Hazard Analysis for Facilitating Community Based Disaster Risk Management of Silchar Town in Assam

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Abstract

Research in the past reveal that communities (local people) inflicted by various disasters are the most ignored sections while formulating disaster risk management strategies. Disaster Management strategies are found to be ineffective at ground level because majority of them are institutional or top-down, which tend to ignore the traditional know-how and skills of the local community, who are the direct victims of various disasters. The The first line responders to disasters are the local community and the part played by themin diminishing vulnerability and building resilience towards disaster are pivotal. Practitioners of Disaster Management universally approve on the crucialrole of local communities towards efficient Disaster Management. One of the important and core components of Disaster Management is to identify potential risks faced by frontline communities in the eventuality of hazard via a risk assessment approach. In-depth evaluation of exposure of communitiesto various hazards and corresponding analysis of vulnerabilities and capacities should form priorities while tackling disaster risks. Motivated by the Community Based Disaster Risk Management (CBDRM) approach of Disaster Management, the present paper focuses on hazard analysis of Silchar Town, in South Assam concerning four hazards viz. earthquake, flood, urban flood and fire based on bottom-up approach involving people's participation. Although a top-down approach hazard analysis of the town exists, it can be further refined by integrating it with hazard analysis obtained by people's participation from the present work.

Keywords: *Hazard, Impact, Exposure, Return Period, Community Based Disaster Risk Management.*

1. Introduction

Disaster Risk Management is of supreme importance in the context of building resilience at the state and national levels. It is found that every year various disaster events have severe impacts onlife and livelihoods resulting ineconomic loss worth billions (GECHS, 2008). Based on socio-economic and physical resilience, disaster impact varies from nation to nation. It has been observed that economic loss in developed countries is extreme due to disasters while developing nations have more human casualties (Rahman, 2010). In such countries, disaster risk is a threat to the poor and has the potential to destroy the economy (World Bank, 2005). As per CRED report (2014), it is observed that frequency of occurrence of disaster events have a rising trendency. Statistics reveal occurrence of 100 disasters per decade (1900-1940) with 2,080 extreme events during the period 1990-2000. Hydrometeorological disasters are also on the rise while the occurrence of geophysical disasters is relatively steady (IPCC, 2007; UNISDR, 2009). As per the CRED (2014) report, Asia is found to be the worst-hit region with the fatality of approximately 88% due to various disasters as against 62% decadal average in 2013.

Research in the past reveal that communities (local people) inflicted by various disasters are the most ignored sections while formulating disaster risk management strategies. Disaster Management strategies are found to be ineffective at ground level because majority of them are institutional or top-down, which tend to ignore the traditional know-how and skills of the local community, who are the direct victims of various disasters. Successful Disaster Management strategies are low, the reason being, at-risk people are neither involved nor their awareness levels channelized. The frontline responders to disasters are the local community and their crucialrole in diminishing vulnerability and building resiliencecannot be ignored. Practitioners of Disaster Management universally approve on the crucial role of local communities towards Disaster Management and building capacity to tackle disaster impacts. Gaillard (2010) emphasises community participation atthe local level for capacity building, vulnerability reduction and risk assessment, for building resilience against disasters. Community Based Disaster Risk Reduction (CBDRR) empowersthe local population to resist unforeseen disasters. Community Based Disaster Risk Management (CBDRM) gained relevance and significance from frequent disasters occurrence (Krummacher, 2014; UNDP, 2016). A top-down approach of Disaster Risk Reduction without involvement of the local community cannotmanage disasters efficiently. As is evident from disaster literature, top-down approach is institutional driven without the involvement of at-risk communities mainlycomprising of expertsand various stake-holders, who are responsible towards formulating various Disaster Management (DM) plans and programs. The traditional know-how and skills of local community are not utilised in this approach. However, the communitiesare the best judgeof their needs and ground realities in eventuality of hazards, and thus, their participation is of utmost importance in the CBDRM approach (Krummacher, 2014; Shaw, 2012). The bottom-up approach involves the communities as one of the stakeholders in devising the DM programs. Consequently, the traditional know-how and skills of the communities are incorporated in DM plans and policies in the bottom-up approach which benefits better disaster resilience. According to Abarquez and Murshed (2004), CBDRM is a progressive development of public safety and community resilience against disasters. Moreover, it leads toan efficient, effective, equitable and sustainable development of the community.

To identify potential risks to a community, risk assessment in CBDRM is a diagnostic approach to tackle those risks (Abarquez and Murshed, 2004). Risk assessment is the process of identifying probable hazards and how they affect the most vulnerable local people (Enarsonet al., 2003). They are the direct victims and they can identify the various hazard related aspects that arise in solutions in the eventuality of a hazard. In order to build resilience, the local people can best suggest precise solutions to build resilience. In-depth evaluation of exposure of communities to various hazards and corresponding analysis of vulnerabilities and capacities should form priorities while tackling disaster risks (Abarquez and Murshed, 2004). Proper risk assessment isthus considered a vital tool for saving lives during disaster (Enarsonet al., 2003).

The present paper focuses on hazard analysis of four hazards, viz. earthquake, flood, urban flood and fire hazard of Silchar Town in South Assam based on people's perspective (Gupta and Barman, 2022). Silchar Town due to its geographical disposition and unplanned urbanization is vulnerable to the above-named hazards. Considering the immense significance of CBDRM in proper Disaster Management, a people based participatory approach has been adopted to carry out the hazard analysis of Silchar Town concerning the four hazards.

2. The Study Area and Methodology

The present study is carried outusing exploratory research involving participatory research techniques for Silchar Town in Assam, India. Silchar Town, isan emerging urban locale, located in the Cachar district is in south Assam.It lies between 92°24”E and 93°15”E longitude and 24°22” and 25° 8”N latitude. Figure 1 depicts the geographical disposition of the study area.

The geographical disposition of Silchar Town makes it vulnerableto various natural disasters and history of the town demonstrates it being affected by earthquakes and riverine floods. Moreover, rapid unplanned urbanization makes it vulnerable to artificial hazards like urban floods, road accidents and fire. Silchar has been affected by earthquakes since 1548 with subsequent events of recurrent earthquakes recorded over past years. (Silchar Atlas, 2014-15). Silchar town lies in Zone V, the zone with the highest seismic risk. As per District Disaster Management Authority (DDMA), Cachar, Assam, most of the earthquakes that occurred in the region had a magnitude of 7 and above with highest 8.7in 1950 with its epicentre in the vicinity of Assam, causing large extent of direct or indirect damage to Silchar Town. Another major problem confronted by the people of the town is the problem of urban floods. Water logging results during the rainy seasons and riverine floods due to the inundation of flood plains by the intricate topology of river Barak and its tributaries. The town had witnessed major floods in 1986, 1991 and 2004 (Silchar Atlas, 2014-15).

The target population in the present study are people of Silchar town residing in 28 existing municipal wards. An additional dummy ward referred to as ward 29 in the study is the area considered inthe immediate periphery of 1km of the defined municipal area. A population count of 2,00,000 is taken as the universe of the study with 1,80,000 people approximately residing in 28 municipal wards and the remaining 20,000 in the immediate periphery of 1 km as is obtained by corroborating with government census data 2010 and voter list 2015-17. 1500 people comprising of individual, member of the family, ward and the Silchar Town per se forms the urban community who are targeted initially. Participatory research technique of CBDRM is used for data collection.

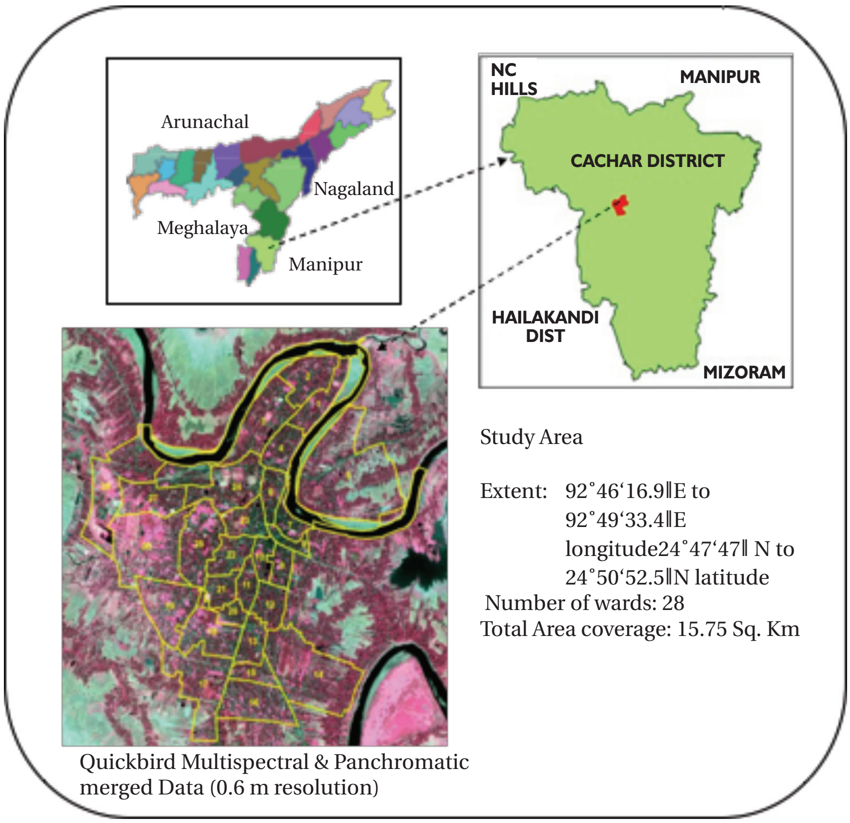

Fig.1 Location Map of Study Area of Silchar Town

(Source: Silchar Atlas, 2014-15, DDMA, Cachar)

using a semi-structured interview. Field Survey cum Focus Group Interview for every member is conducted for obtaining data. Pretesting of the questioninaire by pilot test, test-retest and spilthalf methods are carried out involving 40 random respondents from universe of the study. Corrections in dimensionality, directionality, uniformity and sequencing together with Cornbach's Alpha test for inter and intra reliability of Likert scaled data for $\alpha = 0.789$ is considered prioir to administration of the questionnaire. Respondents are sensitised about the purpose, directions to mark responses, ethics, disaster terminologies, translation to local language for rightful engagement and interpretation of questions. Every group comprised of 30 members on average and 22 such Focus Group Interviews areconducted, thereby obtaining total of 660 responses. Of the 660 responses, 600 are retained based on the missing value test. Guided Personal Interview is carried outon 840 respondents from 29 wards. Every ward is taken to be astratum from which respondents are randomly selected with an average of 30 people taken from each ward. Amongst 840 responses, 301 are retained based on the missing value test (Gupta and Barman, 2022). Missing value test using IBM SPSS21 is employed in dataset of this survey work as respondents are found to skip questions or do not wish to reveal information. The test at significant ststitical level helped in elimiation of cases and not of considered varibles of the study so that error in analytical model be minimal. Thus, a sample size of 901 is obtained for the present study.

