remarks
Kawnpui, (Lowland)					
RCM-9	70.12	12	24.5	34.5	High incidence of leaf folder in RCM-9 and RCM-11
Gomati Dhan	68.7	16.5	30.0	42.0	
RCM-11	78.2	13.6	26.0	36.1	
Local	99.6	15.0	22.6	19.80	High incidence of leaf folder and ear head bug
Khawzwal (Lowland)					
RCM-9	92.2	10.6	24.5	32.5	NIL
Gomati Dhan	100.2	12.2	22.7	41.3	
RCM-11	97.1	9.2	19.5	30.5	
Local	139	9.4	24.8	33.6	
Champhai (Lowland)					
RCM-9	75.56	9.2	21.7	28.4	Late panicle initiation in RCM-9 and RCM-11 due to low temperature
Gomati Dhan	81.8	11.6	23.06	39.5	
RCM-11	84.5	9.8	23.42	27.2	
Local	129.5	7.6	20.5	28.9	

(Champhai district). Among the three varieties, Gomati Dhan recorded maximum yield in all the three locations viz., Kawnpui (42.0 q/ ha.), Khawzwal (41.3 q/ ha.) and Champhai (39.5 q / ha.), whereas local check recorded 19.80 q/ ha in Kawnpui, 33.6 q/ ha. in Khawzwal and 28.9 q/ha in Champhai (Table 3). Leaf folder infestation was very high in RCM-9 and RCM-11, whereas Gomati Dhan was free from leaf folder infestation. However, local check was highly susceptible to leaf folder and ear head bug (Table 3).

3.1.4 Evaluation of different toria cultivars in lowland rice fallow under no till system for enhancing cropping intensity and productivity

Toria is one of the most important oilseed crop in Mizoram state. But due to effect of temperature and occasional rainfall yield has not come at acceptation mark. More over farmers are using local varieties which produced less yield. Three HYV toria varieties was evaluated at rice fallow of research farm of ICAR, Mizoram Centre.

Table 4. Ontogeny of toria cultivars under no-till condition in rice fallow

Name of the variety	Days to emergence	Days to flower initiation	Days to 50% flowering	Days to 100% flowering	Days to pod formation	Harvest (days)
M 27	5	35	43	52	58	95
P 27	6	41	48	54	60	100
NPJ 113	8	48	61	72	81	118

Among all the cultivar, M 27 has taken 43 days to attain 50% flowering and NPJ 113 taken 61 days. Most of the toria cultivars matured in about 95-118 days. M 27 took 95 days for harvest and NPJ 113 matured in 118 days (Table 4).

The tallest plants were observed with NPJ 113 (112.34 cm) followed by P 27 (75.9 cm) and M 27 (72.6 cm). The highest numbers of primary branches/plant were recorded with NPJ 113 (12.5) followed by P 27 (8.6) while the lowest number of primary branches/plant was recorded with M 27 (7.51). Secondary branches/plant was the highest with NPJ 113 (14.3) followed by P 27 (11.06) and M 27 (10.5). Specific leaf area, Leaf area Index and Chlorophyll was higher in NPJ 113 follow by P 27 and M 27 (Table 5)

The maximum number of siliqua/plant was recorded with NPJ 113 (61.5) followed by M 27 (56.3) and P 27 (46.1). Number of seeds/siliqua was the highest in NPJ 113 (9.47) followed by M 27 (8.94) and lowest in P 27 (6.81) (Table 6). Grain weight and biomass weight was higher in NPJ 113 followed by M 27 while lowest was observed in P 27. The test weight (weight of 1000 seed) was recorded to be highest in NPJ 113 (0.42 g) followed by M 27 (0.38) and P 27 (0.34) (Table 6)

Table 5. Flowering parameter of different varieties of toria in lowland rice fellow under zero tillage at Mizoram

Name of the variety	Plant height (cm)	No of primary branches	No of secondary branches	Plant dry matter (g/pt)	Specific Leaf Area	Leaf Area Index	Leaf Area Ratio	Chlorophyll
M 27	72.61	7.51	10.52	14.85	518.18	2.58	178.61	36.45
P 27	75.91	8.61	11.06	15.84	492.91	2.38	168.75	31.02
NPJ 113	112.34	12.75	14.35	19.64	452.73	2.15	157.59	35.24
SEm+	**4.6**	**0.27**	**0.43**	**0.34**	**39.51**	**1.28**	**14.62**	**2.21**
CD (P=0.05)	**13.57**	**0.9**	**1.19**	**1.05**	**113.04**	**3.86**	**41.75**	**6.34**

Table 6. Yield attributes and yield of toria cultivars under no-till condition in rice fallow

Name of the variety	No. of siliqua/pt	No of seed /siliqua	Grain yield (t/ha)	Biomass yield (t/ha)	Harvest Index(%)	Seed Index (g)	Crude protein (%)	Total P (%)
M 27	56.31	8.94	0.84	3.84	21.88	0.38	19.35	0.92
P 27	46.16	6.81	0.79	3.51	22.51	0.34	16.13	0.81
NPJ 113	61.5	9.47	0.98	4.05	24.20	0.42	17.4	1.02
SEm (±)	**0.69**	**0.28**	**0.13**	**0.08**	**0.91**	**2.06**	**0.58**	**0.07**
CD (P=0.05)	**3.12**	**2.14**	**1.19**	**1.05**	**113.04**	**3.86**	**41.75**	**6.34**

3.2 Evaluation of different lentil cultivars in lowland rice fallow under no till system for enhancing cropping intensity and productivity

More than 10 million hectares of land in India is left fallow after rice harvest among which 82% areas of rice-fallow lies in the states like Assam, Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Orissa, West Bengal and North Eastern states and there exists a scope for expansion of area under pulse crops like lentil (Lens culinaris) in rice fallows.

The lentil cultivars were sown on second week of December during 2014 and took 4-5 days for germination (Table 1). The 50% flowering took about 71 to 74 days in different cultivars with cv.IPL316 showing the earliest and cv. IPL 15 the last to come to 50% flowering. Most of the lentil cultivars matured in about 110-115 days. IPL 406 (110) took least days for mature and DPL 62 (119) took highest day for mature (Table 7).

3.2.1 Growth attributes

The tallest plants were observed with IPL-406 (63.8 cm) followed by IPL-316 (63.7 cm) and IPL-15 (59.6 cm). Significantly the shortest lentil plant was recorded with IPL 81 (44.2 cm) followed by DPL 62 (53.3 cm). The highest numbers of primary branches/plant were recorded with DPL 62 (6.91) followed by IPL15 (6.34) while the lowest number of primary branches/plant was recorded with IPL 81 (5.61) followed by IPL 316 (5.74). Secondary branches/plant was the highest with DPL 62 (10.91) followed by IPL-406 (9.67) and IPL 81.

3.2.2 Nodulation

In general, the number of nodules increased between 30 to 60 DAS and thereafter decreased gradually. Maximum number of nodules/plant as well as nodule biomass was recorded with DPL 62 (20.61 and 45.73 mg, respectively) followed by IPL 81 (19.61 and 42.91 mg, respectively). The lowest number of nodules and nodule biomass was recorded with IPL 15 followed by IPL 316 (Table 8).

The highest seed yield was recorded in DPL 62 (1.35 t/ha) followed by IPL 81 (1.33 t/ha) and IPL 15 (1.32 t/ha) (Table 9). The greater

Table 7. Ontogeny of lentil cultivars under no-till condition in rice fallow at Mizoram

Lentil cultivars	Days to emergence	Days to flower initiation	Days to 50% flowering	Days to 100% flowering	Days to pod formation	Maturity (days)
IPL 15	5	68	76	85	91	117
IPL 81	4	68	74	85	90	115
DPL 62	4	67	74	84	95	119
IPL-316	5	65	71	78	85	115
IPL 406	5	65	72	79	84	110

number of pods per plant, seeds per pod and seed index in lentil resulted in higher seed yield in these cultivars. The IPL 15 followed by IPL 81 recorded the highest biomass, while IPL 406 followed by IPL 306 recorded the lowest biomass yield. The variety DPL 62 followed by IPL 81 recorded the highest harvest index while IPL-316 followed by IPL 406 recorded the lowest harvest index. As harvest index indicates the ratio between the economic parts (i.e. in this case seeds) and total biomass production, varieties producing higher seed yield have recorded higher harvest index as compared to others.

3.3 Evaluation of different pea (Pisum Sativum L.) cultivars in lowland rice fallow under no-till system for enhancing cropping intensity and productivity at Mizoram

Pea (Pisum sativum L.), a leguminous crop, belongs to family leguminoseae, and contains higher amount of protein having essential amino acids particularly lysine. Peas are very common nutritious vegetable and are mainly cultivated as winter crop throughout the world. Most e of the rice fallow is unused after rice cultivation. So pulse cultivation is one of the methods to increase crop

Table 8. Plant growth and nodulation parameters of different lentil cultivars at Mizoram

Lentil cultivars	Plant height (cm)	No. of primary branches	No. of secondary branches	No. of nodule/plant	Nodule weight/plant (mg)
IPL 15	59.6	6.34	7.61	16.32	35.81
IPL 81	44.2	5.61	9.24	19.61	42.91
DPL 62	53.3	6.91	10.91	20.61	45.73
IPL-316	63.7	5.74	8.37	13.67	38.91
IPL 406	63.8	5.91	9.67	18.74	40.92
SEm (±)	**1.38**	**0.15**	**0.21**	**0.31**	**0.48**
CD (p=0.05)	**3.72**	**0.34**	**0.57**	**0.85**	**1.42**

Table 9. Yield attributes and yield of lentil cultivars under no-till condition in rice fallow at Mizoram

Lentil cultivars	No. of pods/plant	No. of seeds /pod	Seed index (g)	Seed yield (t/ha)	Biomass yield (t/ha)	Harvest index
IPL 15	49.6	1.36	30.15	1.32	5.27	23.7
IPL 81	46.18	1.29	32.61	1.33	5.42	26.9
DPL 62	51.32	1.67	36.15	1.38	5.57	26.9
IPL-316	47.31	1.37	28.61	1.15	5.35	21.5
IPL 406	48.92	1.48	32.51	1.09	5.03	21.6
SEm+	**1.46**	**0.03**	**0.93**	**0.02**	**0.13**	**0.93**
CD (p=0.05)	**4.18**	**0.09**	**2.67**	**0.07**	**0.36**	**2.67**

Figure 8: Performance of lentil cultivars, IPL 15, IPL 81, DPL 62and IPL 406 under zero tillage practice and bee boxes at ICAR farm

production as well as increase nitrogen level in rice fellow.

Pea cultivars were sown on last week of November during consecutive 2014. Among all varieties/line took 4-6 days for germination (Table 3). Among all varieties/line HUDP 15 (45 days) took least days in flower initiation followed by IPF 1-22 (68 days) and IPF 99-26 (63 days) while IPF 5-19 (75 days) followed by IPF 14 (74days) took highest days for flower initiation. Varieties were performed same for 100% flowering, pod formation and pod maturation. Among all varieties/line HUDP 15 (135 days) took least days in Harvesting followed by IPF 1-22 (142 days) and IPF 99-26 (145 days) while IPF 5-19 (148 days) followed by IPF 14 (150days) took highest days for harvesting (Table No. 10)

Table 10: Ontogeny of pea cultivars under no-till condition in rice fallow at Mizoram

Name of the variety	Emergence (DAS)	Flower initiation (DAS)	50% flowering (DAS)	100% flowering (DAS)	pod formation (DAS)	Pod maturation (DAS)	Harvest (DAS)
IPF 1-22	4	68	77	87	94	115	142
IPF 5-19	5	75	84	97	103	118	148
IPF 99-26	4	71	85	96	104	122	145
IPF 14	6	74	83	98	106	123	150
HUDP 15	5	63	70	85	95	115	135
VL-42	4	58	68	89	99	117	131

Among all varieties, Specific Leaf Area, Leaf Area Index, Leaf Area Ratio, Chlorophyll, No of nodule/pt and Nodule weight (g) was higher in variety VL 42 followed by HUDP 15 and IPF 1-22 and lowest Specific Leaf Area, Leaf Area Index, Leaf Area Ratio, Chlorophyll, No of nodule/pt and Nodule weight has observed in IPF 14 followed by IPF 5-19 and IPF 99-26 (Table 11)

Among all varieties/lines, highest seed yield was recorded in VL 42 (2.33 t/ha) followed by HUDP 15 (2.33 t/ha) and IPF 1-22 (2.29 t/ha) while IPF 14 (1.98 t/ha) followed by IPF 5-19 (2.03 t/ha). Highest biological yield was recorded in VL 42 (9.13 t/ha) followed by HUDP 15 (9.01 t/ha) and IPF 1-22 (8.85 t/ha) while IPF 14 (7.92 t/ha) followed by IPF 5-19 (8.16 t/ha). No. of pod per plant, No of seed per pod and seed index also were higher in VL 42 followed by HUDP 15 and IPF 1-22 while lower in IPF 14 followed by IPF 5-19 (Table 12).

From the study, it can be concluded that there is enough scope for cultivation of pea in lowland rice fallow under no-till system in the North Eastern Hilly (NEH) Region of India. Cultivars like VL 42, HUDP 15 and IPF 1-22, are the most potential in terms of growth and productivity (yielding more than 2.30 t/ha) for the NEH region.

Table 11. Flowering parameters of different pea cultivars at Mizoram

Name of the variety	Specific Leaf Area	Leaf Area Index	Leaf Area Ratio	Chlorophyll	No of nodule/pt	Nodule weight (g)
IPF 1-22	551.42	3.13	166.19	46.38	55.67	3.65
IPF 5-19	514.29	2.84	149.8	42.51	52.34	3.6
IPF 99-26	540.18	3.28	171.92	51.03	59.06	4.16
IPF 14	496.4	2.64	145.1	41.2	51.24	3.28
HUDP 15	611.44	4.37	241.82	48.04	51.02	3.68
VL-42	732.62	5.08	243.81	58.41	53.13	3.75
SEm+	**40.69**	**1.38**	**15.15**	**2.24**	**0.94**	**0.08**
CD (p=0.05)	**116.27**	**3.95**	**43.3**	**6.39**	**2.7**	**0.23**

Table 12. Yield attributes and yields of pea cultivars under no-till condition in rice fallow at Mizoram

Name of the variety	No of pod/plant	No of seed /pod	Grain yield (t/ha)	Biomass yield (t/ha)	Seed Index (g)	Crude protein (%)	Total P (%)
IPF 1-22	28.68	6.14	2.23	8.85	24.81	20.19	0.77
IPF 5-19	23.93	5.52	2.03	8.16	22.81	17.37	0.63
IPF 99-26	27.28	5.81	2.14	8.67	24.19	19.22	0.71
IPF 14	22.84	5.37	1.98	7.92	21.28	18.01	0.62
HUDP 15	33.04	6.39	2.29	9.01	25.25	22.34	0.84
VL-42	32.61	6.52	2.33	9.13	25.94	23.24	0.91
SEm+	**0.3**	**0.12**	**0.05**	**0.07**	**0.23**	**0.97**	**0.03**
CD (p=0.05)	**0.85**	**0.33**	**0.14**	**0.21**	**0.67**	**2.76**	**0.1**

Figure 9. Performance of pea cultivars, VL 42and HUDP-15 under zero tillage practice and bee boxes at ICAR farm

3.4 Evaluation of different Chickpea (Cicer arietinum L.) cultivars in lowland rice fallow under no-till system for enhancing cropping intensity and productivity at Mizoram

Chickpea (Cicer arietinum L.), a leguminous crop, belongs to family leguminoseae, and contains higher amount of protein having essential amino acids particularly lysine. Six varieties were brought from IIPR Kanpur to evaluate the performance of chick pea varieties at Mizoram agro climatic condition.

Chickpea cultivars were sown on last week of November during consecutive 2014. Among all varieties/line took 4-5 days for germination (Table 3). Among all varieties/line JG 14 (62 days) took least days in flower initiation followed by KPG 59 (63 days) and IPC 97-67-11 (64 days) while PUSA 372 (68 days) followed by IPC 02-29 (67days) took highest days for flower initiation. Varieties were performed same for 100% flowering, pod formation and pod maturation. Among all varieties/line JG 14 (125 days) took least days in flower initiation followed by KPG 59 (132 days) and IPC 97-67-11 (133 days) while PUSA 372 (142 days) followed by IPC 02-29 (135days) took highest days for harvesting (Table 13).

