Disaster & Development

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- Disaster within a disaster: social vulnerability of Muthuvan tribes in times of floods
- Psychological impact on resilience among persons with spinal cord injury during covid-19 disaster
- Infrastructure Resilience: An Emerging issue of Disaster Risk Reduction
- Connecting the Unconnected in Post Disaster Phase through Space Technologies for Sustainable Development Goal
- Hazard Analysis for Facilitating Community Based Disaster Risk Management of Silchar Town in Assam
- Selection of Suitable Water Treatment Technologies for Natural Disaster and Emergency Situation
- Public Health Emergency and Disaster management: Indian Perspective
- Morphological Change Analysis of Camorta Island, Nicobar Islands, India using Satellite remote sensing technique: a case study after 2004 Tsunami

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Mailing Address

Disaster & Development
National Institute of Disaster Management
Ministry of Home Affairs
Government of India
Plot No. 15, Pocket 3, Block B, Sector 29, Rohini, Delhi 110042

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Contents

Volume 11, Issue 01,
January to June 2022

Editor-in-Chief

Disaster is a natural or anthropogenic hazard that causes a serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope with its own resources. The concern over natural disasters is increasing globally. Disasters like floods, earthquakes, cyclones, fire, etc., pose serious threat to people. Disaster management education is one approach to reducing the negative consequences of disasters. It is imperative to increase the knowledge and attitude of people regarding the natural and anthropogenic disasters in order to make them able to cope with their adverse effects.

National Institute of Disaster Management (NIDM) under the aegis of the Ministry of Home Affairs, Government of India is mandated to endeavour for disaster resilient India through its training, research, documentation and publications. This issue of the journal collates the original and innovative research work on various aspects of "Disasters" and their management.

I am deeply grateful for the support and contribution of many who have enabled the growth of the journal over the past decade, contributing authors from many disciplines around the world, our reviewers who have volunteered their valuable time and expertise, dedicated editorial board members and our tireless and meticulous editorial team, and readers who share the mission of making our world safer.

Thank you all!

Tajhassan

Shri Taj Hassan, IPS

Editorial Note

I am delighted to introduce Vol. 11, Issue 1, January to June 2022 of the journal 'Disaster & Development'.

It is a great journey over the years starting from the launch of the journal in way back in 2006. The response it has got from all our eminent authors and readers year by year is pretty overwhelming and always motivate us to provide better services in terms of ease of publishing with us, getting quality researches and easy access of them to the readers. In 2022, Disaster & Development journal has got UGC CARE Indexing.

Our objectives for Vol. 11, No. 1, January to June 2022 are to encourage the authors to produce high quality researches on various subjects like Hazards, vulnerabilities, capacities and disasters studies; Disaster Risk Reduction and Resilience (DRR&R); Impacts of and response to disasters; Post-disaster recovery; Community based environment and disaster management; Development, Urbanization, Climate change adaptation and safe sustainable development; Case studies on specific disaster events; Tools, Techniques and technologies for DRR&R, etc.

In the end, on behalf of the journal, I would like to thank and express my gratitude to all the associate editors, publication team, reviewers, authors and readers for keeping their faith on us and associating with us over the years to make this journal a successful peer-reviewed open access journal till now and I am hoping for their continuous support in the coming years as well.

Surya Parkash, Ph.D.

Disaster within a Disaster: Social Vulnerability of Muthuvan Tribes in Times of Floods

Ashique Vadakkuveettil[1] and Aakriti Grover[2]

Abstract

There has been much appreciation all over the world applauding the Kerala model flood rescue, undertaken by the government as well as locals in Kerala, for their overarching methods of disaster management. In a dire situation where almost, the entire population was adversely affected, it is believed that the state machinery along with the people stood together beyond differences and discrimination. But the ground reality does not seem to be as Utopian as it sounds. The levels of destruction have varied across regions, communities and classes. The marginalized society of the Muthuvan tribes of Kerala, who are subjected to socio-economic discrimination for a long time had to face double vulnerability in times of disaster and in post-disaster aids. This is due to several issues like existing social discrimination, lack of knowledge about information technologies, Isolated location, limited social network etc. An exploratory study has been done through qualitative research to locate these problems. This paper intends to shed light on the necessity to create awareness among government, local bodies and communities to give special attention and consideration to the marginalized societies like the Muthuvan tribes in times of any kind of disaster so that more resilient strategies can be thought of and applied in future.

Keywords: *Social Vulnerability, Muthuvan tribe, Kerala Flood, Marginalisation*

1. Introduction

The state of Kerala is extremely prone to natural disasters and altering climatic dynamics due to its coastal location and steep gradient along the Western Ghats

[1&2] Department of Geography, Central University of Tamil Nadu

slopes. In 2018, Kerala witnessed one of its worst catastrophic floods of recent years (Aleem Yoosuf & Unaisudheen, 2021). According to the reports from the state government of Kerala, floods and landslides affected 5 million people, claimed 440 lives, and caused an economic loss of more than $3 billion between 22 May and 29 August 2018 (Mishra & Shah, 2018; Panigrahi & Suar, 2021). The majority of the population was severely got affected in that period. However, the timely rescue work by the government and people altogether was incredible and received international appreciation. Even though, some of the marginalized people in Kerala had to facedouble vulnerability in times of flood because of the pre-existing social vulnerability. Cutter and Finch (2008) described social vulnerability as the inherent instability and sensitivity of social systems to issues such as poverty, inequality, marginalization, social deprivation and social exclusion. While according to Wisner et al., (2004) it is “the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist, or recover from the impact of a hazard.”

Muthuvans are among those marginalized people in Kerala who had faced social vulnerability in times of flood. They are considered to have migrated from Madurai and they speak a unique dialect (Enavan Pech) that combines Tamil and Malayalam (Manjusha, 2013; Mohan et al., 2017). The Muthuvans prefer to live a secluded life, separated from the mainstream land. They have their own system that takes care of the administration and functions of kudy (which means settlement in their local language). They avail things for their survival from the forest which includes raw materials for house construction, food and medicine. Therefore, they hardly have to go out to mainstream society. The education level of Muthuvans is very low in comparison with the other tribal groups of Kerala with a literacy rate of 56.9% (Anusha & Atheeque, 2018; Mohan et al., 2017).

This paper intends to understand the problems that are faced by the Muthavan tribes in times of floods to shed light on the necessity to create awareness among government, local bodies and communities to give special attention and consideration to the marginalized societies like the Muthuvan tribes in times of any kind of disaster so that more resilient strategies can be thought of and applied in future.

2. Methodology

This work is exploratory research that utilized a qualitative research approach to collect data regarding the Kerala flood 2018. In the initial stage of research work, the researcher had met journalists, people working in relief camps and NGOs, etc. The researcher tried to maintain a strong bond with all these people for data collection as well as for creating a strong network for further studies. The target population of this research was the Muthuvan tribes of Odakkayam, a place in Oringattiri village of Malappuram, which is a district in Kerala that is vulnerable to floods and landslides (Singh et al., 2022; Wadhawan et al., 2020) (Fig.1). It was a news report that brought the social vulnerability of the Muthuvan tribe in limelight. The researcher telephoned th journalist to know the precise location of Muthuvan tribes and to acquire information about them in detail. Later along with one NGO named ‘Thanal’, the researcher went to their place to give relief materials for the flood (Fig.2). During this time of reliefwork, a strong relationship has been made with the people to know more about their problems. Only a very few studies have been done previously about the social vulnerability of any kind of tribal people in Kerala during floods. A narrative approach has been used to understand the living conditions of the Muthuvan tribes and their post-flood conditions. Other locals were also interviewed to understand more about the study area. Interviews were done during the relief work and surprisingly most of the people were willing to give the interview without any hesitation. The limitation of the research includes the minimal number of the target population for the study. Nonetheless, it could not be sidestepped as there were a very few people in that area. Still, this research can be expanded to a larger study area by choosing other marginalized people for a better understanding of the social vulnerability faced by marginalized communities during disasters in Kerala.

3. Results and Discussion

There are about 30 Muthuvans in the remote area of Odakkayam in the Oringattiri village of Malappuram district in Kerala (Fig. 1). It’s a hilly area and densely forested. Hence, the accessibility to this area is very limited. The conditions were even worse after the landslide and flood happened (Fig. 3). The families in the far end areas were severely affected. They need to walk a long distance to get daily amenities. During the flood, the government opened relief centres in government schools and also provided accommodation facilities there. Although, most of the tribal people were not willing to go there because they find it difficult to mingle with the local people. Therefore, most of them did not stay there neither they collected any relief materials. Due to the remoteness of their location, even NGOs and other organizations could not provide much relief work. There was a 93 years old lady named Nottiyamma, who was living in complete poverty (Fig. 4). Many parts over there had landslides. People were living in fear expecting landslides any time.

The majority of the population in Kerala followed updates associated with flood through social media only, which was lacking in tribal areas. The deficiency of information technology delayed getting disaster warnings and other updates to the far-flung areas of tribal people. Consequently, their shyness for being in contact with other locals kept them away from getting various aids from the government, NGOs and other organisations. They expressed a sense of negligence by the community. They stated that while some assistance is provided for them, but they have to walk a long distance to collect it. These people are very prone to landslides as their settlements are situated on hillsides. Due to the marginalization, their living conditions are so pathetic, and it becomes even worse and more vulnerable during disasters.

4. Conclusion

The marginalized society of the Muthuvan tribes of Kerala, who are subjected to socio-economic discrimination had to face double vulnerability in times of disaster and in post-disaster aids. The reasons for this were social discrimination, lack of knowledge about information technologies, Isolated location, etc. Being a secluded, separated and most uneducated tribe, they lack the information to access the basic vital needs during these difficult situations.

These tribes were expected to get proper facilities according to their needs and situations but they are socially challenged which made it difficult for them to ask for help. So, the government should provide special attention to them through more resilient strategies in the future.

5. Acknowledgements

The author is thankful to all the respondents especially the Muthuvans in Odakkayam, for their kind cooperation throughout the research. The author extends his sincere thanks to Ashish Kumarand Aisha Wani for their assistance in writing. He extends his deep gratitude to Journalist Shareef from Siraj Newspaper, who gave all the initial information for the research.

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Psychological Impact on Resilience Among Persons with Spinal Cord Injury During Covid-19 Disaster

Josiah Stanely Rose G[1], Udhayakumar P[2],
Robert Ramesh Babu Pushparaj[3], Sigamani Panneer[4]

Abstract

The World Health Organization (WHO) announced the outbreak of COVID-19 as a public health emergency of global concern on 30th January 2020. The uncertainty related to this pandemic has triggered mental health problems such as anxiety, depression, and stress among people with disabilities that includes persons with spinal cord injury. Persons with spinal cord injury are at a high risk of COVID-19 due to their clinical and social characteristics (Barman et. al 2021). Individuals with SCI experience various physiological changes that raise their risk of morbidity due to COVID-19. Resilience is considered a major psychological factor that could help persons with spinal cord injury to cope with the COVID-19 pandemic. Resilience was found to be positively associated with self-efficacy and negatively associated with depressive mood states. Due to the uncertainties and challenges posed by the COVID-19, the mental health of persons with spinal cord injury has become a serious concern (Mikolajczyk, B et. al 2021).

1. To study the socio-demographic profile of persons with spinal cord injury. 2. To assess the levels of depression, anxiety, and stress among persons with spinal cord injury during the COVID-19 lockdown. 3. To understand the level of resilience of persons with spinal cord injury during COVID – 19 pandemic.

Survey method was used for data collection. An e-questionnaire was developed with the help of the Google platform and used for data collection. We have used the snowball sampling technique to identify the participants and collect information.

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[1] Research Scholar, Department of Social Work, Central University of Tamil Nadu, Thiruvarur.
[2] Assistant Professor, Department of Social Work, Central University of Tamil Nadu, Thiruvarur.
[3] Research Scholar, Department of Social Work, Central University of Tamil Nadu, Thiruvarur.
[4] Professor and Head, Department of Social Work, Central University of Tamil Nadu, Thiruvarur. Email id: sigamanip @cutn.ac.in

A total of 60 participants completed the survey. Of the total participants, 47 were males and 13 were females. Depression, Anxiety, and Stress Scale (DASS) and Connor–Davidson Resilience Scale were administered as e-questionnaires with the help of the Google platform in a specific google form.

During the COVID-19 lockdown persons with spinal cord injury had a higher level of depression (55 percent), anxiety (63 percent), and stress symptoms (43 percent). Persons with SCI (Spinal Cord Injury) in the age group of 21-30 years reported mild to extremely severe levels of depression (41.5 percent), anxiety (43.1 percent), and stress (33.2 percent) than the other age groups. An extremely severe level of depression (45 percent), anxiety (50 percent), and stress (35 percent) symptoms were found among unmarried persons with spinal cord injury. Among the persons with SCI, the overall resilience for the majority was "low" on the cumulative burden score. The level of resilience was high among the male respondents compared to their female counterparts. Further, unmarried (41.6 percent) respondents reported a higher level of resilience than married and divorced.

This study indicates that high levels of depression, anxiety, stress, and a low level of resilience among the persons with spinal cord injury during the COVID-19 pandemic lockdown. In the current crisis, it is vital to identify the individuals with spinal cord injury who are prone to mental health problems so that with appropriate interventions, the mental health of this population can be preserved. Healthcare providers and policy makers need to consider the findings and suggestions of this study to develop new health plans to address the psychological needs of persons with SCI during the time of pandemic and to manage the increasing mental illness in the future.

Keywords: *Anxiety, COVID-19, Depression, Pandemic, Resilience, Spinal Cord Injury, Stress*

1. Introduction

The World Health Organization (WHO) announced the outbreak of COVID-19 as a public health emergency of global concern on 30th January 2020 (Gallegos, 2020). To contain the spread of the virus, strict public health measures like avoidance of public contact and quarantine have been implemented across the globe (Adhikari et al. 2020). The uncertainty related to this pandemic has triggered mental health problems such as anxiety, depression, and stress among people with disabilities including persons with spinal cord injury. Owing to the COVID-19 pandemic the elderly population and persons with pre-existing medical conditions are vulnerable to such a pandemic (WHO, 2020). Spinal cord injury (SCI) is associated with a life-long physical and psychological burden that challenges their well-being (Bonanno et al., 2012). Persons with spinal cord injuries are at a high risk of COVID-19 due to their clinical and social characteristics (Palipana, 2020). Individuals with SCI experience various physiological changes that raise their risk of morbidity from COVID-19 (Korupolu et al., 2020). The global COVID-19 pandemic has had a significant impact on populations across the globe and increased the concerns and anxiety of persons with SCI. A cross-sectional study from Ethiopia found that during the COVID-19 pandemic the prevalence of depression, anxiety, and insomnia was high among persons with disabilities.

The prevalence of depression and anxiety among the person with a disability was (46.2 percent) 186 and (48.1 percent) 194 respectively. The findings also revealed that multiple sociodemographic and disability-related factors were associated with this high psychopathology. The prevalence of depression, anxiety, and insomnia were more severe among the persons with disabilities who were single, divorced or separated, uneducated, and unemployed. Further, the results suggest that the government and other stakeholders need to intervene in psychopathology and its associated factors (Necho et al., 2020). Resilience is considered a major psychological factor that could help persons with spinal cord injury to cope with the COVID-19 pandemic. Resilience was found to be positively associated with self-efficacy and negatively associated with depressive mood states (Migliorini et al., 2015). Further, resilience serves as a protective mechanism against negative stressors (Southwick et al., 2014) and mediates the effects of COVID-19 related burden on depressive and anxiety symptoms and perceived stress (Rossi et al., 2021). Giving attention to the mental health of the persons with spinal cord injury during this pandemic is crucial. Several studies have linked COVID -19 with depression, anxiety, and stress. If it is left undiagnosed and untreated, mental illness can negatively impact the wellbeing of the person with SCI. The COVID-19 impact may play a significant role in worsening signs, symptoms, and development of mental health problems. Due to the uncertainties and challenges posed by the COVID-19, the mental health of persons with spinal cord injury has become a serious concern. There were no empirical evidences in the Indian context focusing on the mental health of persons with Spinal Cord Injury during the Covid-19 pandemic. So, the purpose of the study seeks to explore the prevalence of depression, anxiety, and stress among persons with spinal cord injury as well as their resilience during the COVID-19 lockdown.

2. Materials and methods

The study followed a descriptive research design and used a survey method for data collection due to the COVID-19 and its implications. The rehabilitated persons with spinal cord injury from all over the states in India were invited for the study. The questionnaire was used to collect demographic details, depression, anxiety, stress, and resilience-related information. An online Google platform was used to develop an e-questionnaire and called a few persons with SCI over the phone with prior appointments. We have used the snowball sampling technique to identify the participants. Online informed consent was taken from all the participants as per revised ICMR guidelines for Biomedical and health research involving human participants before they answered the questions. The inclusion criteria are a) Rehabilitated individuals with either paraplegia or tetraplegia due to spinal cord injury. b) Age group between 18- 50 years. c) Duration of Spinal Cord Injury not less than 2 years. d) Persons with SCI who do not have access to internet facilities at home and android mobile phones were excluded from the study. E-questionnaire was sent to a total of 94 participants and a total of 60 participants completed the survey. Among participants, 47 were males and 13 were females. The time frame of the study is from June 2021 to August 2021. The data were analyzed with the help of SPSS version 21.

2.1 Measures

A sociodemographic information sheet was prepared to collect background information on the participants.

The *Depression Anxiety Stress Scale* (DASS-21) developed by Lovibond and Lovibond (1995) was used to assess depression, anxiety, and stress. There are 7 items for each subscale. The responses were collected on a 4-point rating scale ranging from 0 “didn’t apply to me at all” to 3 “Applied to me very much or most of the time”. A higher score reflects higher levels of depression, anxiety, and stress. The Cronbach’s Alpha valve of the DASS for the study is 0.950 which has good internal consistency. The Pearson’s correlation valve is more than 0.25 of “r” table product-moment at 5% level of significance. Hence all the items in the DASS are valid.

The *Connor–Davidson Resilience Scale 25* (CD-RISC 25) comprises 25 items, each rated on a 5-point scale (0–4), with higher scores reflecting greater resilience. The scale can be administered to subjects in the following groups: community sample, primary care outpatients, general psychiatric outpatients, clinical trial of generalized anxiety disorder, and two clinical trials of Post-Traumatic Stress Disorder (PTSD). This scale explores seven domains of resilience: hardiness (i.e., commitment/challenge/control), coping, adaptability/flexibility, meaningfulness/purpose, optimism, regulation of emotion and cognition, and finally self-efficacy. Each of the 25 items is rated on a 5- point scale (0–4), with a possible total score ranging from 0 to 100 points. Lower scores indicate less resilience and higher scores indicate greater resilience.

3. Results

3.1 Understanding the profile of the respondents

Out of 60 persons with spinal cord injury (Table 1), the majority (71.7 percent) were male and 28.3 percent were female. The mean age of the respondents 29.8 years and ranged from 16 to 50 years, the majority (46.7 percent) being in the age group of 21- 30 years. The majority of the respondents were Hindus (63.3 percent), Christians (23.3 percent) and the remaining 23.3 percent were Muslims. Most of the persons with SCI are from (53.3 percent) rural background and residing in a nuclear family (71.7 percent). The educational background of the respondents varied at different levels from basic education to professional courses and among them, 36.7 percent have completed under graduation. The reported total monthly family income ranged from Rupees 1000 to 66,666 with a mean of Rupees 15,700 per month. Among the respondents, 36.7 percent of the persons who sustained injury were unemployed and 30 percent of them were students, 16.7 percent were self-employed, 6.7 percent have permanent employment in the government sector. The person sustained a spinal injury resulting from different mechanisms (Table - 2). 35 percent of the persons sustained spinal injuries from falls followed by 51.5 percent of road traffic accidents (RTA) 1.6 percent of the persons sustained injuries due to assault and Transverse myelitis is a non-traumatic spinal cord injury caused by inflammation in the spinal cord. 10 percent sustained injuries due to sports and recreational injuries (sports and leisure-related injuries). The majority 88.3 percent of the respondents have undergone spinal surgery. Out of 60, 35 persons with SCI reported to have health complications such as pressure ulcers (15 percent), urine leaks (20 percent), pain (20 percent), and diabetes (3.3 percent). For mobility, the majority (78.3 percent) of them are using a wheelchair, 11.7 percent use Knee Ankle foot orthosis and crutches (KAFO), and the remaining 10 percent use walker and other mobility devices. Among the respondents Paraplegia (85 percent) refers arms functioning is spared but depending on the level of the injury, the trunk, legs and pelvic organs may be involved was more common the tetraplegia (15 percent) refers impairment of function in the arms as well as typically in the trunk, legs and pelvic organs, including the four extremities.

