RAINFALL INDUCED HAZARDS ANALYSIS OF MIZORAM

DEPARTMENT OF SCIENCE AND TECHNOLOGY
Ministry of Science & Technology
Government of India

NMSHE National Mission For Sustaining the Himalalayan Ecosystem

सत्यमेव जयते

MISTIC MIZORAM

MIZORAM STATE CLIMATE CHANGE CELL

Mizoram Science Technology & Innovation Council

Directorate of Science & Technology

Government of Mizoram

Mizoram State Climate Change Cell's Team

Principal Investigator : Dr. R.K. LALLIANTHANGA

Co – P.I. : Mr. SAMUEL LALMALSAWMA

Scientist B : Mr. LALTHANPUIA

Project Scientist : Dr. JAMES LALNUNZIRA HRAHSEL

Project Scientist : Mrs. H. LALDINPUII

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PREFACE

The whole state of Mizoram, locating in the adjoining areas of the southern foothills of the eastern Himalayas is characterised by series of hill ranges running from north to south with rough terrain with steep slopes and deep valleys. According to the report of Mizoram Remote Sensing Application Centre (MIRSAC), more than 70% of the state geographical area is under 35 percent slope or more. The region also receives heavy rainfall with average annual rainfall of more than 2500 mm. Furthermore, according to the State of Forest Report 2019, Mizoram has a forest cover of 85.41% out of which only 0.74% are under very dense forest which are decreasing due to anthropogenic activities. As such, the state of Mizoram is indeed no doubt vulnerable to climate variability and long-term climate change.

As per different published studies, over the past three decades, the climate of Mizoram has been experiencing changes which includes rising temperature and changes in temporal and spatial distribution of rainfall. The effects of such changes have been evident in the increase events and intensity of climate related hazards and disasters in the state which can be perceived by a common man even without the support of scientific data. Therefore, the State Climate Change Cell feel the need to examine such climate related hazards and disaster events and their relations with meteorological data by analysing recorded data from local sources. The result of this study is published in the report entitled “Rainfall Induced Hazard Analysis of Mizoram”.

We feel that this report will provide useful information for decision makers and planners of the state. We also believed that it will be useful for academicians, researchers and students as well as an awareness material for the general public.

We thank the Department of Disaster Management and Rehabilitation, Government of Mizoram and State Meteorological Centre, Directorate of Science and Technology, Government of Mizoram for providing their valuable data without which this report would not have been possible.

Place: Aizawl
Date: 27th October, 2020

(Dr. R.K. LALLIANTHANGA)
Chief Scientific Officer & Member Secretary
Mizoram Science, Technology & Innovation Council

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INTRODUCTION

Mizoram is prone to natural disasters like earthquake, cyclone, hailstorm, cloudburst, landslide, flood, fire etc. The State is in Seismic Zone–V, which is the highest risk zone to earthquakes. The Tropic of Cancer passes through the middle of the State. Thus, there is always abundant rainfall during the monsoon season. Strong wind/cyclonic storm strikes the State on the onset and post monsoon seasons, which create havoc in the State by damaging houses and crops alike. Due to excess rainfall, landslides are very serious hazard for the State. Landslides disrupt road, communications, damage houses and cause loss of life every year. These disasters result from a combination of the steep terrain, intense rainfall, small intermittent earthquakes and construction activity that undercuts slopes. A strong earthquake, though infrequent, also trigger landslides.

The triggering factor of a landslide is rainfall infiltration into the soil, making the groundwater level increase, resulting in a reduction of the shear strength which is also closely related to antecedent rainfall, cumulative rainfall, and rainfall duration (Jeong, *et al*., 2017). The slope instability increases with high intensity or long duration rainfall but does not relate to rainfall alone. It is affected by other factors such as lithological material, type of soil and depth, the surrounding vegetation, slope inclination or aspect, curvature, altitude, land use patterns, and drainage networks (Youssef, *et al*., 2016; Hong *et al*., 2018). The types of rainfall required to initiate debris flows and landslides include high rainfall intensity within a short duration and high cumulative rainfall over a long duration (Chen, 2020).

Lallianthanga, *et al*., (2013) has pointed out that studies on landslides in Mizoram are meagre. The earliest work on geology of Mizoram was done in 1891 and was reported that the area consisted of great flysch facies of rocks comprising monotonous sequences of shale and sandstone (La Touche, 1891). Few attempts were made to study landslide within the state. These include geotechnical appraisal of Bawngkawn landslide (1994), examining the causes of the slope failure and suggestions for remedial measures (Tiwari and Kumar,1996). The possible causes of South Hlimen landslide (1992) which claimed the lives of almost 100 people were also critically examined and suggestions for mitigation measures were made (Tiwari and Kumar,1997). Geo-data based Total Estimated Landslide Hazard Zonation in the southern part of the state has also been carried out and it was concluded that landslide hazard zonation map is of fundamental importance during planning and implementation of developmental work in a hilly state like Mizoram (Lalnuntluanga 1999). A comprehensive report on Landslide Hazard Zonation of southern part of Mizoram which includes Lunglei, Lawngtlai and Saiha districts (Raju et al., 1999), and Landslide Hazard Zonation Mapping of Serchhip town (Ghosh and Singh, 2001) were also carried out.