For hazard estimation in the study, product of three factors, viz. impact, exposure and return periodare considered. The impact is evaluated as a function of damage from loss of life, property, life and environment. Impact assessment for each hazard is quantified by mathematical formulation obtained fromits driving factors which is subsequently transformed into multiple regression equation where in impact is the dependent variable and its causative factors as independent variables. Earthquake impact assessment is formulated with variables about questions 4, 5, 7 and 8 of Section F of the questionnaire (Appendix A). Label names of variables are *Dwstrngtr1, Dwlosseq1', Dwlosseq2', Dwlosseq3', Dwlosseq4', Dwlosseq5', Dwlosseq6', Dwlosseq7', Dwpplklldeq1, Dwinjrdeq1* (Appendix B). Variables about the impact of the flood are questions 2, 3, 5, 7 and 8 of Section F of the questionnaire (Appendix A). Flood impact variables are labelled as *Dwfldlvl1, Dwdurfld1, Dwlossf1', Dwlossf2', Dwlossf3', Dwlossf4', Dwlossf5', Dwlossf6', Dwlossf7', Dwpplklldf1, Dwinjrdf1* (Appendix B) **(Gupta, 2022)**. Similarly, forthe impact of urban flood variables considered for the impact of the urban flood are questions 2, 3, 5, 7 and 8 of Section F of the questionnaire. The considered variables are labelled in statical models as *Dwfldlvl1, Dwdurfld1, Dwlossuf1', Dwlossuf2', Dwlossuf3', Dwlossuf4', Dwlossuf5', Dwlossuf6', Dwlossuf7', Dwpplklldufl, Dwinjrduf1* (Appendix B). Lastly, for measuring the impact of urban fire, variables considered for statistical analysis are *Dwstrngtr1, Dwlossfr1', Dwlossfr2', Dwlossfr3', Dwlossfr4', Dwlossfr5', Dwlossfr6', Dwlossfr7', Dwpplklldfr1, Dwinjrdfr1* (Appendix B).

Respective variables described above for impact analysis of hazards under study are considered to be linearly associated which is expressed by mathematical formulation given by Eqn. 1 to Eqn. 4. Label name of impact variables for each hazard is *Impcteq1* - earthquake, *Impctf1*- flood, *Impctuf1*- urban flood and *Impctfr1*- fire respectively

*Impcteq1=Dwstrngtr1+Dwlosseq1'+Dwlossueq2'+Dwlosseq3'+Dwlosseq4'+Dwlosseq5'+ Dwlosseq6'+6*Dwlosseq7'+Dwpplklldeq1+Dwinjrdeq1(1)*

*Impctf1=Dwfldlvl1+Dwdurfld1+Dwlossf1'+Dwlossf2'+Dwlossf3'+Dwlossf4'+Dwl ossf5'+Dwlossf6'+6*Dwlossf7'+Dwpplklldf1+Dwinjrdf1(2)*

*Impctuf1=Dwfldlvl1+Dwdurfld1+Dwlossuf1'+Dwlossuf2'+Dwlossuf3'+Dwlossuf4'+ Dwlossuf5'+Dwlossuf6'+6*Dwlossuf7'+Dwpplkllduf1+Dwinjrduf1(3)*

*Impctfr1=Dwstrngtr1+Dwlossfr1'+Dwlossfr2'+Dwlossfr3'+Dwlossfr4'+Dwlossfr 5'+Dwlossfr6'+6*Dwlossfr7'+Dwpplklldfr1+Dwinjrdfr1(4)*

3. Experimental Results and Analysis

From mathematical formulations in Eqn. 6.1 to Eqn. 6.4, impact assessment for earthquake, flood, urban flood and fire hazard is considered to be a multi-variable function that is associated linearly without signifying how these variables affect the impact for each type of hazard. The dataset is thus subjected to multiple regression analysis resulting in a statistical model with impact as the dependent variable and all other determining variables as independent variables. Consequently, statistically significant standardised coefficients are used to as certain how the independent variables affect the dependent variable. The relationship between each predictor variable is established through multiple linear regression analysis and how the variance of each independent variable uniquely affects the variance in the prediction of the dependent variable is determined using Analysis of Variance (ANOVA). Based on the outcome of multiple regression analysis impact variables in Eqn. 1 to Eqn. 4 are converted into new impact variables *ImpcteqR, ImpctfR1, ImpctufR and ImpctfrR* as given by Eqn. 5 to Eqn. 8 respectively.

The model summary and ANOVA table for impact assessment of earthquake hazard are given in Table 1(a) and Table 1(b) respectively.

Table 1 (a) Model summary of impact for earthquake									
Model Summary									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.879[a]	.874	.869	.02423	.874	2976.931	6	895	.000
a. Predictors: *(Constant), Dwinjrdeq1, Dwlosseq3', Dwstrngtr1, Dwlosseq5', Dwlosseq4', Dwpplklldeq1*									

Table 1 (b) ANOVA table of impact for earthquake						
ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	285.787	6	47.631	2976.931	.000[b]
	Residual	14.321	895	.016		
	Total	300.108	901			
a. Dependent Variable: Impcteq1						
b. Predictors: *(Constant), Dwinjrdeq1, Dwlosseq3', Dwstrngtr1, Dwlosseq5', Dwlosseq4', Dwpplklldeq1*						

For earthquake impact, standardised coefficients are presented in Table 2.

Table 2 Standardised coefficients of impact for earthquake							
Model		Standardized Coefficients	t value	Sig. Part	Correlation	Collinearity Statistics	
		Beta			Tolerance	VIF	
1	(Constant)			0			
	Dwstrngtr1	0.642	67.839	.000	0.612	0.908	1.101
	Dwlosseq3'	0.506	84.901	.000	0.458	0.821	1.220
	Dwlosseq4'	0.405	32.601	.000	0.352	0.757	1.321
	Dwlosseq5'	0.083	56.982	.000	0.081	0.955	1.047
	Dwpplklldeq1	0.220	34.672	.000	0.187	0.723	1.383
	Dwinjrdeq1	0.287	112.332	.000	0.242	0.714	1.401
a. Dependent Variable: *Impcteq1*							

From Tables 1 (a), Table 1 (b) and Table 2. it is observed that, F (6, 895) = 2976.931, $p< 0.05$ having adjusted R^2= 0.869, indicating high goodness of fit for the model. F-test at $p<0.05$ justifies a statistically significant variance in the dependent variable *Impcteq1* by variance of independent variables taken as a whole inferred from ANOVA table. t-test significantly demonstrates the variance in Impcteq1 by unique variance of each independent variable for the model. Earthquake intensity labelled as *Dwstrngtr1* is found to exert the most positive effect followed by cracks in buildings denoted by *Dwlosseq3*' house collapse labelled as *Dwlosseq4*' and injuries Dwinjrdeq1 on the dependent variable *Impcteq1*. Impact for earthquake *Impcteq1* is transformed into a new regressed equation with standardised coefficients labelled as *ImpcteqR* given by Eqn. 5.

*ImpcteqR=0.642*Dwstrngtr1+0.001*Dwlosseq1'+0.001*Dwlosseq2'+0.506*Dwlosseq3'+0.405*Dwlosseq4'+0.083*Dwlosseq5'+Dwlosseq6'+6*Dwlosseq7'+0.220*Dwpplklld-eq1+0.287*Dwinjrdeq1(5)*

Model summary and ANOVA table for assessment of the impact of flood hazard, are presented in Table 3 (a) and Table 3 (b) respectively.

Table 3 (a) Model summary of impact for flood

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.873[a]	.868	.865	.001114	.865	786.009	8	893	.000

a. Predictors: *(Constant), Dwinjrdf1, Dwlossf5', Dwdurfld1, Dwlossf3', Dwpplklldf1, Dwfldlvl1, Dwlossf1', Dwlossf4'*

Table 3 (b) ANOVA table of impact for flood

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1276.480	8	159.560	786.009	.000[b]
	Residual	182.012	893	.203		
	Total	1458.492	901			

a. Dependent Variable: Impctf1

b. Predictors: *(Constant), Dwinjrdf1, Dwlossf5', Dwdurfld1, Dwlossf3', Dwpplklldf1, Dwfldlvl1, Dwlossf1', Dwlossf4'*

Standardised coefficients of flood impact are presented in Table 4.

Table 4 Standardised coefficients of impact for flood

Model		Standardized Coefficients	t value	Sig.	Correlation	Collinearity Statistics	
		Beta			Part	Tolerance	VIF
1	(Constant)						
	Dwfldlvl1	0.359	87.253	.000	0.332	0.744	1.344
	Dwdurfld1	0.457	18.195	.000	0.421	0.823	1.216
	Dwlossf1’	0.158	52.614	.000	0.123	0.645	1.550
	Dwlossf3’	0.062	54.203	.020	0.034	0.496	2.016
	Dwlossf4’	0.170	65.902	.000	0.147	0.901	1.109
	Dwlossf5’	0.212	42.176	.000	0.189	0.686	1.456
	Dwpplklldf1	0.182	37.630	.000	0.158	0.302	3.310
	Dwinjrdf1	0.147	83.118	.000	0.108	0.689	1.451
a. Dependent Variable: *Impctf1*							

From Table 3 (a), Table 3 (b) and Table 4, it is observed that, F (8, 893) = 786.009, $p< 0.05$ having adjusted R2= 0.865, showing high goodness of fit for the model. F-test at $p<0.05$ indicates the variance of the dependent variable *Impctf1* statistically significant by the variance of independent variables taken as a whole inferred from the ANOVA table. t-test also demonstrates significant variance in *Impctf1* by unique variance of each independent variable of the model. Flood duration *Dwdurfld1* is found to exert the most positive effect followed by the level of flood *Dwfldlvl1*, cracks in road *Dwlossf5*’, crop damage *Dwlossf1’*, number of people killed *Dwpplklldf1* and number of people injured *Dwinjrdf1* on the dependent variable *Impctf1*. *Impctf1* is transformed into a regression equation withthe new variable of impact for flood denoted by ImpctfR1 as given in Eqn. 6.