Table 1. Socio-demographic Profile of the Respondents

Variables	Frequency	Percent
Gender		
Male	43	71.7
Female	17	28.3
Age		
16 to 20 Years	8	13.3
21 to 30 Years	28	46.7
31 to 40 Years	18	30
41 to 50 Years	6	10
Religion		
Hindu	38	63.3
Christian	14	23.3
Muslim	8	13.3
Monthly Income		
Rs. 1000 to Rs. 5000	18	30.0
Rs. 5001 to Rs. 10000	16	26.7
Rs.10001 to Rs. 15000	7	11.7
Rs.15001 to Rs. 20000	3	5.0
Rs. 20001 to Rs. 25000	2	3.3
Above Rs. 25000	14	23.3

Education		
Primary School	2	3.3
High School	16	26.7
Under Graduate	22	36.7
Post Graduate	6	10.0
ITI	4	6.7
Diploma	3	5.0
Professional Course	7	11.7
Place of Residence		
Urban	28	46.7
Rural	32	53.3
Marital Status		
Married	13	21.7
Unmarried	44	73.3
Divorced/ separated	3	5.0
Occupation		
Government Employee	4	6.7
Private Sector	6	10.0
Business or Self-employed	10	16.7
Student	18	30.0
Unemployed	22	36.7
Family Type		
Nuclear	43	71.7
Joint	17	28.3

Table 2. Clinical Profile of the persons with SCI

Variables	Frequency	Percent
Duration of after injury		
1 to 5 Years	34	56.6
5 to 10 years	13	21.6
10 to 15 Years	4	6.6
15 to 20 Years	3	5.0

Above 21 years	6	10.0
Cause of SCI		
Fall	21	35.0
Motorcycle Accident	16	26.6
Car/Truck Accident	13	21.6
Pedestrian	2	3.3
Assault	1	1.6
Transverse myelitis	1	1.6
Miscellaneous	6	10.0
Spinal Surgery		
Yes	53	88.3
No	7	11.6
Mobility Aid		
Wheelchair	47	78.3
KAFO & Crutches	7	11.6
AFO & Crutches	1	1.6
Walker	2	3.3
Others	3	5.0
Injury Type		
Paraplegia	51	85
Tetraplegia	9	15
Health Complications		
Pressure Sore	9	15
Urine Leak	12	20
Diabetes	2	3.3
Pain	12	20
No Complication	25	41.7
Bladder Evacuation		
ICC	38	63.3
IDC	4	6.7
SPC	7	11.7
Self-Pass	11	18.3
Bowel Elimination		

DE/ DS	31	51.7
Suppository	9	15
Medicines	1	1.7
Self-Pass	19	31.7

3.2 Psychological impact among persons with spinal cord injury

The scores were classified according to the norms suggested by the authors of the DASS in terms of severity. Finding (Table 3) shows that a relatively minority were classified as being "normal" in relation to their level of depression (20 percent), anxiety (17 percent), and stress (28 percent). Similarly, the persons with SCI with "mild" depression (8 percent), anxiety (3 percent), and stress (5 percent) constituted a small group. The majority of them fall in the 'extremely severe' category with a higher level of depressive (55 percent), anxiety (67 percent), and stress (43 percent) symptoms. It is noted that (Table 4) male respondents had higher level of extremely severe depression (40 percent), anxiety (48 percent) and stress (31.6 percent) than their female (extremely severe depression (15 percent), anxiety (18 percent) and stress (11.6 percent) counterparts. The respondents in the age group of 21-30 years reported mild to extremely severe levels of depression (41.5 percent), anxiety (43.1 percent), and stress (33.2 percent) scores than the other age groups. An extremely severe level of depression (45 percent), anxiety (50 percent), and stress (35 percent) symptoms were found among unmarried persons with SCI. Further, the respondents living in the nuclear family scored mild to extremely severe levels of depression (58.2 percent), anxiety (61.5 percent), and stress (50 percent) scores than the respondents who were living in the joint family.

The respondents in the income group of 0 to Rs. 5000 reported extremely severe levels of depression (33.3 percent), anxiety (35 percent), and stress in severe level (42.9 percent) scores than the other income groups. Further, based on the education of the respondents, it was found that those who have completed under graduation have scored extremely severe levels of depression (36.4 percent) and anxiety (37.5 percent), whereas those who have done high school have scored extremely severe in stress (23.1 percent). The respondents living in the rural area reported extremely severe levels of depression (54.5 percent), anxiety (60 percent), and stress (53.8 percent) scores than those living in the urban area. The respondents who were unemployed reported extremely severe levels of depression (45.5 percent), anxiety (45 percent), and stress (46.2 percent).

Table 3. Distribution of respondents by severity across DASS sub-dimensions

Severity					
DASS variable	**Normal**	**Mild**	**Moderate**	**Severe**	**Extremely Severe**
Depression	12(20%)	5(8%)	6(10%)	4(7%)	33(55%)
Anxiety	10(17%)	2(3%)	5(8%)	3(5%)	40(67%)
Stress	17(28%)	3(5%)	7(12%)	7(12%)	26(43%)

Table 4. Distribution of respondents by sociodemographic details across DASS scale

Variable	Depression					Anxiety					Stress				
	Normal	Mild	Moderate	Severe	Extremely Severe	Normal	Mild	Moderate	Severe	Extremely Severe	Normal	Mild	Moderate	Severe	Extremely Severe
GENDER															
Male	10(16.6)	1(1.6)	5(8.3)	3 (5)	24(40)	8(13)	2(3.3)	1(1.6)	3(5)	29(48)	11(18.3)	3(5)	5(8.3)	5(8.3)	19(31.6)
Female	2 (3.3)	4(6.6)	1(1.6)	1(1.6)	9(15)	2(3.3)	0(0.0)	4(6.6)	0(0.0)	11(18.3)	6(10)	0(0.0)	2(3.3)	2(3.3)	7(11.6)
AGE															
16 – 20	1(1.6)	0(0.0)	1(1.6)	0(0.0)	6(10)	1(1.6)	0(0.0)	0(0.0)	1(1.6)	6(10)	1(1.6)	1(1.6)	0(0.0)	2(3.3)	4(6.6)
21 – 30	3 (5)	5(8.3)	2 (3.3)	2 (3.3)	16(26.6)	2(3.3)	1(1.6)	5(8.3)	1(1.6)	19(31.6)	8(13)	1(1.6)	3(5)	2(3.3)	14(23.3)
31 - 40	6(10)	0(0.0)	2 (3.3)	2 (3.3)	8(13.3)	5(8.3)	1(1.6)	0(0.0)	0(0.0)	12(20)	6(10)	0(0.0)	4(6.6)	2(3.3)	6(10)
41- 50	2 (3.3)	0(0.0)	1(1.6)	0(0.0)	3 (5)	2 (3.3)	0(0.0)	0(0.0)	1(1.6)	3(5)	2 (3.3)	1(1.6)	0(0.0)	1(1.6)	2(3.3)
MARITAL STATUS															
Married	5(8.3)	0(0%)	2(3.3)	1(1.6)	5(8.3)	4(6.6)	1(1.6)	0(0.0)	1(1.6)	7(11.6)	5(8.3)	1(1.6)	2(3.3)	1(1.6)	4(6.6)
Unmarried	7(11.6)	5(8.3)	3(5)	2(3.3)	27(45)	6(10)	1(1.6)	5(8.3)	2(3.3)	30(50)	12(20)	2(3.3)	3(5)	6(10)	21(35)
Divorced/ separated	0(0%)	0(0%)	1(1.6)	1(1.6)	1(1.6)	0(0.0)	0(0.0)	0(0.0)	0(0.0)	3(5)	0(0.0)	0(0.0)	2(3.3)	0(0.0)	1(1.6)
RELIGION															
Hindu	6(10)	4(6.6)	6(10)	1(1.6)	21(35)	5(8.3)	1(1.6)	4(6.6)	3(5)	25(41)	10(16)	3(5)	4(6.6)	3(5)	18(30)
Christian	2(3.3)	1(1.6)	0(0.0)	2(3.3)	9(15)	2(3.3)	0(0.0)	1(1.6)	0(0.0)	11(18.3)	3(5)	0(0.0)	2(3.3)	3(5)	6(10)
Muslim	4(6.6)	0(0.0)	0(0.0)	1(1.6)	3(5)	3(5)	1(1.60	0(0.0)	0(0.0)	4(6.6)	4(6.6)	0(0.0)	1(1.6)	1(1.6)	2(3.3)
FAMILY TYPE															
Nuclear	8(13)	5(8.3)	3(5)	2(3.3)	25(41.6)	6(10)	2(3.3)	5(8.3)	1(1.6)	29(48.3)	13(21.6)	1(1.6)	4(6.6)	5(8.3)	20(33.3)
Joint	4(6.6)	0(0.0)	3(5)	2(3.3)	8(13.3)	4(6.6)	0(0.0)	0(0.0)	2(3.3)	11(18.3)	4(6.6)	2(3.3)	3(3.3)	2(3.3)	6(10)

3.3 Resilience among persons with SCI

The respondents were re-classified into low and high categories based on the median score for the overall resilience as well as its sub-dimensions. Concerning the sub-dimensions of resilience, Table-4 reveals that the overall resilience for the majority was "low" on the cumulative burden score (52 percent) as well as its sub-dimensions such as their hardiness (55 percent), coping (52 percent), adaptability (62 percent), optimism (52 percent), regulation of emotions and cognition (53 percent) and meaningfulness (53 percent). Besides, 62 percent of the respondents had a higher level of resilience score in terms of self-efficacy. Out of 60 participants, 38.3 percent of male respondents had lower resilience than their female (13.3 percent) counterparts. The respondents residing in the rural area had a similar score for both low (26 percent) and (26 percent) high resilience. Further, the persons with SCI residing in the rural area had a higher resilience level than the persons from the urban area. The unmarried (41.6 percent) respondents reported a higher level of resilience than married and divorced. Besides, a low level (37 percent) of resilience was found among the persons with SCI living in a nuclear family. The persons in the age group of 21-30 years reported a lower level (25 percent) of resilience compared to other age groups such as 16-20, 31-40 and 41-50. Further, the respondents in the income group of 0 to Rs. 5000 reported a lower resilience level (61.1 percent) than the other income groups. Respondents who were unemployed had lower resilience level (81.8 percent) than those who Mμ were employed.

Table 5. Distribution of respondents on sub-dimensions of Resilience

Sub-dimensions	Low	High	Median
Hardiness	33(55%)	27(45%)	23
Coping	31(52%)	29(48%)	13
Adaptability	37(62%)	23(38%)	9
Optimism	31(52%)	29(48%)	5
Regulation of emotions and cognition	32(53%)	28(47%)	5
Self-Efficacy	23(38%)	37(62%)	6
Meaningfulness	32(53%)	28(47%)	11
Overall Resilience	31(52%)	29(48%)	75

Table 6. Results of Resilience

Variable	Resilience	
	Low	High
Gender		
Male	23(38.3%)	20(33.3%)
Female	8(13.3%)	9(15%)
Age		
16 – 20	4(6.6%)	4(6.6%)
21 – 30	15(25%)	13(21.6%)
31 – 40	7(11.6%)	11(18.3%)
41 – 50	5(8.3%)	1(1.6%)
Place of Residence		
Urban	15(25%)	13(21.6%)
Rural	16(26.6%)	16(26.6%)
Marital Status		
Married	10(16.6%)	3(5%)
Unmarried	19(31.6%)	25(41.6%)
Divorced/ separated	2(3.3%)	1(1.6%)
Family Type		
Nuclear	22(37)	21(35)
Joint	9(15)	8(13.3)

4. Discussion

Depression, anxiety, and stress are wide spread across the globe during the quarantine/ social isolation induced by the COVID-19 pandemic. During this pandemic social isolation, disrupted routines, and health services have greatly impacted the mental health of persons with spinal cord injury. The principal finding of the study shows that during the COVID-19 lockdown the persons with spinal cord injury had a higher level of depression (55 percent), anxiety (63 percent), and stress (43 percent) symptoms. It was found that males (71.7 percent) are more prone to spinal cord injury than females and this could be due to the fact that in most of the families, the males were the primary bread winners and have risk exposure. This is also reported by (Mathur et al. 2015) that the males were four times more prone to SCI than females. The majority of the persons with SCI were in the age range of 21-30 which is in accordance with previous study by (Chamberlain et al. 2015) that a large number of spinal cord injury cases occurred in the age group of 16 to 30 and majority resulted in paraplegia. This is a disturbing state where active human resources are being seriously disabled and that impacted livelihood in many families (Mathur et al., 2015). We also found that persons in the age group of 21-30 years reported mild to extremely severe levels of depression (41.5 percent), anxiety (43.1 percent), and stress (33.2 percent) scores than the other age groups during the COVID pandemic. The unexpected joblessness and financial constraints have put persons with SCI in an unpleasant state, affected their socioeconomic and psychological well-being. Under normal circumstances, persons with spinal cord injury are less likely to access health facilities, education, and employment and the COVID -19 pandemic had further complicated the situation and impacted the persons with SCI directly and indirectly. Persons with SCI experience a myriad of physiological changes that develop the risk of morbidity from COVID-19 and may mask the clinical manifestation of the disease (Cristante et al., 2020).

Recent research evidence state that the COVID-19 pandemic has caused a significant rise in the prevalence of depression, anxiety, and stress symptoms (Rossi et al., 2021 and Salari et al., 2020). Indeed, it is not surprising that our findings showed that the majority of persons with SCI fall in the 'extremely severe' category in terms of depression, anxiety, and stress. Above normal levels of anxiety may weaken the immune system and develop the risk of contracting the virus (WHO, 2020). The persons sustained a spinal injury resulting from a different mechanism.

We found that road traffic accidents (51.1 percent) were the major causes for spinal cord injury and fall from hight is the second major cause for SCI (35 percent). Persons with disabilities are at higher risk of developing more severe health conditions due to COVID-19. They are more sensitive to co-morbidities, such as diabetes, heart disease, lung problems, and obesity that can worsen the outcome of COVID-19 infections (Singh et al., 2020). 35 (58.3 percent) persons with SCI had health complications such as pressure ulcer (15 percent), bladder leaks (20 percent), pain (20 percent), and diabetes (3.3 percent) thus, they are at the great risk of contracting COVID-19 and the lack of accessing health care facilities during pandemic worsen their condition. However, 41.7 percent had no health complications. (Migliorini et al. 2009) found a statistically significant association between health and mental health outcomes and those with better health were less likely to be experiencing depression, anxiety, or stress.

Studies have shown that persons with profitable employment have better physical and mental health than those who are unemployed (Ipsen, 2006; Kamerade et al., 2019). Besides, unemployment, income inequality, and poverty are linked with poor physical and mental health due to the loss of income (McKee- Ryan et al., 2005). The economic recession due to COVID-19 had led to jobless of millions across the globe and for persons with disabilities this pandemic has posed new challenges to secure and maintain employment. In our study, we found that 36.7 percent of the population were unemployed due to SCI. Persons with spinal cord injury are more likely to lose their job and experience greater challenges returning to work and are at greater risk of developing mental health problems. For mobility purposes, we found that majority (78.3 percent) of the persons with SCI using wheelchair. Owing to the pandemic, persons with SCI who use a manual wheelchair must take extra precautions concerning handwashing and cleaning their devices because the coronavirus can remain on surfaces such as the hand rims and tires of wheelchairs, and wearing gloves when moving the wheelchair will help to protect and keep the hand clean (Cristante et al., 2020). An extremely severe level of depression (45 percent), anxiety (50 percent), and stress (35 percent) symptoms were found among unmarried persons. This was also reported by Kessler and Essex (1982) who found that the individuals who were single/divorced/ separated were more likely to have depression, anxiety, insomnia than their married counterparts.

Resilience seems to be important to cope with the COVID-19 pandemic implications (Holmes et al., 2020). Resilience is recognized as a protecting mechanism acting in the light of negative stressors (Southwick et al., 2014), and it is linked with better psychological well-being and lower mental health problems. The findings highlight that among the persons with SCI the overall resilience for the majority was “low” on the cumulative burden score (52 percent) as well as its sub-dimensions such as their hardiness (55 percent), coping (52 percent), adaptability (62 percent), optimism (52 percent), regulation of emotions and cognition (53 percent) and meaningfulness (53 percent). Besides, 62 percent of the respondents had a higher level of resilience score in terms of self-efficacy. The male (33.3 percent) respondents reported a higher level of resilience compared to their female (15 percent) counterparts. The education and employment opportunities given to the male in our country could be the reason for higher resilience among the male (Peter et al., 2012). The respondents living in the rural area had a similar score for both low (26 percent) and (26 percent) high resilience levels. Further, the persons with SCI residing in the rural area had a higher resilience level than the persons from the urban area. The unmarried (41.6 percent) respondents reported a higher level of resilience than married and divorced. Besides, a low level (37 percent) of resilience was found among the persons with SCI living in a nuclear family. Aging increses the risk of COVID-19 and mortality, however, in this study we have found a higher level of depression, anxiety, stress, and low level of resilience among the young persons with SCI at the age group of 21- 30 compared to older age groups such as 31-40 and 41-50. Since this young age group is considered to be a key active working force in society, they are very much concerned about the future consequences and economic challenges caused by the pandemic (Moghanibahi- Mansourieh, 2020).

5. Implications for Intervention

The COVID-19 pandemic has given rise to one of the biggest social and economic crises of our generation that has paved the way for the exclusion of marginalized communities. The unprecedented public health emergency and the subsequent lockdown have impacted persons with spinal cord injury who are considered to be one of the most vulnerable populations during the crisis. Persons with disabilities are among the hardest hit by COVID-19 and if they contract COVID-19, they may develop severe health conditions. The findings of the study highlight the adverse psychological states experienced by persons with spinal cord injury and lower levels of resilience experienced by them across several domains. Alleviating the prevalence of anxiety, stress, depression symptoms and increasing the level of resilience of persons with SCI during the COVID-19 pandemic needs to be an area of intervention. Optimistic thoughts about the COVID-19 spread to persons with SCI will be a protecting factor to reduce anxiety and depression. Resilience plays a significant role in protecting persons with SCI from psychological distress and should be taken into consideration in health policies and treatment strategies. Offering counseling services through electronic media can reduce the psychological issues caused by COVID-19 (Wang et al., 2020). Persons with disabilities confront difficulties in accessing basic health services and as a result, they have poorer health outcomes than those without disabilities. Persons with SCI face unique challenges when accessing health care services, and show poorer health outcomes than the general population due to various factors such as inaccessible facilities, financial constraints, and lack of accessible transport. Telemedicine for persons with SCI had several benefits like reducing travel time, costs associated with medical transport, and limiting the spread of infection to the vulnerable population (Stillman et al., 2020). Since the persons with SCI are more vulnerable to get affected with COVID-19 due to weaker immune systems thus, proper care should be given to this high-risk group those who are from low socioeconomic status, living alone, without close relatives, and with comorbid health conditions or other mental health conditions. To mitigate the effects of physical distancing and isolation, teleconferences can be encouraged. The health care professionals and organizations working for persons with disabilities can develop an alternative support system and promote public awareness of the consequences of the pandemics on persons with spinal cord injury. It is also important to involve persons with SCI, their families, and their caregivers in all the phases of the outbreak response.

6. Suggestions

The study highlights the need for mental health support to the persons with SCI, especially during the disaster like COVID-19. In order to achieve this we suggest that all the district hospitals should be equipped with specially trained mental health rehabilitation professionals to address the mental health issues of the persons with SCI. The intensity and severity of the problem have to be taken into account whenever new schemes are planned. A special mental health helpline number for persons with spinal cord injury can be thought of, with a follow-up monitoring system, so that it would help persons with SCI to overcome their mental health issues. Public Transportation should be accessible to persons with spinal cord injury which provides them access to participation in the community or peer group support system to reduce their psychological and mental issues.

7. Limitations of the study

The sample comprises primarily persons with SCI who have received rehabilitation services thus limiting the portability of our findings to those who have not received the rehabilitation. The study was conducted with a small sample size due to the pandemic and lack of technology such as android mobile, internet facilities in the population.