More than 300,000 people live in Aizawl today, with an expected 820,000 by 2031. They live in multi-story buildings packed on to slopes with unstable geology. Urban growth pushes unauthorized development on to ever more fragile areas, where it increasingly triggers landslides.

Mizoram experiences numerous landslides each year during heavy monsoon rains. One of the deadliest recent landslides occurred on 11 May 2013 in Laipuitlang Veng, Aizawl which killed 17 people.

Aizawl's high landslide hazard is the result of layers of weak sandstone and shale that were compressed and folded to form the anticline on which the city sits (Evans, 1964). On the city's east side, the interbedded layers dip in the same direction and at approximately the same angle as the slope, a condition called adverse bedding, which creates instability when development or erosion removes supporting rock downslope. On the city's west side, joints and fractures in the same weak geologic units also create potentially unstable conditions. (Rodgers & Tobin, 2014)

Huang, *et al*., (2016) identified two, active, slow-moving landslide areas: Ramhlun Sports Complex and Ramthar Veng. These landslides lie to the east and south of the Aizawl town as per their field observations in 2013. Their MT-InSAR time series analysis shows that the mean creep rate of the landslide areas is 25 mm/yr, and the creep rate is significantly higher in the wet seasons (50 mm/yr) than in the dry seasons (19 mm/yr).

STUDY AREA

Mizoram is one of the North Eastern States of India, located in 21º56' and 24º31' N latitude and 92º16' and 93 º 26’ E longitudes with the geographical area of 21,081 sq. km having population of 10,97,206. It is bounded by Bangladesh and Tripura state, India in the West and Myanmar in the East and South; Manipur and Assam state, India in the North. Owing to its geographic, geological and physical features, Mizoram is vulnerable to all-major natural hazards such as cyclones, earthquakes, landslides, etc. The geology of Mizoram comprises N-S trending anticlinal strike ridges with steep slopes, narrow intervening synclinal valleys, dissected ridges with deep gorges, spurs and keels. Faulting in many areas has produced steep fault scarps (GSI, 2011). The present study aims at identifying various natural hazards which can affect the state of Mizoram.

METHODOLOGY

Data Collection

Rainfall : Rainfall data was obtained from State Meteorological Centre, Directorate of Science & Technology, Government of Mizoram. The data consists of 34 years (1986-2019) record from 8 stations located in each of the district headquarters of the state.

Hazards : Hazards occurrence data were collected from Department of Disaster Management and Rehabilitation, Government of Mizoram. The hazard data consists only of 10 years (2009-2019) record.

Rainfall Anomaly Index (RAI)

The Rainfall Anomaly Index is used to classify the positive and negative severities in rainfall anomalies. From the precipitation data, the Annual Rainfall Anomaly Index (RAI) can be used to analyse the frequency and intensity of the dry and rainy years.

RAI, developed and firstly used by Roov (1965) and adapted by Freitas (2005), constitutes the following equations:

$$RAI = 3 \left[\frac{N - \hat{N}}{\hat{M} - \hat{N}}\right] \text{ for}$$

positive anomalies

$$RAI = -3 \left[\frac{N - \hat{N}}{\hat{X} - \hat{N}}\right] \text{ for}$$

negative anomalies

Where:

N = current monthly/seasonal or yearly rainfall, in other words, of the month/season or year when RAI will be generated (mm).

$\hat{N}$ = monthly/seasonal or yearly average rainfall of the historical series (mm).

$\hat{M}$ = average of the ten highest monthly/seasonal or yearly rainfall of the historical series (mm)

$\hat{X}$ = average of the ten lowest monthly/seasonal or yearly rainfall of the historical series (mm)

- Positive anomalies have their values above average and negative anomalies have their values below average

Table 1. Classification of Rainfall Anomaly Index.

Rainfall Anomaly Index (RAI)	**Rainfall Classification**
Greater than 4	Extremely Rainy
Between 2 and 4	Very Rainy
Between 0 and 2	Rainy
0	Neither Rainy nor Dry
Between 0 and -2	Dry
Between -2 and -4	Very Dry
Less than -4	Extremely Dry

- Source: Freitas (2005) adapted by Araújo et al. (2009)

Statistical Analysis

Regression analysis was performed to estimate or predict the nature (+ve or -ve) and magnitude of the relationship among the hazard occurrence (number of villages affected) and rainfall. First, the best fit model was determined for exploring whether there was any significant relationship among hazard occurrence (number of villages affected) and rainfall. The regression model with the best fit (highest r^2) was chosen which in this case was found to be the *polynomial quadratic regression* model. The r^2 value (coefficient of determination) represents the proportion of variance in the dependent variable that can be explained by our independent variable (technically, it is the proportion of variation accounted for by the regression model above and beyond the mean model).