Table 13. Ontogeny of chickpea cultivars under no-till condition in rice fallow at Mizoram

Name of the variety	Emergence (DAS)	flower initiation (DAS)	50% flowering (DAS)	100% flowering (DAS)	Pod formation (DAS)	Harvest (DAS)
JG 14	4	62	71	81	87	125
JG11	5	66	74	84	92	130
KPG 59	4	63	70	81	86	132
IPC 02-29	5	67	76	86	92	135
IPC 97-67-11	5	64	73	82	88	133
PUSA 372	4	68	75	88	94	142

Among all varieties, Specific Leaf Area, Leaf Area Index, Leaf Area Ratio, Chlorophyll, No of nodule/pt and Nodule weight (g) was higher in variety JG 14 followed by JG 11 and KPG 59 and lowest Specific Leaf Area, Leaf Area Index, Leaf Area Ratio, Chlorophyll, No of nodule/pt and Nodule weight has observed in PUSA 372 followed by IPC 97-67-11 and IPC 02-29 (Table 14).

Among all varieties/lines, highest seed yield was recorded in JG 14 (1.81 t/ha) followed by JG 11 (1.78 t/ha) and KPG 59 (1.75 t/ha) while PUSA 372 (1.35 t/ha) followed by IPC 02-29 (1.38 t/ha). Highest biological yield was recorded in JG 14 (6.38 t/ha) followed by JG 11 (6.24 t/ha) and KPG 59 (7.49 t/ha) while PUSA 372 (5.75 t/ha) followed by IPC 02-29 (5.83 t/ ha) No. of pod per plant, no. of seed per pod and seed index also were higher in JG 14 followed by JG 11 and KPG 59 while lower in PUSA 372 followed by IPC 02-29 (Table 15).

4. Conclusion

From the above analysis, it is found that NPJ 113, M 27 and P 27 were the most suitable varieties for Mizoram condition. Among all, NPJ 113 was most suitable variety followed by M 27. Secondly, there is enough

Table 14. Flowering parameters of different chick pea cultivars at Mizoram

Name of the variety	Specific Leaf Area	Leaf Area Index	Leaf Area Ratio	Chlorophyll	No of nodule/pt	Nodule weight (g)
JG 14	587.45	2.95	210.26	46	54.39	3.96
JG11	547.92	2.86	184.76	42.31	52.38	3.68
KPG 59	528.58	2.63	182.11	39.42	48.75	3.52
IPC 02-29	518.18	2.58	178.61	36.45	46.81	3.48
IPC 97-67-11	492.91	2.38	168.75	31.02	38.95	3.55
PUSA 372	452.73	2.15	157.59	35.24	41.95	3.55
SEm+	**40.69**	**1.38**	**15.15**	**2.24**	**0.94**	**0.08**
CD (P=0.05)	**116.27**	**3.95**	**43.3**	**6.39**	**2.7**	**0.23**

Table 15. Yield attributes and yields of chick pea cultivars under no-till condition in rice fallow at Mizoram

Name of the variety	No. of pod/pt	No of seed /pod	No. of branches/ plant	Grain yield (t/ha)	Biomass yield (t/ha)	Seed Index (g)	Crude protein (%)	Total P (%)
JG 14	45.61	1.02	31.21	1.81	6.38	29.39	18.62	0.69
JG11	43.61	1.09	28.91	1.78	6.24	27.37	19.75	0.72
KPG 59	51.67	1.2	35.91	1.75	6.08	29.17	22.3	0.84
IPC 02-29	48.91	0.94	25.91	1.38	5.83	28.57	18.6	0.57
IPC 97-67-11	46.37	1.06	30.75	1.83	6.01	29.09	19.83	0.63
PUSA 372	42.91	1.01	28.61	1.35	5.75	28.55	18.07	0.61
SEm+	**0.3**	**0.02**	**1.27**	**0.05**	**0.07**	**0.23**	**0.97**	**0.03**
CD (P=0.05)	**0.85**	**0.08**	**4.91**	**0.14**	**0.21**	**0.67**	**2.76**	**0.1**

Figure 10. Performance of chickpea cultivars JG 14, JG 11, KPG 59 and PUSA 372 under zero tillage practice and bee boxes at ICAR farm

scope for cultivation of lentil in lowland rice fallow under no-till system in the North Eastern Hilly (NEH) Region of India. Cultivars like DPL 62, IPL 15 and IPL 81, are the most potential in terms of growth and productivity (yielding more than 1.2 t/ha) for the NEH region. Thirdly, it can be concluded that there is enough scope for cultivation of chickpea in lowland rice fallow under no-till system in the North Eastern Hilly (NEH) Region of India. Cultivars like JG 14, JG 11 and KPG 59, are the most potential in terms of growth and productivity (yielding more than 2.12 t/ha) for the NEH region.

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TREND ANALYSIS AND CHANGE POINT DETECTION OF MONTHLY AND SEASONAL PRECIPITATION AND TEMPERATURE SERIES OF AIZAWL CITY

- Lalrinmawia
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Abstract : *Climate change is the most vulnerable change taking place worldwide. The study on temperature and rainfall has received a great concern worldwide as it directly or indirectly influence our ecosystem, cropping system, lives, and livelihood of the society. The study of change in maximum and minimum temperatures as well as rainfall plays a key role particularly in countries where rainfed agriculture is predominant. The present study examines rainfall and temperature of Aizawl City for 12 years from 2010- 2021. For this, temperature and precipitation dataset are statistically tested with respect to homogeneity. Three methods namely standard normal homogeneity test (SNHT), Buishand range test and Pettitt's test, were chosen to detect the inhomogeneity. The magnitudes of the trend were calculated by employing Mann-Kendall and Sen's slope method. To evaluate the performance of the methods used, three different variables were used, which are Maximum temperature, Minimum temperature and rainfall. In terms of change detection and trend assessment, all of the climate variables were investigated at a monthly, seasonal and annual scale. Seasonal trend of both the parameters has been investigated on monthly basis and seasonal basis i.e., Pre monsoon (March- May), (June–September) and Post monsoon (October-November) and Winter (December- February). The results of the tests are condensed into three classes. A qualitative interpretation of this classification is given, as well as recommendations for the use of these labeled series in trend analysis and variability analysis of weather extremes. Significant change points were found in temperature. These points fell in monsoon and winter for the seasonal series, and May for the monthly series in maximum temperature and September in minimum temperature. A change point in rainfall was also detected in July. The study concludes that homogeneity tests are of great importance in such analyses to avoid false trend detections.*

Keywords : *Temperature, Rainfall, Aizawl City, Mann-Kendall, Sen's slope analysis*

1. Introduction

A change in rainfall pattern and raising temperature is going to influence the hydrological cycle as well as the volume of stream flow in any region. It is not possible to attribute individual weather events to climate change but a recent review by the Intergovernmental Panel on Climate Change concluded that there is already strong evidence that the number of extreme cold days around the world is decreasing, while hot days are on the rise, and patterns of rainfall in many regions are being altered as well (IPCC, 2007). Associated with global warming, there are strong indications that

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rainfall changes are already taking place on both the global and regional scales (Bradley et al., 1987). The analysis of long-term changes in climatic variables is a fundamental task in studies on climate change detection. Global climate changes may influence long-term rainfall patterns impacting the availability of water, along with the danger of increasing occurrences of droughts and floods (Pal & Mishra, 2017). Rrainfall and temperatures are the most important fundamental physical parameters among the climate as these parameters determine the environmental condition of the particular region which affects the agricultural productivity (Modarres & da Silva, 2007; Singh et al., 2013; Kumar & Gautam, 2014). The study of change in max and min temperatures as well as rainfall plays a key role in recognizing the adverse impact of change of climate to improve management practices to attain environmental sustainability into development planning.

In India, seasonal rainfall is the most important component of the water cycle and contributes around 75 percent of Indian rainfall. Summer monsoon rainfall across the Indian Subcontinent shows substantial spatial variability with heaviest rainfall along the Western Ghats and the Himalayan foothills due to orographic features, and over central India due to low-level convergence (Kulkarni, 2020). Kothawale (2005) studied the temperature extremes in India by using the data of 40 stations well distributed over India for the period 1970-2002, and noted that heat wave conditions are relatively more frequent in May than in June, while very few heat waves occurred in the months of March and April. He also noted that the number of hot days is maximum over central part of India and minimum along the west coast of India during the pre-monsoon season. Mohammad and Goswami (2009) worked on the temperature and precipitation data of 115 years duration from 1901-2015 for 139 major Indian cities of India, and found decreasing trend in northwest cities and increasing trend in southeast cities with regards to temperature and quite heterogeneous patterns of trend in the rainfall data with decreasing rainfall in eastern part as compared to the western part. Some past studies relating to changes in rainfall over India have concluded that there is no clear trend of increase or decrease in average annual rainfall over the country (Mooley & Parthasarathy, 1984). Pant and Kumar (1997) analysed the seasonal and annual air temperatures from 1881–1997 and have shown that there has been an increasing trend of mean annual temperature, at the rate of 0.57°C per 100 years. Singh et al. (2008) found a warming trend in seven of the nine river basins in northwest and central India.

In India, climate change is causing adverse impact on monsoon timing, temperature, and other weather parameters, thus imposing potential impacts on the atmosphere (Fulekar M and R. Kale, 2010). A number of research papers on rainfall and temperature have been published for North East India. Dash et al. (2012) forecasted that the annual mean surface temperature in Northeast India will rise by 0.64°C between 2011 and 2040 and 5.15°C by the end of the century. Rainfall may increase by 0.09 millimeters/day that amount to an annual increase of 33 mm. (Sangomla, 2021). Jain (2012) has conducted the study on trend analysis of rainfall data series for 1871–2008 and found that rainfall and temperature did not show any clear trend for the region as a whole, although there are seasonal trends for some seasons and for some hydro-meteorological subdivisions. Similar analysis for temperature data showed that all the four temperature variables (maximum, minimum, and mean temperatures and temperature range) had rising trend. Given this, few studies have been conducted in order to detect climate trends in Mizoram. Tiwari (2006) carried out an analytical study on variation of climatic parameters at Aizawl and found out that the rise in mean maximum and mean minimum temperatures is linked to a sharp decline in the forest cover due to various activities like road construction, lack of proper implementation of the forest acts and absence of the monitoring body. According to Balasubramani (2021), the long-term weather data shows that deviation of rainfall and humidity is well associated with ENSO episodes. During the cold (warm) phases of ENSO, high (low) rainfall and humidity was observed. The trend shows that the recorded annual values of rainfall, temperature, and humidity deviate in a cyclical manner, and are gradually increasing in the recent years. 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 (Lalnipari, 2019).

2. Data and Methodology

The purpose of this study is to investigate the variability of the rainfall and temperature of Aizawl districts. The data for temperature has been collected from Mizoram State Climate Change Cell (MCCC) under Mizoram Science Technology, and Innovation Council (MISTIC). Rainfall Data has been obtained from Directorate of Economic and Statistics Department, Government of Mizoram. The climate variables investigated are mean maximum air temperature, mean minimum air temperature and total precipitation. In terms of change detection and trend assessment, all of the climate variables were investigated at a monthly, seasonal and annual scale. Seasonal trend of both the parameters has been investigated on monthly basis and seasonal basis i.e., Pre monsoon (March- May), monsoon (June–September) and Post monsoon (October-November) and Winter (December- February). For all climate variables, 12-year meteorological data (the period 2010–202021) were used in the analyses. In this study, four homogeneity tests were selected; namely Standard Normal Homogeneity Test

(SNHT), Buishand Range Test (BR) and Pettitt's test, Mann Kendal and Sen's Slope estimators has also been employed for trend analysis. The mathematical formulation of the three tests is given as below:

2.1 Standard Normal Homogeneity Test (SNHT)

$$T_y = y\overline{z_1} + (n-y)\overline{z_2}, \; y = 1,2,....,n$$

where,

$$\overline{z_1} = \frac{1}{y}\sum_{i=1}^{y}\frac{(Y_i - \overline{Y})}{s} \quad \text{and} \quad \overline{z_2} = \frac{1}{n-y}\sum_{i=y+1}^{n}\frac{(Y_i - \overline{Y})}{s}$$

The year y consisted of break if value of T is maximum. To reject null hypothesis, the test statistic,

$$T_0 = \max_{1 \le y \le n} T_y$$

is greater than the critical value, which depends on the sample size

2.2 Buishand Range (BR) Test

$$S_0^* = 0 \text{ and } S_y^* = \sum_{i=1}^{y}(Y_i - \overline{Y}), \; y = 1,2,...,n$$

When the series is homogeneous, then the value of S*y will rise and fall around zero. The year y has break when S*y has reached a maximum (negative shift) or minimum (positive shift). Rescaled adjusted range, R is obtained by

$$R = \frac{(\max_{0 \le y \le n} S_y^* - \min_{0 \le y \le n} S_y^*)}{s}$$

The R/ n is then compared with the critical values given by Buishand (1982).

2.3 Pettitt's's Test

This test is a non-parametric test which does not require any assumption of normality. The test is based on the ranking order of the Yi values. The statistic is given as follows:

$$X_d = 2\sum_{i=1}^{d} r_i - d(n+1) \qquad d = 1,2,...,n$$

The break occurs in year k when

$$X_m = \max_{1 \le d \le n} |X_d|$$

The value is then compared with the critical value by Pettitt's (1979).

2.4 Mann-Kendall and Sen's Slope Estimator

$$\sum_{i=1}^{n-1}\sum_{j=i+1}^{n} sgn(x_j - x_i)$$

Where n is the number of the data xj and xi are the sequential data value sgn (.) is the sign function, which can be calculated by the following equation:

$$gn(x_j - x_i) = \begin{Bmatrix} 1 \; x_j - x_i > 0 \\ 0 \; x_j - x_i = 0 \\ -1 \; x_j - x_i < 0 \end{Bmatrix}$$

A positive value of S indicates an upward trend, and a negative value indicates a downward trend. The statistical S is approximately normal distribution when n ê 10. The mean of S is zero and the variance can be calculated as follow:

$$var(s) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)}{18}$$

When *m* is the number of tied groups each with ti tied observations. A set of data that has the same value is a tied group. The standardized test statistic *zmk* is calculated as:

$$Z_{mk} = \begin{bmatrix} \frac{S-1}{\sqrt{Var(S)}}, & S > 0 \\ 0, & S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, & S < 0 \end{bmatrix}$$

Besides, the magnitude of a time series trend was evaluated by a simple non-parametric procedure developed by Sen. The trend is calculated by

$$\beta = Median\left(\frac{x_j - x_i}{j - i}\right),\ j > i$$

where β is Sen's slope estimate. β>0 indicates upward trend in a time series. Otherwise the data series presents downward trend during the time period. In this context, if three of four tests reject the null hypothesis at a 5% significant level, a series is considered as inhomogeneous. Secondly, if three of four tests do not reject the null hypothesis at a 5% significant level, a series is considered homogeneous and thirdly, if only two of four tests reject/ don't reject the null hypothesis at a 5% significant level, a series is considered to be a doubtful series (DF) and such a series should be investigated in detail before further analysis (Jaiswal et al., 2015).

The absolute homogeneity test is widely used to assess the continuous of the time series. Four homogeneity tests namely SNHT, BR test, Pettitt's's test, and VNR test were used. Under the null hypothesis, the annual data records are independent and identically distributed and the series is considered as homogeneous except for VNR test. Meanwhile, under the alternative hypothesis, SNHT, Pettitt's's test and BR test consider that the series contains a break in the mean and classified as inhomogeneous one. The main advantage of the three tests is that each test is capable to detect exactly the year where the break occurs. Contrariwise, VNR test cannot detect the year break because it assumes that series is not randomly distributed under the alternative hypothesis.

3. Results and Discussion

In the analysis, different statistical test were applied to climatological variables for change point detection and trend analysis. In this study, the results of the four tests mention were evaluated together following Wijngaard et al. (2003). This classification was based on number of test rejecting the null hypothesis. Three categories were identified:

1. Class 1: If the test rejected one or none of the null hypothesis under the four test, It was considered as homogeneous (HG) - useful.
2. Class 2: If the test rejected the two null hypotheses of the four tests, it was considered as inhomogeneous (CP) - doubtful.
3. Class 3: If the test rejected three or the four null hypotheses, it was not considered for further analysis- suspect.