*ImpctfR1=0.359*Dwfldlvl1+0.457*Dwdurfld1+0.158*Dwlossf1’+0.001*Dwlossf2’ +0.062*Dwlossf3’+0.170*Dwlossf4’+0.212*Dwlossf5’+0.001*Dwlossf6’+0.001*6* Dw lossf7’+0.182*Dwpplklldf1+0.147*Dwinjrdf1 (6)*

In the case of urban flood hazard, model summary and ANOVA table for impact assessment are presented in Table 5 (a) and Table 5 (b) respectively.

Table 5 (a) Model summary of impact for urban flood

Model Summary									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.987[a]	.983	.976	.32912	.983	657.890	9	892	.000

a. Predictors: *(Constant), Dwinjrduf1, Dwlossuf2', Dwlossuf3', Dwlossuf4', Dwdurfld1, Dwfldlvl1, Dwlossuf1', Dwpplklldduf1, Dwlossuf5*

Table 5 (b) ANOVA table of impact for urban flood

ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1107.237	9	123.026	657.890	.000[b]
	Residual	167.234	892	.187		
	Total	1274.471	901			

a. Dependent Variable: Impctuf1

b. Predictors: *(Constant), Dwinjrduf1, Dwlossuf2', Dwlossuf3', Dwlossuf4', Dwdurfld1, Dwfldlvl1, Dwlossuf1', Dwpplklldduf1, Dwlossuf5'*

Standardised coefficients for impact assessment of urban flood hazards are presented in Table 6.

Table 6 Standardised coefficients of impact for urban flood

Model		Standardized Coefficients	t value	Sig.		Collinearity Statistics	
		Beta			Part	Tolerance	VIF
1	(Constant)						
	Dwfldlvl1	0.385	81.612	.000	0.332	0.744	1.344
	Dwdurfld1	0.491	77.216	.000	0.445	0.822	1.216
	Dwlossuf1'	0.171	45.876	.000	0.137	0.645	1.55
	Dwlossuf2'	0.089	50.630	.000	0.088	0.984	1.016
	Dwlossuf3'	0.067	48.873	.000	0.063	0.902	1.109
	Dwlossuf4'	0.149	32.983	.000	0.123	0.687	1.456
	Dwlossuf5'	0.229	21.764	.;000	0.171	0.558	1.793
	Dwpplklldduf1	0.111	89.973	.000	0.085	0.587	1.704
	Dwinjrduf1	0.159	96.376	.000	0.119	0.556	1.797

a. Dependent Variable: Impctuf1

From Table 5 (a), Table 5 (b) and Table 6, it is observed that, F (21,880) = 657.890, $p< 0.05$ having adjusted $R^2= 0.976$, demonstratinga high goodness of fit for the model. F-test done at $p<0.05$ reveals statistically significant variance of the dependent variable *Impctuf1* by variance of independent variables as inferred from ANOVA table. The t-test of the model demonstrates variance in *Impctuf1* by the unique variance of each independent variable. Urban flood duration, *Dwdurfld1* is found to exert the maximum positive effect followed by urban flood level *Dwfldlvl1*, crop damage due to urban flood *Dwlossuf1'*, house damage *Dwlossuf4'*, damage ofhousehold items *Dwlossuf2'*, cracks in road *Dwlossuf5'*, number of people killed *Dwpplkllduf1* and number of people injured *Dwinjrduf1* on the dependent variable *Impctuf1*. Impctuf1is transformed into a regressed equation with standardised coefficients into a new variable of impact for urban flood labelled as *ImpctufR* given by Eqn.7.

*ImpctufR=0.385*Dwfldlvl+0.491*Dwdurfld+0.171*Dwlosuf1'+ 0.089*Dwlossuf2'+0.067*Dwlossuf3'+0.149*Dwlossuf4'+0.229*Dwlo suf5'+0.001*Dwlossuf6'+6*Dwlossuf7'+0.111*Dwpplkllduf1+0.159*Dwinjrduf1(7)*

The model summary and ANOVA table for impact assessment of fire are presented in Table 7(a) and Table 7 (b) respectively.

Table 7 (a) Model summary of impact for fire

Model Summary									
Model	R	R Square	Adjus-ed R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.981[a]	.977	.974	.00239	.977	.	6	895	.000

a. Dependent variable: Impctfr1

b. Predictors (Constant), *Dwstrngtr1, Dwinjrdfr1, Dwlossfr6', Dwlossfr4', Dwlossfr1', Dwpplklldfr1*

Table 7 (b) ANOVA table of impact for fire

ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	318.113	6	53.019	2650.941	.000[b]
	Residual	18.330	895	.020		
	Total	336.443	901			

a. Dependent Variable: Impctfr1

b. Predictors: (Constant), Dwstrngtr1, Dwinjrdfr1, Dwlossfr6', Dwlossfr4', Dwlossfr1', Dwpplklldfr1

The standardised coefficients of impact assessment of fire hazards are presented in Table 8.

Table 8 Standardised coefficients of impact for fire

Model		Standardized Coefficients	t value	Sig.		Collinearity Statistics	
		Beta			Part	Tolerance	VIF
1	(Constant)						
	Dwlossfr1'	0.19	34.178	.000	0.182	0.918	1.089
	Dwlossfr4'	0.428	78.823	.000	0.412	0.926	1.08
	Dwlossfr6'	0.079	34.108	.000	0.077	0.948	1.055
	Dwpplklldfr1	0.283	7.098	.000	0.246	0.753	1.328
	Dwinjrdfr1	0.295	23.304	.000	0.255	0.747	1.339
	Dwstrngtr1	0.608	41.612	.000	0.581	0.911	1.097
a. Dependent Variable: *Impctfr1*							

From Table 7 (a), Table 7 (b) and Table 8, it is observed that, $F(6, 895) = 2650.941$, $p< 0.05$ having adjusted $R^2= 0.974$, demonstrating a high goodness of fit for the model. F-test done at $p<0.05$ shows significant statistical variance in the dependent variable *Impctfr1* by variance of independent variables inferred from ANOVA table. The t-test of the model reveals the variance in *Impctfr1* by the unique variance of each independent variable of the model. Fire intensity, *Dwstrngtr1* exerts the maximum positive effect followed by the complete gutting of house *Dwlossfr4'*, people injured *Dwinjrdfr1* and killed *Dwpplklldfr1*. *Impctfr1* is transformed into a regressed equation into a new variable for the impact of fire with standardised coefficients labelled as *ImpctfrR* given by Eqn. 8.

*ImpctfrR=0.608*Dwstrngtr1+0.190*Dwlossfr1'+0.001*Dwlossfr2'+0.001Dwlossfr3' +0.428*Dwlossfr4'+0.001*Dwlossfr5'+0.079*Dwlossfr6'+6*Dwlossfr7'+0.283 *Dwpplklldfr1+ 0.295*Dwinjrdfr1 (8)*

Table 9 Ward wise mean and standard deviation of impact, exposure and return period of considered hazards

WARD NO.		Impcte-qR	Impct-fR1	Impc-tufR	Impct-frR	Dwppl-expeq	Dwp-plexpf	Dwppl-expuf	Dwppl-expfr	Dwr-trnprd-eq	Dwr-trnprdf	Dwrtrn-prduf	Dwrtrn-prdfr
1	Mean	2.4843	2.9313	2.9624	2.5476	4.30	4.20	4.10	1.90	2.80	3.20	3.60	1.20
	Std. Deviation	.53479	.57420	.55834	.62220	.494	.317	.524	.316	.789	.317	.966	.632

2	Mean	2.4976	2.5714	2.7632	2.3251	5.00	4.20	4.30	3.50	2.30	2.70	3.30	1.20
	Std. Deviation	.50385	.59762	.63818	.66806	.000	.033	.949	.581	.483	.823	.483	.422
3	Mean	2.7035	3.2138	3.3699	2.3562	4.60	4.50	3.80	1.90	2.80	2.40	3.50	1.20
	Std. Deviation	.39374	.49266	.47798	.40580	.966	.972	.033	.316	.422	.699	.850	.422
4	Mean	2.3541	2.1971	2.3604	2.1705	4.70	3.60	3.70	1.50	2.90	2.10	2.80	1.10
	Std. Deviation	.39090	.70143	.74804	.45634	.483	.516	.949	.527	.316	.568	.789	.316
25	Mean	2.5568	2.7898	2.8762	2.3764	4.90	4.60	3.00	1.60	2.00	2.20	3.30	1.80
	Std. Deviation	.46047	.60646	.52509	.39564	.316	.516	.414	.516	.667	.229	1.337	.789
6	Mean	2.7155	2.7733	2.9022	2.4774	4.60	3.90	3.80	1.80	1.60	1.90	3.40	1.20
	Std. Deviation	.37340	.40568	.43987	.35148	.265	.738	.632	.422	.966	.316	.966	.422
7	Mean	2.3288	2.6844	2.8147	2.2342	5.00	4.30	4.00	1.80	2.10	2.60	3.80	1.20
	Std. Deviation	.39598	.70497	.71156	.45221	.000	.483	.000	.422	.876	.265	.422	.422
8	Mean	2.3490	2.9047	3.1173	2.1914	4.90	4.20	4.10	1.50	2.30	1.90	3.60	1.10
	Std. Deviation	.40879	.42640	.45142	.40750	.316	.422	.316	.527	.675	.316	.699	.316
9	Mean	2.3221	2.7357	2.8057	2.2950	4.40	1.30	3.50	2.30	1.50	1.50	4.20	1.10
	Std. Deviation	.44579	.59514	.62020	.35256	.265	.483	.080	1.494	.527	.527	.789	.316
10	Mean	2.2883	2.6420	2.7350	2.2342	4.10	1.40	3.30	1.40	1.50	1.30	2.70	1.10
	Std. Deviation	.43020	.63813	.61986	.45221	.449	.516	.160	.516	.527	.483	.675	.316
11	Mean	2.1532	2.2332	2.3633	2.1444	4.60	2.20	3.70	1.50	2.30	1.70	2.90	1.10
	Std. Deviation	.44542	.68910	.71281	.41073	.966	.317	.949	.972	.675	.483	.876	.316
12	Mean	2.4334	2.3119	2.4687	2.2660	4.90	2.60	3.40	1.20	2.30	1.70	3.10	1.20
	Std. Deviation	.45560	.44898	.44634	.27358	.316	.843	.516	.422	.675	.483	.568	.422
13	Mean	2.2544	2.0346	2.1654	2.1016	4.10	2.30	2.80	1.30	2.60	1.90	2.90	1.00
	Std. Deviation	.40334	.57365	.56257	.33821	.197	.823	.919	.483	.516	.568	.568	.000
14	Mean	2.3455	2.8627	3.1084	2.1924	4.80	1.70	3.90	1.10	2.30	1.50	3.80	1.00
	Std. Deviation	.34776	.62460	.63459	.43841	.422	.823	.568	.316	.823	.527	.422	.000
15	Mean	2.0890	2.3179	2.5460	2.0698	4.90	2.40	3.50	1.10	2.50	1.20	3.10	1.10
	Std. Deviation	.35688	.56187	.55641	.34171	.316	.075	.527	.316	.707	.422	.994	.316
16	Mean	2.1177	2.7961	3.0459	1.9709	5.00	2.40	4.60	1.50	1.90	1.50	3.30	1.00
	Std. Deviation	.38591	.58522	.65779	.33897	.000	.843	.516	.527	.876	.527	.483	.000
17	Mean	2.1260	2.9296	3.1134	1.9234	5.00	2.40	4.60	1.20	1.90	1.50	3.30	1.10
	Std. Deviation	.23397	.48313	.51609	.20674	.000	.699	.516	.422	.994	.527	.483	.316

