Fourth World Congress on Disaster Management

Volume I

Mumbai | India

Edited by

Dr S. Ananda Babu

President and Convener

DMICS-WCDM

This is the first in the series of three-volume compendium of 56 papers, presented at the Fourth World Congress on Disaster Management held in Mumbai in 2019. Authored by researchers, policy makers and practitioners, the papers cover a wide range of themes arranged around hazards, vulnerabilities and risks of disasters.

Dr S. Ananda Babu is a PhD from Osmania University (OU), India. He is a societal awareness specialist and scholar, an author and editor of numerous books including *Disaster Risk Reduction, Community Resilience and Responses*. In addition, Dr S. Ananda Babu is the Founder President of the Disaster Management, Initiatives and Convergence Society (DMICS) and the Convener of the World Congress on Disaster Management (WCDM) established in 2005. In the aftermath of the Indian Ocean Tsunami, to enhance understanding and awareness among people about the risk of various types, dimensions of disasters and the measures to be taken for reducing the risks, for better preparedness, response and recovery, the DMICS and the WCDM takes on the task of creating awareness through multi-disciplinary research, publications and multi-stake holder's consultations.

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Disaster Management, Initiatives and Convergence Society
Envisioning a Disaster Resilient Future

World Congress on Disaster Management

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Hazards, Vulnerabilities and Risks of Disasters

World Congress on Disaster Management

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Papers Presented at the Fourth World Congress on Disaster Management, Mumbai, January 29–February 1, 2019

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DISASTER RESPONSE

Preface

The Fourth World Congress on Disaster Management (WCDM) was organised in Mumbai from January 29 to February 1, 2019 jointly by the Government of Maharashtra, the Indian Institute of Technology Bombay, the Tata Institute of Social Sciences Mumbai and the Disaster Management Initiative and Convergence Society Hyderabad which created the platform of WCDM. Over the years WCDM has emerged as the largest biennial conference on disaster management in the developing world.

The theme of the fourth WCDM was *The Future We Want: Bridging Gaps between Promises and Action.* Nine Plenary Sessions, 62 Thematic Sessions, five Special Thematic Sessions and five Special Feature Events were organised around this overarching theme. More than 2000 participants from 68 countries attended these sessions.

While the Plenary Sessions were addressed by eminent speakers, the Special Thematic Sessions and the Special Feature Events were organised by the knowledge partners on different themes. It is the Thematic Sessions that received longest traction as Call for Papers was issued for these sessions months in advance and more than 600 researchers, practitioners and policy makers responded with abstracts of their ideas. These were reviewed by experts and 525 abstracts were selected for presentation in the 62 Thematic Sessions of the WCDM. Subsequently, 165 of these abstracts were developed as full papers. This is the first of three-volume series of compendium of these papers.

The papers have been published in the same form these were received without any peer review to provide a flavour of the raw ideas that emerged from the Thematic Sessions of the conference. Some of these papers presented by the young researchers and practitioners may not have the rigours of academic disciplines, but these do reflect the cross-current of thoughts that went around in these sessions of the Conference. These provide new ideas and insights that provide value to the current discourses on the subject.

These papers have been arranged under three broad themes – first: hazard, vulnerability and risks of disasters, second: disaster impacts and risk governance, and third: technology, infrastructure and resilience of urban systems.

The present volume is a compilation of 56 papers on the theme of hazards, vulnerabilities and risks of disasters. The papers have been arranged in three broad themes of nature induced disasters, human induced disasters and disaster response. Understandably the papers do not cover every aspect of the themes, these discuss only those aspects that the authors have chosen to highlight.

The Conference secretariat has brought the papers together, but the credit lies solely and exclusively with the authors.

Dr S. Anandababu
Convener
Fourth World Conference on Disaster Management

Acknowledgements

The DMICS team and WCDM organising committee would like to convey utmost thanks to the Government of Maharashtra, IIT Bombay and Tata Institute of Social Sciences for the outstanding collaboration and support to the Fourth World Congress on Disaster Management.

We would also like to thank the co-partners: NDMA, NIDM & NDRF – Ministry of Home Affairs, Government of India, JNU-SCDR, UNICEF, Tata Trust, UNDP, HPCL, BPCL, IOCL, ACT, JSW, ADPC, Save the Children, KE and FICCI for their great support and contributions.

We sincerely thank all the speakers, presenters and delegates for their dedication and active participation in the conference activities.

Our special thanks to Dr P. G. Dhar Chakrabarti, Dr Muzaffar Ahmad, Prof. Ravi Sinha, Prof. Janki Andharia, Maj. Gen. Dr Naresh Chander Badhani, Mr Ray Kancherla, Dr A Kishan, Prof. (Dr) Namrata Agrawal, Prof. B. Gopal Rao, Dr Ram Bhavani, Mr Mohan Kasthala, Prof. V. Prakasam, Mr Pavan Parlapalli, Mr Y. Satyanarayana, Mr D. Sridhar, Dr A. Gayatri Devi, Ms Suparna Dutta and Mr Mahesh for their constant support and remarkable contribution in making the event a huge success.