RESULTS AND DISCUSSIONS

Rainfall:

During the study period, the maximum rainfall recorded was during the year 2009-10 (4317.09 mm) and the lowest was during the year 2014-15 (1798.14 mm). During the year 2009-10 and 2010-11, rainfall record soar above 4000 mm which triggered various hazards and caused heavy loss and damage to properties and agricultural production in the state. The average annual rainfall in Mizoram during the study period is 2555.23 mm (Table 2).

Table 2. Annual rainfall and Rainfall Anomaly Index (RAI) of Mizoram (1986-2019)

Year	Rain (N)	N – Average	RAI	Year	Rain (N)	N – Average	RAI
1986-87	2633.24	78.04	0.45	2003-04	2479.85	-75.35	-0.46
1987-88	2445.43	-109.77	-0.67	2004-05	2799.75	244.55	1.42
1988-89	2608.73	53.53	0.31	2005-06	1928.00	-627.20	-3.82
1989-90	2718.00	162.80	0.95	2006-07	2347.48	-207.72	-1.27
1990-91	2560.20	5.00	0.03	2007-08	3170.46	615.26	3.58
1991-92	2709.29	154.09	0.90	2008-09	2050.53	-504.68	-3.08
1992-93	2501.76	-53.44	-0.33	2009-10	4317.09	1761.89	10.24
1993-94	2694.67	139.47	0.81	2010-11	4023.06	1467.86	8.53
1994-95	1914.96	-640.24	-3.90	2011-12	2403.11	-152.09	-0.93
1995-96	2744.97	189.77	1.10	2012-13	2307.53	-247.68	-1.51
1996-97	2381.30	-173.90	-1.06	2013-14	2524.89	-30.31	-0.18
1997-98	2721.56	166.36	0.97	2014-15	1798.14	-757.06	-4.62
1998-99	2459.53	-95.67	-0.58	2015-16	2136.44	-418.76	-2.55
1999-00	2645.99	90.79	0.53	2016-17	2294.23	-260.97	-1.59
2000-01	2801.61	246.41	1.43	2017-18	2623.53	68.33	0.40
2001-02	2569.88	14.68	0.09	2018-19	2077.15	-478.05	-2.91
2002-03	2708.51	153.31	0.89	**Average**	2555.23		

Rainfall Anomaly Index:

During the study period, rainfall anomaly index indicates that 2009 to 2011 was the year with extreme rain (10.24 & 8.53) with excess of 1761.89 mm during 2009-10 and 1467.86 mm during 2010-11 from the average annual rainfall of 2555.23 mm in the last 33 years (Table 2).

The analysis of the Rainfall Anomaly Index reveals that there is a decline in the amount of total annual rainfall since 2012 from the average annual rainfall of 1986 – 2019 (Fig 1). It also reveals that there occurs an incidence of *two* extremely rainy years (2010 and 2011) with *fourteen* rainy years followed by *ten* dry years and *seven* very dry spells (Table 3).