The findings of the study relevant to Indian spine populations and may differ with other counties due to sociocultural variations that limits the scope for generalization.

8. Conclusion

The COVID-19 pandemic has raised serious concerns over the persons with spinal cord injury. This study indicates high level of depression, anxiety, and stress among persons with spinal cord injury during the COVID-19 pandemic lockdown. According to our results, it can be concluded that the COVID-19 pandemic can affect the mental health of persons with SCI. Therefore, in the current crisis, it is vital to identify the individuals with spinal cord injury who are prone to mental health problems so that with appropriate interventions, the mental health of this population can be preserved. The findings of the study align with the spinal cord literature from other countries and point to key areas that need to be addressed through appropriate intervention. Healthcare providers and policy makers need to consider the findings and suggestions of this study to develop new health policy and plans to address the psychological needs of persons with SCI during the time of pandemic and to manage the raising mental illness in the future. The current study can be repeated with the large SCI population and include other variables to have a better understanding of depression, anxiety, stress, and resilience among them.

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"Infrastructure Resilience: An Emerging issue of Disaster Risk Reduction"

Dr. N. Bhagya Lakshmi

Abstract

Flash floods, sizzling temperatures, droughts and intense cyclones are likely to occur in India due to climate change and will continue to devastate regions in the world. Natural disasters have a significant impact on the quality of life by destroying food crops and livestock, as well as shelter and other parts of the built environment, and forcing households and communities to relocate. Their most devastating effect, though, is the toll they take on people and the instantaneous consequences. As a result of human intervention in natural processes, the destructive force and frequency of natural disasters have increased considerably. Disasters disturb people's lives by upsetting their routines. Direct effects on commercial real estate and infrastructure can result in production shortages.

The Disaster Cycle Disasters are complex emergencies requiring external assistance due to lack of adequate own resources of the society to recover. Disasters recur periodically in many regions of the world. While the exact timing and extent of future disasters can rarely be predicted, the expectation of their occurrence in the form of future risk can and should be incorporated into development efforts in disaster-prone areas. Reconstruction and recovery itself can therefore be construed as risk mitigation in preparation for the next expected disaster event. In addition, activities during any of these phases shape the circumstances and the available policy options during the next.

The aim of this paper is to understand the interrelationship between disasters and developmental infrastructural projects.

Keywords: *Disasters and Infrastructure, Risk Reduction, Risk & Disasters, Disaster Vulnerability*

1. Introduction

Since the start of civilization, natural calamities have been a part of human history. There are several natural calamities that are beyond human control. They're bound to bring with them the terrible consequences of human extinction. As a result of human intervention in natural processes, the destructive force and frequency of natural disasters have increased considerably. Disasters disturb people's lives by upsetting their routines. As a result of high winds and flooding, tropical cyclones cause widespread damage in specific areas. Direct effects on commercial real estate and infrastructure can result in production shortages. Certain disasters, such as Hud-Hud, have a severe impact on key infrastructure, such as electricity, water supply, and roadways, depending on the intensity of the disaster. Several trees fell, obstructing highways and destroying neighboring structures, causing damage to the airport, showroom automobiles, and city electrical poles. Infrastructure loss/damage is a sort of economic effect caused by disaster.

India is a disaster-prone country. With increasing global warming, the disaster has become frequent than it was earlier where natural disasters hit once or twice in a year. Since pre-independent there were only local laws in tackling disaster events. Disasters like cyclones, floods, landslides etc., affects both humans and animals. People are forced to become homeless. Houses have been damaged or have collapsed. Industries have been stymied. Floodwater has submerged crops. Domestic and wild animals both perish. In coastal areas, boats, fishing nets, and other items are lost or damaged. Following a flood, illnesses such as malaria and diarrhea are widespread. Potable water is contaminated and can be scarce at times. When food grains go missing or deteriorate, obtaining supplies from outside sources becomes difficult.

Systemic hazards are posing a challenge to emergency relief organizations’ ability to contain and reduce the spread and scale of disaster impacts on communities around the world. International rules, such as those issued by the United Nations, are a good place to start The Sendai Framework for Disaster Risk Reduction reflects the international community's commitment to disaster risk reduction. There is a need for research on ways to limit exposure and susceptibility while also addressing the underlying risk causes. Critical infrastructure, which includes assets and networks that are critical to society's operation, such as electric power plants and roadways, presents a unique challenge for recognizing new types of disaster risk. critical infrastructure disruptions can escalate crises triggered by natural hazard events, creating cascading effects by which emergency relief is challenged by non-linear and exponential multiplication of secondary crises.

The word “disaster” means a catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or manmade causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of, property, or damage to, or degradation of, environment, and is of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area.

Disaster risk is created by the interaction of natural hazard a potentially damaging natural phenomenon and vulnerability, the conditions and processes that define the susceptibility of a community to natural hazard. Risk mitigation can target either of these risk components. For instance, the likelihood of the occurrence of certain types of natural hazards, such as floods, can be influenced by human activity, such as the maintenance of natural drainage courses or the construction of levees. Reducing vulnerability to natural hazards, in turn, is in many cases easier to achieve than targeting hazards themselves, and in some cases, it is the only available option for disaster risk mitigation.

Restoring livelihoods and creating new economic opportunities is of fundamental importance to all in a post-disaster context. The aim of disaster management law is to improve the humanitarian response to both man-made and natural disasters. Disasters impact negatively on infrastructure projects as the cost involved in building the infrastructure destruction, loss of land and harm to people living in the vicinity of the site of disaster is huge and difficult to re-gain normalcy. The destruction caused by disasters possess significant challenges in re-building the basic infrastructure to the original state.

Tropical cyclones strike Asia and the Pacific region more frequently than any other part of the world, and they are frequently accompanied by severe flooding. Riverine flooding continues to be a common occurrence in the region that causes substantial damage every year. The dangers of flash floods are also growing more prevalent. Urban flooding has become a major potential hazard in terms of its economic and social impact as a result of the rapid urbanisation process and uncoordinated infrastructure development.

Environmental degradation taking place in many countries of the region only intensifies the damage inflicted by natural disasters. Deforestation, erosion, overgrazing, overcultivation and incorrect agricultural practices and the degradation of natural buffers amplify the effects of natural hazards. Land degradation and desertification pose a serious threat in the region in the wake of growing populations and enhanced food demand.

2. Physical Infrastructures

Dams are defined as physical structures built across a stream or a river to control or store water for various purposes which may include water supply, flood control, increasing river depth for navigation of barges/ships, or for recreational use. Traditionally, dams were seen as a means to overcome the vagaries of rainfall to benefit agriculture and mitigate droughts and floods. In India, man-made structures for irrigation have existed since time immemorial.

3. Effects of Disasters on Infrastructures

The most prevalent natural disasters that effect human society and economy are extreme precipitation events, landslides, and floods. Floods are becoming more common in India as a result of recent changes in climatic circumstances combined with increased human activity. Floods not only destroy property, but they also kill people and animals. Flood damage has grown in recent years compared to earlier periods, owing to increased flood frequency, encroachment of flood plains, and other anthropogenic activities such as mining, deforestation, and so on. Disasters had a significant impact on critical infrastructure, such as electricity, water supply, and roadways etc., Seaport is a critical coastal infrastructure serving important economic purposes but at the same time is unprotected to a wide range of natural perils or hazards including tropical cyclones.

Among the many disasters, cyclones have increased in frequency and severity at an alarming rate in the last two decades, which is related to climatic change. The state administration has made significant progress in reducing the number of people killed in the state, but an increase in economic losses and damage to key infrastructure has been a source of concern, with the power sector being the most important of all critical infrastructures.

The importance of good infrastructure in minimizing the effects of natural disasters has long been recognized by numerous authors. Infrastructure can be defined in many forms. Community infrastructure consists of both physical infrastructure and organisational infrastructure or “hard” and “soft” assets of societies. Infrastructural Resilience, in general terms, refers to ”the ability of a system exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management”. The effectiveness of a resilient infrastructure rests on its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event.

Environmental degradation is a process that reduces the capacity of the environment for meeting the social and ecological objectives, and related needs. The potential effects of degradation vary, and may contribute to increase in vulnerable conditions along and intensity in occurrence of natural hazards.

4. Legal infrastructure

Legislation: Although this is not usually addressed at the national level as a disaster preparedness issue, the legal environment can greatly influence the resilience of women and men to disasters both in terms of the general legal structure and in terms of specific disaster-related regulation. It is particularly important to have concerns such as those considered below recognised in the legal system in advance of any disasters occurring, to avoid effective discrimination in the urgency of the relief phase, and in reconstruction when the deadline for aid registration is tight. Of wider importance is that provisions such as allowing for equal property and inheritance rights, or sensitising law enforcement officers to domestic and sexual violence brings empowerment and with it, better disaster resilience, on a broader scale. One fundamentally important step towards improving disaster resilience is to recognise in legislation the inheritance rights of both genders in an equitable manner.

Tenth Five Year Plan (2002-07) recognizing disaster management as a development issue for the first time & Eleventh Five Year Plan also came up with a number of 0guidelines and disaster management continuum today comprises of six elements. Prevention, Mitigation and Preparedness in pre-disaster phase, and Response, Rehabilitation and Reconstruction in post-disaster phase.

5. Constitutional Provisions

Constitutional and Legal framework constitutes the foundational pivot around which different aspects of an activity are interwoven. Conceptually, legal arrangements refer to the framework of laws, executive orders, and other legal instruments that set the ground rules for governmental and non-governmental activities related to disaster mitigation and management.

The right to life and personal liberty is guaranteed in Article 21 of the Indian Constitution. It imposes a positive obligation on the state to take all reasonable precautions for disaster prevention, preparedness, and mitigation. The Supreme Court has liberally interpreted Article 21 to broaden the scope of life, and it can be said to be the repository of all important human rights. "Furthermore, Article 38 directs the state 'to promote the welfare of the people. Article 51 requires states to fulfil their international treaty obligations'. India is a signatory to a number of international environmental treaties, many of which include provisions for disaster management. Aside from that, the state is responsible. Even other than this, State is responsible under the doctrine of *parens patriae*. The Doctrine of *parens patriae* imposes an obligation on the State or sovereign authority to protect persons under disability. This doctrine which was originally applicable to the king has been applied by Courts in a number of cases to make the State responsible for providing relief to victims of disaster.

Article 43 of the Indian Constitution "The State shall endeavour to secure, by suitable legislation or economic organisation or in any other way, to all workers, agricultural, industrial or otherwise, work, a living wage, conditions of work ensuring a decent standard of life standard of life and full enjoyment of leisure and social and cultural opportunities and, in particular, the State shall endeavour to promote cottage industries on an individual or co-operative basis in rural areas."

According to Article 47 of the Constitution which provides that 'one of the primary duties of the State is to raise the level of nutrition and the standard of living of the people, there is considerable moral force and authority in this provision to persuade the State Governments and the Government of India to attempt at ensuring that the people, particularly those in drought affected areas, are provided adequate food grains and a cooking medium for the preparation of their meals'.

Entries in Schedule VII of the Constitution (List I), the State governments are allotted funds to meet financial expenditure on meeting identified natural calamities based on the Finance Commission's recommendations. The two entries in the State List that are remotely related to disaster management are entry 14, which deals with agriculture, including pest and plant disease prevention, and entry 17, which deals with water, including water supply, drainage, and flood control.

6. Disaster Management Act, 2005

The Government of India (GOI), Ministry of Home Affairs (MHA) and United Nations Development Program (UNDP) signed an agreement in August 2002 for the implementation of "Disaster Risk Management" Program to reduce the vulnerability of the communities to natural disasters, in identified multi– hazard disaster prone areas. Goal of this agreement is "Sustainable Reduction in Natural Disaster Risk" in some of the most hazard prone districts in selected states of India"

In 2005, the Indian legislature passed the National Disaster Management Act. This Act frames the development towards a proactive disaster management system. It mandates the creation of a number of policies, plans and organizations for a coherent and multi-level disaster management system. At the national level, it established a National Disaster Management Authority (NDMA) and also created the National Executive Committee. The mandate of the Committee includes the development of a National Disaster Management Plan to be approved by NDMA. Every ministry and department in the Government of India is obliged to mainstream disaster management into their policies, and to prepare a disaster management plan. The National Institute of Disaster Management was put in charge for heading the national efforts in training and research. A National Disaster Response Force, supervised by the National Authority, a National Fund for Disaster Response and a National Mitigation Fund are also established.

As per the Disaster Management Act 2005, each SDMA (State Disaster Management Authority) can establish a State Disaster Mitigation Fund (SDMF), review mitigation works and approve disaster management plans of the departments. As a result, the national mitigation funds do not flow into the SDMF which would have been beneficial for carrying out mitigation work. The National Disaster Management Authority was established to spearhead the development of a disaster-resilient culture.

Powers and functions of National Authority: National Authority shall have the responsibility for laying down the policies, plans and guidelines for disaster management for ensuring timely and effective response to disaster, lay down policies on disaster management; lay down guidelines to be followed by the different Ministries or Departments of the Government of India for the purpose of integrating the measures for prevention of disaster or the mitigation of its effects in their development plans and projects; coordinate the enforcement and implementation of the policy and plan for disaster management.

7. State's Liability

The Government schemes like Indira Awas Yojana (IAY) and other government welfare and development schemes, will also be reexamined to ensure hazard safety. Building codes will be updated every five years as a mandatory requirement and also put in the public domain. Training of engineers, architects, small builders, construction managers and artisans has already been started and needs to be intensified at the State and District level. Central Ministries/Departments concerned and the State Governments should create dedicated project teams to speed up the reconstruction process. State governments will have to lay emphasis on the restoration of permanent livelihood of those affected by disasters and special attention to the needs of women headed households, artisans, farmers and people belonging to marginalised and vulnerable sections.

Apex Court Stated in the case of Gaurav Kumar Bansal and Ors. v Union of India (UOI) and Ors 'it is absolutely necessary for the NDMA constituted at the national level and the State Disaster Management Authority at the State level to be ever vigilant and ensure that if any unfortunate disaster strikes there should be total preparedness and that minimum standards of relief are provided to all concerned. However, it would be advisable for the NDMA to regularly publish its Annual Report (the last one on our record is of 2013-14), to review and update all plans on the basis of experiences and to make its website ndma.gov.in multilingual so that all concerned may benefit'.

8. International Frame Work

A number of global frameworks for catastrophe risk reduction have been created in recent decades (DRR). The Hyogo Framework for Action 2005–2015, as well as its successor document, the Sendai Framework for Disaster Risk Reduction, enacted in Japan on March 2015, provide general recommendations for minimizing natural disaster risks.

9. Hyogo Frame Work

Between 2005 and 2015, the Hyogo Framework for Action (HFA) served as the global template for disaster risk reduction activities. In 2005, during the World Conference on Disaster Reduction in Kobe, Hyogo, Japan, the HFA was adopted. Its goal was to significantly reduce catastrophic losses by 2015, both in terms of lives and in terms of communities' social, economic, and environmental assets.

The approval and execution of Hyogo Frame work Action was a pivotal moment in the development of regional strategies, plans, and policies, catalyzing National and local DRR activities and enhancing international cooperation. The HFA aided in the development of catastrophe risk reduction organizations, policies, and legislation. Stakeholders at all levels improved their risk assessment and detection, disaster preparedness, response, and early warning capabilities.

Sendai Framework:

The Sendai Framework for Disaster Risk Reduction (DRR) 2015–2030 included infrastructure resilience as one of the seven global goals (UNISDR 2019). The fact that two of the four priorities directly relate to resilient infrastructure development, namely "investing in DRR for resilience" through collaboration between public and private entities and "enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation, and reconstruction," emphasizes the importance of quality infrastructure (UNISDR 2019).

The Sendai Framework for Disaster Risk Reduction aims to achieve, over the next 15 years, a substantial reduction of disaster risks and loss of lives, livelihoods, and health and the economic, physical, social, cultural, and environmental assets of people, businesses, communities, and countries by preventing new disaster risks and reducing existing ones through the implementation of integrated and inclusive measures that strengthen resilience (SFDRR 2015). This goal calls for a strong integration of DRR into development, including mountain development

10. Resilience of Infrastructure

Disasters cause primary and secondary impacts on the environment, affecting natural processes, resources and ecosystems, thereby creating conditions for future disasters or for a complex environment related emergency. Currently, emphasis is being placed on developing resilient infrastructure that can withstand calamities while still remaining operational during emergencies. Society needs resilient infrastructure systems to resist and recover quickly from natural and human-caused disasters, but electric power, transportation, and other infrastructures are all highly sensitive and interdependent.

At neighbourhood and regional dimensions, new ways to characterising the resilience of sets of infrastructure systems are critically needed.

"Sufficient and well-built infrastructure, such as high-quality power and transportation networks, can mitigate the effects of natural disasters in terms of both human loss and economic damage. At the same time, the failure of infrastructure nodes such as airports or power plants can have far-reaching consequences that extend far beyond the actual extent of the hazard. Before a disaster strikes, the international community must increase investments in critical infrastructure. We currently place far too much emphasis on short-term relief following disasters and far too little emphasis on ensuring that resilient infrastructure is in place before hazards occur".

In Ashok Kumar v. Delhi Disaster Management Authority and Others Court held that in accordance with the statutory provisions of the Section 66 of the Disaster Management Act, 2005 Disaster victims are entitled for the compensation and the same shall also be paid in accordance with law after proper identification of the victims, as early as possible and practicable.

Despite the ecological richness and the contribution to economy, coastal and marine areas are under stress due to increased commercial exploitation, biotic and abiotic pressure, urbanization and industrialization, infrastructure growth and impacts of climate change. This is affecting the coastal ecology, and thereby, the livelihood, health and well-being of the coastal population; affecting in turn prospects for sustained economic growth. Coast is subject to severe hazards including weather events, tsunami, oil spills, erosion, flooding, drought, etc. and resilience of the communities to extreme weather variability had been low, mostly because of impoverishment.

The experiences of the Republic of Korea and Japan demonstrate the importance of investing in infrastructure in order to mitigate the effects of disasters. However, investment in disaster management infrastructure falls into two categories: (a) investment in infrastructure to support sustainable socioeconomic development; and (b) investment in infrastructure for reconstruction and recovery.

India is a fast urbanizing growing country, ensuring the resilience of essential infrastructure is critical to the country's sustainable progress. The infrastructure can be categorized into majorly Object-oriented system and Network oriented system. Public emergency services like hospitals, police station and fire station etc., can be previewed as object oriented where as crucial necessities of daily life such as power, gas and water can be known as network-oriented system Prevention and mitigation contribute to long-term safety improvements and should be included in catastrophe management plans. India's government has made mitigation and prevention critical components of its growth strategy. As a result, the tenth five-year plan includes a comprehensive chapter on catastrophe management. The strategy emphasizes the importance of incorporating mitigation into the development process if development is to be sustainable. The vital infrastructure serves as the backbone for not only saving human lives but also decreasing physical and financial losses. Resilience of the network-oriented system needs to be prioritized.

“Critical infrastructures can be defined either individually or as a combination of physical structures, facilities, networks and other assets which provide services that are essential to the social and economic functioning of a community or society”. Infrastructure development and investment has played a critical role in furthering social and economic development. The ability of a resilient infrastructure to foresee, absorb, adapt to, and/or quickly recover from a potentially disruptive event determines its effectiveness.

Building Back Better Recovery and reconstruction activity is clearly demarcated by temporal indicators, taking place as it does in the wake of natural disasters, and by its focus on longer-term needs beyond the immediate survival necessities of disaster victims. At the same time, the boundaries between relief and recovery can become blurred if relief arrangements such as the erection of temporary shelters become a longer-term feature, effectively acting as recovery structures when resource scarcity or political failure hinders durable reconstruction. The links between reconstruction activity and preparedness are yet stronger. While reconstruction used to be viewed as a one-time response to a specific disaster, it is increasingly recognised that building back better, with a view to strengthening resilience against future disasters, has great advantages both economically and in terms of quality-of-life improvements. Building back better encompasses a number of dimensions with gender-specific implications, beyond the erection of strengthened physical infrastructure. It involves paying express attention to a range of issues from compensating women for the losses of their tools and assets that is often overlooked, through providing childcare for fathers and for mothers, to supporting the formation of men’s and women’s groups and strengthening human development.