18	Mean	2.2695	2.3697	2.5156	1.9992	4.80	3.20	4.10	1.00	1.90	1.20	3.10	2.80
	Std. Deviation	.40479	.46318	.49228	.36668	.422	.632	.738	.000	.876	.422	.994	.422
19	Mean	2.5618	2.4471	2.6435	2.4743	4.90	3.40	4.40	1.10	1.50	1.10	2.80	2.40
	Std. Deviation	.48035	.74715	.78576	.43334	.316	.516	.516	.316	.850	.316	.687	.843
20	Mean	2.2544	2.3698	2.5459	1.9166	4.20	3.20	3.60	2.50	1.70	1.40	3.80	2.10
	Std. Deviation	.40334	.50917	.54175	.25636	.229	.229	.174	1.354	.675	.516	.229	.876
21	Mean	2.1263	2.2967	2.4990	2.0497	4.10	3.60	3.40	1.30	2.00	1.60	3.20	1.30
	Std. Deviation	.55668	.83965	.92024	.42577	.663	.516	.075	.483	.816	.516	.229	.483
22	Mean	2.0097	2.1453	2.3229	1.9088	4.10	3.40	4.10	1.20	1.60	1.60	2.70	1.10
	Std. Deviation	.72667	.61379	.67751	.57188	.994	.075	.994	.422	.843	.516	.418	.316
23	Mean	2.1092	1.7988	1.9358	1.8841	4.70	3.20	3.60	1.30	2.30	1.50	3.10	1.10
	Std. Deviation	.40968	.40594	.43589	.40191	.483	.919	.075	.483	.483	.527	.197	.316
24	Mean	2.7272	2.2954	2.4518	2.1598	4.60	3.70	3.90	1.30	2.50	1.70	2.30	1.10
	Std. Deviation	.37898	.19942	.19169	.31397	.516	.494	.994	.483	.850	.483	.675	.316
25	Mean	1.8018	2.1448	2.3074	1.6126	3.70	1.40	2.40	1.30	1.90	1.30	3.20	1.10
	Std. Deviation	.65898	.65344	.70205	.50055	.703	.699	.174	.483	.876	.483	.317	.316
26	Mean	1.9926	2.4262	2.6094	1.8673	2.80	2.30	3.10	1.10	2.20	2.10	2.90	1.20
	Std. Deviation	.75677	.69871	.75042	.71296	.549	.949	.197	.316	.919	.663	.449	.422
27	Mean	1.9302	2.3602	2.5384	1.7342	4.70	2.60	3.40	1.10	2.20	1.70	3.30	1.10
	Std. Deviation	.49936	.83911	.90119	.44862	.483	.265	.699	.316	.789	.483	.252	.316
28	Mean	2.2310	2.5622	2.7527	2.1238	4.70	3.80	3.70	1.40	2.60	2.30	3.60	1.30
	Std. Deviation	.34666	.45942	.48810	.37777	.483	.789	.675	.516	.516	.483	.699	.483
29	Mean	2.0637	2.3583	2.5016	1.9768	3.57	2.90	2.90	1.24	2.00	1.76	2.00	1.38
	Std. Deviation	.68393	.90494	.92849	.67834	.535	.995	.091	.436	.949	.091	.949	.669
Silchar	Mean	2.2746	2.4952	2.6544	2.1182	4.47	3.06	3.65	1.50	2.13	1.79	3.15	1.30
	Std. Deviation	.51526	.66830	.68974	.48627	.066	.271	.033	.794	.818	.851	.056	.604

Table 9 represents the mean and standard deviation of impact, exposure and return period for each of the considered hazards. Ward wise mean value of impact, exposure and return period for the considered hazards for various wards of the Silchar Town are presented in Fig. 1 to Fig. 3. Impact for an earthquake is labelled *ImpcteqR*, exposure for earthquake denoted by *Dwpplexpeq* and return period for an earthquake by Dwrtrn-prdeq. Impact for flood is given by variable *ImpctfR1*, exposure for flood by *Dwpplexpf* and return period of flood denoted by *Dwrtrnprdf*. Impact for urban flood is denoted by variable name *ImpctufR*, exposure for urban flood labelled as *Dwpplexpuf* and return period for urban flood by variable name *Dwrtrnprduf*. Fire hazard impact is measured by *ImpctfrR*, exposure for fire denoted by variable name *Dwpplexpfr* and return period for fire by *Dwrtrnprdfr*.

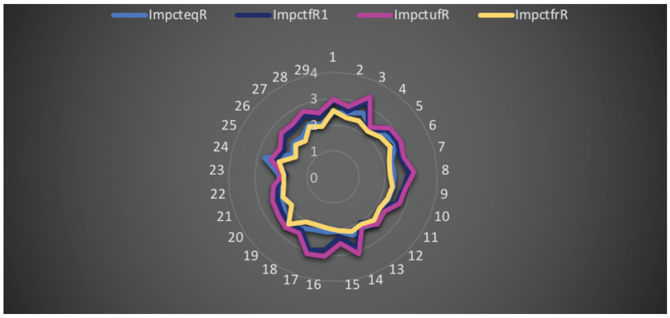

Fig. 1 Ward wise mean value of the impact of considered hazards

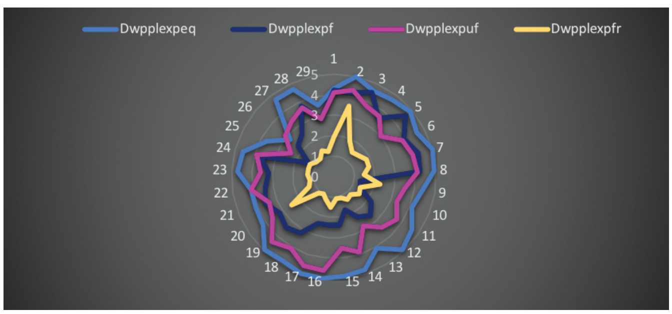

Fig. 2 Ward wise mean value of exposure of considered hazards

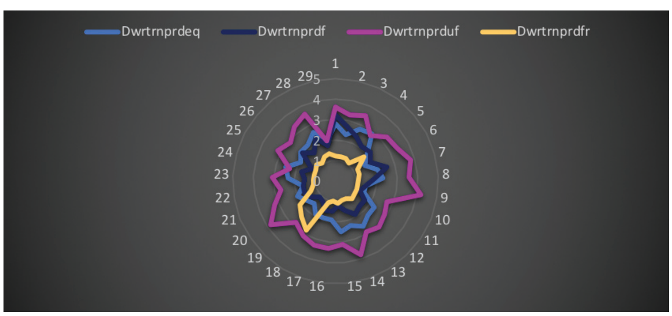

Fig. 3 Ward wise mean value of return period of considered hazards

In the present study, the hazard is considered as a probabilistic type of hazard and is expressed as a function of impact, exposure and return period of the hazard given by Eqn. 9 to Eqn. 12. The variables *PrHQ1R, PrHFL1R, PrHUFL1R* and *PrHFR1R* denotes the intensity of earthquake, flood, urban flood and fire hazard respectively.

*PrHQ1R=ImpcteqR*Dwrtrnprdeq* Dwpplexpeq* (9)

*PrHFL1R=ImpctfR*Dwrtrnprdf *Dwpplexpf* (10)

*PrHUFL1R=ImpctufR*Dwrtrnprduf *Dwpplexpuf* (11)

*PrHFRR=ImpctfrR*Dwrtrnprdfr* Dwpplexpfr* (12)

Carreno et al. (2005, 2006) designed risk and vulnerability indices using quantitative or qualitative indicators involving measurement on five levels low, incipient, significant, outstanding, and optimal from 1 (low) to 5 (optimal) for risk evaluation and management. Assessment of hazards and vulnerability with estimatimation of potential impacts for anexposure is methodologically widely adopted. In this study, earthquake indices are calculated on impact, exposure and return period for earthquake denoted by variable name *ImpcteqR*, *Dwpplexpeq* and return period denoted by variable name *Dwrtrnprdeq*. For flood, hazard indices are calculated on impact *ImpctfR1*, exposure *Dwpplexpf* and return period *Dwrtrnprdf*. In the case of urban flood, indices are prepared considering impact *ImpctufR*, exposure *Dwpplexpuf* and return period *Dwrtrnprduf*. For fire hazard, indices are prepared considering impact for fire *ImpctfrR*, exposure Dwpplexpfr and return period *Dwrtrnprdfr*. The mean value of hazard estimate with standard deviation at significant level is obtained for each wardwise observations and then the difference in range from the lowest wards wise mean value score to the highest is evenly distributed with equal weightage into three scales of low, medium and high. Table 10 presents indices for considered hazards.