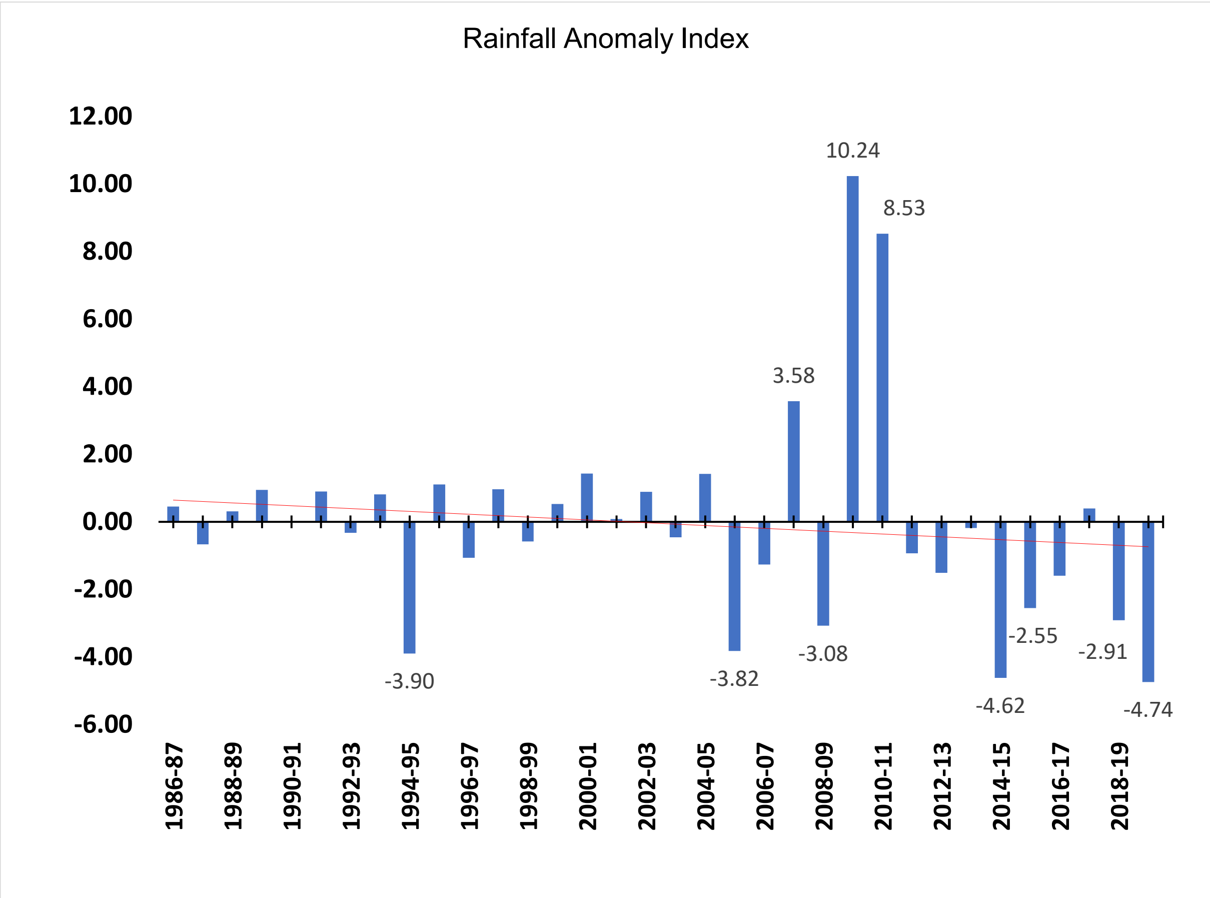

Fig 1. Rainfall Anomaly Index of Mizoram (1986 – 2019)

Table 3. Rainfall Anomaly Index of Mizoram (1986-2019)

RAI range	Rainfall Classification	Number of years
≥ 4	Extremely Rainy	2
2 to 4	Very Rainy	1
0 to 2	Rainy	14
0	Neither Rainy nor Dry	0
0 to -2	Dry	10
-2 to -4	Very Dry	7

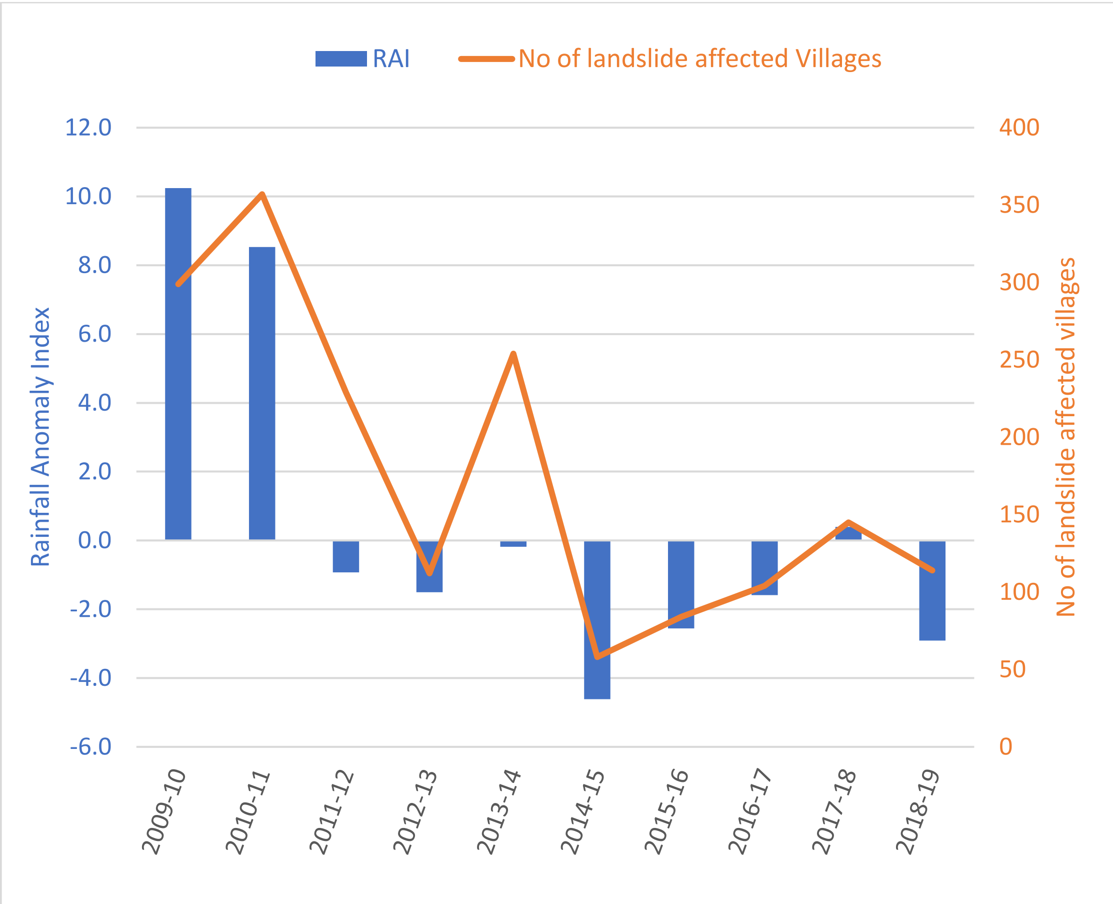

Fig 2. Rainfall Anomaly Index with respect to number of landslides affected villages

Hazards analysis:

Rainfall induced hazards occurrences in Mizoram consists mainly of landslides, cyclones, floods, hailstorms and storm (Table 4). DM&R, Govt. of Mizoram.