3.1 Maximum Temperature (T_{max})

The result of the four different tests and the Mann-Kendall trend shows that the time series belongs to Monsoon and winter. The other is homogeneous. Homogeneity test indicated statistically significant change point in the year 2015 in monsoon (mu1: 30.894, mu2: 31.880) and 2018 in winter (m1: 28.673, m2: 26.808) both in Pettitt's's and Buishand test. Buishand test also detected upward change point on May in 2018 (m1: 31.613, mu2: 34.325) but falls under class 1. Mann-Kendall and Sen's slope showed statistically significant trends in monsoon T_{max} (z=0.626, p<0.05), winter T_{max} (z=0.455, p<0.05). Sen's slope showing the magnitude of the increase/ decrease in the trend changes from 0.100-0.163, so the highest Sen's slope value is found in monsoon T_{max}.

3.2 Minimum Temperature (T_{min})

The result of the homogeneity test and Mann-Kendall test are shown in Table 2. In terms of this climate variable, the time series belong to the month of September only (mu1:18.575, mu2: 13.675) both in SNHT and Buishand test.

Homogeneity test indicated statistically significant change point in the year 2014 (for September T_{min}). Man-Kendall test also showed September statistically decreasing trend (z=-0.469, p<0.05).

3.3 Precipitation (P_{tot})

In terms of P_{tot}, only the time series belongs to July is inhomogeneous both in Pettitt's's and Buishand test (mu1: 274.500, mu2: 375.234). Mann-Kendall test also showed statistically significant increasing trend in the month of July (z=0.485, p<0.05). Moreover despite

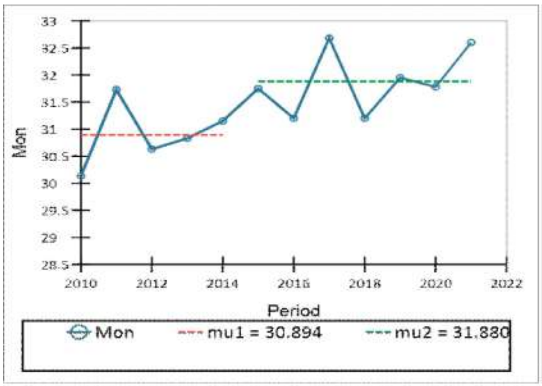

Figure 2. Maximum temperature (Monsoon)

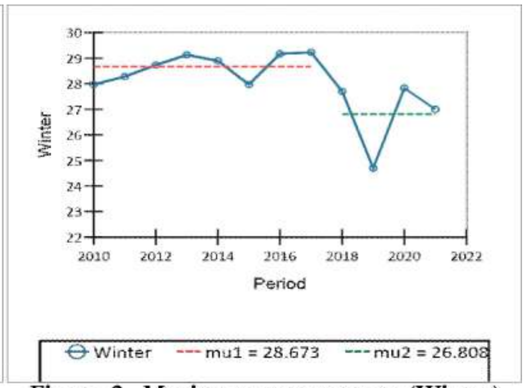

Figure 2. Maximum temperature (Winter)

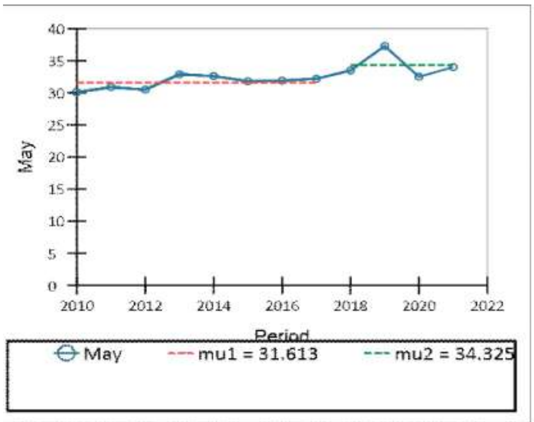

Figure 4. Minimum temperature (May)

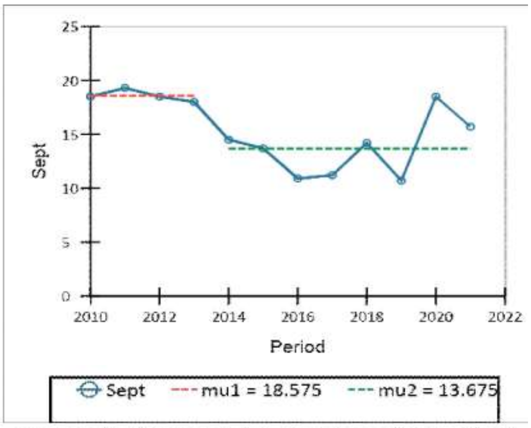

Figure 4. Minimum temperature (September)

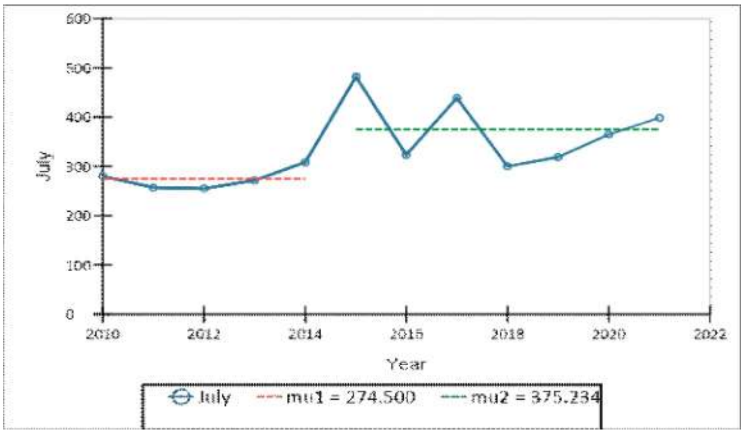

Figure 5. Maximum Temper

being a homogeneous series January, February, June, October, November, December, Post Monsoon and Winter are showing an increasing trend in Sen's slope but did not indicate any statistical significant in Mann-Kendall test.

The result indicates that the inhomogeneous for maximum temperature is observed in monsoon and winter seasons. The monsoon seasons shows upward trend both in Pettitt's's and Buishand tests in 2015 and 2018. Further it was seen that the inhomogeneous structure was detected on the month of May in Buishand test. Mann-Kendall and Sens slope also show a significant level at 0.05. In winter maximum temperature show a downward structure in 2018. A change point in winter was detected both in Pettitt's and Buishand tests. Mann-Kendall also show a statistical confidence level at 95%. Overall, the table indicates that two seasons and one month were found to be inhomogeneous by one or two test, and falling under Class 1 and Class 2. For minimum temperature, homogeneity test indicated statistically significant change point in the year 2014 in the month of September. SNH Test and Buishand detected this break point. Mann-Kendall test shows an increasing minimum temperature on July, November, December and post monsoon period while the other period shows a declining minimum temperature. The table reveals that the month of September falls under Class 3.

In terms of precipitation, only the time series belong to July and Pre-monsoon were inhomogeneous and the Mann-Kendall test also indicated a significant trend for the two periods. However, Sen's trend analysis displays a partially increase of precipitation in the month of January, February, June, July, October and December and moderate decreases of precipitation in Annual and monsoon seasons. A high increase of precipitation was observed on November, post monsoon and winter periods while a high decrease of precipitation was found on march, April, May, August, September and Pre Monsoon periods.

4. Conclusion

The study focused on the change point detection and trend analysis of maximum, minimum temperature and rainfall based on monthly, seasonal and annual scale. Since the data were obtained from different agencies, it was essential to test the data for homogeneity. Three tests - Pettitt's, SNHT, and Buishand were applied. The result for precipitation indicated that from the seasonal and monthly periods only 1 out of 17 periods (Seasonal and monthly period) belong to Class 2 or doubtful and other periods belong to the Class 1 or useful. In Maximum temperature, it was found that 2 periods (Monsoon and winter periods) belonged to Class 2 and the other periods belonged to Class 1 or useful. In minimum temperature, it was also found that only 1 period (September) belonged to Class 2 and the rest of the period falls under Class 1 or useful. The study shows that all the three tests are very sensitive to homogeneity in the series and can be effectively used for temperature as well as precipitation data.

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Table 1 Maximum Temperature

Period	Pettitt test				SNH Test				Buishand range test				Final result		Man kendall test			
	Statistic		Shift	Year of Shift	Statistic		Shift	Year of Shift	Statistic		Shift	Year of Shift	Nature	Year of Shift	Z-Value	Sen Slope	Significance	Trend
Jan	20	0.578	No		2.53	0.530	No		2.14	0.737	No		HG		-0.171	-0.044	0.489	No
Feb	16	0.939	No		6.94	0.083	No		2.96	0.291	No		HG		0.061	0.024	0.837	No
March	15	0.773	No		2.71	0.630	No		2.71	0.396	No		HG		-0.215	-0.200	0.370	No
April	22	0.411	No		2.25	0.549	No		2.67	0.432	No		HG		0.137	0.058	0.582	No
May	28	0.090	No		5.43	0.216	No		3.98	**0.030**	Yes	2018	HG		0.606	0.305	**0.007**	Yes +
Jun	25	0.215	No		4.54	0.141	No		3.4	0.167	No		HG		0.443	0.193	0.054	No
July	22	0.429	No		4.003	0.194	No		3.57	0.123	No		HG		0.412	0.173	0.074	No
Aug	26	0.183	No		3.81	0.309	No		3.44	0.145	No		HG		0.412	0.178	0.074	No
Sept	21	0.479	No		1.92	0.680	No		2.47	0.472	No		HG		0.246	0.094	0.301	No
Oct	21	0.495	No		3.38	0.465	No		3.11	0.249	No		HG		0.154	0.058	0.535	No
Nov	23	0.332	No		5.22	0.224	No		3.58	0.086	No		HG		-0.212	-0.271	0.373	No
Dec	29	0.083	No		4.39	0.247	No		3.42	0.064	No		HG		-0.364	-0.297	0.115	No
Annual	19	0.708	No		2.23	0.695	No		2.34	0.580	No		HG		0.076	0.006	0.783	No
pre-Mon	27	0.125	No		4.7	0.253	No		3.4	0.117	No		HG		-0.299	-0.089	**0.336**	No
Mon	31	**0.041**	Yes	2015	4.9	0.126	No		3.95	**0.050**	Yes	2015	CP		0.626	0.163	**0.006**	Yes +
Post-Mon	21	0.477	No		4.01	0.307	No		3.14	0.257	No		HG		-0.123	-0.100	0.630	No
Winter	32	**0.030**	Yes	2018	5.95	0.193	No		4.11	**0.008**	Yes	2018	CP		0.455	0.100	0.047	Yes +

Table 2 Minimum Temperature

Period	Pettitt test				SNH Test				Buishand range test				Final result		Man kendall test			
	Statistic		Shift	Year of Shift	Statistic		Shift	Year of Shift	Statistic		Shift	Year of Shift	Nature	Year of Shift	Z- Value	Sen Slope	Significance	Trend
Jan	21	0.480	No		3.48	0.288	No		2.92	0.308	No		HG		-0.076	-0.183	0.783	No
Feb	24	0.266	No		4.63	0.118	No		3.67	0.117	No		HG		-0.107	-0.195	0.680	No
March	19	0.700	No		2.54	0.503	No		2.56	0.489	No		HG		-0.015	-0.014	1.000	No
April	26	0.164	No		4.44	0.149	No		3.3	0.181	No		HG		-0.107	-0.200	0.680	No
May	26	0.179	No		4.92	0.077	No		3.47	0.143	No		HG		-0.412	-0.607	0.074	No
Jun	19	0.714	No		2.64	0.505	No		2.65	0.434	No		HG		-0.182	-0.350	0.451	No
July	18	0.803	No		2.62	0.465	No		2.54	0.463	No		HG		0.000	0.000	1.000	No
Aug	24	0.267	No		5.11	0.098	No		3.86	0.070	No		HG		-0.364	-0.780	0.115	No
Sept	28	0.083	No		6.08	**0.035**	Yes	2014	4.2	**0.033**	Yes	2014	Cp	2014	-0.469	-0.643	**0.044**	yes +
Oct	21	0.482	No		4.05	0.182	No		3.15	0.242	No		HG		-0.137	-0.259	0.582	No
Nov	19	0.724	No		3.08	0.436	No		2.75	0.401	No		HG		0.015	0.007	1.000	No
Dec	19	0.717	No		2.54	0.575	No		2.29	0.536	No		HG		0.030	0.025	0.945	No
Annual	19	0.706	No		3.6	0.266	No		3.23	0.211	No		HG		-0.212	-0.182	0.373	No
pre-Mon	19	0.688	No		2.89	0.464	No		2.9	0.327	No		HG		-0.198	-0.366	0.409	No
Mon	24	0.265	No		4.1	0.195	No		3.49	0.150	No		HG		-0.242	-0.338	0.304	No
Post-Mon	27	0.126	No		3.94	0.202	No		3.11	0.244	No		HG		0.030	0.023	0.945	No
Winter	18	0.841	No		3.29	0.397	No		2.84	0.329	No		HG		-0.152	-0.208	0.537	No

Table 3 Rainfall

Period	Pettitt test				SNH Test				Buishand range test				Final result		Man kendall test			
	Statistic		Shift	Year of Shift	Statistic		Shift	Year of Shift	Statistic		Shift	Year of Shift	Nature	Year of Shift	Z- Value	Sen Slope	Signifi cance	Trend
Jan	16	0.999	No		2.32	0.518	No		2.53	0.507	No		HG		0.159	0.281	0.529	No
Feb	14	0.635	No		1.87	0.761	No		1.9	0.768	No		HG		0.091	0.388	0.732	No
March	14	0.644	No		2.61	0.486	No		2.04	0.727	No		HG		-0.152	-3.119	0.537	No
April	17	0.947	No		2.23	0.643	No		2.55	0.466	No		HG		-0.242	-11.955	0.304	No
May	22	0.415	No		3.48	0.376	No		2.85	0.328	No		HG		-0.394	-8.527	0.086	No
Jun	16	0.914	No		1.93	0.687	No		2.51	0.472	No		HG		0.091	1.263	0.732	No
July	33	**0.019**	Yes	2015	5.51	0.070	No		4.19	**0.036**	Yes	2015	CP	2015	0.485	10.599	**0.034**	Yes +
Aug	19	0.113	No		1.14	0.924	No		1.61	0.902	No		HG		-0.182	-12.295	0.451	No
Sept	29	0.072	No		4.75	0.258	No		3.89	0.071	No		HG		-0.394	-12.848	0.086	No
Oct	17	0.976	No		1.6	0.825	No		1.98	0.719	No		HG		0.212	4.554	0.373	No
Nov	22	0.399	No		4.87	0.127	No		2.62	0.423	No		HG		0.382	4.017	0.099	No
Dec	21	0.398	No		7.64	0.113	No		2.86	0.293	No		HG		0.230	0.600	0.353	No
Annual	12	0.371	No		1.2	0.908	No		1.87	0.828	No		HG		-0.091	-22.871	0.732	No
pre-Mon	26	0.181	No		4.68	0.110	No		3.57	0.114	No		HG		-0.455	-25.892	**0.047**	Yes +
Mon	0	0.058	No		0.78	0.988	No		1.51	0.942	No		HG		-0.091	-9.268	0.732	No
Post-Mon	16	0.919	No		2.01	0.759	No		2.23	0.609	No		HG		0.273	13.111	0.244	No
Winter	29	0.067	No		6.25	0.127	No		3.81	0.086	No		HG		0.424	5.021	0.064	No

IMPLICATIONS OF CLIMATE CHANGE FOR INDIAN AGRICULTURAL PRODUCTIVITY AND ITS ADAPTATION

- C. Sangṭhuamluaia
Lalrinmawia

Abstract : *Impact of climate change on Indian agriculture will be one of the major deciding factors influencing the future nutrition food security and livelihoods of millions of smallholder farmers. A significant rise in the surface temperature and the frequency of extremes climates such as droughts, floods, heat waves in the future is going to have negative impact. Understanding the pattern of weather changes over a period of time and modifying the management practices in relation to climate change are challenges to the growth of Indian agricultural sector as a whole in the future. Simple adaptation strategies, such as change in seeds planting dates and development of seeds varieties that could tolerant climate change and improved land-use policies and risk management through early warning system and crop-weather insurance.*

Keywords : *Climate change, impact on Indian agriculture and mitigation measures*

1. Introduction

Climate change refers to changes beyond the average atmospheric condition that are caused by both natural factors such as the orbit of earth's revolution, volcanic activities and crustal movements and artificial factors such as the increase in the concentration of greenhouse gases and aerosol. Global warming, which refers to the average increase in global temperature, has become a megatrend that will lead to significant global changes in the future. According to the fourth report of UN Intergovernmental Panel on Climate Change (IPCC, 2007) on climate change, it is indisputable that global warming has serious impacts on the earth and it is very likely that the increase in greenhouse gas emission by anthropogenic activities has caused global warming since the mid 20th century. This report warns us that, if mankind continues its present level of consumption of fossil fuels, the average temperature of the earth will rise by up to 6.4°C by the end of the 21st century and the sea level will rise by 59 cm (IPCC, 2007).