In India the enormous number of people living in low-lying and coastal areas, as well as the substantial inter-annual variation associated with hydro-meteorological hazards, a high-quality disaster-control infrastructure is urgently needed. Disasters cause enormous losses in life, livelihood, property, and the environment in India, preventing growth. Our disaster mitigation and response plans and mechanisms are frequently limited by legal issues. Disaster Control Infrastructure is a type of infrastructure designed to safeguard people and property in hazard-prone areas from the effects of the hazard. River embankments, sea walls, dikes, storm surge barriers, cyclone shelters, and other structures are included in the Disaster Control Infrastructure. The design of these infrastructure systems is based on a knowledge of past hazard patterns and predicted extreme hazard event return periods.

Furthermore, effective climate and disaster risk reduction activities require access to information and knowledge, as well as the availability of capability. Infrastructure development decision-makers, investors, and practitioners need access to actionable data and expertise that allows them to establish policies, programs, and projects that support their climate and development goals. Furthermore, given the numerous uncertainties connected with climate change and its consequences, as well as the complex requirements for successful climate and disaster risk management, all infrastructure development stakeholders must be aided in strengthening their capacity to plan, develop, design and implement climate-resilient policies and programs or projects.

The Coalition for Disaster Resilient Infrastructure (CDRI), which is being hosted by India and includes countries, the United Nations (UN), banks, the private sector, and research agencies, is focusing on infrastructure resilience through capacity building, partnerships, research, and knowledge management. CDRI also contributes to the UN Sustainable Development Goals (SDGs), particularly SDG on creating resilient infrastructure, which aim to make the world a better place for everyone by 2030. Restoring livelihoods and creating new economic opportunities is of fundamental importance to all in a post-disaster context.

Honourable Apex Court opined that “The aesthetic use and pristine glory of our country's natural resources, environment, and ecosystem cannot be eroded for private, commercial, or any other use unless the courts find it necessary, in good faith, for the public good and in public interest to encroach upon the said resources.”

11. Conclusion

Sustainable development requires a systematic and integrated risk management approach in order to avoid or reduce future losses. **Restoring livelihoods and creating new economic opportunities is of fundamental importance to all in a post-disaster context. Community infrastructure consists physical infrastructure and organisational infrastructure i.e. "hard" and "soft" assets of societies.** It is evident that disaster management is not a stand-alone endeavor; rather, dealing with disasters and emergencies in the country necessitates a well-structured, people-centered, coordinated, and integrated effort. They can act swiftly in a cohesive and efficient manner once they've been educated, and their capacities are limitless. If we wish to improve our systems professionalism and effectiveness in dealing with disasters and decrease the impact of catastrophes on human life and property in India, there is dire need to strengthen the infrastructure facilities.

Connecting the Unconnected in Post Disaster Phase through Space Technologies for Sustainable Development Goal #4

Ms. Kavya Kamepalli

Abstract

A quality education is a force multiplier and can lay a foundation for sustainable development. Accordingly, the United Nations made education as Sustainable Development Goal (SDG) #4. If education is supported before, during and after a disaster, it can save lives, protect children and benefit communities and countries. But education is generally not prioritized in a disaster response, and reconstruction or rehabilitation to ensure continued education. Limited allocation of resources is one of the reasons and thus the gulf between education and student expands in a post-disaster phase. Under such circumstances, space based technologies can help in optimizing the limited resources efficiently and effectively. An exploratory strategy for the realization of SDG#4 is suggested and the same can be scaled-up entire South Asian region as well.

Keywords: *Disruption to learning process; Space based Technologies: South Asia; Sustainability of Education; Education for Sustainability.*

1. Introduction

India, due to its geographical location is vulnerable to numerous natural hazards such as earthquakes, floods, cyclones, droughts, landslides, hailstorms etc. Risk of these hazards becoming disaster looms large on account of India's demographics, socio-economic conditions, unplanned urbanization, development within high-risk zones, environmental degradation, climate change etc. All these factors contribute to India's higher vulnerability and often these disasters seriously threaten India's economy, its population and sustainable development. Over and above, it is projected that by 2030, India will become the most populous nation. To add to the woes, global climate change projections indicate that both frequency and intensity of these natural disasters will increase and so is its vulnerability with consequent damages shooting up several folds (IPCC AR 6). Such a situation warrants effective disaster management encompassing all stakeholders at every step of Disaster Management process, viz., preparedness, awareness, response, recovery and mitigation.

Every disaster is unique in the way it impacts the community and among the various sections of the society, it is the women, children and the elderly that are the most vulnerable to disasters. In along run, it is the children of vulnerable communities that bear burden the most. A child, sensitive and being in formative years, is not only put to hardships due to disaster impacts and effects, but also, in all probability, miss the process of learning/ education. For instance, cyclones, floods may result in damage to the educational infrastructure or private property and thus disrupt the child education, while, slow onset disasters like drought may disrupt learning process due to processes like out-migration. In post-disaster phase, inter-alia, limited resources, education is generally not prioritized in a response, reconstruction or rehabilitation of damaged schools for continued educationas high demand for resources from other sectors. In this context, this article argues that, Space Based Technologies (SBTs) can help to overcome the disruptions in learning processsignificantly and help in realization of SDG # 4.

2 Education

Quality education is not only the foundation for sustainable development, but also is a force multiplier which enables self-reliance, boosts economic growth by enhancing skills, and improves people's lives by opening up opportunities for better livelihoods. Accordingly, attention to education was stressed in every planning process. Millennium Development Goals (MDG) prioritized education and incorporated it as MDG #2. It aimed to achieve 'Universal Primary Education' to be monitored using three indicators, viz.,

- Target # 2.1 - Net Enrolment Ratio in Primary Education,
- Target # 2.2 - Proportion of Pupils Starting Grade 1 who Reach Last Grade of Primary School, and
- Target # 2.3 - Literacy rate of 15-24-year-olds, women and men, to be realized during the time period 2000 - 2015.

South Asian countries for long have made investments in education sector to achieve Universal Primary Education and in this regard, Sri Lanka and Bangladesh have been early movers. Sri Lanka has implemented the Free Education Act as early as in year 1945 and Bangladesh has implemented the Primary Education Compulsory Act of 1990. India has adopted the right-to-education legislation in August 2009. Pakistan has passed legislation in 2012 to guarantee the Right to Education (Bajaj et al 2016). A comparison of the progress made on three indicators of MDG #2, indicates that SAC are still away from the realization of the goal of University Primary Education (Table 1).

Table 1: Indicators and progress on MDG # 2

Country	Base year 1990	Status in 2000	Status Vs MDG in 2015
MDG # 2.1:- Progress in MDG Indicator #2.1 - Net enrolment in primary education (%)			
Bangladesh	60.5	85.5	97.7
Bhutan	55	90.7	94.8
Nepal	69.3	98.7	94.8
India	78.2	98.6	94.8
Pakistan	56.2	71.9	94.8
Sri Lanka	99.8	94.3	94.8
MDG # 2.2 - Proportion of pupils starting grade 1 who reach grade 5 (in %)			
Country	Base year 1991	Status in 2000	Status (Year)
Bangladesh	44.7	66.3	79.9 (2012)
Bhutan	31 (1993)	84.2 (2003)	78.9 (2012)
Nepal	35.7	65.3 (2002)	60.4 (2013)
India	57.3 (1995)	61.4	96 (2011)*
Pakistan	-	69.7 (2004)	62.2 (2012)
Sri Lanka	96.9	97.8	98.5 (2012)
MDG Indicator # 2.3 - Literacy Rate of 15–24 Year Olds			
Country	Base year 1990	Status in 2000	Status (year)
Bangladesh	44.7 (1991)	63.6 (2001)	79.9 (2012)
Bhutan	-	74.4 (2005)	-
Nepal	49.61	70.11	82.4 (2011)
India	61.91	76.41	81.1 (2006)1
Pakistan	55.3 (1998)	69.21 (2006)	70.8 (2011)
Sri Lanka	-	96.6 (2001)	98.2 (2010)

Source: Compiled from http://mdgs.un.org/unsd/mdg/Host.aspx?Content=Data/snapshots.htm, *https://unstats.un.org/unsd/mdg/SeriesDetail.aspx?srid=743

As the nation inch towards achieving Universal Primary Education, other associated issues become a concern, for instance, educational infrastructure for later stages of education, i.e., secondary and higher education, both in terms of access and also quality. The United Nations General Assembly (UN) has addressed these concerns in the Sustainable Development Goals (SDGs). In view of its utmost importance, education has been made as a full-fledged goal # 4 and has set for itself the goal, 'by 2030, ensure inclusive and equitable quality education and promote lifelong learning opportunities for all'. It encompasses two key components, viz., a) Access, b) Quality Education. Different Indicators have been selected to monitor the progress. For the purpose of monitoring the progress, NITI Aayog has selected indicators based on the availability pan-India data. Scores pertaining to SDG # 4 of various states in 2020 is given in Fig 1 and a comparison with the score in 2018, most of the states have registered lower score in subsequent years (Table 2). State of Kerala has highest score at 80, followed by the Himachal Pradesh and Goa with a score of 74 and 71 respectively and Bihar occupies the lowest place with a score of 29.

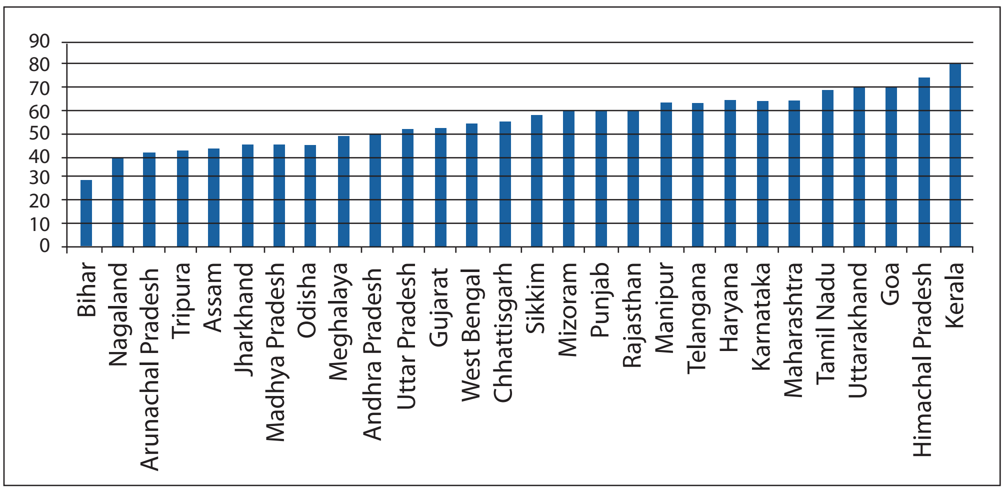

Fig 1: Status of SDG #4 in different states in 2020 (source NITI Aayog reports)

Based on the score, NITI Aayog has made four categories, viz., Achiever (with a score of 100), Front Runners (with score between 65 to 99), Performer (Score between 50 to 64) and Aspirant (Score below 49). Based on the SDG #4 Score, it is surprising to find that there are no states that fall in Achiever Group and majority of Indian States falling into the Performer Group (Table 3). In this backdrop, any disturbances in the form of natural disasters could have an adverse impact on realization of the Goal. Disasters, by their nature, are divided into two, viz., rapid and slow onset. Rapid disasters such as floods, cyclones, earthquakes may result in loss of life and damage to the infrastructure, with severe impact on the process of schooling. For instance, schools, in general, are preferred as relief centers. Cumulatively, they bound to have impact on both access and quality of education and harnessing the space based technologies could provide additional traction for the realization of the SDG # 4 in general and particularly for quality aspects.

Table 2: Categorization of States

Sl no	Category (score)	States and UTs
1	Achiever (100)	
2	Front Runner (65-99)	Chandigarh, Delhi, Goa, Himachal Pradesh, Kerala, Puducherry, Tamil Nadu, Uttarakhand
3	Performer (50-64)	A& N Islands, Andhra Pradesh, Chhattisgarh, Dadra and Nagar Haveli, Daman and Diu, Gujarat, Haryana, Karnataka, Maharashtra, Manipur, Mizoram, Punjab, Rajasthan, Sikkim, Telangana, Uttar Pradesh, West Bengal
4	Aspirant (0- 49)	Arunachal Pradesh, Assam, Bihar, Jammu and Kashmir, Jharkhand, Ladakh, Madhya Pradesh, Meghalaya, Nagaland, Odisha, Tripura

Source: NITI Aayog 2021

3 Niche for SBT

Due to its geographical location, India is often subject to different types of natural disasters such as floods, drought and effective large population across the country. Consequently, both access and quality of education may get effected and further intensify the un-employability (World Bank 2009, NASSCOM and McKinsey 2005). Different scenarios may emerge in post-disaster and may create disruptions in the process of learning, viz.,

- Student community effected by disaster and thus unable to attend to the education

- Teaching community is either effected by the disaster or engaged in post-disaster related activities and thus unable to attend to the teaching, and
- Education infrastructure itself damaged by disaster or it is being used for post-disaster activities, for instance, as relief centers

Under such circumstances, using satellite mode of communication, linkages can very easily be established between two distant places, if the required infrastructure is in place. This technology can be adopted to establish linkage between two institutions, representing two extremes in terms of infrastructure and resources. The satellite link can be used to disseminate, transfer of knowledge and facilitate interaction between the stakeholders of two or more institutions representing ‘Haves’ and ‘Have Nots’ respectively. Such an arrangement can help an educational institution to leapfrog the limitations of inadequate trained resource persons, overcome the physical distance, meet the aspirations and also inspire younger generations.

Financially, implementation of SDG related programs requires significant budgetary allocations. For instance, to close their infrastructure gaps, South Asian Countries require an estimated $2.5 trillion by 2020 and $4-5 trillion by 2030 (NPC Website). By Adopting SBT, entire mountainous region can be assured of both quality and access in education immediately and traditional infrastructure can be developed as and when resources permit. Exploration of avenues such as pooling the resources, leveraging public-private partnerships (PPPs), international development cooperation etc. can ensure earlier adoption of SBT.

3.1 Regional Cooperation in the Field of Education

To promote the welfare of the people of South Asia and to improve their quality of life, South Asian Countries viz., Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka formed an association - The South Asian Association for Regional Cooperation (SAARC) in 1985 and the member countries agreed to promote active collaboration and mutual assistance in the economic, social, cultural, technical and scientific fields at regional level. The SAARC has recognized that literacy is a fundamental human right and the foundation for lifelong learning through education and have explicitly agreed that education may be included as an agreed area of cooperation since all children were the principal means of human resources development (SAARC Website, ISRO Website). These regional agreements of cooperation may be invoked to achieve regional development, with reference to SDG #4. South Asia Satellite (GSAT 9) put into orbit by India could be one such platform for such regional cooperation.

Table 3: Potential Niche for SBT in SDG#4

Indicator		Extent of Disruptions	Potential for SBT
Participation	4.3.1	Significant	Access to learning nearby, serves as catalyst for higher participation
	4.3.2	Moderate	Higher value addition tend to attract more students to tertiary education
	4.3.3	Significant	Value addition and higher potential for gainful employment encourages enrollment into vocational programmes
Target 4.4			
Skills	4.4.1	Moderate	Virtual classrooms and exposure to SBTs has positive influence
	4.4.2	Moderate	Adoption of SBT increases the per cent of youth with digital literacy
	4.4.3	Significant	Adoption of suitable SBT certainly increase the levels of attainment
Target 4.5			
Policy	4.5.1	Significant	Gender disparities are significant in Mountain communities, and reasons vary from access to affordability. SBT can bring down the opportunity costs significantly.
	4.5.2	Negligible	-
	4.5.3	Significant	Through SBT, access can be ensured to remote population as well
	4.5.4	Moderate	SBT can bring down per student cost of knowledge delivery
	4.5.5	NA	NA

Target 4.6			
Skills	4.6.1	Moderate	SBT can enhance the rate of delivery of service and number of beneficiaries
	4.6.2	Moderate	SBT can help to increase the literacy rate
Participation	4.6.3	Moderate	SBT can make the programs more interesting and thereby better participation

3.2 Earlier Experiments of SBT for Education

- Indian Space Research Organization (ISRO) has helped to evolve and functionalize a satellite-based education program 'Satellite Instructional Television Experiment (SITE)' in 1975. Supported by UNDP, UNESCO, and UNICEF, the SITE initiative was deployed by using the state-of-the-art technological support extended by United States of America (USA). A cluster of 400 villages in 20 districts of six different states were shortlisted for this experiment and two components, viz.,

  a) Educational Television for the school children in the age group of 5-12 years

  b) Instructional Television for adult audience in the areas of agriculture, family planning, health and hygiene, occupation skills constituted the SITE. (Romesh Chander and Kiran Karnik 1978).

    o Success of SITE led to Satellite Telecommunication Experiments Project (STEP), a Joint program with Franco-German Symphonie Satellite during 1977-79. (Kiran Karnik 2015).

World's first education satellite - EDUSAT launched in 2004, exclusively devoted to educational purposes - the virtual classroom concept to provide education to children in remote villages, adult literacy programs and training modules for teachers and quality higher education to students in areas without access to good technical institutes. This program has enabled the dissemination of knowledge/information to thousands of students at once, making classrooms barrierless. The tele-education networking systemoperating in the Ku-band constituted an uplink facility, Satellite Interactive Terminals (SITs) and Receive Only Terminals (ROTs) connecting 56,164 schools and colleges (4,943 SITs and 51,221 ROTs) covering 26 States and 3 Union Territories of the country as of the year 2013.

4.0 Proposed Model Ecosystem of Convergence

Before presenting the outline of ecosystem of Satellite based program to enhance access and quality of education in the mountain regions, the caveat of argument is that, this is not the debate for either technology or teacher mode. Neither it is the argument of which one is better. Rather it subscribes to argument that teacher is in a position which is irreplaceable and prime importance is accorded to the teacher only. SBT can fill in the gaps if any created by the disasters, to a limited extent only. In addition, SBT can help teachers to play a more effective role in entire process, thus, complimenting each other. An outline of the model is presented here and has been drawn significantly from the Indian context. Similarities with other south Asian countries, make this model suitable for consideration and adoption in other South Asian countries after suitable changes.

Satellites can help overcoming the geographical distance and provide a reliable and continuous communication channel between two institutions. Taking advantage of this aspect, any institution that was not affected by disaster can play the role of 'Mentor' to guide the students of the institution that was affected by the disasters. Teachers from the mentor institution, through uplink facility can interact with students in subject related matters as the case with 'Virtual Class Room'(VCR). Such a mechanism helps to avoid the discontinuity in the process of learning. With very high rates of penetration of mobile, communication has helped to reach out to a larger audience. Use of SBTin post-disaster can also fill this gap between the desired and actual skill sets of youth/ students to some extent (UNESCAP 2017, NSDC web stie). It can be used at both secondary and higher levels and help overcoming issues like continuity and skill gap.

Of the ten targets of SDG #4, Targets 4.1 to 4.6 is prone to disruptions and adoption of SBTs has the potential to overcome those disruptions. For instance, participation under Target 4.3 is directly vulnerable to disruptions caused by disasters and SBT can help to overcome disruptions in participation and also ensure the continuity in terms of quality education. Certainty of continuity helps to increase the enrollment in tertiary education as well as (Indicator 4.3.2). SBT can provide higher levels of exposure to the student and help students of technical and vocational courses, thus helping in the progress of 4.3.3. Similarly, Target 4.4 can be benefitted from adoption of SBTs in as it can facilitate the quality and access in institutions nearby and thus improve the skill sets of youth and also encourage girl child participation. Similar is the influence of SBTs on Target 4.5 and its indicators. By facilitating effective and easy to understand videos, every indicator under Target 4.6 also can be benefitted by SBTs (Table 4).

Way Forward

Space based Technologies have found wide usage in several sectors, but slow in the education sector, in spite of their potential to help in realization of SDG Indicators from 4.3 to 4.6. In view of several advantages of SBT, such as quality, access and economic benefits, efforts should be made to harness and adopt SBTs to overcome the disruptions caused by the disasters and for faster realization of SDG # 4.

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

Dr. Rajib Gupta and Arup Barman

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.