Table 4. Rainfall and Hazard data of Mizoram

Years	Average rainfall Mizoram	No of Village affected by Landslide	No of Village affected by cyclone	No of Village affected by floods	No of Village affected Hailstorm	No of Village affected by storm
2009 -2010	4317.09	299	594	32	213	DD
2010 -2011	4023.06	357	506	68	409	DD
2011 -2012	2403.11	229	283	32	166	DD
2012 -2013	2307.53	112	103	2	36	DD
2013 -2014	2524.89	254	329	DD	60	165
2014 -2015	1798.14	58	93	5	2	5
2015 -2016	2136.44	84	136	47	47	47
2016 -2017	2294.23	104	104	47	DD	97
2017 -2018	2623.53	145	200	186	DD	46
2018 -2019	2077.15	114	60	59	50	DD

*DD = Data Deficit

Landslides:

The extreme rainy years (2009-2011) resulted in 656 villages affected by landslide, 1100 villages affected by cyclone, 100 villages affected by floods and 622 villages affected by hailstorm causing deaths and massive damage to houses. It also incurred huge loss of properties, crops and livestock (Table 4). Past records (from DM&R Dept., Govt. of Mizoram) of massive landslides that were known to cause disruption to normal life during 2010 - 2011 showed that 167 villages were affected in the Aizawl district alone. The affected villages during the past year (2008 - 2009) from the same source recorded as much as 186 (Fig 3).

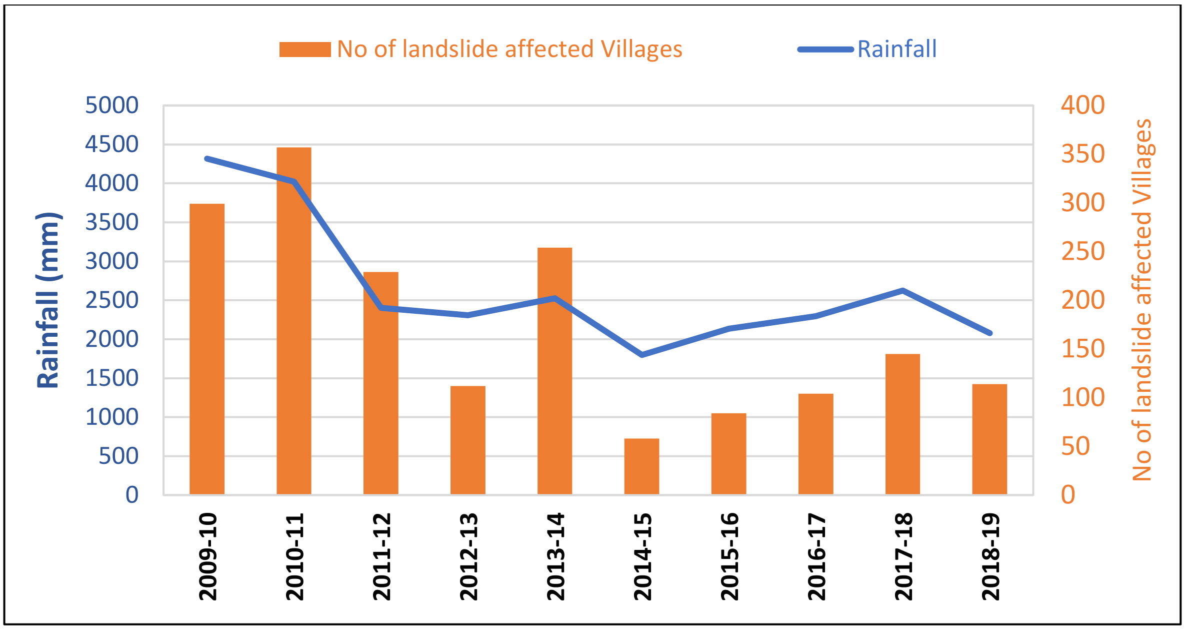

Fig 3. Rainfall and total number of landslides affected villages (2009-10 to 2018-19)

During the monsoon season of 2010, Bazar veng locality of Mamit town was severely affected by subsidence and landslides endangering the lives and properties of hundreds of people. About 50 families were evacuated and about 43 houses dismantled (Lallianthanga, *et al*., 2013). This coincides with the two years (2009 & 2010) when the received rainfall recorded the highest for the state during the past three decades. Heavy rainfall during monsoon caused landslides in many places of the district. The main Lengpui Airport road was also blocked for several days. Within Aizawl city, around 10 nos. of houses were dismantled which affected about 15 families and required evacuation during 2010-11. The following year there was a long linear crack at Ramhlun Sport Complex area. Around 10 nos. of houses were dismantled and almost 60 families were shifted to safe areas. Landslide occurring at a stone-quarry near Keifang village claimed the lives of 18 nos. of persons. Apart from these, rainfall induced hazards especially landslides and flash floods befell Mizoram every year causing many losses of lives and damage to properties.