Global warming not only affects ecological systems but also human life. The impact of climate change has become an important issue both at national and international level. Approaches to deal with the issue of global warming are divided largely into mitigation measures, focusing that focus on reduction and absorption of greenhouse gases, the causative factors, and adaptation measures to minimize the damages by climate change. For agriculture, the focus has shifted to adaptation and adaptability based on the assessment of the impacts of climate change and vulnerability to it. The IPCC emphasizes that it is very important for the agricultural sector to

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adapt to climate change and local government should establish mid to long-term agricultural development plans and for farming households to prepare their production plans.

Agriculture is strongly influenced by weather and climate in terms of decreasing area, production, and productivity of crops. Even though, farmers are often flexible in dealing with weather and year to year variability, there is a high degree of adaptation to the local climate in the form of established infrastructure, local farming practice and individual experience. Climate change can be expected to impact on agriculture, potentially threatening established aspects of farming systems and also providing opportunities for improvement. Climate change means changes in global weather patterns in long and short terms. Climate generally changed when its patterns and sequence shift from the original place to another, over time (FAO 2008). The society which depends completely on agriculture, livestock, and forest resources for carrying their livelihoods are mostly worst affected due to the menace of climate change. It has been observed that in mountain regions climate change impact is tremendous due to landscape vulnerability and fragility, and high dependency on agriculture.

2. Review of Literatures

The nature of agriculture and farming practices in any particular location are strongly influenced by the long term mean climate state - the experience and infrastructure of local farming communities are generally appropriate to particular types of farming and to a particular group of crops which are known to be productive under the current climate. Changes in the mean climate away from current states may require adjustments to current practices in order to maintain productivity, and in some cases the optimum type of farming may change (Gornall et al., 2010). Agricultural production is carried out through the selection of crops suitable for the climate of a specific region and application of proper farming methods. Therefore, agriculture is a climate dependent bio-industry with specific regional characteristics. Regional characteristics refer to the ecosystem characteristics determined by the climate of the region. Climate change disturbs the agricultural ecosystem, resulting in the change in agricultural climatic elements such as temperature, precipitation, and sunlight, while further influencing the arable, livestock, and hydrology sectors (Chang-Gil Kim, 2009).

The impact of climate change on arable land and livestock sector are made known by biological changes including the change of flowering and harvesting seasons, quality change, and shift of areas suitable for cultivation (Na et al., 2007). Climate change affects the agricultural ecosystem, giving rise to blights and pests and causing population movement and change in biodiversity. Climate change affects the hydrology including underground water level, water temperature, river flow, and water quality of lakes and marshes, by impacting precipitation, evaporation, and soil moisture content. Water is vital to plant growth, so varying precipitation patterns have a significant impact on agriculture. As over 80 per cent of total agriculture is rain-fed, projections of future precipitation changes often influence the magnitude and direction of climate impacts on crop production (Olesen & Bindi 2002; Tubiello et al., 2002; Reilly et al., 2003). Climate change has a wide range of impacts on the rural economy including agricultural productivity, revenues of the farm household and asset values, and it also affects the agricultural infrastructure through the change in water sources available for agriculture.

The impact of global warming on regional precipitation is difficult to predict owing to strong dependencies on changes in atmospheric circulation, although there is increasing confidence in projections of a general increase in high-latitude precipitation, especially in winter, and an overall decrease in many parts of the tropics and sub-tropics (IPCC 2007). The difference in precipitations projections arise for a number of reasons. A key factor is the strong dependence on changes in atmospheric circulation which itself depends on the relative rates of warming in different regions.

The uncertainty in precipitation change over India arises partly from the expected weakening of the dynamical monsoon circulation (decreasing the Indian monsoon precipitation) versus the increase in atmospheric water content associated with warming (increasing the Indian monsoon precipitation) (Meehl et al., 2007). However, changes in seasonal precipitation may be more relevant to agriculture than annual mean changes. In India, climate models generally project a decrease in dry season precipitation and an increase during the rest of the year including the monsoon season, but still with a large inter-model spread (Christensen et al., 2007).

3. Impact of Climate change on Indian agriculture

Indian agriculture is highly dependent on the spatial and temporal distribution of monsoon rainfall (Kumar et al., 2004). The analysis on the relationship between district level crop yield data (rainy season 'Kharif' rice) and precipitation for 1960-2000 by Asada and Matsumoto (2009) shown that different regions were sensitive to precipitation extremes in different ways. These relationships were not consistent through time, in part owing to precipitation trends. Crop yield in the upper Ganges basin is linked to total precipitation during the relatively short growing season and is sensitive to drought. Conversely, the lower Ganges basin was sensitive to flooding and the Brahmaputra basin demonstrated an increasing effect of precipitation variability on crop yield, in particular drought. Variation between districts implied the importance of social factors and the introduction of irrigation techniques.

In India, food grain production has increased from 50 MT in 1951 to 212 MT in 2002 and cereal production increased from 500 kg/ha to almost 1800 kg/ha due to Green Revolution (Government of India, 2004). The increases in food grain and cereal production were largely due to area expansion, large scale used of high yielding semi-dwarf varieties since the early 1960s and an increase application of irrigation, fertilizers and biocides, supported by progressive government policies.

Currently, Indian agriculture has 195 million Ha gross sown areas and 141 million Ha net sown areas, of which 40% is irrigated and the rest 51.2 % is rain fed. The mean productivity of rain fed area is about 1.1 tonne per Ha compared to 2.8 tonne per Ha of irrigated land. The country received annual precipitation of almost 4,000 billion cubic metre, which results into estimated average water potential of 1,869 billion cubic metre. But, its per capita availability is reducing year by year (ICAR, 2019). The per capita annual water availability has declined from 5,177 cubic metre in 1951 to 1,508 cubic metre by 2014, and is likely to reduce further to 1,465 cubic metre and 1,235 cubic metre by 2025 and 2050, respectively. This reducing availability of water compounded by climate change would further deteriorate the condition (ICAR, 2019). Food production in India, on aggregated scale, is still considerably dependent on the rainfall quantity and its distribution. The summer monsoon contributes to 78% of India's annual rainfall and is a major water resource. It is important to recognize that the Green Revolution was largely confined to the irrigated areas. As current farming systems are highly adapted to local climate growing suitable crops and varieties, the definition of what constitutes extreme weather depends on geographical location. In the past 50 years, there has been around 22 major drought, due to which the production of rain fed crops in those year was affected. Limited option for other income and widespread poverty continue to threaten the livelihoods of millions of small and marginal farmers in the region.

By 2050, India's population is projected to grow to 1.6 billion. This rapid and continuing increase in the population implies a greater demand for food. The predominant staple food of rice and wheat demand are expected to increase to 102.1 million tonnes and 65.9 million tonnes, respectively, by 2026 assuming medium income growth (Mittal 2008). The demand for pulses, fruits, vegetables, milk, meat and marine products is also expected to increase very sharply. Although there is pressure to increase production in order to meet higher demand, but there is great concern about decline in soil fertility, change in water table depth, rising salinity, resistance of harmful organisms to many pesticides, and degradation of irrigation water quality. Nutrient removal by crops over time has exceeded its application and consequently, farmers now have to apply more fertilizers to realize the same yield as achieved 20 – 30 years ago. Several pathogens and insect pests have also shown a tendency to increase under the intensive farming systems such as the rice and wheat system.

One of the great challenges in the

21st century for Indian agriculture is to ensure food production is in line with both poverty reduction and environmental preservation. The roadmap of sustainable agricultural development may also have to consider two additional important global drivers of change in agriculture in the coming decades; globalization and climate change. The on-going globalization process and multilateral trade liberalization is forcing India to make structural adjustments in the agricultural sector to increase its competitiveness and efficiency.

4. Countermeasures against Climate change

Anthropogenic greenhouse gas emissions and climate change have a number of implications for agricultural productivity. But the aggregate impact of these is not yet known and indeed many such impacts and their interactions have not yet been reliably quantified, especially at the global scale (Jemma et al., 2010.). Components of the climate system are initially affected by climate change by being exposed to it and attempting to adapt themselves to that stimulus voluntarily. As it is difficult for systems to adapt to climate change, efforts have focused on reducing the scale of climate change through mitigation measures such as greenhouse gas reduction and absorption. Mitigation contributes to avoiding, reducing and postponing various impacts of climate change. Adaptation and Climate change mitigation are closely interrelated with each other. Sometimes it can be considered as mitigation belongs to adaptation measures in the long-term perspectives. So, adaptation to climate change is not optional but rather a compulsory countermeasure against climate change.

The adaptability of crops to climate variability would acquire significant dimension as frequent occurrence of extreme weather conditions may dictate as to how to cope up with the situation. Framework for adaptation to climate change provide by global integrated impact assessment models are inadequate for countries like India. India needs an integrated assessment simulation model that encompasses cropping systems, water use and socio-economic parameters. Mall et.al (2006) has shown a model concerning environmental and biophysical factors along with socio-economic parameters with respect to adaptation to climate change in agricultural production system. The assessment of climate on Indian agriculture can be more precise and provide sound basis for regional policy planning when uncertainties and certain limitations have been considered in the crop simulation modelling. In fact, developing adaptation strategies exclusively for minimising the negative impact of climate change may be risky considering the number of uncertainties associated with its spatial and temporal magnitude (Agarwal et al., 2010). Therefore, adaptation strategies which may lead to sustainable development of agriculture is needed for region, state or at a national level.

Integrated farming systems based on locally available resources like trees, water management can help mitigate climate change to a large extent and improve the quality of life of the farmers and sustainable practices of organic farming, natural farming also help farmers adapt to changing climate. 21% of greenhouse gases emissions in India is come from agriculture(Pathak: 2014). Methane (CH_4) emissions from irrigated rice production, nitrous oxide (N_2O) from the use of nitrogenous fertilizers, and the release of carbon dioxide(CO_2) from energy sources used to pump groundwater for irrigation are the primary sources. The appropriate approaches of mitigation include changes in agricultural land management like conservation tillage, agro forestry, and rehabilitation of degraded crop and pasture land, overall improvement of nutrition and genetics of ruminant livestock, storage and capture technologies for manure, and conversions of emission into biogas. These approaches resulted positive outcomes in terms of higher productivity and better management of natural resources.

5. Conclusion

Climate changes become the foremost environmental problem of the 21st century. It has been recognized as to lead to adverse, irreversible impact on earth and the ecosystem as a whole (Sasmita and Mohanty, 2009). Agricultural production, water resources, natural ecosystem, biodiversity and human health are directly affected by climate change. Agriculture is strongly influence by weather and climate. There is nevertheless a high degree of adaptation to the local climate in the form of established infrastructure, local farming practice and individual experiences, farmers are often flexible in dealing with weather and year to year variability. Climate change has, therefore, impact on agriculture, potentially threatening established aspects of farming systems but also providing opportunities for improvement. The adaptation in agriculture to climate variability would acquire significant dimension as frequent occurrence of extreme weather conditions may dictate as to how to cope with the situation. Some region have already developed adaptation programme which include crop improvement, risk financing, draught proofing, disaster management, better pest and disease control for crops, encouraging resource conserving technologies etc. Though the impact of climate change on Indian agriculture and water resources are of great concern to the policy makers and development experts, India is poorly equipped to cope with impact of climate change due to low capabilities, weak institutional mechanism and lack of access to adequate resources. Economic and environmental indicator clearly shows that the agricultural production is under threat and needs immediate attention (Joshi et al., 2003). The adaptation measures that the agricultural sector can undertake to cope with future climate change is urgent as its impact is already evident and the trends will continue even if greenhouse gases emissions are stabilized at current levels. Effective and result-based measures should be supported for the development of approaches at all levels on vulnerability and adaptation, as well as capacity building for the integration of adaptation concerns into sustainable agricultural development strategy in the nation.

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IMPLEMENTATION OF PRADHAN MANTRI AWAAS YOJANA (GRAMIN) IN MIZORAM

- Khuangthansanga Pakhuangte

Abstract : *The Government of India committed to provide every family with housing under the programme of 'Housing for All by 2022'. The Central Government has been implementing the Rural and Urban Housing Programmes as part of the enabling approach to shelter for all, taking cognizance of the fact that rural housing is one of the major anti-poverty measures for the marginalised. Therefore, the Pradhan Mantri Awaas Yajona (Gramin) has been implemented since 2015. The Nodal Ministry of Rural Housing Programme is the Ministry of Rural Development. The main objectives is to provide a pucca house with basic amenities to all houseless households and households living in kutcha and dilapidated houses in rural areas by 2024. A minimum unit (house) sizeof 25 sq.m including a dedicated area for hygienic cooking to enable the construction of quality houses by the beneficiaries using local materials, designs and trained masons. The unit of assistance is Rs.1.30 lakh in hilly/difficult areas like Mizoram and the cost of the unit will be shared between Central and State Governments in the ratio 90:10 for North-Eastern and 3 Himalayan States. Convergence with other Government schemes is allowed for the provision of basic amenities viz., toilet, drinking water, electricity, clean and efficient cooking fuel, treatment of social and liquid waste. As such, more than 4,860 houses have been already constructed by the Government of Mizoram, Rural Development Department under the PMAY (G) and more than more than 64 cubic ft. of Wood planks (Thingzai) have been used for construction of houses.*

Keywords : *Rural housing, PMAY(G), Impact, Perception, Mizoram,*

1. Introduction

Sorkar laipui chuan kum 2022 ral hma ngeiin India rama chenna in la neilo zawng zawngte hnenah In sak ṭanpuina pek vek a tum a, he ṭanpuina hi Pradhan Mantri Awaas Yojana (Prime MinisterHousingScheme) hming a vuah a. Thingtlang lam tan PMAY-G (Gramin) kalpui anih lain Khawpui lam tan PMAY (Urban) kalpui a ni thung.

Abraham Maslow (1943) chuan mihring mamawh te hi chi 7 ah a ṭhensawm a, chung zingah chuan 'Chenna In' hi a pawimawh zinga chhiar a ni. Chenna in neih hi thil pawimawh tak mai a ni a. A bik takin Thingtlang mirethei te, chenna in neihtir hi sorkar pawhin a ngai pawimawh hle a, Article 246 ah chuan State subject-ah a dah a, Article 243G hmanga 11thSchedule ah pawh PRI ten an hnathawh tur pawimawh tak niin a sawi. India ram hi Istanbul Declaration of Human Settlement (1996) ziaktu pawimawh tak a ni a, chutah chuan a mite hnena chenna tur in pe turin a intiam nghe nghe a ni.

1947-a India rama loin dan tirh khan Refugee-te tan Rehabilitation programme kalpui nghal a ni a. 1952-a Community Development Prorgamme-a

Khuangthansanga Pakhuangte is an Associate Professor, SIRD & PR, Mizoram kalpui ṭan aṭang khan Miretheite khaichhuahna tur prorgamme hrang hrang kalpui ṭan a ni a, 1957 khanVillage Housing Programme chu mimal leh pawl ho angin pakhat zelah Rs. 5,000/- loan anga kalpui a ni a. A hnuah House Sites-cum-Construction Assistance Scheme chu 1974 aṭangin kal pui leh a ni a. National Rural Employment Programme (1980) leh Rural Landless Employment Guarantee Programme (1983) a kalpui anih khan In sak ṭanpuina hi a scheme-ah beh tel tir a ni a, amaherawh chu, common norm siam a ni lo. 1985 ah RLEGP hnuaiah Indira Awaas Yojana belh tel tir a ni a, chutah chuan SC/ST leh Freed Bonded Labourers-te tana sum ṭhenkhat kha hman phal a ni a. Jawahar Rozgar Yojana (JRY) scheme, April 1985-a hman ṭan anih khan 6% (a hnuaah 10%) chu Mirethei in sak ṭanpuina hman rem tih a ni a. 1996 khan Ministry of Rural Development, Government of India chuan Indira Awaas Yojana chu thingtlang mirethei te In sak ṭanpuina turin Scheme thar a rawn siam hrang ta hlak a. he scheme hi tihdanglam hret hret a ni a, 2015 thleng khan hman a ni, June 25th 2015 aṭang erawh chuan Pradhan Mantri Awaas Yojana – Gramin hming puin mirethei in sak ṭanpuina hi kalpui a ni ta a, tun thlengin. Kan sawi tak ang khan PMAY G hian India rama In leh lo nei lote in sak sak vek a tum a. Thingtlang khua bikah 11th Plan chhung (2007-12) khan WorkingGroup-in a chhut danin 474.3 lakhs sak ngai niin a chhut a, 12th Plan thung kha chuan 2012-17 chhungin 434.0 lakhs ni turin a chhut thung. Mithiam dang chuan 2016-17 chhungin 436.7 lakhs a ni thung ah an ngai a. PMAY-Ghian 1stphase chhungin (2016-19) khan State-te chu 39.19 lakhs target-a set sak a, Second phase (2020 – 22) chhungin 44.38 lakhs-a set sak thung. SECC Data 2011-ah khan chhungkaw 1.57 lakhs te chuan chenna an nei lova, In 106.30 lakhs te chu sak ṭhat ngai ngawih ngawih a ni.