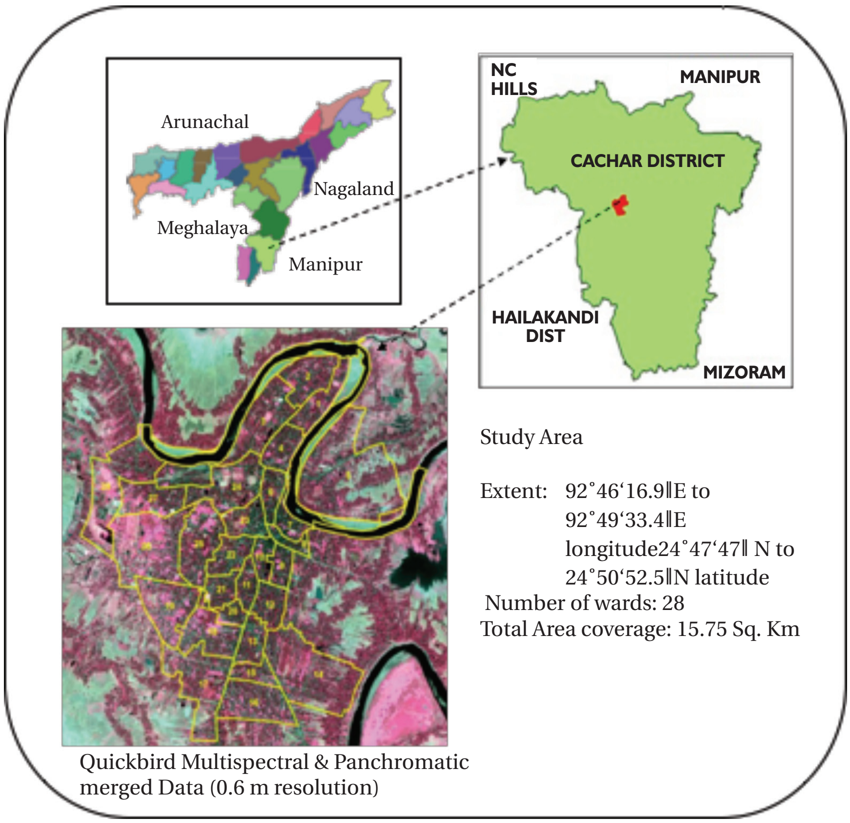

Fig.1 Location Map of Study Area of Silchar Town

(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', Dwpplklllduf1, 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	
	(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
1	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*Dwpplkllddeq1+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', Dwpplkllduf1, 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', Dwpplkllduf1, 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
	Dwpplkllduf1	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*.

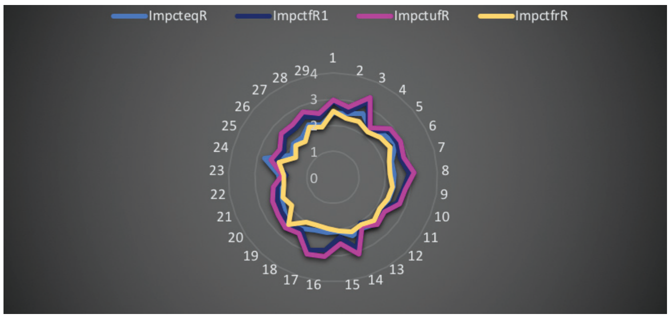

Fig. 1 Ward wise mean value of the impact of considered hazards

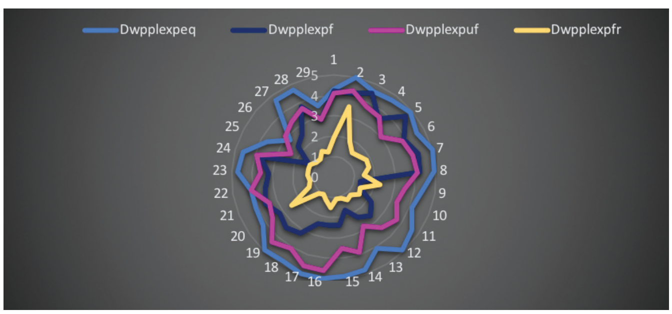

Fig. 2 Ward wise mean value of exposure of considered hazards

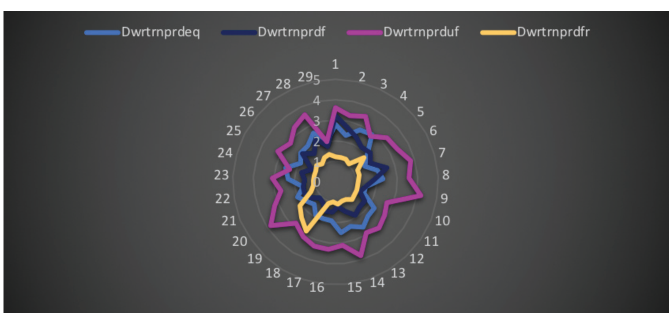

Fig. 3 Ward wise mean value of return period of considered hazards

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

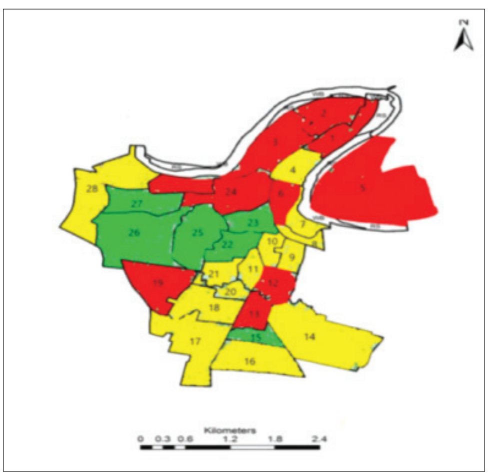

Fig. 4 Impact mapping for earthquake

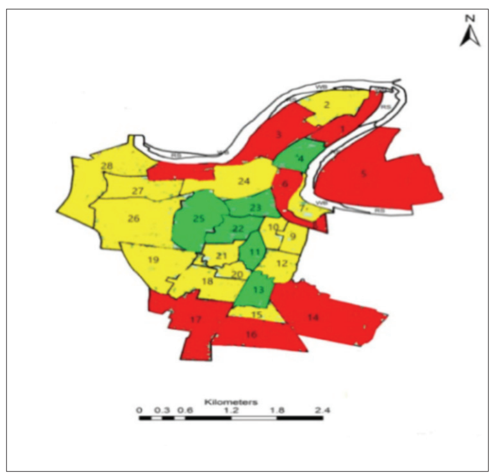

Fig. 5 Impact mapping for flood

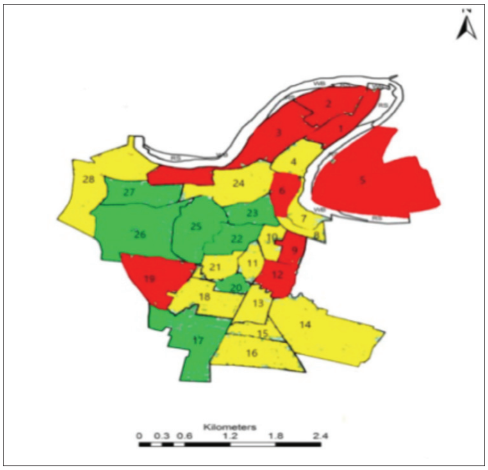

Fig. 6 Impact mapping for urban flood

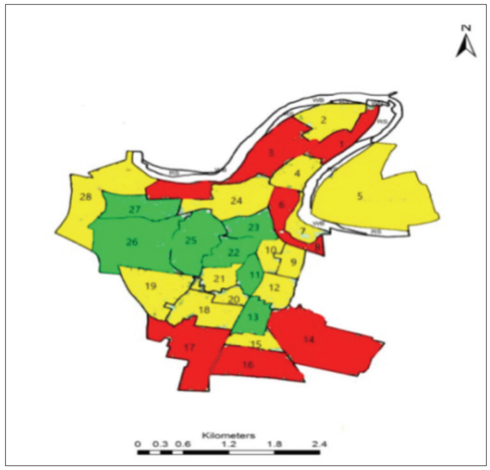

Fig. 7 Impact mapping for fire

Medium		Low		High	

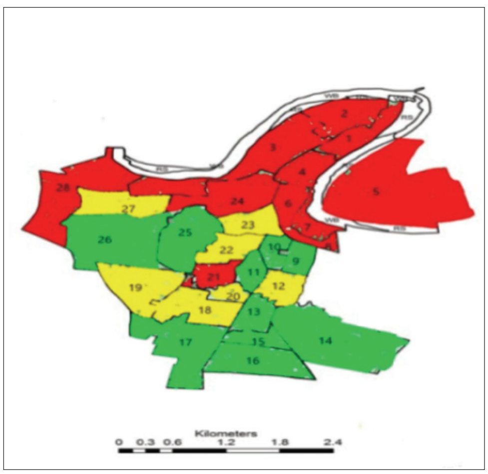

Fig. 8 Exposure mapping for earthquake

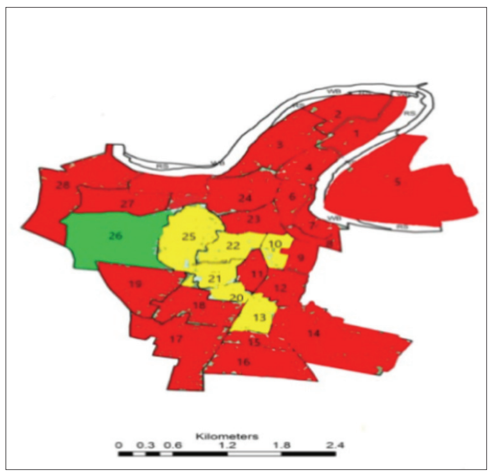

Fig. 9 Exposure mapping for flood

Low		Medium		High	

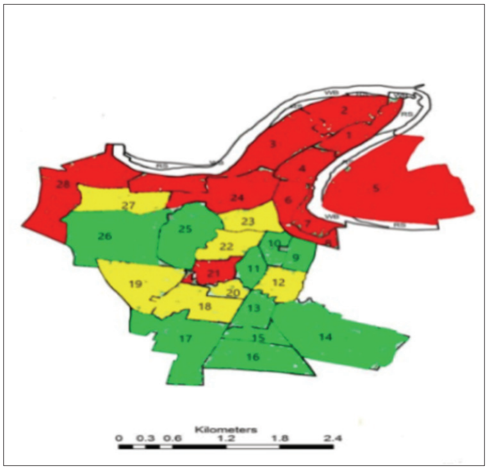

Fig. 10 Exposure mapping for urban flood

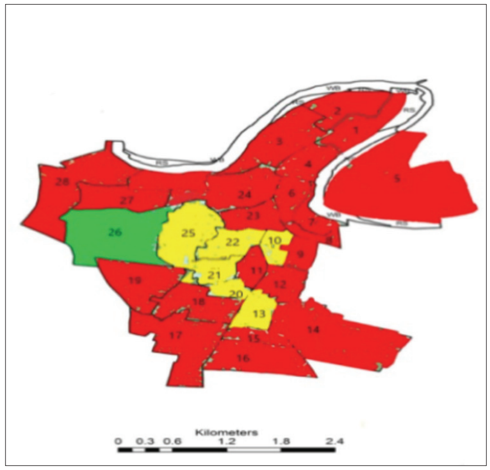

Fig. 11 Exposure mapping for fire

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

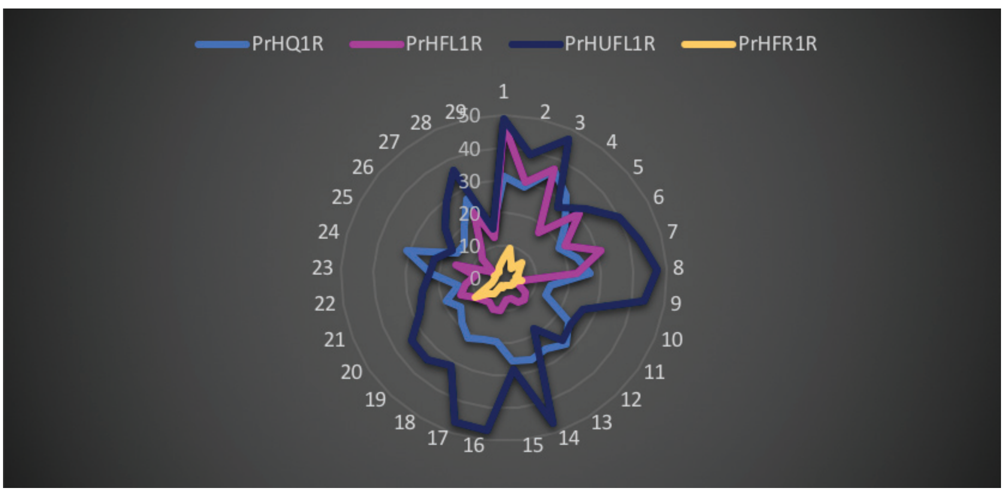

Fig. 12 Ward wise mean value of intensity of hazards

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.

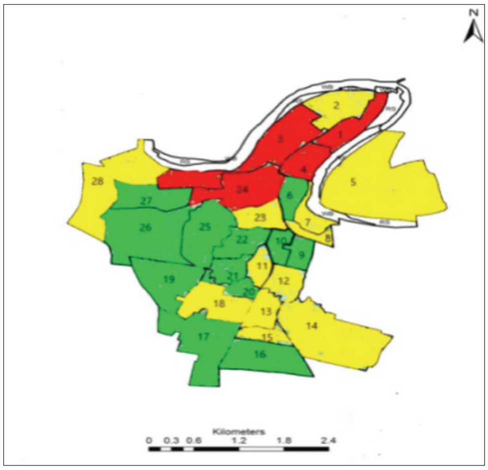

Fig. 13 Earthquake hazard mapping

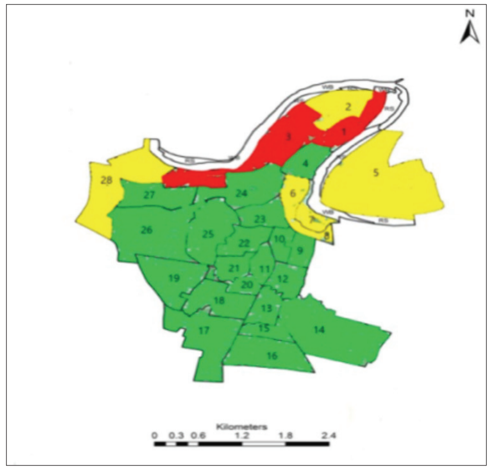

Fig. 14 Flood hazard mapping

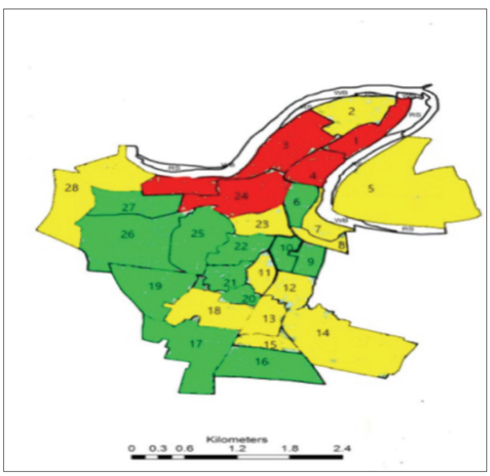

Fig. 15 Urban flood hazard mapping

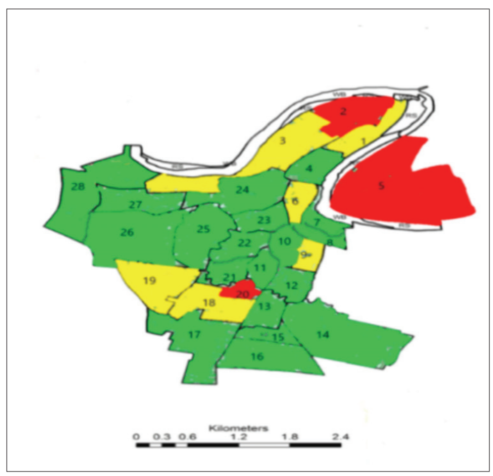

Fig. 16 Fire hazard mapping

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

Selection of Suitable Water Treatment Technologies for Natural Disaster and Emergency Situation

Sunil Kumar Meena[1*], Urmila Brighu[2], P Jagan[1]

Abstract

This review paper emphasises the selection criteria for deployment of water treatment technologies during the immediate emergency phase of 1-2 weeks followed by a disastrous natural event. Selection of the water treatment technologies by assigning a score in the range of 1 to 5 for the selected six evaluation criteria i.e. ease of deployment, ease of use, performance, throughput, energy requirement & public acceptance. Secondly, the deplorability of available treatment technology was assessed with respect to the magnitude of impact of any natural disasters. Based on the performance, treatment capacity & energy requirement, the various available membrane and non-membrane water treatment technologies are reviewed. The treatment technologies are scored based on selected evaluation criteria followed by their suitability during the disaster to bring an idea of deployment of suitable technology.

Keywords: *Natural Disaster, Water Treatment, Membrane, Evaluation Criteria*

1. Introduction

As per the Centre for Research on the Epidemiology of Disasters (CRED) disaster as "a situation or event that overwhelms local capacity, necessitating a request at the national or international level for external assistance; an unforeseen and often sudden

[1.] Sunil Kumar Meena, P Jagan,Central Pollution Control Board, Regional Directorate, Bhopal, MadhyaPradesh
[*] Corresponding Author E-mail:biosunil2006@gmail.com
[2.] Urmila Brighu, Professor, Department of Civil Engineering, Malviya National Institute of Technology, Jaipur, Rajasthan

event that causes great damage, destruction and human suffering". Further, survey was carried out by CRED that in the year 2015 total 376 natural disasters are main cause of death of around 22,765 people, made 110.3 million victims and caused US$ 70.3 billion damages. Natural disasters like flooding, hurricanes, landslide, tornados, earthquakes or a national emergency can happen anywhere, anytime (CRED, 2015). Natural disasters impact magnitude results in power failure, water shortage, infrastructure damage, contamination or pathogenic spread and transportation failure.

Due to compromised water supply & contamination; outbreaks of diseases such as dysentery, typhoid and hepatitis are reported widely. (WHO, 2002). Agencies have to provide a minimum of 7.5-15 liters per day water for drinking, basic hygiene & cooking. (Sphere Project, 2011). In the absence of preparedness-centric approach; disaster management agencies follow relief-centric approach and deploy conventional or advanced water treatment technologies without considering the success criteria like their ease of deployment, through put volume with quality, cost of treatment, maintenance, operator's skill, consumables supply, public acceptability and energy requirement. (Loo et al., 2012). That results in the failure of safe water supply strategy.

1.2 Disaster: Statistical Overview

In the year 2015, globally, approximate 376 natural disasters were the main cause of the death of nearly 22,765 people. Wherein, made 110.3 million victims and caused US$ 70.3 billion in damages.

India has been traditionally vulnerable to natural disasters due to a number of factors as its unique geo-climatic conditions, topographic features, non-scientific development practices population growth etc. Also, earthquakes, floods, cyclones and landslides have been recurrent phenomena. About 60% of the landmass is prone to earthquakes of various intensities. In the decade 1990-2000, an average of about 4344 people lost their lives and nearly 30 million people were affected by disasters every year (DMI, 2009).

1.3 Magnitude of Impacts

Natural disasters like earthquakes, cyclones, floods, tsunamis, volcanic eruptions etc. can cause significant impact on the basic amenities related to their intensity. The impact over water supply infrastructure, transportation, power supply, personnel shortage etc.

significantly disturbs the basic lifeline of a city, town or village. The common levels of impact of natural disasters on environmental health services are represented below in Table 1 (Pan American Health Organization, PAHO, 2000).