Table 10 Indices of impact, exposure and return period of considered hazards

Variables	L	M	H
ImpcteqR	1.8018-2.1102	2.1103-2.4186	2.4187-2.7272
ImpctfR1	1.7988-2.2704	2.2705-2.7420	2.7421-3.2138
ImpctufR	1.9358-2.4138	2.4139-2.8918	2.8919-3.3699
ImpctfrR	1.6216-1.9302	1.9303-2.2388	2.2389-2.5476
Dwpplexpeq	2.8-3.5333	3.5333-4.2666	4.2667-5.000

Dwpplexpf	1.3-2.4	2.5-3.5	3.6-4.6
Dwpplexpuf	2.4-3.1333	3.1334-3.8666	3.8667-4.6
Dwpplexpfr	1-1.8333	1.8334-2.6666	2.6667-3.5
Dwrtrnprdeq	1.5-1.9666	1.9667-2.4332	2.4333-2.9
Dwrtrnprdf	1.1-1.8-	1.9-2.5	2.6-3.2
Dwrtrnprduf	2-2.7333	2.7334-3.4666	3.4667-4.2
Dwrtrnprdfr	1-1.6	1.7-2.2	2.3-2.8

According to indices for earthquake, low impact level is considered in range 1.8018 to 2.1102, medium in range 2.1103 to 2.4186 and high range 2.4187 to 2.7272. Exposure is considered low in the range 2.8 to 3.5333, a medium between 3.5333 to 4.2666 and high in the range of 4.2667 to 5.000. Index of return period is considered low in range 1.5 to 1.9666, medium in the range of 1.9667 to 2.4332 and high between 2.4333 to 2.9. For flood, the impact is marked as low if in the range of1.7988 to 2.2704, a medium between 2.2705 to 2.7420 and a high between 2.7421 to 3.2138. Index of exposure is low in interval 1.3 to 2.4, a medium between 2.5 to 3.5 and high in range 3.6 to 4.6. The return period is considered low in the range of 1.1 to 1.8, a medium between 1.9 to 2.5 and a high between 2.6 to 3.2. Indices ofthe urban flood arelow if in range 1.9358 to 2.41381, medium in the range of 2.4139 to 2.8918 and high in range 2.8919 to 3.3699. Exposure is low if it lies in the range of 2.4 to 3.1333, a medium between 3.1334 to 3.8666 and a high between 3.8667 to 4.6. Index of return period is low between 2 to 2.7333, medium 2.7334 to 3.4666 and high 3.4667 to 4.2. For fire, the impact is marked low between 1.6216 to 1.9302, the medium between 1.9303 to 2.2388 and high between 2.2389 to 2.5476. Index of exposure is considered low in interval 1 to 1.8333, the medium between 1.8334 to 2.6666 and high between 2.6667 to 3.5. The return period is set as low if in range 1 to 1.6, medium in range 1.7 to 2.2 and high in range 2.3 to 2.8.

Based onthe grouping of mean value into low, medium and high indices of impact, exposure and return period for earthquake, flood, urban flood and fire hazard of each ward of Silchar Town is presented in Table 11.

The Zonation map of impact, exposure and return period with geographical North and in the scale of 1cm = 1km is prepared for the considered hazards for different wards of Silchar Town depicted in Fig. 4 to Fig. 11. Colour-code is assigned as green denoting low, yellow as medium and red colour signifying high.

Table 11 Impact, exposure and return period indices of considered hazards for various wards of Silchar Town

WARD NO.		ImpcteqR	ImpctfR1	ImpctufR	ImpctfrR	Dwpplexpeq	Dwpplexpf	Dwpplexpuf	Dwpplexpfr	Dwrtrnprdeq	Dwrtrnprdf	Dwrtrnprduf	Dwrtrnprdfr
1	Mean	2.4843	2.9313	2.9624	2.5476	4.3	4.2	4.1	1.9	2.8	3.2	3.6	1.2
	Index	H	H	H	H	H	H	H	M	H	H	H	L
2	Mean	2.4976	2.5714	2.7632	2.3251	5	4.2	4.3	3.5	2.3	2.7	3.3	1.2
	Index	H	M	M	H	H	H	H	H	M	H	M	L
3	Mean	2.7035	3.2138	3.3699	2.3562	4.6	4.5	3.8	1.9	2.8	2.4	3.5	1.2
	Index	H	H	H	H	H	H	M	M	H	M	H	L
4	Mean	2.3541	2.1971	2.3604	2.1705	4.7	3.6	3.7	1.5	2.9	2.1	2.8	1.1
	Index	M	L	M	M	H	H	M	L	H	M	M	L
5	Mean	2.5568	2.7898	2.8762	2.3764	4.9	4.6	3	1.6	2	2.2	3.3	1.8
	Index	H	H	M	H	H	H	L	L	M	M	M	M
6	Mean	2.7155	2.7733	2.9022	2.4774	4.6	3.9	3.8	1.8	1.6	1.9	3.4	1.2
	Index	H	H	H	H	H	H	M	L	L	M	M	L
7	Mean	2.3288	2.6844	2.8147	2.2342	5	4.3	4	1.8	2.1	2.6	3.8	1.2
	Index	M	M	M	M	H	H	H	L	M	H	H	L
8	Mean	2.349	2.9047	3.1173	2.1914	4.9	4.2	4.1	1.5	2.3	1.9	3.6	1.1
	Index	M	H	H	M	H	H	H	L	M	M	H	L
9	Mean	2.3221	2.7357	2.8057	2.295	4.4	1.3	3.5	2.3	1.5	1.5	4.2	1.1
	Index	M	M	M	H	H	L	M	M	L	L	H	L
10	Mean	2.2883	2.642	2.735	2.2342	4.1	1.4	3.3	1.4	1.5	1.3	2.7	1.1
	Index	M	M	M	M	M	L	M	L	L	L	L	L
11	Mean	2.1532	2.2332	2.3633	2.1444	4.6	2.2	3.7	1.5	2.3	1.7	2.9	1.1
	Index	M	L	L	M	H	L	M	L	M	L	M	L
12	Mean	2.4334	2.3119	2.4687	2.266	4.9	2.6	3.4	1.2	2.3	1.7	3.1	1.2
	Index	H	M	M	H	H	M	M	L	M	L	M	L
13	Mean	2.2544	2.0346	2.1654	2.1016	4.1	2.3	2.8	1.3	2.6	1.9	2.9	1
	Index	H	L	L	M	M	L	L	L	H	M	M	L
14	Mean	2.3455	2.8627	3.1084	2.1924	4.8	1.7	3.9	1.1	2.3	1.5	3.8	1
	Index	M	H	H	M	H	L	H	L	M	L	H	L
15	Mean	2.089	2.3179	2.546	2.0698	4.9	2.4	3.5	1.1	2.5	1.2	3.1	1.1
	Index	L	M	M	M	H	L	M	L	H	L	M	L
16	Mean	2.1177	2.7961	3.0459	1.9709	5	2.4	4.6	1.5	1.9	1.5	3.3	1
	Index	M	H	H	M	H	L	H	L	L	L	M	L
17	Mean	2.126	2.9296	3.1134	1.9234	5	2.4	4.6	1.2	1.9	1.5	3.3	1.1
	Index	M	H	H	L	H	L	H	L	L	L	M	L
18	Mean	2.2695	2.3697	2.5156	1.9992	4.8	3.2	4.1	1	1.9	1.2	3.1	2.8
	Index	M	M	M	M	H	M	H	L	L	L	M	H

19	Mean	2.5618	2.4471	2.6435	2.4743	4.9	3.4	4.4	1.1	1.5	1.1	2.8	2.4
	Index	H	M	M	H	H	M	H	L	L	L	M	H
20	Mean	2.2544	2.3698	2.5459	1.9166	4.2	3.2	3.6	2.5	1.7	1.4	3.8	2.1
	Index	M	M	M	L	M	M	M	M	L	L	H	M
21	Mean	2.1263	2.2967	2.499	2.0497	4.1	3.6	3.4	1.3	2	1.6	3.2	1.3
	Index	M	M	M	M	M	H	M	L	M	L	M	L
22	Mean	2.0097	2.1453	2.3229	1.9088	4.1	3.4	4.1	1.2	1.6	1.6	2.7	1.1
	Index	L	L	L	L	M	M	H	L	L	L	L	L
23	Mean	2.1092	1.7988	1.9358	1.8841	4.7	3.2	3.6	1.3	2.3	1.5	3.1	1.1
	Index	L	L	L	L	H	M	M	L	M	L	M	L
24	Mean	2.7272	2.2954	2.4518	2.1598	4.6	3.7	3.9	1.3	2.5	1.7	2.3	1.1
	Index	H	M	M	M	H	H	H	L	H	L	L	L
25	Mean	1.8018	2.1448	2.3074	1.6126	3.7	1.4	2.4	1.3	1.9	1.3	3.2	1.1
	Index	L	L	L	L	M	L	L	L	L	L	M	L
26	Mean	1.9926	2.4262	2.6094	1.8673	2.8	2.3	3.1	1.1	2.2	2.1	2.9	1.2
	Index	L	M	M	L	L	L	L	L	M	M	M	L
27	Mean	1.9302	2.3602	2.5384	1.7342	4.7	2.6	3.4	1.1	2.2	1.7	3.3	1.1
	Index	L	M	M	L	H	M	M	L	M	L	M	L
28	Mean	2.231	2.5622	2.7527	2.1238	4.7	3.8	3.7	1.4	2.6	2.3	3.6	1.3
	Index	M	M	M	M	H	H	M	L	H	M	H	L
29	Mean	2.0637	2.3583	2.5016	1.9768	3.57	2.9	2.9	1.24	2	1.76	2	1.38
	Index	L	M	M	M	M	M	L	L	M	L	L	L
30	Mean	2.2746	2.4952	2.6544	2.1182	4.47	3.06	3.65	1.5	2.13	1.79	3.15	1.3
	Index	M	M	M	M	H	M	M	L	M	L	M	L