2. Review of Literatures

Mirethei te in sak sakna tur atan hian sorkar leh pawl ho angin hmalakna tam taka lo awm tawh ṭhin a. Chenga, (1996)[1], chuan a article 'Rural Housing programmes in Zimbabwe : A contribution to Social Development' tih Journal of Social Development in Africa ah chuan Zimbabwe sorkarin rural housing programme-a neih dan leh a nghawngchhuah a ziak a. An rama an tih ah man tlem leh daih rei si hmang turin a ti a, chu chuan sum senso kawngah pawh samkhaina a pe dawn niin a sawi a. Jain, (2000), in a article ziah ve, 'Slum Rehabilitation and Housing the Poor' tih Social Change Journal chhuah ah chuan action plan mumal tak siam hmasak a, a hmun leh hmanraw hman tur thlan uluk hle tur a ni a ni a, Mipui nena thawh ho hian a hlawkthlak ber niin a ngai a ni. Basin-South Asia, (2007) in a an sawi dan chuan Chaw leh Thuamhnaw tih lovah chuan Chenna in hi a pawimawh ber a. Chenna insakah hian 16 per cent of Workforce (1997) khan India ramah a awm niin a chhut a. Natural Hazards hian in zaa 1 hi kumtin a ti chhia niin a chhut bawk. Kadrolkar & Muggur (2012), ten an sawi dan chuan India rama Chenna in indaih loh chhan chu miring pung chak mila in a a pung ve lo leh sorkarin mipui mamawh (Civic amenities) a pek ṭhat vak loh avang a ni a ti. Dwijendra (2013) in a article, 'Quality of affordable housing projects by public and private developersin Indonesia : The case of Sarbagita Metropolitan, Bali, Indonesia' tih Journal of Geographyand Regional Planning-a a sawi dan chuan an rama private developer-te in sak chu a neitu in a sak te aiin a tlo lo bik a, a chhan chu hmanrua an hman chhiat vang a ni a ti a. An rama thiltlo leh ṭha tak tak, in sakna bungrua atana an hman loh ṭhin vang niin a sawi. Building Materials & Technology Promotion Council, (2013), ten an lehkhabu tih chhuah, 'Design Concept for Rural Housing in Western India for IAY and Other Similar Scheme done a pilot study in the rural areas of Gandhinagar and Anand districts of Gujarat' ah chuan Chhungkaw pakhat chenna atan 4x3.5m, a bang brick, a chung rangva hi a tawk khawpin an hria. Kumuda (2014) in a article, 'Homeless Population in India : A Study' tih ah chuan India hian 4,49,761 In hi In neilote tan an mamawh a, kumtin 55,000-60,000 sa ta ila, 2022 ah chuan in neilo kan awm tawh vang tiin a chhut.

3. Housing - problems leh challenge

A hnuaia Table - 1 hi en ta la, India rama chenna in awm si, chhe tawh tam zia hi i hmu thei ang a. India ramah chenna in Nuai 983 chuang zet chu luah tlak loh, siam ṭhat ngai a ni tih hetable ah hian i hmu ang a, chung zinga Nuai 765 chuang zet chu thingtlang a mi an la ni zui leh ta nghal a ni.

Mizoram-ah hian 2011 Census-a a lan danin mihring 10.97 lakhs kan cheng a, chung zinga 5.55 lakhs hi mipa niin, 5.42 lakhs hi hmeichhia an ni a. Thingtlanga cheng hi 49.36% niin an sawi a. 11th Plan Working group chhut dan khan Mizoram-ah in 30,250 sak ngai niin an chhut a. SECC Data 2011-a a lan dan chuan Mizoram-ah chhungkaw 2,26,147 an awm a, chung zinga 49.36% chu thingtlang a cheng an ni a. Thingtlang mi chenna tur nei miahlo Chhungkaw 10 an awm a. Mi inluah 11,239 chhungkua an awm a. Mi inluaha khawsa hi Aizawl District-ah an tam ber a, 2,668 an awm a, Siaha District-ah 809 an tlem ber thung. A percentage-a lak pawhin Aizawl tam ber in, Lawngtlai-a tlem ber thung.

Table 1. Residence Housing Conditions in India, 2011 Census

Housing Conditions	All India	Rural	Urban
Total	23,82,36,358	16,16,78,619	7,65,57,739
Good	12,70,78,686	7,44,98,278	5,25,80,408
Liveable	9,83,14,394	7,65,50,023	2,17,64,371
Dilapidated	1,28,43,278	1,06,30,318	22,12,960

***Source :** Census of India, 2011*

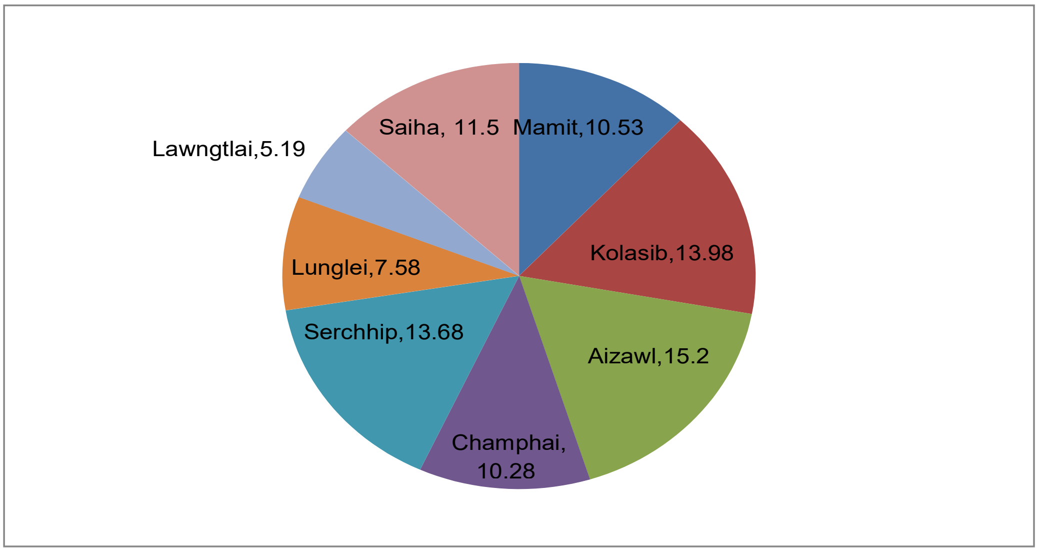


Figure 1. Percentage of Houseless household in Mizoram (*Source : SECC Data 2011)*

A hnuaia Table-2-ah hian Mizoram chhunga District hrang hranga in leh lo neih dan chu a ni a. Thingtlanga khawsa Chhungkaw 1,11,626 zingah mahni in nei chu chhungkaw 98,228(87.99%) chu mahni in leh lo nei an ni.

Table 2. District wise Household ownership in Mizoram

District Name	Total Households	No. of Households with house ownership status as Owned	No. of Households with house ownership status as Rented	No. of Households with house ownership Status as Other
Mamit	15169	13408	1597	164
Kolasib	7353	5743	1028	580
Aizawl	17557	14629	2668	254
Champhai	15250	13598	1568	83
Serchhip	6359	5386	870	103
Lunglei	19733	18059	1496	178
Lawngtlai	23173	21330	1203	639
Saiha	7032	6075	809	148
State Total	**111626**	**98228**	**11239**	**2149**

Source : SECC Data, 2011

Thingtlang a in zinga in 35,705 chu Kutcha house (Kum 30 tlin hmaa sak ṭhat ngai) a ni a, In 46208 chu Pucca house (Kum 30 aia rei sak ṭhat ngai lo tur) angin survey ah tarlan a ni.

Kum 2015 khan Mizoram-a khaw 922-ah Economic & Statistic Department, Mizoram chuan Below Poverty Level (BPL) survey a nei a, hetiang hi Mizoram a District wise BPL awm dan chu a ni (Table-3).

Mizoram-ah hian state dangte angin State Own Fund hnuaiah Thingtlang miretheite in sak ṭanpuina hi a hranpain kan nei ngai lem lova. Central sorkar aṭanga Centrally Sponsored Scheme (CSS) leh a dang te aṭanga lo kal hi kan lo kalpui ve mai ṭhin. Kum 2016–19 erawh kha chuan New Economic Development Policy (NEDP) hnuaiah Chief Minister's Rural Housing Scheme hi kal pui ve chin a ni a. Chutah chuan In sak ṭanpuina atan Chhungkaw pakhat zelah Rs. 50,000/- zel instalment 3 ah pek a ni. Amaherawhchu, kum eng emaw ti lai chuan Centrally Aided Project (CAP) hmangin Thingtlang mirethei in sakna atana hmanraw pek erawh hi chu a awm zeuh zeuh a, chu chu Rural Housing Support (provision of G.I Sheet) hming vuahin kum 2009 aṭang khan kan lo nei tawh a. mahse, 2020 aṭang khan la sanction a la ni leh ta lo. Sawi tak ang khan CSS aṭangin RLEGP hnuaiah kum 1985

Table 3. District-wise type of House in Mizoram

District	Total Households	No. of Household with Kutcha house	No. of Household with Pucca house	No. of Household swith Semi Kuccha (Kuccha Wall & Pucca Roof) House	No. of Households with Semi Pucca (Pucca Wall & Kuccha Roof) House
Mamit	15169	6572	5780	2566	119
Kolasib	7353	2549	2710	1961	65
Aizawl	17557	934	9498	5371	142
Champhai	15250	1117	9235	4143	156
Serchhip	6359	334	4236	807	41
Lunglei	19733	6794	9193	3373	121
Lawngtlai	23173	14771	3131	4738	154
Saiha	7032	2634	2425	1759	81
State Total	**111626**	**35705**	**46208**	**24718**	**879**

Source : SECC data, 2011

Table 3. District-wise BPL and APL in Mizoram

Sl. No	Name of District	No. Of Villages	No. of Household Population	No. of BPL	No. of APL	Percentage of BPL
1	Mamit	87	20163	7186	12977	53.64
2	Kolasib	52	19359	34012	16028	17.50
3	Aizawl	178	85312	7475	77902	8.76
4	Serchhip	48	13841	1770	12071	12.79
5	Champhai	106	29043	2715	26561	9.35
6	Lunglei	186	37997	11437	26561	30.10
7	Lawngtlai	173	61593	13162	48427	21.37
8	Siaha	92	13416	42416	9172	31.64
9	Mizoram	922	280724	51391	229450	18.31

Source : Economics & Statistic Department, Mizoram 2015

aṭang khan Central sorkar puihnain Rural Housing Programme erawh chu kalpui a lo ni reng tawh.

IAY chu Independent scheme angin 1st January 1996 aṭangin 2015 thlengin kalpui a ni a. IAY hian a tum ber chu BPL te hnenah in sak ṭanpuina pek tur a ni a, chu chu Gram Sabbha-in a thlan chhuah te an ni tur a ni a. Kum 5 chhung atan Permanent Waist List siam tur a ni. IAY-ah hian in sak ṭanpuina leh a hmun lei theihna a awm a, a hmun leina erawh chu state sorkar tum tur a ni. A senso hi 90:10 in Central leh State-in Mizoram ah chuan an in tum sem tur a ni. IAY hnuaiah chuan in pakhat chu 20 sq. mts aia zim lova sak tur a ni a, Pucca in emaw semi pucca in emaw sak tur a ni. Pucca tih hian Cement Concrete (RCC) kher a ni lova, sak ṭhat ngai lova, kum 30 ṭha taka luah theih kha a ni tur a ni. A in neitu in a duh dan anga sak tur a ni a, Smokeless chulha leh Toilet-a awm ngei tur a ni bawk. A chunga kan sawi tak ang hian IAY ṭanpuina hi kum hrang hrangah tihdang a ni fo va, Mizoram a In pakhat atana IAY kan pek dan chu hetiang hi a ni a. A tirah (1986) in pakhat sak nan Rs. 10,000/- pek anih laiin kum 27 chhungin vawi 7 zet an pawisa dawn tur hi Central sorkar chuan a tihdanglam sak a, a hnuhnung ber chu 2013 kha niin Rs. 75,000/- in pakhat sak nan pek a ni.

4. Perception on PMAY-G

Kan sawi tak ang khan PMAY-G hi 1st April 2016 khan hman ṭan a ni a. PMAY tan dawn hian IAY-a sanction tawh, la sak zawh loh in 75 awmin sak tur In 28 a awm bawk a. Heng te hi a chhan chu Awaasoft lamah thil fel hlel awm vang a ni a, Cheng nuai 21.75 hman bang a awm bawk. 2015 aṭanga tun (September 2021) thlengin PMAY-G hnuaiah hian In 13,532 zet Central sorkar chuan sak zawh turin target min tuk a. Data kan lak khawm aṭanga a lan danin In 4860 sak zawh tawh a ni a. Sak lai mek te, sak zawh tawh si, Online reporting format avanga la sak zawh loh anga lang leh sum la pek kim loh avanga sak zawh loh engemaw zat a awm. Eng pawh nise, Achievement report erawh chu 35.91 % chauh anga tarlan theih a ni. A tak takah chuan hei ai hian a sang zawk.

He thu ziaktu hian Pradhan Mantri Awaas Yojana-Gramin (PMAY-G chungchangah Research-a tia, chuta a hmuh dan ṭhenkhat rawn tarlang ila. Field study heng district – Kolasib, Serchhip, Lunglei leh Lawngtlai aṭanga beneficiaries 150-a interview aṭanga a hmuh chhuah te chu.

4.1 Beneficiary thlanchungchang

Langtlang leh thianghlim taka a dawng awm tak ten an dawn ngei hi PMAY-G tum bul pui a ni a. Tun hma lama Housing scheme awm ṭhinte-ah diklo taka thiltih a awm ṭhin ni a study leh research findings-a awm tawh avangin PMAY-G ah hi chuan ṭha taka tih tum a ni a, chuta tan chuan SECC Data 2011 hman a ni a, chu chu Gram Sabha-in a lo thlifim leh tur a tih a ni. Amaherawh chu, Mizoram-a SECC data an lak lai hian tih kim lo leh fel hlel eng emaw zat a awm a. Chung te chu a khaw pum anga telh loh vek te, chhungkua ṭhenkhat telh miah loh te, an telh ṭhenkhat pawh data diklo thun luh te

Table 4. Target and Achievement of PMAY-G in Mizoram

Sl. No	Year	Target		Achievement		Remarks
		Phy.	Fin.	Phy.	Fin.	
1	2015-16	0	0	0	0	PMAY-Ghas not Yet commenced.
2	2016 -17	4806	6497.40	4431	6497.40	
3	2017-18	1794	1795.79	429	1794.35	
3	2018-19	0	0	0	0	MoRD does not allocate target to the State.
4	2019-20	1500	0	0	0	Fund for the respective FY not sanctioned by the MoRD
5	2020-21	5432	0	0	0	Fund for the respective FY not sanctioned by the MoRD

Source : Rural Development Department, Government of Mizoram Dt.11.8.2021

a awm ṭeuh a ni. Chuti chuang chuan a chhangtu mi 64.7% zet chuan a fair tawk ni ah an ngai.