Table 1. Common levels of impact of disasters on environmental health services (PAHO, 2000)

Most common effects on enviromental health		Earthquake	Cyclone	Flood	Tsunami	Volcano
Water supply & Wastewater disposal	Damage to civil engineering structures	1	1	1	3	1
	Broken mains	1	2	2	1	1
	Damage to water sources	1	2	2	3	1
	Power outages	1	1	2	2	1
	Contamination (Biological or chemical)	2	1	1	1	1
	Transportation failures	1	1	1	2	1
	Personnel shortages	1	2	2	3	1
	System overload due to population shift	3	1	1	3	1
	Equipment, Parts and supply shortages	1	1	1	2	1
Vector control	Proliferation of vector breeding sites	1	1	1	1	3
	Increase in human/vector contacts	1	1	1	2	1
	Disruption of vector-borne disease control Programmes	1	1	1	1	1
NOTE : 1 - Severe possible effect ; 2 - Less severe possible effect ; 3 - Least or no possible effect						

(Source: PAHO, 2000)

1.4 Water Requirement during Emergency

Insufficient quantity & poor quality of water are the foremost reason for the ill health & water-borne diseases among the disaster affected (WHO, 2002). The minimum requirement of safe drinking water may vary among rural & urban community. Minimum 20 litres of safe water is required during short-term survival for drinking &

cooking (Maslow, 1943). During relief camp or post-disaster management this water requirement increased significantly for carrying out personal sanitation & washing. Sphere guidelines for water supply stipulate that at least 15 litres/day/person should be provided, with water quality at point of delivery with turbidity <5 NTU (nephelometric turbidity units), zero faecal coliforms per 100 ml, and free residual chlorine of 0.5 mg/l (in the case of piped water or diarrheal disease outbreaks) (Sphere, 2011). Furthermore, basic water needs vary based on social and cultural norms, climate and the degree of displacement. It is required to consider leakages and other losses of water in the catchment, treatment or distribution process and spare capacity (Sphere, 2011). The source of water needs to be within 500 meters reach from camp. If no such specific water purification technology available then at least double chlorination shall be carried out.

1.5 Water Treatment Technologies

The most common water treatment method practiced by the affected population is either boiling or chlorination (WHO, 2002). However, the water quality compromised severely after the disaster in respect of turbidity, salinity, microbial contamination & odor. A four weeks pilot survey of 48 households of Aceh, Indonesia by NGO CARE during Tsunami (December, 2014); the water sources like shallow wells, boreholes and streams were all positive for *E. coli*, shallow wells (450 CFU/100ml; high risk), boreholes (15 CFU/100ml; low risk) and streams (>2500 CFU/100ml; very high risk). It was surprising that, 67% of the 43 samples from water stored at the house hold were positive for *E.coli*, with 15% havingcounts>101 CFU/100ml (the WHO “high risk” level) and 22% between 11 and 100 (“intermediate risk”) (Albert et al, 2006). While inadequate disinfection of supplied water presents an apparent health risk. Also, over-dosing is also problematic since it encourages people to consume water from untreated sources. Against chlorinated water which may be difficult to reverse (Albert et al, 2006). Considering the failure of boiling and chlorination in providing safe drinking water to the affected population; it is important to explore other available non-membrane and membrane-based water treatment technologies with respect to their performance, energy requirement & through put to accommodate the need of the population as per the prescribed minimum standards. The water treatment technologies are tabulated in Table 2 & 3.

Table 2. Available non-membrane based water treatment technologies (Loo et al, 2012 as modified)

Available Water treatment Technology for Emergency	Particulars	Treatment Capacity (Liters/ hr)	Performance	Energy Requirement	Other treatment required	Reference
Activated Carbon & UV disinfection	Activated carbon-based filter candle followed by UV	160	6 LRV bacteria 3 LRV protozoa 4 LRV virus	3/4 hp centrifugal water pump (60 psi)	-	Abbaszadegn et al., 1997
Biosand filter	sized granite, gravels or sand (for 95 cm x 36 cm filter column)	30-40	0.3-4 LRV Bacteria 3.8-5 LRV Protozoa 0-1.3 LRV Virus 96% turbidity	Gravity filtration	-	Mahmood et al., 2011
Boiling	Rolling boil for at least 1 minute	Varies	86-99% bacterial removal	Fuel	-	Rosa et al., 2010
Chlorination tablets	-	Varies	1-2.8 LRV bacteria	None	Filtration	Jain et al.,2010
Chulli purifier	Chulli & Aluminium coil	30	>5 LRV bacteria	cooking fuel	Sand filtration	Gupta et al., 2008
Combined Flocculation-disinfection	PUR® sachet	10 (per sachet)	4-8 LRV bacteria >2.5LRV protozoa 1-4 LRV virus	none	Cloth filtration	Mclennan et al., 2009
SODIS	PET bottles	varies	3-5.5 LRV bacteria 1-3 LRV protozoa 2-3 LRV virus	Solar radiation	Filtration	Sobsey et al., 2008
Upflow clarifier	Oxfam tank, clarifier cone, non-woven fabric polishing filter, coagulant dose (10-60mg/l)	5000	<5 NTU 2 LRV bacteria	Diesel Generator	Chlorination	Dorea and Clarke, 2006

UVdisinfection portable	UV lamp	500	>2.3 LRV virus	Powered by hand crank, bicycle or electric	Filtration	Berg, 2010
NEERI-ZAR	$KMnO_4$, sand filtration & chlorination	20	1-2 LRV bacteria <3 NTU	Gravity filtration	-	CSIR NEWS 57 (8) 30.4.2007
DIVVY 250 System™	2-step water purification Super Chlorination (3-5ppm) & Micro filtration	250	6LRV Bacteria 3LRV Protozoa 4LRV virus	Hand powered	-	www. espwater products. com

Table 3. Available membrane-based water treatment technologies (Loo et al, 2012 as modified)

Water treatment Technology	Particulars	Treatment Capacity (Liters/hr)	Performance	Energy Requirement	Other treatment required	Reference
Ceramic filter	Varied pore sizes	2.4-18	2-4 LRV bacteria 2-6 LRV protozoa 1-2.3 LRV virus	Gravity filtration	-	Brown and Sobsey, 2010
Bicycle powered Microfiltration	Micro filter ceramic pore size	240	67% Total Coliform 89% Feacal Coliform <1 NTU	Pedal powered pumps	Upflow rapid sand filter	McBean, 2009
FO pouch	0.04 micron pore sized membrane	50	>5 LRV bacteria	Gravity filtration	Mesh sieve	Frechan et al, 2011
Bicycle powered Ultra filtration	UF membrane	800	<1 CFU/100ml <1 bacteria/ml <1 NTU	Pedal powered	Pre-filter	He, 2009

Supremus Aquastandal one water purification system	Low pressure hollow fibre membranes (0.4micron pore size)	500-700	>4LRVBacteria >4LRVprotozoa >3LRV virus <0.1NTU	Hand powered	2 minutes backwash everyday	Ministry of Drinking water & Sanitation, 2015
LifeStraw®	UF hollow fiber membrane 20nm	8.6-12	6-7 LRV bacteria 2-4.7 LRV Virus 3.6 LRV protozoa	Gravity or suction	Prefilter& halogen chamber	www. lifestraw. com
Outback Plus™ (OB-25NF)	4-stage (Pre-filter,0.5 micron filter, Nano filter & multimedia filter)	1-3	4LRV Protozoa 6LRV Bacteria 4LRV Virus	Gravity filtration	-	www. espwater products. com
Bicycle powered Nanofiltration	60cm^2 poly acromatic flatsheet NF	12-18	90% of total Arsenic	Pedal Powered (0.2-0.7MPa)	Pre-oxidation	Oh et al., 2000
Small ScaleRO system	RO module for brackish water desalination at 6 bar pressure	240	<100mg/l TDS	Electric power	Prefilter, GAC, UV dis-infection	Elfil et al., 2007
Photovoltaic RO	Seawater RO membrane module at 65bar pressure	50	<500mg/l TDS	68.5Kwh powered PV & DG set for power backup	-	Tzen et al., 1998
Wind Powered RO System	Brackish water RO at 600- 1100KPa pressure	9	83% salt rejection	150W powered wind pump & DG set for power backup	Activated carbon filter if organics are present in feed	Robinson et al.,1992

(Source: Loo et al, 2012)

2. Methodology:

2.1 Evaluation Criteria for Water Treatment Technologies:

To evaluate the water treatment technologies for emergency, criteria should be its ease of deployment, throughput volume with quality & cost of treatment (Quinn et al, 1997). Whereas (Steele and Clarke, 2008) emphasize on maintenance, operator's skill, simplicity of system, consumables along with the above criteria. Loo et al, 2012 suggested considering the energy required torun the technology along with the acceptability of the treatment by affected population. It also suggests including impact on environment as well as supply-chain requirement. All these technology evaluation criteria are not assessed for their suitability during the immediate response phase of 1 to 2 weeks after a disaster strike.

In this review paper, the most important criteria are considered to give score on the scale of 1 to 5 for the selection of the technology in emergency and their arithmetic total score provide the key of technologies acceptance or rejection. The criteria adopted are ease of deployment, ease of use, performance (Log removal value for bacteria, protozoa & virus and turbidity), potential acceptance, energy requirement & through put (Table 4). The ease of deployment & potential acceptance are two partially subjective criteria i.e. size of technology large, moderate or small & its weight heavy or light; similarly, the objectionable taste & visual improvement are the parameters of subjectivity. As construction of treatment technology at disasters it is not suitable & easy and supply of large power after power failure is not possible during the immediate response phase; it is decided not to give minimal acceptable score of 1 for these two evaluation criteria i.e. ease of deployment & energy requirement. For these two criteria minimum acceptable score set is 2 i.e. no construction required only onsite assembly is enough to deploy the technology & technology that can also run on renewable energy is selected on a minimal acceptable score. The other evaluation criteria i.e., ease of use, performance, potential acceptance & through put minimum score set is 3 respectively. Under ease of use the minimal acceptability is based on the basic operator skill requirement with more than 1 hr treatment time required.

Earlier studies (Loo et al, 2012) defined evaluation criteria i.e. performance as subjective in nature viz. modest or excellent treatment. Effort is made in this paper to avoid subjectivity by allotting specific log removal values. The technology with minimal performance of <3LRV of bacteria & protozoa and 2-3 LRV of virus along with poor turbidity removal is selected. The treatment that gives visual improvement & no objectionable taste are selected as minimal acceptability score. The minimal through put of 50-100 litres/hr selected as it can cater the need of 10 to 20 affected populations hourly i.e. suitable for an immediate response for 100-200 peoples.

The total score was calculated after assigning equal weight to each evaluation criteria as all the parameters selected are equally important. The final score is added arithmetically i.e.

$$\textbf{Totalscore} = \sum_{i=1}^{i=6} (x1, x2\ldots\ldots xn) = 30$$

i - Evaluation criteria

X1, X2…..Xnis assigned score for 6 evaluation criteria respectively

$$\textbf{The minimum acceptablescore} = \sum_{i=1}^{i=6} (2+3+3+3+2+3) = 16$$

The total score for the assessment of water treatment technology for 6 criteria is 30 whereas, for the acceptance of the technology, the minimum score needs to be equivalent or more than 16. Technology selection based on 06 evaluation criteria is represented below in Table 5 (Loo et al, 2012, Jozwiakowski et al, 2015 & Balckwood et al, 2016)

Table 4. Description of scoring scale of Water treatment technology's 06 evaluation criteria (Loo et al, 2012 as modified)

Criteria 1		Description of the score on a scale of 1 to 5				
		2	**3**	**4**	**5**	
Ease of deployment		Large & heavy Require construction & onsite assembly	Large & heavy require onsite assembly	Moderately large & heavy require simple set-up	Light & small require simpleset-up	Light & small require no set-up
Ease of use		Advance operational skill required; complicated process design	Require skilled operator; proper chemical dose	Require basic training to operator; treatment time >1h	Require basic training to operator; treatment time <1h	Essentially no training required; treatment time <1 h
Performance	Bacteria	<1LRV*	<2LRV	<3LRV	<4LRV	>4LRV
	Protozoa	<1LRV	<2LRV	<3LRV	<4LRV	>4LRV
	Virus	1 LRV	2 LRV	2-3 LRV	3-4 LRV	>4 LRV
	Turbidity	Can't remove	Can remove	Can't remove	Can remove	Can remove turbidity & other contaminants
Throughput (Litres/hr)		<10	10-50; meteorological Conditions dependency	50-100	100-500	>500
Energy requirement		Uses a large amount of energy and cannot be powered by renewable energy	Uses a large amount of energy but can be powered by renewable energy	Can be powered by a small hand pump or bicycle	Require energy/fuel for operation but does not involve additional use of energy	No power requirement (gravity fedor mouthsuction)
Potential acceptance		No visual improvement; objectionable taste; harmful byproducts	No visual improvement; No objectionable taste;	Visual improvement; No objectionable taste; Use chemicals	Visual improvement; No objectionable taste; No harmful byproducts	Common practice among users

(Source: Loo et al, 2012)

*LRV – *Log removal value (90% - 1LRV; 99% - 2 LRV, 99.9% - 3 LRV; 99.99% - 4 LRV)*

S.No.	Water treatment technologies	Scoring of Evaluation Criteria									Total Score
		Ease of deployment	Ease of use	Performance in Log Removal Value (LRV)			Average performance	Throughput (Litres hr)	Energy requirement	Potential acceptance	
				Bacteria	Protozoa	Virus					
1	AC & UV disinfection	4	5	5	3	4	4	4	2	4	23
2	Biosand filter	1	4	3	4	1	3	2	5	4	19
3	Boiling	4	5	2	1	1	1	2	2	5	19
4	Chlorination tablets	4	2	2	1	1	1	4	5	1	17
5	Chulli purifier	1	5	5	1	1	2	2	4	4	18
6	PUR® sachet	5	4	5	2	3	3	4	5	3	24
7	SODIS	5	3	5	2	3	3	2	5	2	20
8	Upflow clarifier	1	2	2	1	1	1	5	1	3	13
9	UV disinfection portable	5	5	1	1	1	1	5	1	2	19
10	NEERI-ZAR	1	2	2	3	1	2	2	5	3	15
11	DIVVY 250 System™	3	2	5	3	4	4	4	3	3	19
12	Ceramic filter	1	3	3	4	2	3	1	5	4	17
13	Bicycle powered MF	1	3	3	4	1	3	4	3	4	18
14	Bicycle powered UF	1	3	4	4	2	3	5	3	4	19
15	Supremus Aqua® UF	4	5	4	4	3	4	5	5	3	26
16	LifeStraw®	3	2	5	4	3	4	1	5	3	18
17	Outback Plus™ (OB-25NF)	3	3	5	4	4	4	1	5	4	20
18	Bicycle powered NF	1	3	5	4	4	4	2	3	3	16
19	Small Scale RO	2	3	5	5	5	5	4	1	5	20
20	Photovoltaic RO	1	3	5	5	5	5	2	2	4	17
21	Wind Powered RO	1	3	5	5	5	5	1	2	4	16
22	FO pouch (0.04µ membrane)	5	5	5	1	1	2	1	5	4	22

(Source: Loot et al, 2012& https://sswm.info)

(AC – Activated carbon; UV – Ultraviolet; MF- Microfiltration; UF – Ultrafiltration; NF- Nano-filtration; RO- Reverse Osmosis; FO- Forward Osmosis)

NOTE: - Scoring may vary based on field & meteorological conditions

Scores(colorcoding)

MostSuitable

Least Suitable

Acceptability ore

=>16 ACCEPT

<16 REJECT

3. Discussion:

3.1 Selection of Water Treatment Technology's Deployment Based on Disaster

The geophysical, hydrological, meteorological & climatological disasters occurrence frequency increased significantly due to anthropogenic intervention with nature, increasing needs & climate change. The crude mortality rate i.e. 1 death per day in 10,000 guide administration to call for an emergency. After the strike of disaster, the immediate emergency response phase of 1-2 weeks is crucial in all sort of manner whether it is drinking water, food, sanitation, shelter etc (Smith & Reed, 1991). To have an effective immediate response system helps in reducing the chance of disease outbreak. Due to compromised water supply & contamination; outbreak of diseases such as dysentery, typhoid and hepatitis are reported widely. All water of uncertain source or quality should be treated before using it for drinking, food preparation or hygiene. Agencies have to provide minimum 7.5-15 litres per day of water for drinking, basic hygiene & cooking.

Loo et al, 2012 has reported the technology selection based on road accessibility, utilizable renewable energies and source water quality. This kind of selection criteria is only useful for post-disaster relief as road conditions, source water quality & renewable energy sources can only be assessed on reaching the affected population. This may delay the speedy relief support. This review paper brought a disaster based selection of technology as the magnitude of effects caused by natural disasters vary significantly there is minimal water shortage during landslides, hurricanes & floods whereas it's severely affected during draught. The structural damage to system infrastructure is minimally affected during volcanic eruptions & drought whereas earthquakes, landslides, hurricanes & floods severely affect the infrastructure. (Pan American Health Organization, 2000).

It is pertinent to mention that administration has very less time to respond against these disasters and in that hurry without understanding the common level & magnitude of the impact of disaster similar kind of approach is followed for all kind of disaster by deploying the same water treatment technology. It is to mention that during flood, hurricane & cyclone meteorological condition are humid, speedy wind with minimum solar radiation prevails; deploying solar based water treatment technology are meaningless.

Similarly, deploying high-end RO or NF technology during minimal affected water of pathogenic contamination during draught & landslide is not useful. Considering the common level & magnitude of disaster impact for the selection of treatment technology is tabulated in table 6.

Further, Safe water supply of <5NTU turbidity, 0.5ppm residual protection & zero coliform contamination is on priority of administration and humanitarian communities. Based on the 6 evaluation criteria of water treatment technologies total score, it is suggested that Upflow clarifier and NEERI-ZAR are not suitable for emergency water supply. SODIS, PUR purifier, UV disinfection portable & FO pouch scored highest i.e. 5 for the ease of deployment whereas Bios and, Chulli purifier, Upflow clarifier, NEERI-ZAR, Ceramic filter, Bicycle powered based MF, UF & NF alongwith Photo voltaicRO and wind powered RO scored lowest i.e. 1.

The Chlorination tablets, NEERI-ZAR, & DIVVY 250 system is least suitable on the criteria of ease of use due to the involvement of doses of disinfectant. Whereas, membrane-based water treatment technologies are most suitable on the evaluation criteria of performance; the boiling, chlorination, upflow clarifier, UV disinfection & FO pouch are least suitable for the required quality of treatment (Rikhi et al, 2018).

The most suitable technology on the criteria of throughput is Upflow clarifier, UV disinfection, Supremus aqua & UV disinfection. Due to energy requirement; UV disinfection, Small scale RO & Upflow clarifier are least suitable whereas Chlorination, SODIS & Upflow clarifier are least suitable on the criteria of potential acceptance. However, considering the cost, maintenance and supply of consumables as additional evaluation criteria, this scoring may change & acceptability or rejection of technology mayvary.

Table 6. Selection of water treatment technologies based on the impact of disaster

Natural disaster	Meteoro-logical condition (Humid, Solar radiation)	Common effects of natural disaster on water supply & disease outbreak (Pan American Health Organization (PAHO), 2000)						Suitable treatment technology $
		Damage to water sources	Power outages	Contamination (Biological or chemical)	Trans-portation failures	Personnel shortages	Pro-liferation of vector breeding sites	
Earth quake	**	+	+	++	+	+	+	3,4,6,7,10,11,15,16,17, 20,21,22
Cyclone	*	++	+	+	+	++	+	4,6,10,11,15,16,17,22
Flood	*	++	++	+	+	++	+	2,6,10,11,15,16,17,19,22
Tsunami	*	+++	++	+	++	+++	+	1,2,6,10,11,12,13,14,15, 16,17,18,19,22
Volcano	**	+	+	+	+	+	+++	6,7,10,11,15,16,17,20, 21,22

**No rain/less humid, good solar radiation

*Raining/too much humid, very low solar radiation

+++ Least or no possible effect

++Less severe possible effect &

+Severe possible effect

$Water treatment Technologies {1.AC & UV disinfection 2. Biosand filter 3. Boiling 4. Chlorination tablets 5. Chulli purifier 6.PUR® sachet 7.SODIS 8.Upflow clarifier 9.UV disinfection portable 10.NEERI-ZAR 11. DIVVY 250 System™ 12. Ceramic filter 13. Bicycle powered MF 14. Bicycle powered UF 15. Supremus Aqua® UF 16. LifeStraw® 17.Outback Plus™ (OB-25NF) 18. Bicycle powered NF 19. Small Scale RO 20.Photovoltaic RO 21. Wind Powered RO & 22. FO pouch (0.04μ membrane)}.

4. Conclusion

The selection of technology based on common level of disaster impact shows that SODIS, Photovoltaic RO, Solar still & Wind-powered RO is suitable in earthquake due to good solar radiation and proved itself to be simple, robust for long periods as SODIS method can only be evaluated in the context of other household water treatment technologies, and the benefits it offers can vary significantly from one location to another. As a low-cost method that is independent from supply chains for products other than PET bottles, SODIS has comparative advantages particularly among the poorest segments of the population, and in areas where no other household water treatment technologies are marketed as only sunlight and PET bottles are required for the application of the method.