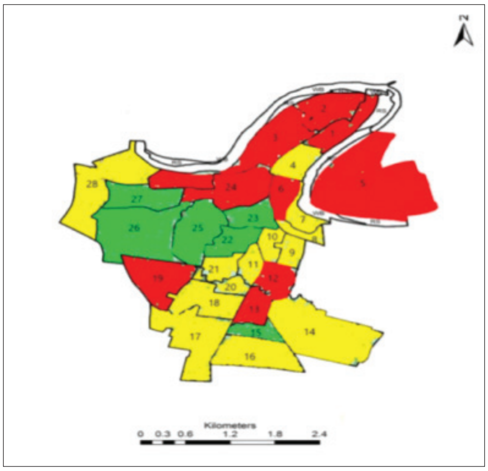

Fig. 4 Impact mapping for earthquake

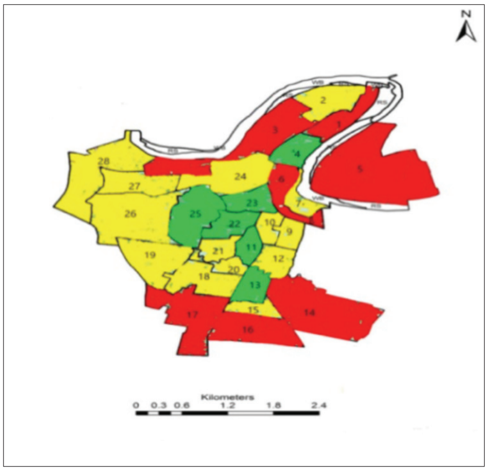

Fig. 5 Impact mapping for flood

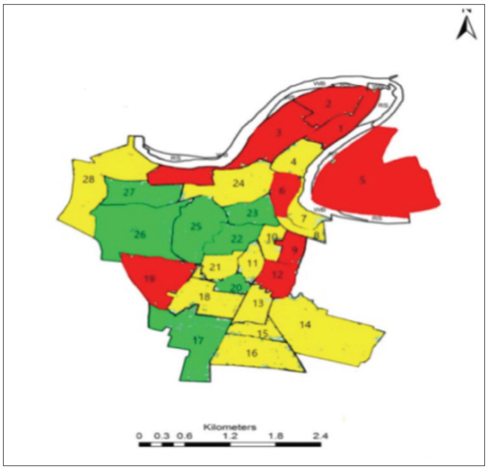

Fig. 6 Impact mapping for urban flood

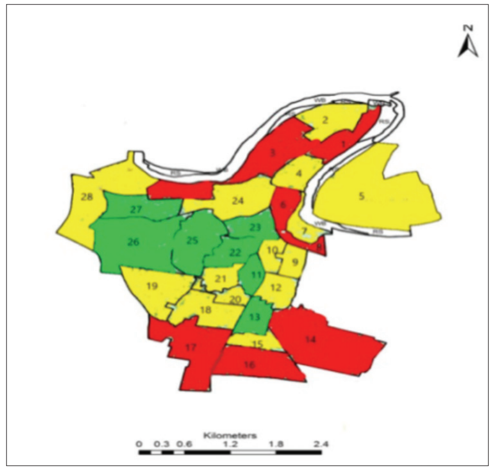

Fig. 7 Impact mapping for fire

Medium		Low		High	

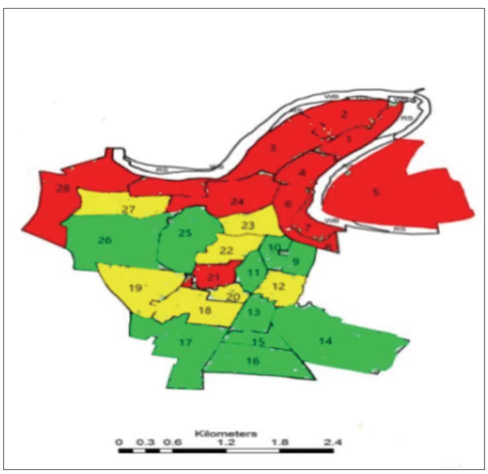

Fig. 8 Exposure mapping for earthquake

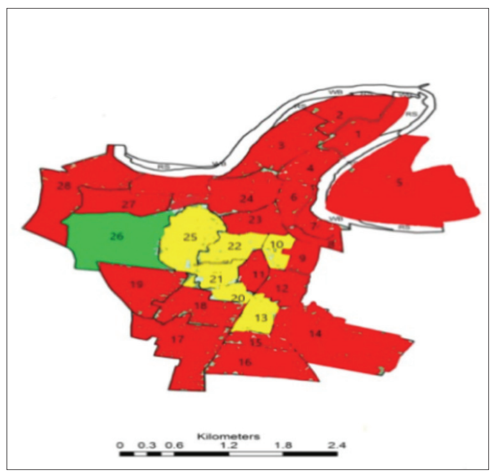

Fig. 9 Exposure mapping for flood

Low		Medium		High	

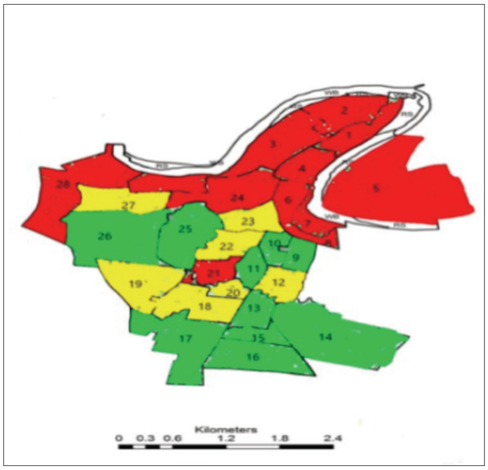

Fig. 10 Exposure mapping for urban flood

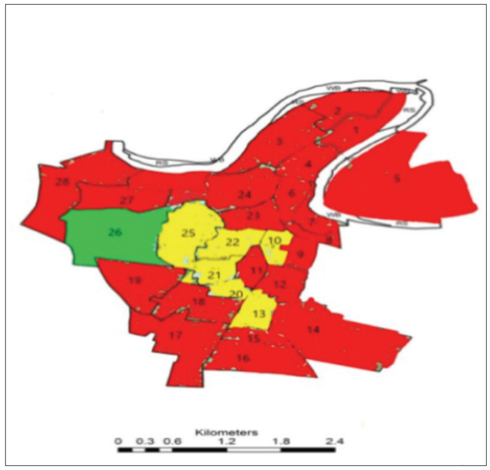

Fig. 11 Exposure mapping for fire

Impact of earthquake is found low in wards 15, 22, 23, 25, 26, 27 and 29, medium in wards 4, 7, 8, 9, 10, 11, 14, 16, 17, 18, 20, 21 and 28, while high in 1, 2, 3, 5, 6, 12, 13, 19 and 24. Impact of earthquake for Silchar Town is found medium. Impact of flood is observed low in wards 4, 11, 13, 22, 23 and 25, medium in wards 2, 7, 9, 10, 12, 15, 18, 19, 20, 21, 24, 26, 27, 28 and 29 while high in wards 1, 3, 5, 6, 8, 14, 16 and 17. Impact of flood for Silchar Town is found medium. Low impact of urban flood is observed in wards 11, 13, 22, 23 and 25, medium in wards 2, 4, 5, 7, 9, 10, 12, 15, 18, 19, 20, 21, 24, 26, 27, 28 and 29 while high in wards 1, 3, 6, 8, 14, 16 and 17. Silchar Town has a medium impact onthe urban flood. Fire impact is low in wards 17, 20, 22, 23, 25, 26 and 27, medium in wards 4, 7, 8, 10, 11, 13, 14, 15, 16, 18, 21, 24, 28 and 29 while high in wards 1, 2, 3, 5, 6, 9, 12 and 19. Fire impact for Silchar Town is found medium.

Low exposure for earthquake is observed inward 26 only, medium in wards 10, 13, 20, 21, 22, 25 and 29 while high exposure is found in wards 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 14, 15, 16, 17, 18, 19, 23, 24, 27 and 28. For Silchar Town, exposure to earthquakes is found high. Flood exposure is found low in wards 9, 10, 11, 13, 14, 15, 16, 17, 25 and 26, medium in wards 12, 18, 19, 20, 22, 23, 27 and 29 while high in wards 1, 2, 3, 4, 5, 6, 7, 8, 21. 24 and 28. Exposure due to flood for Silchar Town is observed medium. For urban flood, low exposure is found in wards 5, 13, 25, 26 and 29, medium in wards 3, 4, 6, 9, 10, 11, 12, 15, 20, 21, 23, 27 and 28 while high in wards 1, 2, 7, 8, 14, 16, 17, 18, 19, 22 and 24. Overall for Silchar Town, exposure due to urban flood hazards is found medium. For fire hazard, low exposure is found in wards 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 24, 25, 26, 27, 28 and 29, medium in wards 1, 3, 9 and 20 while high inward 2 only. Exposure to fire hazards for Silchar Town is found low. Low return period of earthquake is observed in wards 6, 9, 10, 16, 17, 18, 19, 20, 22 and 25, medium in wards 2, 5, 7, 8, 11, 12, 14, 21, 23, 26, 27 and 29 while high in wards 1, 3, 4, 13, 15, 24 and 28. The return period of earthquake for Silchar Town is found medium. Low return period of flood is found in wards 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 27 and 29, medium in wards 3, 4, 5, 6, 8, 13, 26 and 28 while high in wards 1, 2 and 7. The return period of flood for Silchar Town is found below. Low return period of urban flood is found in wards 10, 22, 24 and 29, medium in wards 2, 4, 5, 6, 11, 12, 13, 15, 16, 17, 18, 19, 21, 23, 25, 26 and 27 while high return period in wards 1, 3, 7, 8, 9, 14, 20, and 28. The return period of urban flood for Silchar Town is found medium.

Low return period of fire is found in wards 1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 21, 22, 23, 24, 25, 26, 27, 28 and 29, medium in wards 5 and 20 while high return period in wards 18 and 19. The return period of fire for Silchar Town is found low.

Table 12 gives the mean and standard deviation of intensity for the considered hazards for various wards of Silchar Town. Figure 12 represents the mean value of the intensity of hazard with standard deviation for different wards of Silchar Town.