Table 5. Status of fairness in selection of beneficiaries of PMAY-G

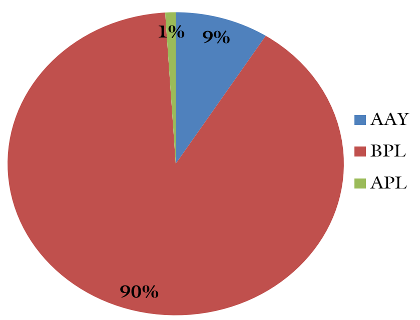
Scale	Percentage of respondents
Fair	64.7
Not Fair	0.7
Very Fair	34.7

Source : Field study 2019-21.

A chunga table kan en hian a chhangtu zawng zawng zinga 0.7 chauh hian an fair lo niin an ngai a. A fair tawh nia ngai hi 64.7% lai niin, 34.7% zet phei chuan a fair lutuk an ti nghe nghe a ni. Chuvangin, beneficiary thlan chhuah te hi a dik tawk niah pawm theih ani.

A hnuaia Figure-1 hi en ta ila, Beneficiary zinga 1% hi APL an ni nawlh a. PMAY-G kaihhruaina naah chuan BPL chauh an ni tur a ni a, a nih loh vek chuan Ral kuta thi chhungte leh vohbik te an ni tur a ni. He data en hian a dawng awm takin an dawng tih a ti fiah viau mai.

Figure 1. Economic status of the beneficiaries of PMAY-G (Source : Field study 2019-21)



Tin, ka zirchianna zelah Beneficiary-te kum khat chhunga sum lak luh hi Rs. 50,000/- leh ahnuai lam niin chhan min pe a ni. Chhangtu zinga mi 2 hian sorkar-ah thlatin hlawhnei an chhung zingah an awm a. Hna nghet erawh a ni lem lo.

Table 6. Main occupation of beneficiaries

		Value	Count	Percent
	Agri-Labourer		42	28.0
	Agriculture		87	58.0
	Artisan		2	1.3
Valid Values	Labourer		13	8.7
	Regular employee		2	1.3
	Small Bussiness		3	2.0
	Unemployed		1	0.7

Source : Field study 2019-21

4.2 Sum pek dan leh pek dan

Funding pattern hi Mizoram ang tan chuan 90:10 a ni a. Central sorkar hian 90% a tum a, state sorkar hian 10% a tum thung. A hnuaia Chart hi han en la ta la, Beneficiaries ten Installment tina an pawisa dawn dan a lang a. Installment khat an dawn aṭanga installment dang an dawn inkar hi a khat ang reng hle mai. A district-a zirin a che rang deuh leh che muang deuh an awm tih a hriat a. Fund awmsa release chungchang ah pawh an che rang teh chianglo tih hei hian min hrilh chiang thei ang.

4.3 Insak chungchang leh Ram ngawa suat dan tur.

National Housing and Habitat Policy-ah chuan Chenna in sak reng reng chu min hual vel tu thing leh mau te ti chereu lo zawng a hmalak a, hmanraw hman pawh a tlawm leh ṭha thei ang ber hmang turin a ti a. State level-ah Housing design hi PMAY(G) hnuaiah tun thlengin neih a la ni lova, District ṭhenkhat chuan an nei niin an sawi a. Tunah hian SIRD&PR-te nena ṭangkawpa hmalak mek a ni. In hmun lei hi PMAYG

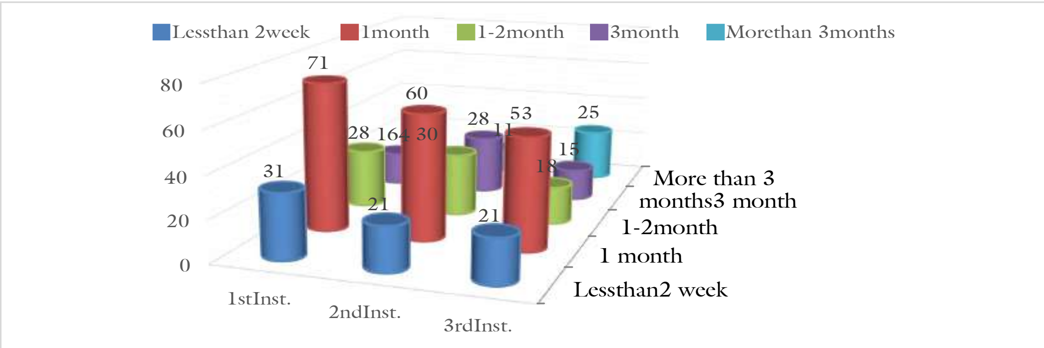


Figure 2. Time taken of Fund received of beneficiaries in each installment
(Source : Field study 2019–21)

Guideline chuan a phalsak a zat tur leh engtia tih tur nge tih chiang taka tarlan a ni lo. State sorkar ngaihtuah tura nih thu erawh a tarlang a. IAY-ah kha chuan Rs. 20,000/- emaw 10% of the assistance cost emaw aia tam lo a phal. A hnuaia Table hi kan en chuan In hmun an neih dan chu a langchiang a, a zahve zet chu V/C ten an pek a ni tih a lang a. The Mizoram (Land Revenue) Act, 2013 ah hian hemi chungchang a V/C te thuneihna pawh tarlan a ni a, V/C ṭhenkhat chuan a khua a zira In hmun la pek theihna an nei a ni.

Table 7. Possession of House

	Count	Percent
Govt. allot	3	2.0
Inherit	41	27.3
Lend	3	2.0
Purchase	9	6.0
VC allot	94	62.7

Source : Field study 2019–21.

Kan sawi tak angin PMAY(G) in zau 25 Sq.M (=267 Sq.ft) (12x22=264 Sq.ft.or 18x15=270 Sq.ft. or 24x11=264 Sq.ft.) a zim lova sak tur a ni. A tlangpuiin recommend area angin an sa a, a aia lian sa hi 15% zet an awm thung. Chutih lai erawh chuan Housing design hi sorkar-in duang tur a tih a ni na chungin a zah vaia tam daih chuan anmahni duh dan ang angin an sa mai ni in a lang.

Table 8. Housing design of PMAY-G houses

	Value	Count	Percent
Govt. design		29	19.3%
No design		16	10.7%
Self design		105	70.0%

Source : Field study 2019–21

In sak anih hma hian a hmun hi VLAA (Athawktu)ten thla lain AwaasApp-ah an geo-tagging tiin a thlalak an upload tur a ni a, chu chu chung lamin an lo sanction hnuah First installment pek chuah tur a ni. Level tinah thlalak upload zel a ngai a, vawi 3 aia tlemlo a hmunah en dik ngei ngei a ngai. A pawisa sanction tlem deuh ṭhin mahse, hnatlang leh chhung leh khatte in pei zawnin an sa zo ve thei ṭhin. A neitute hian an in sak hian ṭha anti hle a ni ang, a hnuaia table hi en ta ila, a ṭha ti hi an tam em mai.

In sakah chuan Toilet leh thuk changkang a awm ngei ngei tur a ni a. Thuk changkang erawh hi chu inchhung

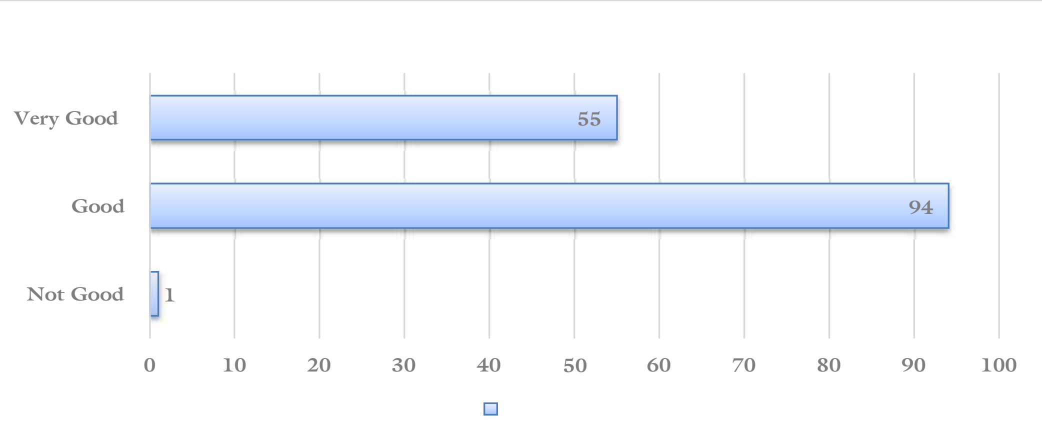


Figure 3. Perception of the quality of Construction by beneficiaries
(Source : Field study 2019–21)

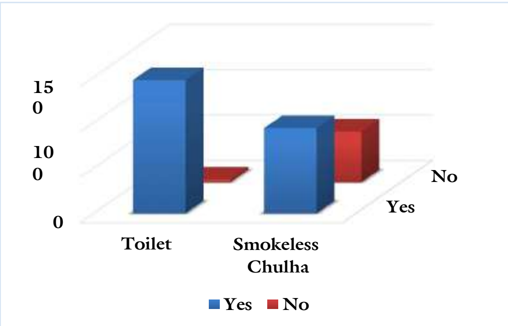


Figure 4. Construction of Toilet and Smokeless Chulha
(Source : Field study 2019–21)

ah an siam ta meuh lo tih a hnuaia Figure 4 kan hmuh ah hian a lang thei.

A tlangpuiin Mizoram-a PMAY satute hian an khua a zirin an in sak dan an tidanglam a. Khawpui hnaih leh kawngpui ṭha in a pawhna hmunah chuan a ban leh beam (Kal) atan RCC-an hmang tlangpui a, a bak hi thingzai leh rangva in an sa ṭhin. Hmun kilkhawr leh Kawngpui ṭha vak lovah chuan Thingzai leh rangva, Assam Type kan tih ang khan an sa tlangpui a. Thil lak awlsamna, Mamit leh Kolasib leh Aizawl-ah hian RCC-a sa a, a chung rangva hmang an awm nual. Semi RCC-a sa hi an tam ber a, mi pakhat erawh chuan Thingzai leh Thingtuai a hman pawlh ve tlat thung.

Table 9. Type of houses

	Count	Percent
Assam type	64	42.7
RCC	8	5.3
Semi RCC	77	51.3
Wooden	1	0.7

Source : Field study 2019–21

A tlangpuiin in hi thla 3 chhungin an sazo deuh zel a. In ṭhenkhat chu pawisa neih loh vang leh thildang vanga thla 18 chhung pawha sa zo theilo an awm bawk. A chunga Table 9 hi kan en chuan in sak zawng zawng 42 percent hian Thingzai inhlang, Assam type kan tih mai angin an sa a, 51.3 percent hian a ban leh beam ah RCC an hmang a, a dang zawngah Thingzai. 0.7 percent hian Thingzai leh Thingtuai an hmang a ni. Kan zawh chianna ah In sak nana an pawisa dawn Rs. 80,000 vel hi chu thingzai leh nan an hmang tlangpui niin an sawi a. Thingzai hi Cubic khat Rs. 750 chawhrualin a ni tlangpui bawk a. Chutiang anih chuan in pakhat zel atan a tlem berah 100 – 150 cubic ft. an hmang dawn tihna a ni ta. Tun thlenga PMAY(G) a In sak tawh chu a chunga kan tarlan tak ang hian 4860 a ni a, chu chu a tlem lama chhutin Thingzai 58 lakhs Cubic ft vel an ni tawh tihna a ni a. Mizoram-a target set zawng zawng 13,532 House phei hi chu sa ta se, 162 lakhs Cubic ft. vel hman a ni dawn a ni. Chuvangin, Thingzai In (Assam type) hmanga PMAY(G) sak arang thei ang bera bansan hi kan environment atana pawimawh tak zet a ni.

4.4 Bank Loan

Bank loan hi a awm tih pawh an hre lova. A awm tih hre zingah pawh a harsat an rin avanga dillo an tam a. Mi 9 hian an dil ve bawk naa, Loan hi tun thlengin an la hmu chuang lo.

Table 10. Status of apply for borrowing Bank Loan/Subsidy

	Count	Percent
No	141	94.0
Yes	9	6.0

Source : Field study 2019–21.

4.5 Monitoring

Tun hma lama IAY in sak te a hmunah en a, thlaka te hard copy-a submit ngai ang ṭhin kha tunlai thiamna hmangin Mobile phone hmanga engkim tih theih deuh tho hman a lo nita a. Monitoring tam zawk chu Phone hmanga tih a ni tawh. Secretariat, RD-ah PMU din a ni a, chutiang bawkin DRDA leh Block level-ah pawh din tur a tih a ni. BDO-te hian an Block chhunga PMAY G in hi 10% tal an sak laiin a hmunah an endik tur a ni a, Project Director-te hian 2% tal. Field data aṭang a landan chuan official-ten min tlawh miah lo ti hi mi 40 zet an awm a, vawi 7 aia tam min rawn tlawh titu hi mi 16 an awm thung.

5. Conclusion

PMAY-G hi Mizoram hi a tihlawhtling pawl tak India ramah chuan kan ni awm e. Official level-ah lo tham ṭhen a awm lem lo niin Research aṭanga hmuhchhuah a ni a. A dawngtute pawh hian an sa deuh vek niin a lang. Fund dawn dan kal mumal loh avanga hun engemaw chen khailak erawh chu a awm deuh nual a ni. 2017 khan Mizoram state pawhin tih ṭhat vangin Gold Medal pawh Ministry of Rural Development, Government of India aṭangin a dawng nghe nghe a ni.

Hetih rual hian in sakna atana bungraw hman chungchang hi ennawn a pawimawh hle mai. Thingzai an hman te hi Thing thang tawp tawh kih a ni vek lo tih kan hre tlangpui awm a. Tunlaiah thing lian leh zai tlaka upa a van tawh avangin Thing naupang te te chu Chain shaw hmangin an zai a, chung te chu In sak nan an hmang ṭhin a ni. Heng te hi senso tlem si, ṭha zawk sia kan tih theih dan tur zawn a ṭha hle mai a. A thlakna tur senso tlem si, Mau leh thildang kan ngaihtuah vat a pawimawh tak zet a ni. Cost norm hi revise tura Central sorkar ngen nise, tun dinhmunah chuan thil man sang zelah Assam type in pawh sak a harsa ta deuh

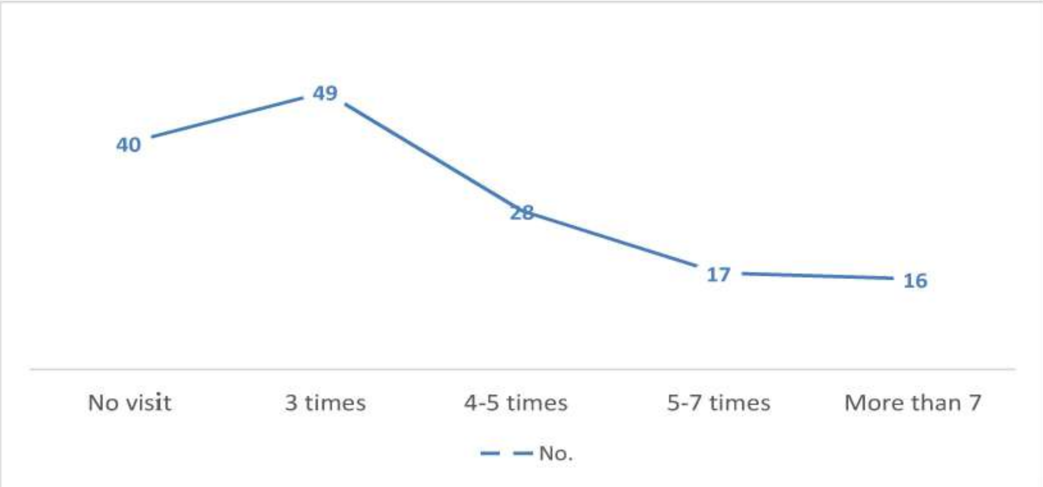


Figure 6. Numbers of visit performed by officials at the Block and District level
(Source : Field study 2019–21)

va, environment-a tichhe nasa bawk si. Chuvangin, in pakhat sakna atan Rs. 2.5 lakhs tal a tihsan nise hei ai hian in sak a ṭha deuh thei ang a, RCC-a an sak vek theih loh pawhin In sak nana Thingzai hman a ti tlem thei ang.