Further, Solar still & Wind-powered RO is economically competitive with other sources. The systems offer realistic solutions to many regions without any grid connection. One of the main objectives of this study was to verify the integration of the several components, which were tested and modeled, and their performance over a wide operational range. Whereas, the same technologies are not suitable during cyclone, flood & tsunami. During tsunami, transportation failure is not too severe & personnel shortage is also not severe; that allows us to select ceramic filter, bicycle-powered MF.

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Public Health Emergency and Disaster Management: Indian Perspective

Rajeev Sharma[1]; Raju Thapa[2*]; Surya Parkash[3]; Ajay Dogra[2]; Harjeet Kaur[3]

Abstract

The COVID-19 pandemic in the past was accompanied by an abrupt increase in cases, and since health emergencies and disasters are unexpected, preparation is crucial. With a stretched-thin staff and a rise in signals, events, resource requests, deliveries, and deployments, maintaining supervision and keeping track of public health initiatives will become increasingly difficult within an over-stretched and limited workforce context. This pandemic has taught many lessons. Perhaps one of the most pervasive weaknesses was the constant challenge of coordination. Both the response and the preparedness pillars in many countries had highly intelligent leaders and dedicated responders with extraordinary skill sets, however, the coordination within and between the pillars kept breaking down. Three factors may have contributed to this. Firstly, expertise at all levels may be lacking the tools, training, and experienced staff to rapidly implement the strategic guidance. Secondly, leaders of the response at all levels similarly lacking the tools, training and work force to be able to shift their staffs from a slow, deliberative, consensus management ("peacetime footing") to a rapid, higher risk, delegated functioning ("war footing"). Finally, the principles of public health emergency and disaster management (including Incident Response Systems or Incident Management System and EOC emergency operations) were not disseminated, understood, embraced or practised by a sufficiently large group of individuals to enable the response to function in a coordinated fashion under emergency conditions. The Government of India (GoI) is making all essential preparations to be well-equipped to handle any sudden increase in cases. We need to strengthen the capabilities in terms of "Public Health Emergency and Disaster

[1] Centers for Disease Control and Prevention, Country Office-India.
[2] Voluntary Health Services- Centers for Disease Control and Prevention (VHS-CDC), India.
[3] National Institute for Disaster Management, Ministry of Home Affairs, Government of India.

Management" in order to handle present and new risks to public health as well as the requirement for effective resource and information management in addition to the use of subject matter expertise.

Keywords: *Public Health Emergency and Disaster management; COVID-19 pandemic; capacity building; community engagement; Government of India*

1. Introduction

Severe Acute Respiratory Syndrome Coronavirus (SARS-1), H1N1 (Swine Flu), Nipah, Zika, Ebola, Avian Influenza, Dengue, Japanese Encephalitis, Acute Encephalitis Syndrome (AES), Crimean Congo Hemorrhagic Fever (CCHF), Plague, and recent pandemic of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), among other emerging infections, have caused public health emergencies. There have reportedly been more natural and chemical disasters in the nation during the past several decades, including cyclones, floods, earthquakes, tsunamis, cloud bursts, and the Bhopal tragedy.

The factors responsible for such an increase have been observed to be due to more close interaction between human and animal populations, emergence of newer pathogens, increased travel and trade (domestic and international), climate change, lifestyle changes, dietary habits, water storage practices etc. The aspiration and need for public health preparedness and response during large conglomerations like Kumbh Melas etc. has also been realized. As a consequence of migration, transitioning into shelters/camps, social unrest, financial loss, lifestyle changes, damage to healthcare facilities, infrastructure, environment, and adjustments to the larger political and socioeconomic backdrop, these can lead to direct effect on one's physical and mental health.

There are similarities across disasters despite the fact that each one differs from the others in that it impacts areas with various degrees of susceptibility as well as particular social, health, and economic aspects. The management of health humanitarian aid and resource usage can be improved by taking into account certain common variables (PAHO 2000).

- There is a connection between a disaster's types and its impact on health. This is especially true of the direct injury-causing impact. For instance, floods and tidal waves cause relatively few injuries that require medical attention, whereas earthquakes frequently have large casualties.

- Some consequences pose a possible risk to health rather than an unavoidable one. For instance, although epidemics typically do not originate from natural catastrophes, population shifts and other environmental changes may raise the likelihood of disease transmission.
- Following a tragedy, not all health risks actual and potential occur at once. Instead, within a disaster-affected area, they often occur at various periods and have varying degrees of relevance. The hazards of increased disease transmission take longer to develop and are highest where there is overcrowding, and standards of cleanliness have dropped. As a result, casualties mostly occur at the time and location of impact and require prompt medical care.
- Food, housing, and basic medical care requirements brought on by disasters are typically not fully met. Even those who have been forced to flee frequently manage to preserve some essentials. Additionally, individuals typically bounce back fast from their initial shock and spontaneously take part in search and rescue operations, the transportation of injured persons, and other private relief efforts.
- Complex emergencies such as conflicts and civil unrest produce a unique mix of operational challenges and public health issues.

2. Impact of Public Health Emergency and Disaster on the Economy

These public health emergencies and disasters result in significant financial losses and have a negative influence on the Gross Domestic Product (GDP), which in turn affects economic activity across several sectors.

The COVID-19 pandemic has had a major negative impact on all communities and individuals, as well as the global economy. The spread of the virus has benefited from the underlying interconnectedness and frailties of globalisation, moving quickly across borders and along the main arteries of the global economy. As a result, a global health crisis has turned into a global economic shock that has hit the most vulnerable people the hardest. The coronavirus epidemic, which sprang from the natural environment and is crippling our communities and economy, shows the interconnectedness implied by the Sustainable Development Goals, but it is impeding global attempts to fulfil them.

Across India, there is an estimated average yearly economic loss of $9.8 billion, of which more than $7 billion is attributable to floods, which are a frequent occurrence in the majority of the nation's states (GAR 2015). Lack of awareness about risks and access to risk information, both of which are necessary to take any action aimed at reducing risk, is one of the main causes of the rising economic loss resulting from catastrophes. Additionally, novel risks are continuously accumulating as a result of growing exposure to dangers brought on by risk-insensitive planning practices, environmental degradation, population increase, and poverty. The hazards brought on by climate change are giving India's current catastrophe risk profile a whole new dimension (NIDM-IUINDRR 2022).

Despite the uncertainties surrounding the effects of climate change, average climatic conditions and variability have changed, and extreme climate events have become more frequent in recent years, worsening economic loss and damage. India's expanding economy also leads to significant investment in new industries, infrastructure, and other revenue-generating sectors and enterprises. Rarely do these investment decisions consider risk exposure, which increases the risk that economic assets will be exposed to numerous types of natural and man-made risks (NIDM-IUINDRR 2022).

3. Public Health Emergency and Disaster Management

India's response to natural disasters and public health emergencies has substantially improved over time and is now recognized on a worldwide level by the government, non-governmental organisations (NGOs), and civil society. Satellite photography, remote sensing, mobile-phone mobility data, real-time monitoring, genetic sequencing, artificial intelligence (AI), machine learning, online training, and other contemporary technologies are enhancing prediction and readiness as well. Mobile platform and social media such as aarogya setu, facebook, tweeter have played a significant role during pandemic and disasters.

The government of India has been undertaking several initiatives to prioritize efforts towards enhancing Public Health Emergency and Disaster Management. This is demonstrated by the Union Budget 2021–2022 announcement to strengthen the National Center for Disease Control (NCDC), its five regional branches, twenty metropolitan health surveillance units, and fifteen health emergency operation centres (HEOCs) for preparedness and response to disease epidemics and pandemics under the "PM Atma Nirbhar Swasth Bharat Yojna." has now renamed PM – Ayushman Bharat Health Infrastructure Mission (PM-ABHIM). The Strategic Health Operation Centre

(SHOC) of the NCDC in Delhi, the Integrated Disease Surveillance Programme (IDSP), and the Emergency Medical Relief (EMR) Division of the Directorate General of Health Services serve as the hub for coordinating the response to public health emergencies. Similar structures exist in the States and Municipal Corporations. The program's actions are geared toward strengthening the capacity of healthcare institutions and systems at all levels of care primary, secondary, and tertiary as well as getting health systems ready to successfully handle current and upcoming pandemics and disasters. By creating a network of surveillance laboratories at block, district, regional, and national levels in metropolitan areas and strengthening health units at the Points of Entry, the PMASBY aims to create an IT-enabled disease surveillance system for efficiently identifying, looking into, preventing, and combating public health emergencies and disease outbreaks. Increased funding is also planned for research on COVID-19 and other infectious diseases, as well as biomedical research to produce data for short- and medium-term responses to pandemics similar to COVID-19 and to build core capabilities for implementing the One Health Approach to prevent, detect, and address infectious disease outbreaks in both humans and animals. The National Health Policy (NHP), published in 2017, calls for a time-bound increase in public health spending from the current 1.15 percent of GDP to 2.5 percent by 2025 (PIB-GoI, 2021).

In the current COVID-19 pandemic, the provisions of the Epidemic Diseases Act of 1897, National Disaster Management Act (NDMA), 2005, and International Health Regulations (IHR), 2005, have also assumed a prominent role. The National Health Mission (NHM) infrastructure and the funding's availability have improved the system's readiness to respond by enabling flexibility and need-based decisions at the District and Sub-District levels. However, in light of rising demand and necessity, expectations for such a system have increased over time.

Building local capacities, beginning with the poor, to significantly reduce the loss of lives, livelihoods, and assets in various forms including economic, physical, social, cultural, and environmental while enhancing India's capacity to cope with disasters at all levels is the current government's vision for making India disaster resilient across all sectors. Under the guidance of the Hon'ble Prime Minister and Chairman of NDMA, Shri Narendra Modi, the first National Disaster Management Plan (NDMP) was created in a brief six-month period and launched in June 2016. Including disaster risk reduction, mitigation, readiness, response, recovery, and rehabilitation, the

NDMP offers a framework for all phases of the disaster management cycle. The Sendai framework has been greatly aided by India's zero casualty strategy to managing extreme weather disasters, which has also helped to reduce the number of people who die in such incidents.

India is one of the most disaster-prone countries in the world. The country is vulnerable to a wide range of natural disasters because of its geo-climatic and socio-economic conditions, including floods, earthquakes, tsunamis, landslides, cyclones, droughts, thunderstorms, lightning strikes, glacial lake outburst floods (GLOFs), heat waves, biological and public health emergencies, fires (including forest fires), etc. In order to reduce the danger of catastrophe in India, a national strategy for disaster management is crucial. A national plan for disaster management for the entire nation is mandated by Section 11 of the Disaster Management (DM) Act 2005 (NDMA 2022). In this regard, a NDMP (was formulated).

3.1 Community engagement

The community is the first responder of any kind of disaster and public health emergency. Therefore, the active participation and involvement of the community is important in every phase of Disaster starting from planning to rehabilitation. Community plays a crucial role in any disaster management and health emergency because:

- Having a local understanding of the hazards guarantees that the community's genuine requirements are met.
- Local activities reduce risks by minimising exposure to local dangers at the source.
- A well-prepared, active and well-organized community can reduce risks and mitigate the impact of emergencies.
- Many lives can be saved in the first hours after an emergency before external help arrives.

A few illustrations of the positive outcome of community involvement in health emergencies are mentioned below.

3.1.1 Dharavi Slum Mumbai

Because of the overcrowding, lack of knowledge, and lack of adoption of COVID-19 appropriate behaviours, there was concern that the problem of COVID-19 infection in migrant workers, the "Dharavi Slum" of Mumbai, and the slums of Pune would worsen exponentially. However, once the community was involved to adopt the COVID-

19-appropriate behaviour, hygienic practices, early reporting, isolation, and early admission of at-risk patients in health facilities, infection could be contained quickly.

3.1.2 Fani (2019) and Amphan (2020)

Similar events occurred during numerous natural disasters, such as the cyclones Fani (2019) and Amphan (2020) in Odisha, when early warning to the community and their readiness to leave high-risk regions prevented accidents, trauma, and fatalities.

3.1.3 Tsunami-Ready villages in Odisha

In Odisha, India has become the first nation in the Indian Ocean to host communities that are prepared for a tsunami. The UNESCO-Intergovernmental Oceanographic Commission (IOC) has awarded the two villages, Noliasahi in the Jagatsinghpur district and Venkatraipur in the Ganjam district, certificates of appreciation and recognition. Indian villages have never received such distinction from UNESCO.

3.1.4 Early warning signals of the plague, avian flu, malaria/dengue etc

The importance of spotting early warning signs of the plague, avian flu, malaria, and dengue, as well as preventing the effects of public health emergencies, is demonstrated by the community's prompt reporting of rat falls, abnormal behaviour and bird deaths, high fever rates, and fever-related deaths.

All of these initiatives would require skilled health professionals to sensitise the population. It has also been demonstrated that raising awareness of these issues among middle-level managers is a good strategy to improve the effectiveness of the response system. In addition to the leadership role of District/ State and National Level Officials and the involvement of Civil Society in the early detection and response to public health emergencies, it has been observed that frontline workers and middle-level managers play a particularly significant role in the management of health emergencies.

3.1.5 Studies on need for community engagement

There have been scientific studies conducted to support the significance, necessity, and involvement of community health professionals in catastrophe circumstances. Illustrations are as under:

I. The George Institute for Global Health in India was commissioned by the National Health Systems Resource Centre (NHSRC) to conduct a study in order to assess the evidence and determine the potential role, enablers, and barriers for Community Health Workers (CHWs) during COVID-19 prevention and control. The study found that contact tracking, community awareness, participation, and sensitization (including for overcoming stigma) were the most frequent supplementary actions during pandemics. All facets of contact tracing were reportedly handled by CHWs, which had an impact on everyday service delivery. CHWs have frequently experienced stigmatisation or social exclusion during pandemics.

The study came to the conclusion that CHWs are crucial to pandemics. The provision of Personal Protective Equipment (PPE), housing allowance, equal training opportunities, transportation allowance, improving salaries (paid on time and for a broad range of services), and awards in high-profile public events was suggested as contributing to better recruitment and retention. It is important to ensure role clarity, training, supportive supervision, as well as their work satisfaction, health, and well-being (Bhaumik et al., 2020).

II. In August 2020, a descriptive cross-sectional survey was done among health professionals from Rajasthan's District Hospitals (DHs) and Community Health Centers (CHCs) who had participated in a training session on hospital disaster preparation. The goal of the study was to comprehend the standardised indicators of public hospital readiness and resilience during health emergencies, including pandemics as the most recent COVID-19 pandemic. Rajasthan's District Hospitals (DHs) and Community Health Centers (CHCs) appear to be only somewhat resilient and prepared. Only 37.9% of healthcare personnel received the required training and instruction on disasters like the current COVID-19, which is critical for those in the profession. The significance of the additional public health emergency training programme was stressed by more than 93% of the health authorities.

The study found that despite the availability of an emergency medication supply, the isolation room lacked the necessary amenities and equipment to stabilise a critical patient. Staff members may mark and perform in the triage area as needed. The operational state of DHs and CHCs indicated that the level of emergency preparation was variable from hospital to hospital and from CHC to CHC, falling between low and medium. As a result, it was advised to review and improve emergency preparation strategies, which need to address mitigation, readiness, response, and recovery (Sharma and Sharma 2020).

4. Strengthen Public Health Emergency and Disaster Management capacity

4.1 Essential Elements of PHEDM

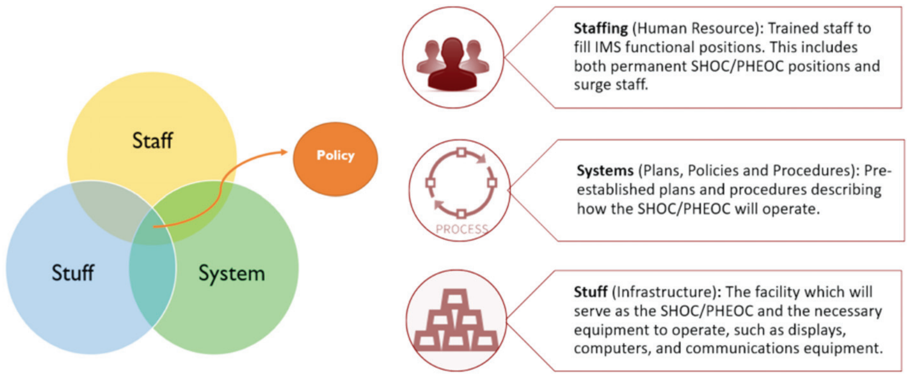

Figure 1: Essential Elements of PHEDM.

For carrying out any initiatives towards strengthening Public Health Emergency and Disaster Management capacity, following elements of PHEDM needs to be consider:

I. Staffing (Human Resource): Trained staff at all Incident Management System (IMS) functional positions. This includes both permanent Strategic Health Operations Centre (SHOC)/ Public Health Emergency Operations Centre (PHEOC) positions and surge staff.

II. Systems (Plans, Policies and Procedures): Pre-established plans, procedures and protocols describing how the SHOC/PHEOC will operate.

III. Stuff (Infrastructure): The facility which will serve as the SHOC/PHEOC and the necessary equipment to operate, such as displays, computers, and communications equipment etc.

For achieving all the objectives of Staff, System and Stuff commitment and willingness from the policy level is paramount.

The national ability to prevent, identify, and respond to public health emergencies and new infectious illnesses has to be strengthened in light of the aforementioned findings. In this approach, it is suggested to boost emergency management capability on two different levels: a. institutional capacity building; and b. community capacity building.

4.2 Institutional Capacity Building: It is suggested that the following three-tier framework be used for educating professionals and employees:

I. **First Tier- Community Level**: Front line Healthcare Workers, Accredited Social Health Activist (ASHA), Anganwadi Worker (ANM), Multi-purpose Health Worker (MPHW), Volunteers from Disaster Management (Aapda Mitra), Civil Defense etc.

II. **Second Tier - First Referral Unity/ Points of Care**: Medical doctors, nursing staff, pharmacists, and technicians (develop their capacities: to respond to health aspects of disasters, to develop contingency plan, to report to district level and state level, to strengthen surveillance, surge, coordination, management, and preparedness, to work with multi layered multi sectoral response etc.)

III. **Third Tier - Tactical Level:** Front line Healthcare Workers, Accredited Social Health Activist (ASHA), Anganwadi Worker (ANM), Multi-purpose Health Worker (MPHW), Volunteers from Disaster Management (Aapda Mitra), Civil Defense etc.

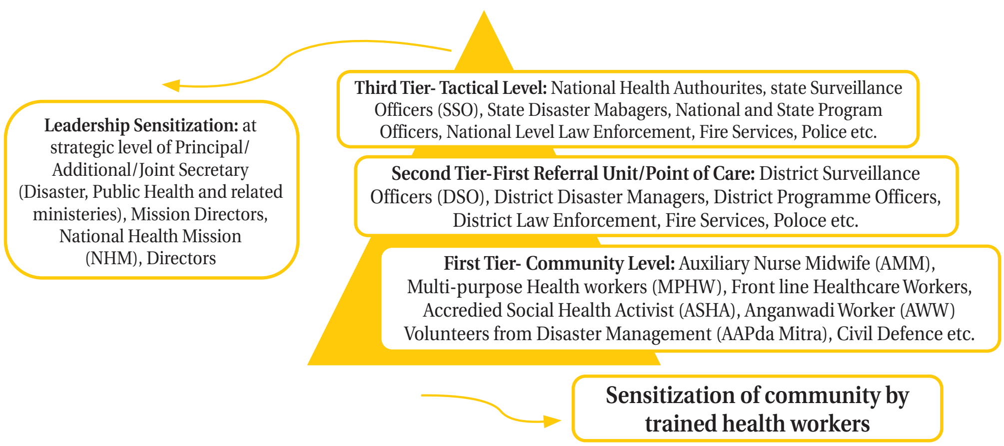

Figure 2: A three-tiered institutional PHEM capacity-building model

4.2 Community Capacity Building: Preparing Individuals and communities to work together to improve preparedness and respond to disasters and emergencies and to help build capacity and plan for the unexpected. To build a culture of preparedness it's important to work with the whole community, including central, state, district and local governments; Panchayati Raj Institutions; non-governmental partners from all sectors; self-help groups; faith-based organizations; youth children, daycares.