Table 12 Ward wise mean value and standard deviation of intensity of considered hazards

WARD NO.		PrHQ1R	PrHFL1R	PrHUFL1R	PrHFR1R
1	Mean	31.3185	47.5390	48.9561	6.1081
	Std. Deviation	0.2117	0.4344	.0193	0.4115
2	Mean	28.4910	30.1874	38.6983	9.2809
	Std. Deviation	.3867	.2963	.2465	.7076
3	Mean	36.4622	36.7271	47.0159	5.5449
	Std. Deviation	.36507	.16662	.6270	.0821
4	Mean	31.9470	17.4751	27.1818	3.7759
	Std. Deviation	.84076	.08641	.6781	.6589

5	Mean	24.5910	30.4843	32.9469	7.1904
	Std. Deviation	.04533	.37540	.0493	.4267
6	Mean	19.1811	21.2286	40.1592	5.5818
	Std. Deviation	.56673	.39048	.4523	.9223
7	Mean	23.4740	31.0836	43.2548	4.4684
	Std. Deviation	.88705	.93703	.4416	.9044
8	Mean	26.5961	22.6530	47.1048	3.6371
	Std. Deviation	.36547	.16718	.6113	.7926
9	Mean	14.6433	5.6301	43.6960	5.5152
	Std. Deviation	.52852	.93788	.9580	.39725
10	Mean	13.8153	4.8629	26.2422	3.3389
	Std. Deviation	.34977	.28653	.6660	.38885
11	Mean	23.9344	8.1720	25.1124	3.3961
	Std. Deviation	.85974	.21435	.6894	.94595
12	Mean	27.7609	9.3981	26.4782	3.2340
	Std. Deviation	.78382	.02744	.4416	.43182
13	Mean	25.2643	8.6356	18.1938	2.6829
	Std. Deviation	.67603	.42414	.71126	.90520
14	Mean	26.4930	6.6203	47.0530	2.4755
	Std. Deviation	.40982	.85939	.71035	.18128
15	Mean	25.5584	6.8268	28.3058	2.4288
	Std. Deviation	.22088	.52208	.21172	.68581
16	Mean	19.6645	9.9831	47.2488	3.0148
	Std. Deviation	.21867	.51263	.98188	.36851
17	Mean	19.9590	10.2883	46.7235	2.4619
	Std. Deviation	.28244	.79561	.04875	.80056
18	Mean	21.5241	8.8223	31.4258	5.5350
	Std. Deviation	.27771	.71171	.61019	.08831
19	Mean	18.8027	9.4190	34.3432	6.7680
	Std. Deviation	.36780	.44222	.80771	.52864
20	Mean	15.9590	10.6004	34.2264	10.6021
	Std. Deviation	.00089	.40286	.19064	.00773
21	Mean	18.9979	14.2104	27.8498	3.8573
	Std. Deviation	.81182	.73740	.01557	.16920

22	Mean	14.0152	11.8537	25.3246	3.0464
	Std. Deviation	.62785	.73963	.99684	.31719
23	Mean	22.2784	8.6839	22.9798	2.6304
	Std. Deviation	.25361	.54732	.88344	.20023
24	Mean	30.9146	15.2546	22.1205	2.9994
	Std. Deviation	.98510	.96222	.69962	.13280
25	Mean	16.0936	3.8783	18.0564	2.2698
	Std. Deviation	.68323	.57221	.57357	.05224
26	Mean	15.8934	8.7023	23.8068	2.4961
	Std. Deviation	.53057	.55699	.27638	.42624
27	Mean	20.1276	11.2444	28.8665	2.1540
	Std. Deviation	.35504	.01823	.23793	.17747
28	Mean	26.6269	22.0142	36.5166	3.6483
	Std. Deviation	.39292	.95960	.32657	.32507
29	Mean	15.9533	12.7997	15.4929	4.1872
	Std. Deviation	.93995	.42685	.62327	.60950
Silchar	Mean	22.3883	15.2829	32.3347	4.2836
	Std. Deviation	.61150	.44524	.08521	.57725

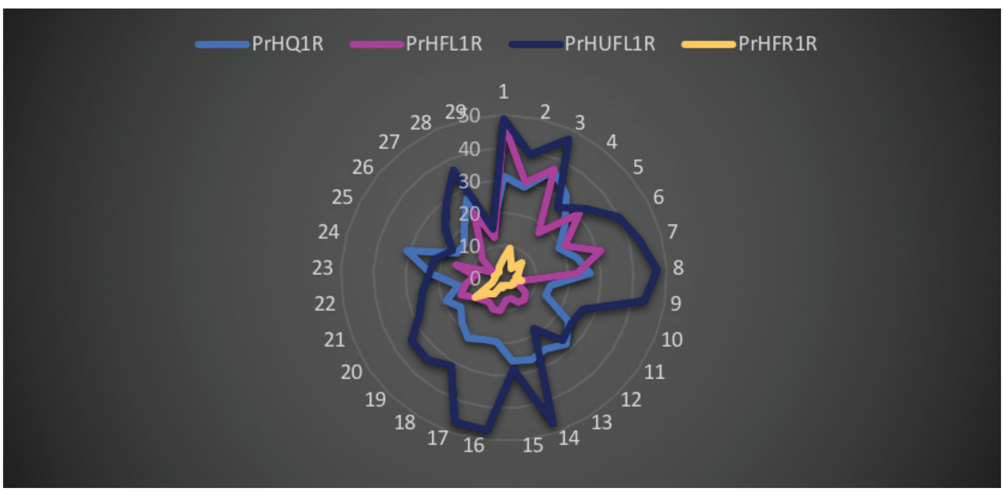

Fig. 12 Ward wise mean value of intensity of hazards

Table 13 records indices of considered hazards for different wards of Silchar Town. The indices are graded into three categories low, medium and high. The indices are calculated based on the mean value using descriptive statistical analysis using IBM SPSS 21 Low severity of earthquake is considered if the meanvalue lies between 13.8153 to 21.3642, medium in range 21.3643 to 28.9131 and high in range 28.9132 to 36.4622. The low intensity of flood hazard is considered if the mean value lies between 3.873 to 18.4283, medium in range 21.3643 to 28.9131 and high in range 32.9837 to 47.539.

For urban flood low intensity is considered if the mean value lies between 15.4929 to 26.6473, medium in range 26.6474 to 37.8017 and high in range 37.8018 to 48.9561. Fire hazard is of low intensity if mean value between 2.154 to 4.9700, medium if it is in the interval 4.9701 to 7.7860 and high in the interval 7.7861 to 10.6020.

Table 13 Indices of the intensity of considered hazards

Variables	L	M	H
PrHQ1R	13.8153-21.3642	21.3643-28.9131	28.9132-36.4622
PrHFL1R	3.873-18.4283	18.4284-32.9836	32.9837-47.539
PrHUFL1R	15.4929-26.6473	26.6474-37.8017	37.8018-48.9561
PrHFR1R	2.154-4.9700	4.9701-7.7860	7.7861-10.6020

Indices representing the strength of the earthquake, flood, urban flood and fire hazard for each ward of Silchar Town are given in Table 14.

Table 14 Ward wise indices of intensity of considered hazards for Silchar Town

WARD NO.		PrHQ1R	PrHFL1R	PrHUFL1R	PrHFR1R
1	Mean	31.3185	47.539	48.9561	6.1081
	Index	H	H	H	M
2	Mean	28.491	30.1874	38.6983	9.2809
	Index	M	M	M	H
3	Mean	36.4622	36.7271	47.0159	5.5449
	Index	H	H	H	M
4	Mean	31.947	17.4751	27.1818	3.7759
	Index	H	L	M	L

5	Mean	24.591	30.4843	32.9469	7.1904
	Index	M	M	M	H
6	Mean	19.1811	21.2286	40.1592	5.5818
	Index	L	M	H	M
7	Mean	23.474	31.0836	43.2548	4.4684
	Index	M	M	H	L
8	Mean	26.5961	22.653	47.1048	3.6371
	Index	M	M	H	L
9	Mean	14.6433	5.6301	43.696	5.5152
	Index	L	L	H	M
10	Mean	13.8153	4.8629	26.2422	3.3389
	Index	L	L	L	L
11	Mean	23.9344	8.172	25.1124	3.3961
	Index	M	L	L	L
12	Mean	27.7609	9.3981	26.4782	3.234
	Index	M	L	L	L
13	Mean	25.2643	8.6356	18.1938	2.6829
	Index	M	L	L	L
14	Mean	26.493	6.6203	47.053	2.4755
	Index	M	L	H	L
15	Mean	25.5584	6.8268	28.3058	2.4288
	Index	M	L	M	L
16	Mean	19.6645	9.9831	47.2488	3.0148
	Index	L	L	H	L
17	Mean	19.959	10.2883	46.7235	2.4619
	Index	L	L	H	L
18	Mean	21.5241	8.8223	31.4258	5.535
	Index	M	L	M	M
19	Mean	18.8027	9.419	34.3432	6.768
	Index	L	L	M	M
20	Mean	15.959	10.6004	34.2264	10.6021
	Index	L	L	M	H
21	Mean	18.9979	14.2104	27.8498	3.8573
	Index	L	L	M	L
22	Mean	14.0152	11.8537	25.3246	3.0464
	Index	L	L	L	L

23	Mean	22.2784	8.6839	22.9798	2.6304
	Index	M	L	L	L
24	Mean	30.9146	15.2546	22.1205	2.9994
	Index	H	L	L	L
25	Mean	16.0936	3.8783	18.0564	2.2698
	Index	L	L	L	L
26	Mean	15.8934	8.7023	23.8068	2.4961
	Index	L	L	L	L
27	Mean	20.1276	11.2444	28.8665	2.154
	Index	L	L	M	L
28	Mean	26.6269	22.0142	36.5166	3.6483
	Index	M	M	M	L
29	Mean	15.9533	12.7997	15.4929	4.1872
	Index	L	L	L	L
Silchar	Mean	22.3883	15.2829	32.3347	4.2836
	Index	M	L	M	L

Based on indices developed for considered hazards, hazard mapping of Silchar Town for various wards is done. Colour-code is used to signify indices. Green colour indicates the low intensity of hazard, yellow indicates medium and red indicates high. Fig.13 to Fig.16 represents hazard mapping for earthquake, flood, urban flood and fire respectively for different wards of Silchar Town. For earthquake, low intensity is found in wards 6, 9, 10, 16, 17, 19, 20, 21, 22, 25, 26, 27 and 29, medium in wards 2, 5, 7, 8, 11, 12, 13, 14, 15, 18, 23 and 28 while high in wards 1, 3, 4 and 24. Overall earthquake hazard intensity for Silchar Town is medium. Low intensity of flood hazard is found in wards 4, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27 and 29, medium in wards 2, 5, 6, 7, 8 and 28 while high in wards 1 and 3 only. Overall hazard intensity due to flood for Silchar Town is found medium. For urban flood, low intensity is found in wards 10, 11, 12, 13, 22, 23, 24, 25, 26 and 29, medium in wards 2, 4, 5, 15, 18, 19, 20, 21, 27 and 28 while high in wards 1, 3, 6, 7, 8, 9, 14, 16 and 17. Urban Flood hazard intensity for Silchar Town is found medium. Low intensity of fire hazard is found in wards 4, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 21, 22, 23, 24, 25, 26, 27, 28 and 29, medium in wards 1, 3, 6, 9, 18 and 19 while high in wards 2, 5 and 20. Fire hazard intensity for Silchar Town as a whole is found low.