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LENGTH OF RIVERS IN MIZORAM : AN EVALUATION OF CURRENT RECORDS

- V. Lalnunmawia
Lalrinmawia

Abstract : *Kan chenna leilung leh a chhunga awmte chanchinhre tura zirchian hi Geography Subject bul intanna a tih theih ang. Greek hunlai atanga vawiin thlengin Geography Subject zir dan phung leh a huam chinte inthlak danglam deuh thin mahse, he kan chenna leilung leh a chhunga awmte (physical features) hi chu a innghahna bulpui ber a ni reng a. Chuvangin, heng kan awmna leilung, lui leh tlang, kawr leh phai leh a chhunga khuaruata awmsate(environment) hriat chian mai baka hriat dik hi, heng kaihhnawih leh an rahchhuah, zirdan kawng zauzawka kan chhui zelna turah pawh a pawimawhin, tuna kan luh khung turah pawh hian, Mizoram zimte a, kan luilian neih tlemte te, kan tarchhuahdan leh an sei zawng leh seidan indawt kan ziah in anglo awm thinte hi kan bih chiang dawn a ni.*

Keywords : *Rivers, Mizoram, Twin Method*

1. Introduction

Mizoram hi ram zimte, 21087 sq. km. chauh a ni a, amaherawhchu, 'he ram zimte chhung hi tlangram, tlangdung hniam leh tawi te te leh tlang bawk tak te te, an inkar kawr tina tui leh luite in a hual vel hlang awmkhawmna', tiin a sawi theih. Chutih rualin zirna leh zirbingna lamah te kan ram hi kan la daidar hneh tawklo hle a, Mizoramalui liante, a bik takin an sei zawng leh a indawt dan pawh hi ziak hrang hrang leh report te a in anglo fo mai. Chutih rual chuan kan rinpui ber pakhat, Statistical Handbook of Mizoram ami han en pawh hian, a luipui luan dan leh lenzawngte nen han mitthla kawpin, hei hi chu a ni thei dawn em ni han tih theih mai, dik hlel deuha ngaih theih te, chik leh zuala han bih chuan a awm thei awm e. Chuvangin, Mizorama kan luipui hrang hrangte bihchiang chungin, pawmdan leh ngaihdan thuhmun kan neih tlan theihna kawng zawng chungin vawiina ziak (record) kan hmuh thinte hi an dik reng emtihte, he chhuinaah hian kan bih chiang dawn a ni.

2. Zirna huamchin (Study area)

He zirchianna in a huam chin chu tuna Mizoram State chhung chin zawng hi ni in, Square Kilometer 21,087 a zau huamchhung hi a ni a.Hmar lamah $24^0$31'15"North Latitude; Chhim lamah $21^0$56'24"North Latitude huamchhungah a tla a. Khawthlang lamah $92^0$15'48"East Longitude leh Khawchhak lamah $93^0$26'21"East Longitude inkarah a awm thung. Chhim leh hmar zawngin Mizoram huamchhung hi a thui lai berah $2^0$33'51" niin, chu chu 285 km. a thui a ni. Tin, chhak leh thlang zawnga a huamchin zau lai ber chin chu $1^0$10'33" huamchhung niin, chu chu 119 km. a zau a ni.

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3. Zirchhuah tum (Objectives):

(1) Mizoram a Luilian leh Te deuh zawk hrang hrangte, an seizawng diktak bihchian leh indawt (rank) anga rualkhai leh inangtlang taka kan hriat leh hman theih nan.

(2) Mizoram chhung hmun hrang hranga lui lian deuh deuh te, hmaih leh telhloh bik nei lova, rualkhai leh mumal taka thliara, an awmdan leh dinhmun bihchian.

4. Thulakna hnar leh Kalpui dan (Data base and Methodology)

Kan innghahna bulpuiber ah chuan Survey of India Topographical Map, Surveyed 1969-70, leh Open Series Map, 2009, Sheet No. 83 C/13, 83 D/8, 83 D/11, 83 D/12, 83 D/15, 83 D/16, 83 H/4, 83 H/8, 84 A/5, 84 A/6,84 A/7,84 A/8,84 A/9,84 A/10,84 A/11,84 A/12,84 A/13,84 A/14,84 A/15, 84 A/16, 84 E/1, 84 E/2, 84 E/3, 84 E/4, 84 E/5, 84 E/6, 84 E/7, 84 E/8, 84 B/5, 84 B/9, 84 B/10, 84 B/11, 84 B/12, 84 B/13, 84 B/14, 84 B/15, 84 B/16, 84 F/1, 84 F/2,84 F/3, 84 F/4, te (Sawrkar kutchhuak, Official a nih angin) hman an ni a. Hengte tanpui tur hian Google Earth Map, Google Map, Satellite Images (GDEM), te hman an nih bakah Mizoram khaw hrang hrang a mite biakrawn an ni.

Lui hrang hrang seizawng te hi, Google Earth Map atanga Measure Distance hmanga Toposheet enmil chung te, Toposheet Map atanga, Twin Method leh Rotameter hmang te a teh an ni ber a. Lui pui leh te zawk te hi, an luan kawi ang zel a, single-line river (polygonal lines), a lian deuh hoah chuan a laiah(Centerline/mid-point axis method) zuia lui dung tluana teh an ni. Tin, Lui hnar lamah hian kum tluana kangchat lo chin (last perennial source) atanga teh tan an ni (after Lijuan et al., 2008)

5. Mizoram lui liante (Tuna Record)

Mizorama lui sei zualte, an seidan indawta ziak, Statistical Handbook of Mizoram, 2020 leh a hmalam kum te a a lo tarlan thin ang chuan, a hnuaia Table 1 a tarlan ang hi a ni.

Table 1. Mizoram a Lui pawimawh leh an seizawng

Sl. No	Name of River	Length (kms)	Sl. No	Name of River	Length (kms)
1	Tlawng	185.15	9	Tuichawng	107.87
2	Tiau	159.39	10	Mat	90.16
3	Chhimtuipui (Kolodyne)	138.25	11	Tuipui	86.84
4	Tut	138.25	12	Langkaih	85.43
5	Tuivai	134.61	13	Tuivawl	72.45
6	Khawthlangtuipui (Karnaphuli)	128.08	14	Teirei	70.84
7	Tuichang	120.75	15	Tuirini	59.57
8	Tuirial	117.53	16	Serlui	56.35

Source: Mizoram Statistical Handbook, 2020

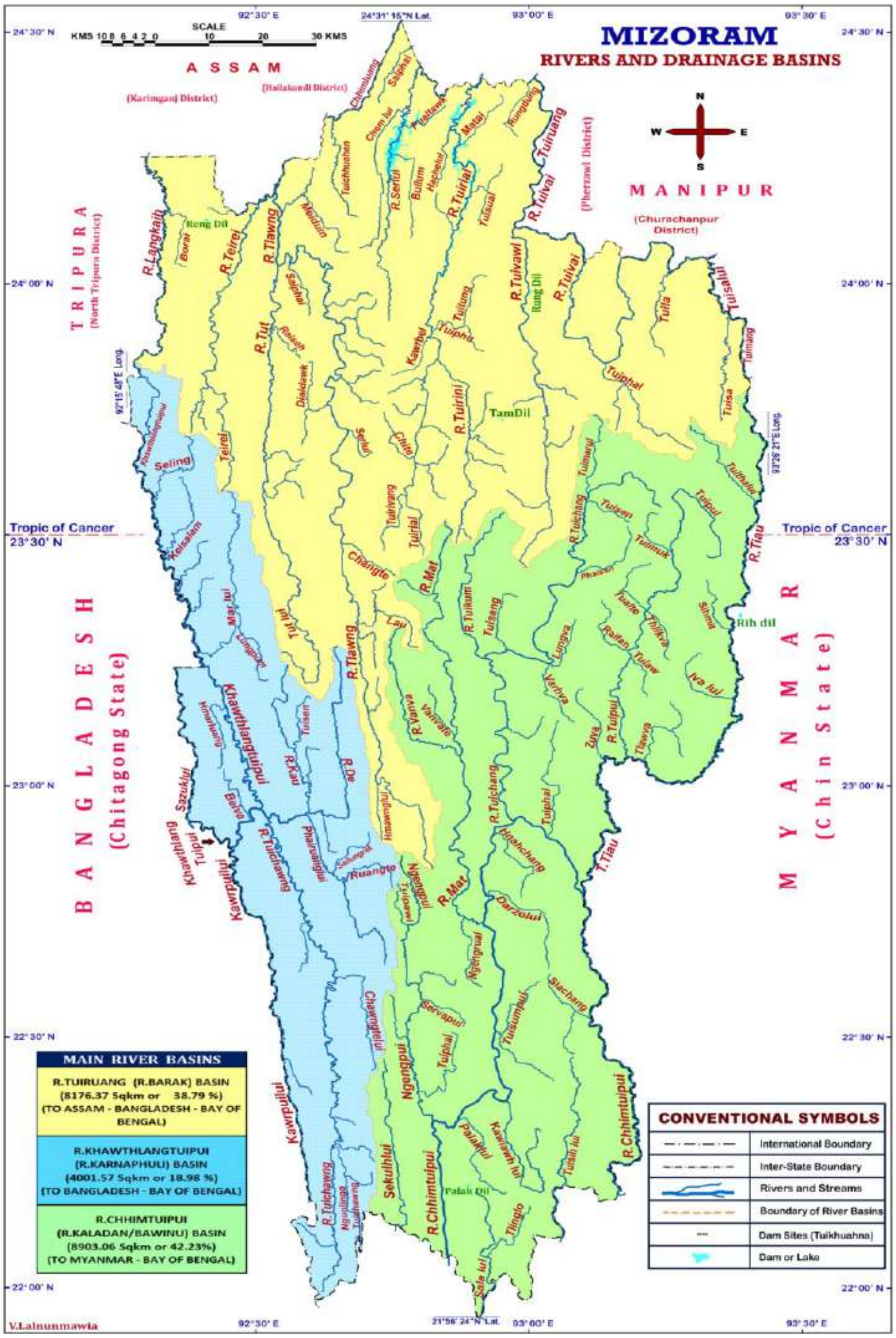

Figure 1. Mizoram a luilian leh pawimawh zualte

6. Bihchianna

Mizoram chhunga Luite hi infinkhawm lova hlawm hrang hranga luanga rampawn lamah an chhuah hlawm avangin hian, Luipui han lian fal leh Lawng pangngai ve deuh chin pawhin a zawh a, River Transport pawh mumal taka a fur a thal a han tihve theihnachin kan neipha meuh lo. A state pum enin hlawmthum (Basin thum) in an then hlawk theih awm e (See Figure 1). Hetiangin –

1) Chhimtuipui Basin (42.23%)
2) Tuiruang (Barak) Basin (38.79%) leh
3) Khawthlangtuipui Basin (18.98%)

TunaMizoram luiliante kan han bih chianna turah pawh hian, lui zirchian dan peng hrang hrang, an lo pianchhuah leh leilung mila an in siam danglam dan (drainage system) te, Leilunga an luan darh dan leh ziarang (drainage pattern) leh an in suih/fin chhawn dan (drainage network) lam te luh chilh lovin, Mizoram chhunga lui kan neih lian deuh deuh te, tuna an seizawng indawt kan ziah leh rem dante hi an dik reng em tih lam hi kan han chhui lai tur berte an ni.

7. Luilian ṭhenkhatte sei zawng :

Mizorama kan lui neih lian deuh deuh te, an seizawng Table 1 kan han hmuh te hi, eng tiang chiahin nge an lo teh a, eng kalphung (method) leh software te nge an hman kan hre chiah lova, atamber te hi chu Geometrical Axis anga a lai a lakmar a teh ni te pawhin a lang a, thenkhat te erawh chu an luan kawi ang anga teh nite pawhin a lang thung.Chuvangin, lui thenkhat, an luan leh paltlang ram te, an luankawi leh kual dan te han thlir vang vang hian, heng kan record neihsa te hi en nawn ngai ni in a lang. An chanchin a mal mal in chhuiin kan sawi vek seng dawn lova, Table 2 ah kan han teh a, an seizawng kan hmuh chhuah te kan tarlan hlawm tho a vangin, tun tumah chuan tlema han chhui zau deuh ngai ni a lang leh, an seizawng kan han hmuhchhuah, record kan neihsa te nena in hlat zual deuh te kan han bih chiang dawn chauh a ni.

7.1 Chhimtuipui Lui

Chhimtuipui hian Myanmar ram Chin State lama hnar neiin a rawn luang chhuk a, Mizoram leilung a rawn tawh tirh pawha lui liansa tak a ni a. Mizoram chhim chhak kil, Chapi khaw chhak lawk, Raphu Va (luite) chhuahah chiah Mizoram leilung rawn thlengin, hmar zawng a luang zelin India leh Myanmar ramri a kham a.Hmar lam atanga Myanmar leh Mizoram (India) ramri a rawn luang tho Tiau lui nen an infin atang chiah a Mizoram chhung lamah rawn lutin engemaw chen khawthlang lam hawia a luan hnuah chhim zawngin a in her a, Mizoram chhim tawp Lomasu khaw chhimlam Kumai luite chhuahah Mizoram chhuahsanin Myanmar (Arakan) lamah a lut leh ta a ni.Mizoram a rawn thlen chinah a fintu lui lian zualte chu, Tiau (leh a fin tu Tuipui), Tuichang, Mat, Kawilawhlui lehNgengpui te an ni.

Chhimtuipui sei zawng hi Mizoram Statistical Handbook ah chuan 138.46 km anga dah niin Mizoram lui seidan indawt ah 3-na ah dah thin a ni. Amaherawhchu, chik taka alui luankawi dan zawng zawng han en a, han chhui hian Chhimtuipui hi

138.46 km chiah hi a ni thei dawn em ni aw? a tih theih awm e. Mizoram leilung a rawn tawh tan atanga, Myanmar leh Mizoram border a hmar zawnga luang phei, Tiau lui nena a infin hma zawng pawh hi uluk taka han teh hian 95 kms vel niin a lang a (heihi Geometrical axis ah chuan 70 kms vel). Tiau nen an infin atang chiah hian Mizoram chhungah luang lut in, Chhim lamah Mizoram chhuahsanin Myanmar lamah a lut leh a, heta Mizoram chhung chin a luang han chhui pawh hian 155 kms vel laia sei niin a lang. Chutiang a nih chuan, Mizoram chhung chin a luang leh Mizoram leh Myanmar Bordera luang thuizawng belhkhawm phei chuan 249 km vel zeta sei a ni ta. Hetiang a nih chuan, Chhimtuipui hi, Mizorama lui lianber ni mai lovin, lui seiber pawh a ni in a lang.

Hetiang a lo nih chuan kan record neih mek a 138.25 kms hi engtia teh nge ni anga, khawi chin nge teh a nih tak ang? Teh dan chi khat GeometricalAxis (Lui luan kual ang diak diaka zui lova, a axis ang a pawh tlang zawr zawr) a lak em ni ang. Tin,lo ni pawh nise, Myanmar nena kan inkar ramri a luang zawng zawng chhut tel vek chuan, Chhimtuipui hi Mizorama 'Luisei ber' ti a kan sawi mek Tlawng Lui ai hian (Geometrical axis a la a teh ve ve in) a thui zawk tho in a lang.

Thlirna dang awm leh thei chu, Chhimtuipui seizawng record kan neih mek hi, Tiaului nen an infinna atanga Mizoram chhung bika luanglut chin chiah teh a, Myanmar nen kan inkar ramri a luang chin zawng hi telh loh em ni ang? Chutiang a nih chuan Mizoram chhung china luang kan han teh chhuah 155 km nen chuan la inmil lo viau mahse Geometrical axis laka teh ang chuan a inmil hnaivai khawp mai. Amaherawhchu, Mizoram chhung chin chiah lak ringawt a nih chuan, heng lui Tiau - Mizoram chhung a luanglut miahlo, Myanmar leh Mizoram in ramrinaa luang tluan te, Langkaih - Mizoram chhung bika luanglo, Tripura State leh Mizoram inkar ramri a luang tluan te hi a seizawng tluanin kan tarlangtho si. Khawthlangtuipui – a then Mizoram chhunga luanga, athen Bangladesh nena kaninkar ramri a luang pawh a lui dung tluan seizawng ka la in alang bawk a. Tuivailui, Mizoram pawn, Manipura hnar nei ve tho, Manipur leh Myanmar inrina atanga Tuisalui chhuaha Mizoram leh Manipur ramri atana hman leh rawn lut, athen Mizoram chhunga luang lut a, atamber Mizoram leh Manipur ramri a luang pawh hi Mizoram leilung a rawn tawh atanga a dungtluan seizawng teh a tarlan a ni si a. Chuvangin Chhimtuipui pawh hi Mizoram leilung a rawn thlenna chin chin atangin, hleih bik awm lova chhiar a lak mai tur niin a lang. Ngun taka chik a ennawn leh tulin a lang.