During June 2018, 10 people were killed and another injured when a building was swept away by a landslide triggered by heavy rains in the Lunglawn area of south Mizoram’s Lunglei town.

Cyclone:

The first incidence of cyclone (Thlichhia) has been noticed in 1876 in Mizoram and the year is being remembered as **THLI CHHE TLEH KUM**, a local term for the '*year of cyclone*'. Past records on the occurrence of cyclone that were known to cause disruption to normal life and property during 2010 - 2011 showed that 167 villages were affected in the Aizawl district alone (DM&R).

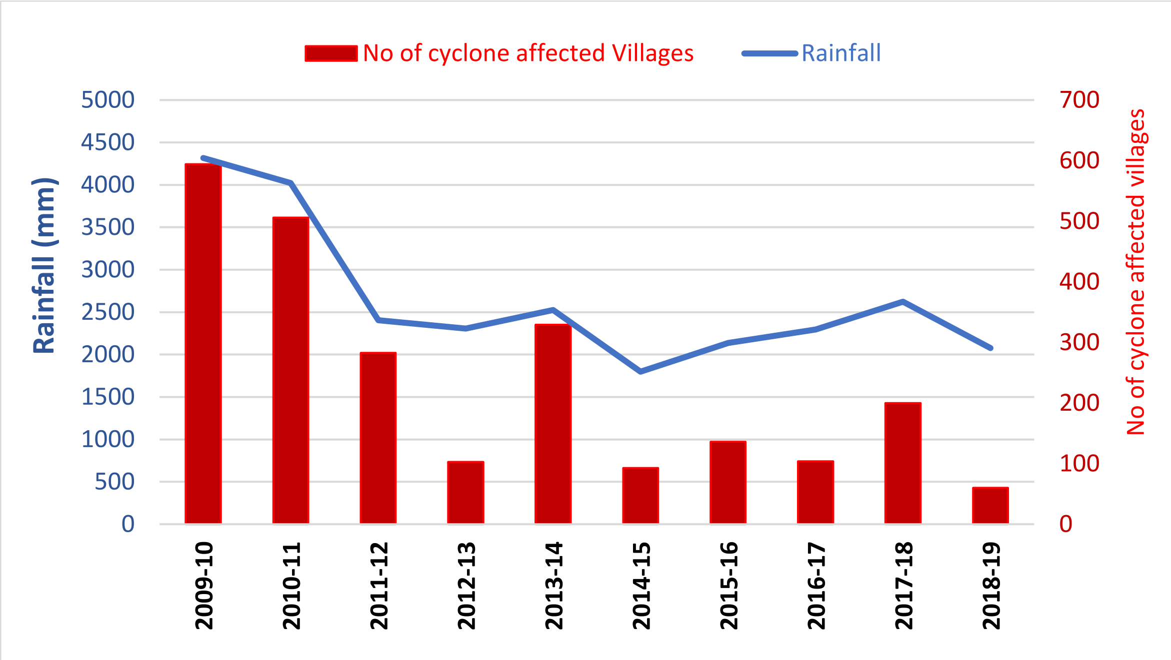

Fig 4. Rainfall and total number of cyclones affected villages (2009-10 to 2018-19)

The affected villages during the past years (2008 - 2009) from the same source recorded as much as 186. Further, during 2004-2005 heavy rain with cyclonic- hailstorm caused reported damage to a large number of houses particularly roofing portion. Horticulture and agriculture crops were also seriously affected by this incident. Data collected by MIRSAC during 2004 and the consequent reports indicated that 15 villages in Aizawl district were highly vulnerable to cyclone.

Floods:

Records on flood incidences in the district is meagre as most of the affected areas are confined to low lying fluvial plains only. Past records (from DM & R Dept., Govt. of Mizoram) of flood that caused disruption to normal life during 2009 - 2010 shows that 15 villages were affected in the Aizawl district. In the consequent years (2010 - 2011), the number of affected villages recorded an increase with as much as 67. Previously, during 1993-1994 heavy rainfall during monsoon season induced flash floods at Keifang and reports on the death of 5 persons was recorded. Similar sources recorded that during 1995-1996, floods caused due to heavy rains resulted in destruction of 60 nos. of local boats and 2000 quintals of paddy crops on the banks of River Tlawng within Sairang village.