The main objective of this plan is capacity building of the community with Health Focus and develop their infrastructure, capacity building, community disaster preparedness planning integrating with health and pandemic parameters, table tops simulation exercises, system, plans, procedures and SOPs. Develop systemic challenges and systems approach (Community gathers their own resources) and develop a Community Emergency Response Team (CERT) responding to emergencies.

4.3 Leadership sensitization

In order to strengthen the above 3-tier institutional capacity building, it is also necessary to **sensitize leadership** at the strategic level of Principal/Additional/Joint Secretary (Public Health), Mission Directors, National Health Mission (NHM); Directors; for the Incident Management System (IMS) with globally accepted principles for working with multi-layered/multi-sectoral response more effectively would be required.

Conclusion

There is a need to strengthen national and regional capacities to effectively prevent, prepare for, detect and respond to disaster and public health threats and emergencies. Any nation's progress depends critically on the population's and community's health. Every nation has a duty to protect its citizens' health, welfare, and well-being. It also has a duty to maintain the health system's self-sufficiency and resilience, which are essential for lowering health risks and vulnerabilities and delivering efficient response and recovery in times of emergencies and disasters. Enhancing the capabilities in terms of "Public Health Emergency and Disaster Management" would help us handle present and upcoming dangers to the public's health as well as the requirement for effective resource use and management.

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Morphological Change Analysis of Camorta Island, Nicobar Group of Islands, India using Satellite Remote Sensing Technique: A Case Study after 2004 Tsunami

Goutham Krishna Teja Gunda[1, 2*], Ajmal S[3], Surya Parkash[1], Mamta Chauhan[4], Sudhakar Goud[3], Balaji S[5]

Abstract

The December 26, 2004, Indian Ocean Tsunami generated an undersea and megathrust earthquake with the epicentre at the west coast of Northern Sumatra that had made a very critical impact on coastal environments in the 16 Indian Ocean countries. This Massive tsunami registered a magnitude of 9.3 MW caused unexpected sea level rise and resulted in change in shoreline along most of the Andaman and Nicobar Island. Camorta Island, one of the Nicobar group of islands experienced worst damages. The study of coastline and morphology changes of Andaman and Nicobar Island was significant for understanding the damages caused by this tsunami. The delineation of shorelines and analysis of shoreline changes of Andaman and Nicobar Island for 22 years from 1992 to 2014 were done utilising the satellite imageries acquired by Landsat in ArcGIS environment. Landsat images collected on 1992, 2005 and 2014 were used for the study. The results showed that about 19 Sq.Kms of area had been eroded or submerged due to the Tsunami-genic and Non-Tsunami-genic activities. The Average Linear Regression Rate of the Eastern Coast of the Island between 1992 and 2014 is about -11.78m. The average Net Shoreline Movement is about - 239m observed on the eastern coast of the Island. In the Western Coast many regions were transgressed by the seawater and those regions show

[1] Geo-Meteorological Risks Management Division, National Institute of Disaster Management, Ministry of Home Minister, GoI, Delhi, India.
[2] Department of Geo-informatics, Telangana University, Nizamabad, Telangana, India.
[3] Department of Remote Sensing, Bharathidsan University,Trichy, Tamil nadu, India.
[4] Geoscience Department, Indian Institute of Remote Sensing, Dehardun, Uttarakhand, India.
[5] Department of Disaster Management, Pondicherry University, Port Blair campus, Andaman & Nicobar Islands, India.

a High Linear Regression Rate of - 13m. Thus, this study gives an outlook of the changes that occurred due to the 2004 Tsunami.

1. Introduction

Shore line is a dynamic geomorphic feature that corresponds to the physical boundary between land and ocean (Maselli 2004). These Shore linesare being modified due to incessant waves, tides, near shore currents that results in transportation of sediments (Passeri et al. 2015). These changes may be due to unpredictable rapid or slow long-term natural processes as well as man-made involvements. In most of the cases, morphology of shoreline will change dramatically due to rapid-on set and slow-onset events like tsunami, earthquake, cyclone, sea-level changes, storm surge, flooding, wave action, tidal changes (Mukhopadhyay et al., 2011) which will have severe impact on life and livelihood of that region. The shoreline changes are analysed in terms of erosion and accretion, whereas the coastline moves towards land and ocean, (Chandramohan et al., 1993; Mahendra et al., 2017). These studies are significant and plays crucial role in designing the coastal sustainable management plan.

Andaman and Nicobar Islands drew the attention of various global communities for the huge morphological changes (Narayana et al., 2007) and losses to life and properties during the 2004 Indian Ocean tsunami triggered by the 9.3 Mw great earthquake (Bahuguna. A and Nayak. S 2008). This tsunami waves caused destruction to many countries that were associated with Indian Ocean i.e., India, Indonesia, Sri Lanka, Maldives etc. (Kench et al. 2006). Consequent to the tsunami, the Nicobar group of Islands of India which is close to the focus of the Great earthquake became first victim in India and witnessed huge damage to the coast. Moreover, it is believed that kilometres of coast were eroded and few Islands were submerged hundreds of meters below the earlier level. In current study, we have focused on Camorta Island that belongs to Nicobar group of Islands for understanding the coastal morphological changes that occurred in recent decades.

2. Study Area

Camorta Island (Kamorta Island) is part of Nicobar Group of Islands of India and located near to south-eastern coast of India (Figure 1). It is situated at 8.133°N latitude and 93.5°E longitude with highest elevation of 186 above MSL. This Island consists of about 3688 (2011 census) population and extended upto~136 km^2 in area with ~26 km length and ~8 km width. Camorta Island have ~108 km of coastline length and covered with dense forest/mangroves, wetlands, wastelands etc.

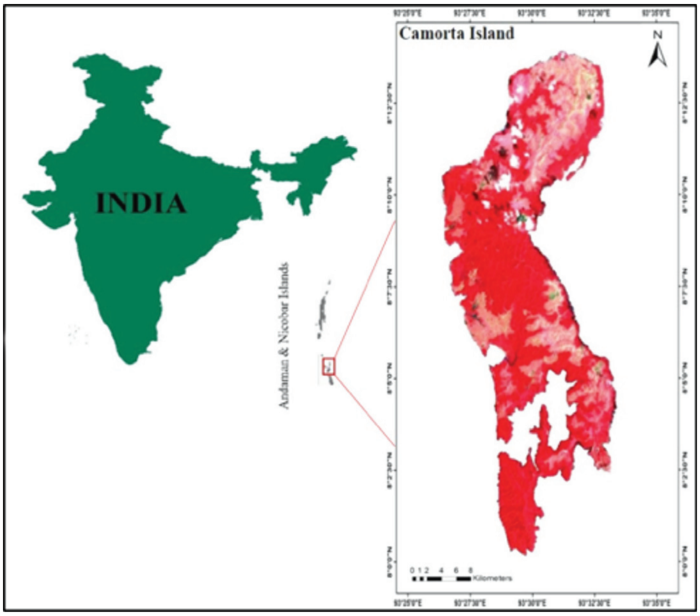

Figure 1: Study area map of Camorta Island, Nicobar Group of Islands, India.

3. Methodology and Materials

In this study, we have utilised the Landsat series satellite images for selected three years i.e., 1992, 2005, and 2014 (Table 1), from the USGS Earth Explorer for analysing the coastal morphological changes of Camorta Island that was induced by the 2004 tsunami (Figure 2) (Dolan et al. 1991; Fletcher et al. 2003; Ford 2013; White, K., and H. M. El Asmar, 1999). The selected satellite images were used to create False Colour Composite (FCC) and the shorelines changes of respective years and were digitized manually for better accuracy using Arc GIS environment. The digitized shorelines were further processed in Digital Shoreline Analyses System (DSAS) (Theiler et al. 2009) a plugin of USGS, which is added to Arc GIS. The DSAS used to estimate the rate of change of shoreline with the help of temporal data. Initially, the baseline is generated parallel to the shorelines by buffering them and followed by the DSAS manual procedures

(Himmel stoss 2009). This automated tool creates the series of lines i.e., transects perpendicular to these shorelines and baseline at our defined distance and then was used for calculating the rate of change statistics (Crowell and Leatherman, 1991). The DSAS can help us in providing the various types of shoreline change statistics such as Net Shoreline Movement (NSM), Linear Regression Rate (LRR) (Crowell and Leatherman, 1999), and End Point Rate (EPR). The detail methodology is shown in Figure 2. In addition, we also prepared the Land use and Landcover map of 1992 and 2014 for land use/land cover change analysis Figure 3.

Table 1: Data Specification and Land Area changes around Camorta Island during 1992-2014

Image acquisition date	Sensor	Source	Total Land Area (KM²)	Net Change (KM²)
1992/02/02	Landsat 5 TM	US Geological Survey	136 km²	-
2005/01/04	Landsat 5 TM	US Geological Survey	128 km²	8 km²
2014/03/02	Landsat 8 OLITIRS	US Geological Survey	117 km²	19 km²

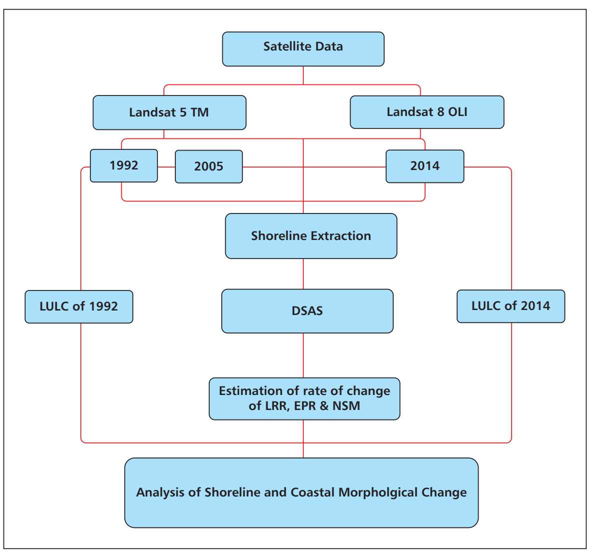

Figure 2: Methodology adopted for current study

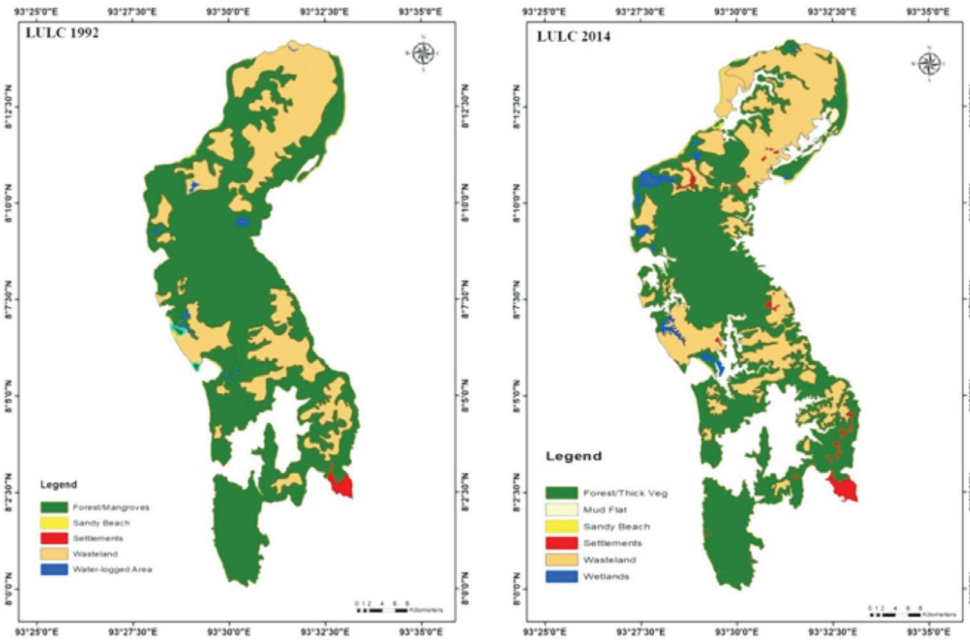

Figure 3: Land Use and Land Cover Maps for the year of 1992 & 2014

4. Results And Discussion

After processing the satellite images, the shorelines of 1992, 2005 & 2014 were digitized following the standard manual procedures and were interpreted for further analysis. The shoreline change statistics like Net Shoreline Movement (NSM) is calculated for 1992 to 2005 shorelines (Figure 4 (a)) and also for 1992, 2005, & 2014 shorelines (Figure 4(b)) of Camorta Island using the DSAS. The average NSM recorded is about -239 m/year and average LRR recorded is about the -11.78 m (Figure 5a). In addition, we also calculated the average EPR value as -11 m to understand the damages that caused by the tsunami-genic and non-tsunami-genic activities (Figure 5b). Further, we also prepared the land use and land cover map by analysing the changes that have occurred over the time (Figure 3) which clearly depicts that the West coast experienced the huge loss of land when compared with the East coast. After the 2004 tsunami, we can also see the increase in settlements inwards the Island and sandy beaches at the East coast. The results highlights the high rate of erosion occurred over all along the coastal line of

Camorta Island in 1992, 2005 and 2014. In 1992, the Island had of ~ 136 land km^2 total area. From 1992 to 2005, the total area is reduced to the 128 km^2 with Net change of 8 km^2 which means that this Island had experienced substantial reduction in land area due to the 2004 tsunami (Table 1) (Figure 6). This rapid changes have not only resulted in loss of land area but also costed its ecosystems. In continuation, we also calculated the shoreline change upto the year 2014 which again has shown the reduction of land upto 117 km^2. Again the rate of change was 11 km^2 which means that the total Net change was 19 km^2 (Figure 6). Thus, this Island has undergone significant loss of land not only due to 2004 Tsunami but also of other natural process till date. Overall, the Camorta Island lost its major portion of coast at West side than the East side (Figure 7).

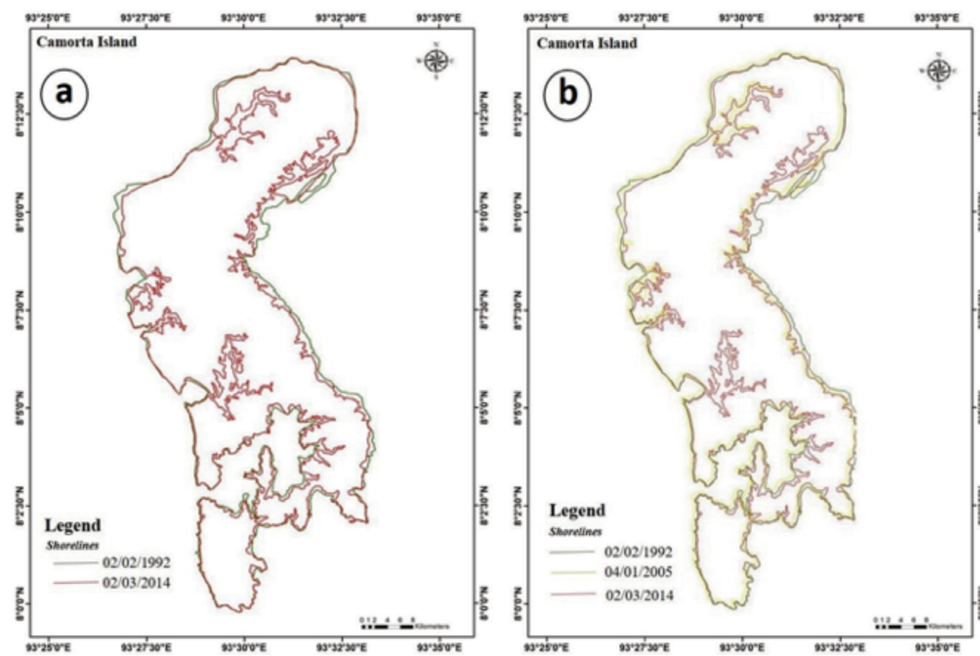

Figure 4: (a) Shorelines extracted for the year 1992 to 2014;
b) Shorelines extracted for the years of 1992, 2005, & 2014

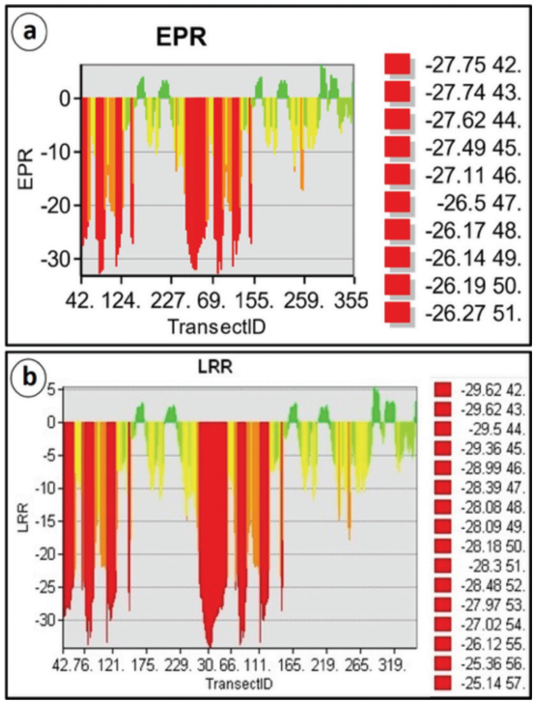

Figure 5: (a) Linear Regression Rate Graph from 1992 to 2014; (b) End Point Rate Graph from 1992 to 2014r

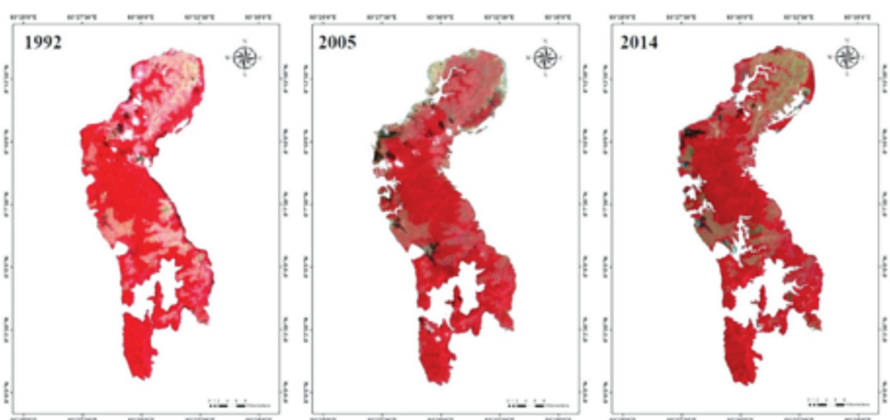

Figure 6: Shoreline and Coastal morphological change of Camorta Island before (1992), after 2004 Tsunami (2005), and latest (2014).

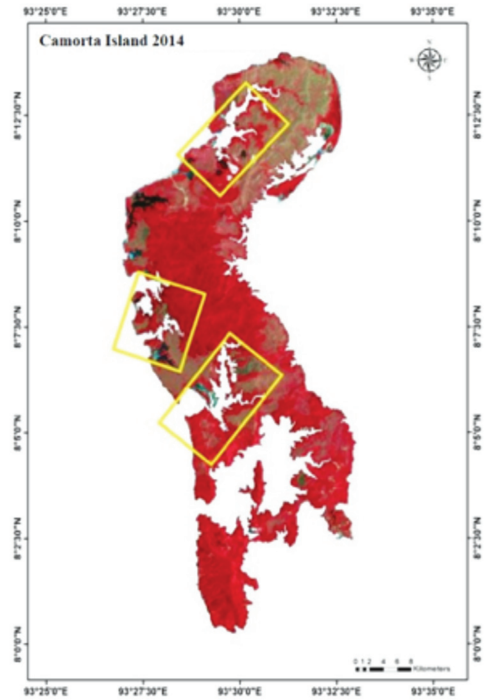

Figure 7: Major Morphological changes in the Camorta Island after the Tsunami 2004 to 2014.

CONCLUSION

The current study reveals the impact of 2004 tsunami and other natural processes on Camorta Island by using the archived satellite images and DSAS. This Island is highly vulnerable to rapid erosion not only due to rapid-onset disaster but also slow-onset disasters. The following results concludes that this Island is witnessing a high rate of erosion than accretion which shows that recovery of this land of this Island difficult and time taking. The recent developments in earth observation technologies and advanced tools like DSAS helps us to understand and continuously monitor the coastal morphological changes. In addition, we can also use the same methodology for analysing shoreline movements and the morphological changes for other coastal regions.

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