7.2 Tlawng Lui

Mizoram lui seiber ti a record kan neih mek Tlawng Lui hi Lunglei kiang mai, Zobawk bul chhim lam Zopui tlangpangah hnar neiin a rawn in tan a, hmar zawnga luang ngar ngarin Mizorama lui langtham deuhah chuan Tut leh Teirei ten an fin hnu ah Bairabi hmar lamah Mizoram a chhuahsan ta a ni. Tlawng lui hi record kan neih mekah chuan 185.15 km a sei niin ziah a ni a, heihi Geometric Axis laka teh niin a lang.River Rejuvenation Committee (RRC), Mizoram (2019) chuan Project a siamah chuan 206 km tiin a dah thung. Amaherawhchu hei pawh hi a hnar kang lo chin atanga ngun taka han teh a,a lui luan kawi ang zel (Twin method) a teh chuan a a thui zawk hle. A dung tluan, Assamnen kan in ramrina pawh tel a, Mizoram a chhuahsanna thleng han teh hian 238 kms vel niin a ngaih theih awm e. Mizoram china a lui mawng lam, Teirei nen an infin atanga Mizoram pawn a chhuah (Bairabi luichhuah) thleng, 2.5 km huamchin hi Mizoram leh Assam State te kan in daidanna ramri khamtu niin, a bak a hnar lam zawng hi Mizoram chhung a luang a ni.

7.3 Khawthlangtuipui

Khawthlangtuipui chungchang hi, tlema sawi fuhloh, ziak leh ngaihdan a awm theih avangin han sawi zau hmasa hlek ila. Wikipedia ah pawh a hnar neihna chu Saithah khawbul, Mamit district, ti a ziah a ni a, hei hi chu Khawthlang tuipui fintu, Mar lui hnar neihna zawk a ni a.

Tin, Buarpui khaw bula hnar nei, De lui a chhimluan a, Lunglei hmar-thlanglam zawn a khawthlang lam hawia akual lehhnu ah, Kau lui, Phairuang lui leh luite engemawzahin an fin hnu hian a lolian ta hle mai a, Chhimtawp lama tanga rawn luang lui lian leh sei tak Tuichawng luiin a han fin leh meuh phei chuan lui lian tak a nih tawh avangin helai lui infinkhawm lian tak hi, Hmarlam atanga rawn fintu Khawthlangtuipui ziding bera sawi ai hian a len zawk a vangin, thenkhat (abik in Tlabung bawr velah) chuan helai lui infinkhawm lian tak chin, khawchhak lam atanga rawn luangthla hi Khawthlang tuipui angin an sawi bawk. Khawthlang tuipui ziding ber hi chu Sazeklui tiin, a rawn finna pawh Sazekchhuah ti a koh a ni nghe nghe. SOI Toposheet pawh hian hmarlam atanga rawn luang, Khawthlang tuipui hnar bera kan neih hi Tuilianpui/ tuipui/sazailui/ tih leh a hnar lamah chuan Saza lui tiin a dah bawk. Amaherawhchu, a lui hnar lama khawsate chuan Sajeklui, ti tho mahse, Khawthlang Tuipui hnar ani tih hi an pawm tlan dan ani.

Engpawhnise, Khawthlangtuipui ziding ber ti a kan sawi hi hanluhchilh chho ta ila. He lui hian Mizoram hmar thlang lam, Jampui Tlangdung chhuahlam, Phuldungseileh Sabual inkarah hnar neiin he laihi Langkaih lui hnar atang pawha hlalo tak a ni. He luite hi chhimzawnga rawn luangin Tripura leh Mizoram ramri chuan 3.5km vel a zawh hnuin ramri hi Jampui tlangdungah a pakai a. Mizoram chhung chinah a lui hi luang lutin 28 km vel zet a chhim luan hnu in Jampui tlangdung atanga ramri rawn chhukthla chuan rawn pawh lehin heta tang hian Mizoramleh Bangladesh inkar khamtu ah a tang ngar ngar a, Mar luiin a rawn finna atanga chhimlam hnaite ah Bangladesh-India Ramri chu khawthlang lama Sazalui hnar tinzawna a penleh tak avanginMizoram chhung lamah lui hi a luang lut leh ta ani. Tlabung thlanglawk a Kawrpuiluiin a rawn finna thlengin Mizoram chhung huamchhungah luangin, Kawrpui chhuah atang hian Mizoram chin a chhuahsanna Sazalui chhuah thlengin Bangladesh leh India ramri khamtu a nileh ta a ni.

Khawthlangtuipui hi record kan neih

Table 2. Mizoram lui lian zualte seizawng (as measured by Author)

Sl. No.	Name of Rivers	Twin Method			Length by Geometrical Axis (km)	Statistical Hand Book of Mizoram 2020	Sources (Hnar neihna)
		Length (within Mizoram)	Length (Share with other State or Country as Boundary)	TOTAL Length (in KM)			
1	Chhimtuipui	155	94	249	214	138.46	Myanmar
2	Tlawng	236.5	2.5	238	193	185.15	Mizoram
3	Tiau	0	205.5	205.5	154	159.39	Miz-Mya Border
4	Khawthlangtuipui	96.15	110.45	206.6	134	128.08	Miz-Tri Border
5	Tuichang	154	0	154	131	120.75	Mizoram
6	Tuirial	156.5	3.5	160	121	117.53	Mizoram
7	Tuichawng	180.5	0	180.5	120	107.87	Mizoram
8	Tuivai	66	71	137	119	134.61	Manipur
9	Tut	142	0	142	111	138.46	Mizoram
10	Mat	141.5	0	141.5	110	90.16	Mizoram
11	Tuipui	116	0	116	91	86.84	Mizoram
12	Teirei	101.1	7.4	108.5	87	70.84	Mizoram
13	Tuivawl	104	0	104	84	72.45	Mizoram
14	Kawrpuilui	0	131.5	131.5	82		Bangladesh
15	Ngengpui Lui	92	0	92	66		Mizoram
16	Serlui	82	0	82	63	56.35	Mizoram
17	R.DEH (Up To Sazek)	82.4	0	82.4	59		Mizoram
18	Langkaih	0	89	89	51	85.43	Miz-Tri Border
19	R.Tuirini	59	0	59	47	59.57	Mizoram
20	Tuisalui	48	28	76	45		Mizoram
21	Tuisihlui	42.3	19.2	61.5	44		Mizoram
22	Phairuanglui	63	0	63	43		Mizoram
23	Marlui	62	0	62	42		Mizoram
24	Kawiawhlui	52	0	52	41		Mizoram
25	Sekulhlui	49	1.5	50.5	40		Mizoram
26	Kau Lui	51.4	0	51.4	39		Mizoram
27	Sazuklui	0	55.4	55.4	37		Miz-Bang Border
28	Vanva	47	0	47	37		Mizoram
29	Tuikum	49	0	49	36		Mizoram
30	Chemlui	48	0	48	36		Mizoram
31	Salalui	30.3	11.4	41.7	31		Mizoram
*	R.Tuiruang(R.Barak)	0	25	25			Manipur

* Tuiruang hi Mizoram chinah tawi mahse luilian tak a nih avangin dah tel a ni.

NOTE : ***Lui seizawng tarlante hi Twin method- Centerline method a, an luan kual kawi dan ang zel a dungtluana teh leh pawhmar/geometrical axis la a teh chhuah dahve ve an ni)*** mek (Table 1) ah chuan 128.08km anga dah a ni a. Amaherawhchu, a ruam dung zuia pawt mar (Geometrical Axis lak) mai lova a luan kawi ang anga teh (centerpoint or twin method) chuan, a lui kuang a hniamin a zawl a, a luang kawi kual nasa si a, a lui hi a sei hle. Tripura –Mizoram ramri ah 3.5 km, Bangladesh – India ramri ah 107.5km vel leh Mizoram chhungah 96 km vel, a vaia belhkhawmin 206.6 km velin a chhut theih a ni.Mizoram chhunga luilangsar lehpawimawh tak tak, Mar lui, De lui, Kau lui, Phairuanglui,Tuichawng lui, Kawrpuilui, Sazalui leh luite tamtak an in chhunglut a ni.

Heng baklui dangte hi chu a mal malin an chanchin chhui zui tawh lo mai ila. Kan han bihchianna a seilamkan han tehchhuahte Table 2 ah tarlan an ni thoa.Lui thenkhat (Tut, Tuivai, Tuirini,Langkaih, etc) tehi chu record awmsa leh kan han tehchhuahte an in hnaih viau lain Lui tamtak, a bikin nasa taka luang kual kawi ho te (Tiau, Tuichawng, Mat, etc) erawh chu in thlau tak tak tean ni. Chuvangin, heng kan record neihsa te hi teh dan kalphung (Method) thuhmun vek ateh an nilo deuh em ni aw, 'a then Geometrical Axis alak a teh a mil theih laiin a then erawh a lui kuang kawi ang zel a teh (center line/twin method) a dik viau, a axis a lak a han teh chuan record awmsa aia tawileh viau thung an ni si', a tih theih awm e.

8. Tarlan ngailoh luite

Tarlan ngailoh han tih hian lui te deuh ho, zir chiana, Table 2 a an seizawng kan han tarlante zawng zawng hi ni lovin, Mizoram lui lian leh pawimawhte (Table 1) kan tarlan thin te tluk ve phak tho a lang, mahse an hming kan hmuh tel ngai loh tlem te han tar lang ila.

8.2 Kawrpuilui

Kawrpuilui (Thega Thal) hi Mizoram chhimthlang kil lam, Bangladesh leh India inrina bul, Andermanik khaw thlang zawn Bangladesh ramchin a hnar nei a niin, a hnar atanga km 3/4 vel lek a chhak zawnga a rawn luan hnu in Vathuampui lui nen an infin a. Heta tang hian hmar luanin Khawthlang tuipui a fin thlengin Bangladesh-India Ramri kham nan hman a ni. He luiin Khawthlangtuipui a finna hmun chu Kawrpuichhuah tih niin tun hnai atang phei chuan Border Trade (Indo-Bangla) Centre pawimawh tak ni tura ruahman chhoh mek a ni nghe nghe.

Kawrpuilui hi a luanna hmun a hniamin a kuang a zawl bawk a, a luang kawi kual (meandering) nasa hle mai a, hei hian en mai aiin a lui a hi teh a ti tlovin a ti sei zual a tih theih awm e. Mizoram lui lian leh pawimawh ahte tarlan ve thin a nilo na in lui sei ve tak, Mizoram leilung a deh chinah pawh 131.5 km vel zet a sei a ni (Geometrical Axis a laka teh chuan 82 km vel). He lui hi Mizoram lui lian leh pawimawhte zinga kan tarlan ve ngailoh nachhan hre chiah lo mah ila, a sei zawng han en a luidang kan tarlan thinte nen han khaikhin te, sawi tawh anga tunhnaia Border Trade atana a pawimawh chhoh dan te thlirin leh, a dinhmun anga ding lui dang Mizoram chhung bik a luang chuanglo, ramri luite pawh kan tarlan tho chuan, tarlan ve awmtak niin a lang.

8.2 Ngengpui Lui

Ngengpui Lui hi Mizoram chhimlam lui lianve pangngai tak niin, Lunglei khawpui kiang mai chhim lamah hnar a nei a. Heta tang hian chhimlam pana luang zelin, Saizawh khaw hmarlam hnaiteah Chhimtuipui a fin ta a ni. He luipui kam zau ngaw, 110 km2 huamchhung hi a lui hming chawiin tun hnai maiah chuan Wildlife Sanctuary atana puan chhoh a ni nghe nge a ni. Ngengpui Lui hi 92 km vel laia thui (Geometrical axis lak a 66 km) a ni a, a pawimawh chhohna mai bakah a sei zawng pawh hi Mizoram lui lian leh pawimawhte kan tarlan thin thenkhat te (Tuirini, Serlui, Langkaih) chen phak ve tho niin a lang.

8.3 De Lui

De Lui hian Buarpui khaw bulah hnar neiin a chhim luan a, engemaw chen a chhimluan hnu hian Lunglei thlang zawnah khawthlang zawngin in herin a thlang luan leh a, hemi hnu (ahnar atanga 67.5 km vel) hian Kau luiin a rawn fin a, a thlanglawk (1 km vel) ah Phairuang luiin a rawn fin leh zui a. Hemi hnu hian thlang luan zelin (a hnar atanga 80 km, Phairuang chhuah atanga 11km vel) chhim lam atanga lo luang Tuichawng lui nen an infin leh a, Hemi thlang lawk (82.4 km / Tuichawng chhuah atanga 2.4 km) velah hian, a tir lama kan chhui Khawtlang-tuipui ziding ber, Sazeklui tia sawi bawk, hmarlam atanga lo luang a zuk fin ta a ni.

De Lui sei zawng hi, a luia kan chhiar chin a zira danglam thei ani awm e. S.O.I Toposheetah chuan Kau lui leh Phairuang lui ten an rawn fin hnu, Tuichawng in a rawn fin hma chin hi De lui niin a dah a, Tuichawng nen aninfin hnu hi chuan Khawthlangtuipui ti a daha ni thung. Tin, a awmna ram vela cheng thenkhattephei chuan, De,Phairuang leh Kau lui te an infinkhawmna thlanglam lolian ta viau, Tuichawng luipawh a la thlenthlakhma atang hian Khawthlangtuipui ti a sawi tawk an awm bawk. Amaherawhchu, chik zawka bih chuan, Khawthlangtuipui ti a kan sawi ber, Tripura leh Mizoram ramri atanga rawn hmar luan nena an in fin hma hauh a, a lui a len em avanga Khawthlangtuipui hminga lo koh mai hi a dik angem? Tuichawng leh De lui infinna thlanglam hiKhawthlangtuipui anih chuan De lui chu Tuichawngchhuah thleng chuan 80 km ang vela chhiartheih a ni anga, Khawthlangtuipui (Sazek chhuah thlenga kanchhiar thlak thung erawh chuan 82.4 km vel (Geometrical Axis-59 km) a ni thung anga, Mizorama lui sei leh pawimawhte zinga lang tel pha ve hial tur niin a lang.

8.4 Luite dangte

Heng kan han tarlante bakah hian Mizoramah a lian lam nilo mahse, mahni awmna hmuna pawimawh leh lar ve tak tak lui, a hla lam atanga kan in hriat pui em em siloh, engemawzat an awm a, Chung zinga la sei zualte chu Table 2 ah an seizawng te nen tarlan an ni a, a mal mal in an chanchin chu kan chhui lo mai ang.

Heta Table 2 a kan tarlante zinga la tel pha chiah silo, mahse luite lian ve tak tak, a dung tluana km 30 vel bawr han kai pha emaw, hnaih ve phak tamtak an la awm awm e. chung zinga tlema la lang sar deuhte chu- Tuichhuahen, Builum lui, Meidumlui, Tuiphu, Tuiphal, Tuila, Diakdawklui, Tuithalui, Tuimang, Selinglui, Keisalam, Tuiphai, Darzolui, Palaklui, Chawngtelui, Ngunlinga Tuichawng te niin heng bakah pawh hian an aia te deuh adang engemawzah an la awm bawk a ni (See Figure 1).

9. Hmathlir leh Tlangkawmna (Suggestions and Conclusion):

A tawp berah chuan, hetianga Mizoram zimte chhunga lui kan neih ve hote hi, mumal tak leh dik tak, tehdan (method) pawh thuhmun leh inang tlangin tehin record ila, an awmna hmun a zira ngaih pawimawh bik emaw, dah lansarh bik emaw nei chuang lovin, lehkhabu hrang hrang, Internet site hrang hrang leh Sawrkar lam lehkha leh Project Report hrang hrang te thlenga, dik leh inangtlang taka ziak leh hman tlan a nih theih nan, mimal nilova official taka mawhphurtu department lamin emaw, a hmun ngeia (field observation) endik a tul a nih pawha hma la in, Tunlai khawvel thiamna thang zel leh hmanraw changkang zawk lo chhuak zelte hmang tangkaiin, thutlukna mumal tak siama hmalak theih ni se a duhawm hle. Thangthar zel te tan pawh a rin ngam report leh record dik leh kim nei tura hmalak hi, kan ram Lui, Tlangte leh Tuikhawthla chen hian a tul tak meuh a ni.

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