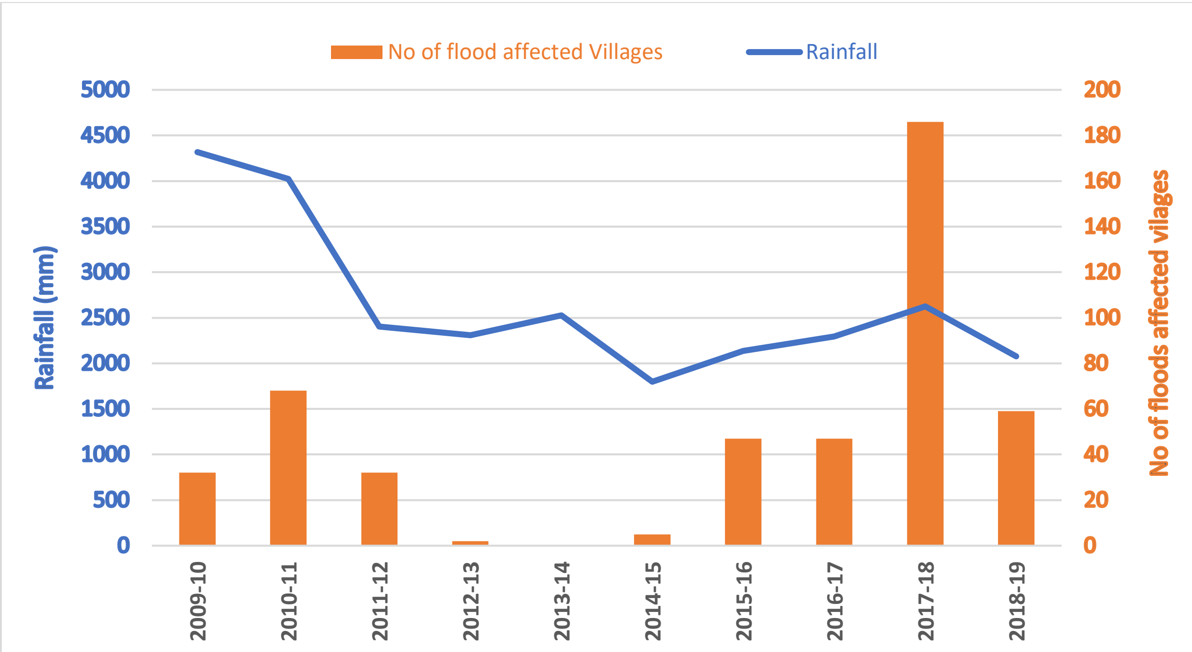

Fig 5. Rainfall and total number of floods affected villages (2009-10 to 2018-19)

In June 2017, Mizoram faces the worst flooding of Tlawng river in 50 years, hundreds were left homeless compelling them to seek refuge in community halls and schools. This happen due to incessant rains amounting to almost 500 mm of rainfall just within the first two weeks.

Approximately 350 houses have been completely submerged by the floods and 8 fatalities in the state. Many other areas have also reported collapsed bridges and roads, which has brought traffic to a complete halt and cutting off interconnectivity of various district headquarters. Many water pipelines in the state have also been severely damaged and the pump house heavily sedimented. The flood also damaged 137 hectares of cultivated areas and 62 fish ponds.

In Tlabung, which falls under the Lunglei District, more than 80 families have been evacuated from their homes, and close to 70 houses have been submerged by the floods, while in Serhmun, over a hundred houses have been swept away by the floods. The people have been shifted to friends' and families' homes and their belongings are being kept in community and church halls.

Statistical analysis:

The results of the statistical analysis with the polynomial quadratic regression model showed that the number of villages affected by landslides (r = 0.80), cyclone (r = 0.88) and hailstorm (r = 0.73) occurrence is significantly correlated with rainfall.

The rainfall anomaly index is also significantly correlated with the number of villages affected by landslides (r = 0.80), cyclone (r = 0.88) and hailstorm (r = 0.72) occurrence. It is clear that in most of the cases, extreme rainfall events are associated with landslide developments, occurrences of floods, cyclones and hailstorms. The maximum occurrences of landslides in most cases can be attributed to lithological reasons, earth cuttings, quaternary deposits (gravel, sand and silt with clay) and lack of proper drainage systems which tends to increase infiltration thereby decreasing the shear strength of the lithologies in the state.