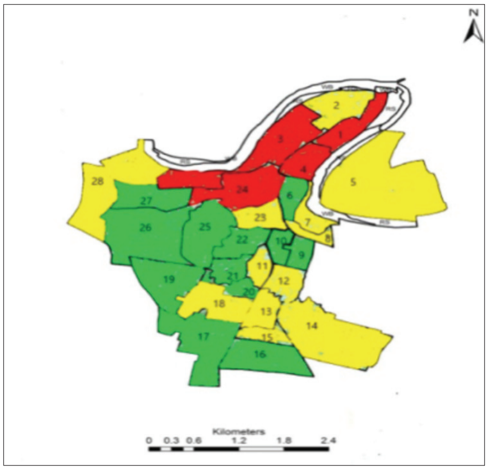

Fig. 13 Earthquake hazard mapping

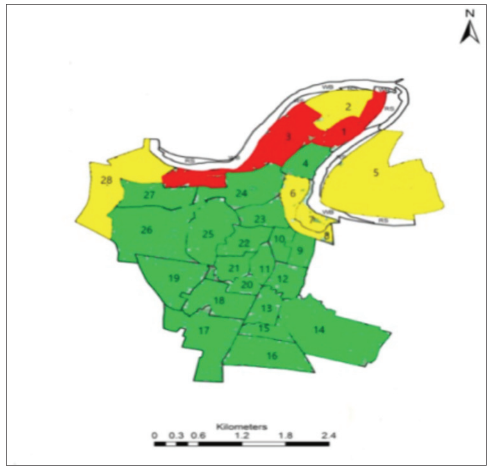

Fig. 14 Flood hazard mapping

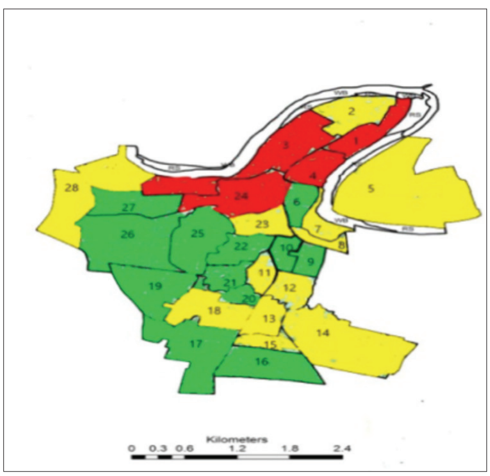

Fig. 15 Urban flood hazard mapping

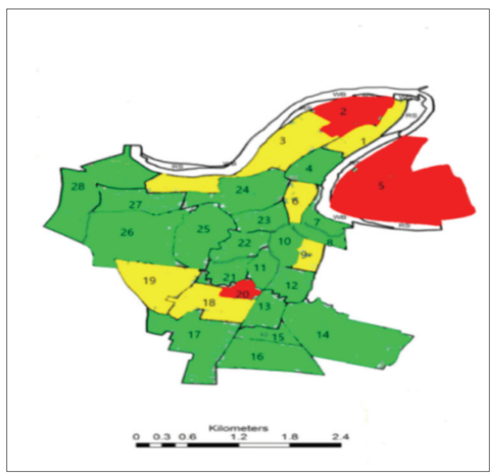

Fig. 16 Fire hazard mapping

Low **Medium** **High**

4. Conclusion

For hazard assessment based on people's perception, a probabilistic approach of hazard measurement is adopted considering impact, exposure and return period as influencing factors. Impact of hazarde valuates potential and or actual loss, damage in terms of death, injury, loss of socio-economic assets, psychological health, degradation of environmental resources etc. Exposure of hazard ascertains several people or sections of the population who are subjected to loss or damage due to it. Greater is the exposure and at-risk elements of a vulnerable community greater are the risk due to disaster. Finally, the return period measures the frequency of occurrence of a hazard in a given time frame. Greater is the return period more is the disaster risk. In impact assessment of earthquake, intensity expressed by tremor indicators in common parlance is found to exert the maximum positive effect followed by cracks in the building, house collapse and injuries. For impact assessment of flood, duration of flood exerts the maximum positive effect followed by flood level, cracks in the road, damage of crops, people killed and injured. Impact assessment of urban flood reveals that duration of urban flood exerts the maximum positive effect followed by flood level, damage of crops, house and household items, cracks in the road, people killed and injured. In the case of fire, impact assessment reveals the intensity of fire exerts maximum positive effect followed by the complete gutting of a house, people injured and killed. From statistical models and analyses, it is found that the impact of earthquake, flood, urban flood and fire is medium for Silchar Town as a whole with inter ward variations of low, medium and high. Results also suggest that exposure of people of Silchar Town is high for earthquake, medium for flood and urban flood while the low for fire hazard with inter ward variations. The return period of the earthquake and urban flood is medium, low for flood and fire hazard with inter ward variations is also inferred from statistical analysis. Based on impact, exposure and return period, hazard assessment of Silchar Town show a low value for flood and fire while the medium value for earthquake and urban flood with inter ward variations. To shape the Disaster Management policy of a country, Community Based Disaster Risk Reduction Plans have immense potential, consequently, the institutional nature of DM policies needs modification. Policy makers, risk administrators and experts need to comprehend the significance of community participation for formulating DM plans and programs. Local-level policies need to be integrated with people's know how and expertise on risk prevention, protection, mitigation and rehabilitation. The government needs to undertake programs to enhance disaster literacy amongst people to build a disaster-resilient community. Most importantly, the institutional level gapcan be bridged by involving the community in strategizing Disaster Risk Management policies. The present study is the first of its kind hazard analysis study in the context of a multi-hazard scenario based on a bottom-up approach. Observations and inferences from the present study need to be compared with other existing institutional-based studies on Disaster Risk Management for Silchar Town. The existing DM programs for Silchar Town can be further consolidatedby integrating them with the present study for a feasible and flexible people-centric DM program for the region.

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APPENDIX A

Excerpts of Questionnaire

Questionnaire on Community Based Disaster Risk Management
(Individual Response)

Kindly mark (√) against every response in appropriate place/cells for sharing your valued opinion. AOT means All of these, **NOT** means None of these in the questionnaire.

F. Disaster information of my ward

1	People in my ward are effected by	Earthquake	Flood	Urban Flood	Fire	AOT	NOT
2	Flood level in my ward	Ankle deep	Knee level	Waist level	Chest level or more .		
3	Duration of flood in my ward	1-2 days	3-4 days	4-5 days	5-6 days	6-7 days	>7 days
4	Strength of tremor in the houses of my ward indicated by	Slight jerk. Suspended objects swing.	Jerk with door/ wind owrattle	Doors/ windows rattle, heavy furniture overturned/ fallen plaster/ damage on poorly built structures.	Difficult to stand, heavy furniture overturned, cases of allen plaster, slight damage on mo de-rate to well built structures	Partial collapses, most masonry and frame structure destroyed, bridges, rails bent	

5	Loss in my ward caused by		Crops	House-hold	Cracks in building	Build-ing collapse	Cracks in roads	Casual-ity	AOT
		Flood							
		Earthquake							
		Fire							
		Urban flood							

6	No. of people (approx.) suffered/ exposed in my ward by		None	<100	<100-500	500-1000	>1000
		Flood					
		Earthquake					
		Fire					
		Urban flood					
7	No. of people (approx) killed in my ward by		None	<100	<100-500	500-1000	>1000
		Flood					
		Earthquake					
		Fire					
		Urban flood					
8	No. of people (approx) injured in my ward by		None	<100	<100-500	500-1000	>1000
		Flood					
		Earthquake					
		Fire					
		Urban flood					

9	Return period/ cycle (per year) of						
		Flood	Can't say	1	2	3	>3
		Earthquake	Can't say	1	2	3	>3
		Fire	Can't say	1	2	3	>3
		Urban flood	Can't say	1	2	3	>3

APPENDIX B

Implication of Variables

Dwppleff1'	People in ward affected by earthquake
Dwppleff2'	People in ward affected by flood
Dwppleff3'	People in ward affected by urban flood
Dwppleff4'	People in ward affected by fire
Dwppleff5'	People in ward affected by these hazards
Dwppleff6'	People in ward not affected by any of these hazards
Dwfldlvl1	Flood level in ward
Dwdurfld1	Duration of flood in ward
Dwstrngtr1	Strength of houses in ward
Dwlossf1	Loss in ward due to flood
Dwlossfr1	Loss in ward due to fire
Dwlosseq1'	Loss in crops due to earthquake
Dwlosseq2'	Loss in household due to earthquake
Dwlosseq3'	Loss in buildings due to earthquake
Dwlosseq4'	Loss from buiding collapse due to earthquake
Dwlosseq5'	Loss in roads due to earthquake
Dwlosseq6'	Loss as casualty due to earthquake
Dwlosseq7'	None of these loss due to earthquake
Dwlossf1'	Loss in crops due to flood
Dwlossf2'	Loss in household due to flood
Dwlossf3'	Loss in buildings due to flood
Dwlossf4'	Loss from buiding collapse due to flood
Dwlossf5'	Loss in roads due to flood
Dwlossf6'	Loss as casualty due to flood
Dwlossf7'	None of these loss due to flood
Dwlossuf1'	Loss in crops due to urban flood
Dwlossuf2'	Loss in household due to urban flood

Dwlossuf3'	Loss in buildings due to urban flood
Dwlossuf4'	Loss from buiding collapse due to urban flood
Dwlossuf5'	Loss in roads due to urban flood
Dwlossuf6'	Loss as casualty due to urban flood
Dwlossuf7'	None of these loss due to urban flood
Dwlossfr1'	Loss in crops due to fire
Dwlossfr2'	Loss in household due to fire
Dwlossfr3'	Loss in buildings due to fire
Dwlossfr4'	Loss from buiding collapse due to fire
Dwlossfr5'	Loss in roads due to fire
Dwlossfr6'	Loss as casualty due to fire
Dwlossfr7'	None of these loss due to urban flood
Dwpplexpf	Approx. number of people in ward exposed to flood
Dwpplexpeq	Approx. number of people in ward exposed to earthquake
Dwpplexpfr	Approx. number of people in ward exposed to fire
Dwpplexpuf	Approx. number of people in ward exposed to urban flood
Dwpplklldf1	Approx. number of people killed in ward due to flood
Dwpplklldeq1	Approx. number of people killed in ward due to earthquake
Dwpplklldfr1	Approx. number of people killed in ward due to fire
Dwpplkllduf1	Approx. number of people killed in ward due to urban flood
Dwinjrdf1	Approx. number of people injured in ward due to flood
Dwinjrdeq1	Approx. number of people injured in ward due to earthquake
Dwinjrdfr1	Approx. number of people injured in ward due to fire
Dwinjrduf1	Approx. number of people injured in ward due to urban flood
Dwrtrnprdf	Return period of flood
Dwrtrnprdeq	Return period of earthquake
Dwrtrnprdfr	Return period of fire
Dwrtrnprduf	Return period of urban flood
Impcteq1	Impact of eartquake
Impctf1	Impact of flood
Impctuf1	Impact of urban flood
Impctfr1	Imapct of fire