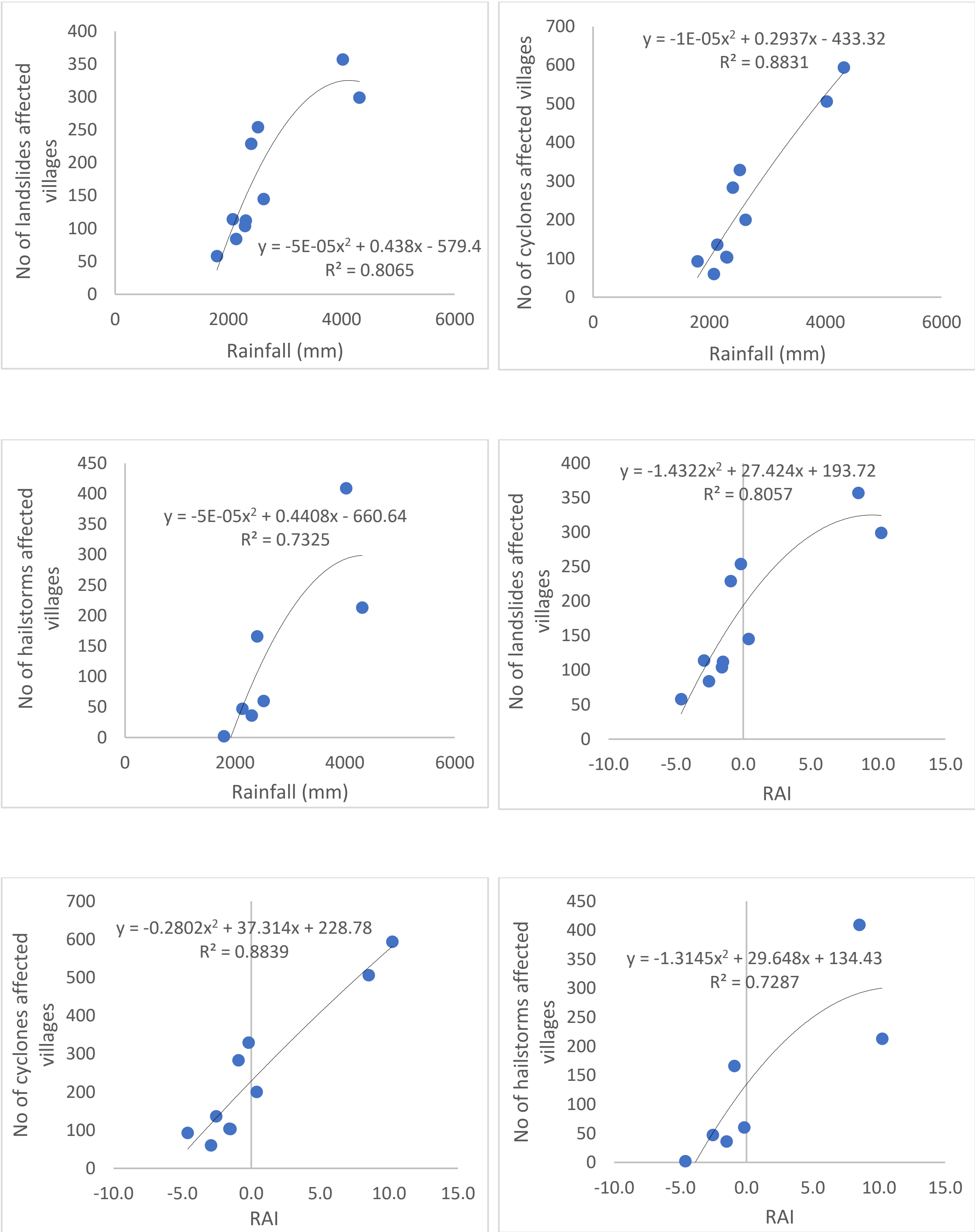

Fig 6. Statistical analysis of hazards in relations to rainfall and rainfall anomaly with polynomial quadratic regression model.

CONCLUSION

Since landslides present a huge risk to the human life and property, studies about their origin, movement, identification, and management become very extremely important for (making something as small as possible/treating something important as unimportant) the losses. An identification and management of landslides will be possible only after the identification of causative factors which are responsible for landslide event. Rainfall has always been a first (or most important) cause in triggering landslides that too at high/higher places with high slope and unstable topography like one in the Himalayas.

In the present study, a relationship has been shown between hazards (landslides, cyclones and hailstorms) with rainfall within the state. Analysis of such recorded data reveals that most of the occurrences and the number of villages being affected increases with heavy rainfall events.

Mizoram, especially the capital city of Aizawl has experienced numerous landslides, which have all too often caused loss of life and the destruction of homes, community buildings, and important infrastructure. Anthropogenic and developmental activities such as slope cutting, filling, and disposing of sewerage and drainage onto slopes in a poorly controlled manner plays a great role in triggering landslides. As such proper implementation and enforcement of **"The Aizawl Municipal Corporation Site Development and Slope Modification Regulations, 2017"**, a very crucial initiatives taken up by the Aizawl Municipal Corporation is the need of the hour to reduce/mitigate hazards especially landslides which in the case of Mizoram are basically anthropogenically triggered.

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Hazard Incidence Pictures

Rockslide at Chanmary West, Aizawl

Stranded travellers, Mizoram

Collapse of retaining wall at Chhinga Veng, Aizawl

Road damaged at Republic Veng, Aizawl

Floods at Sairang Village, Aizawl

House damaged by hailstorms, Mizoram

Landslide at Bawngkawn, Aizawl cutting off vehicular movements

Landslide at Bawngkawn, Aizawl cutting off vehicular movements

Landslide at Tuithiang Veng, Aizawl