The support of Macmillan Publishers India Private Limited in publishing the Fourth WCDM proceedings is also appreciable.

PART I NATURE-INDUCED DISASTERS

I Living with Floods

Hydrological Study of the August 2018 Kerala Floods

Abby Varghese[a], Meera Nair M. S.[b], Gayathri Mohan, Midhun M. P.[a], Anjana Thomas[c] and Reshma J.[c]

ABSTRACT: On August 15, 2018, severe floods affected the South Indian state of Kerala due to unusually heavy rainfall during the monsoon season. It has been considered the worst flooding of the century, putting all its 14 districts on red alert and killing around 500 people. The heavy rainfall forced the state to open 35 out of 54 dams within the state and caused severe landslides in Wayanad and Idukki districts. At least a million people were evacuated to safety from Chengannur, Pandand, Edanad, Aranmula, Ayirror, Kuttanad, Aluva and Chalakudy. The Government of India declared it a Level 3 Calamity.

Our study area of Kerala has a total geographical area of 38,863 km², with a North-South orientation and elongated shape. It has an approximate length of 561 km but has a very short width of approximately 100 km, which means that it takes very little time for water to reach downstream areas from its farthest point at the ridgeline. Another interesting factor is that even as the elevation of the land ranges from -48m below sea level to +2690m above mean sea level, around 35 per cent of the area of the state falls between 0 and 50m and around 40 per cent between 50 and 500m elevation. Another major characteristic is that all sub-watersheds of Kerala are in South and Southwestern direction with almost flat slope ranges towards the coast.

From a Land Use Land Cover Analysis we have discovered that the area is divided into the following pattern: Plantation (22,255 km² 58.23 per cent), Deciduous and Evergreen Broad Leaf Forest (7849 km², 20.5 per cent), Cropland/Scrubland/Grassland (4307 km², 11.27 per cent) and Waterbody/Urban/Others (3806.5 km², 9.95 per cent). Another factor observed is that 83.89 per cent of soil in Kerala is clay, which could potentially cause high runoff during heavy rainfall in the catchments areas. For our study purpose, we delineated the watershed using SRTM-30M DEM with a minimum area assigned as 50km². The major flood-affected river basins were Periyar, Kambini and Puzhakal. Using Hydrological Modelling we estimate the potential flood flow in major rivers of Kerala and identify regions at risk due to heavy rainfall-induced flooding. Flood inundation mapping methods using the topography-based index HAND and hydrodynamic modelling were used to simulate flood inundation in main river reaches. Apart from simulating the floods, we have identified several key issues and put forward suggestions to minimise these factors, thus reducing the impact of such rain-triggered floods in future towards the end of the paper.

KEYWORDS: hydrological study, Kerala flood, Sentinel 1A

Introduction

In 2018, Kerala faced unusally heavy rainfall during the monsoon season, particularly in the month of August, leading to flooding of most parts of the state. It has been considered the worst flooding of the century, putting all its 14 districts on red alert and killing around 500 people. The heavy rainfall forced the state

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[b] Department of Geography, University of Madras
[c] Department of Sciences, Central University of Tamil Nadu

to open 35 out of 54 dams within the state and caused severe landslides in Wayanad and Idukki districts. At least a million people were evacuated to safety from Chengannur, Pandand, Edanad, Aranmula, Ayirror, Kuttanad, Aluva and Chalakudy. The Government of India declared the August 2018 Kerala floods a Level 3 Calamity.

Kerala is one of the richest states in India with 41 rivers that cover almost 580km of land and it has a total geographical area of 38863 km. It is surrounded by its coastline extension of 595 km, which opens the opportunity for the people in those areas to engage in the fishery industry, which contributes to 3 per cent of the state's income and is a livelihood for 1.1 million people in the state. The state, which witnessed a tsunami in 2004, made the people aware of how to handle natural calamities, but the flood that caused mass destruction was still a disturbing episode in Kerala's history. Even though the common people were evacuated and saved, the loss of their personal property and public property is not something that could be regained in a short period of time. The environmentalists who are researching what caused this flood have many different explanations. One of the approaches that this particular paper has highlighted is how the hydrological study will result in an effective way to explain the causes of the flood and a solution that can be put into action to prevent floods and be cautious in future.

As mentioned above, there are many views on what caused the flood. One of the main factors that was alleged was the opening of the five dams, which had never been done in the previous 26 years. However, some researchers have contributed to this idea in a different way, that is, the cause of the flood was heavy rainfall in the August 2018 monsoon. Areas like Wayanad and Idukki were grievously affected by rain and isolated during the flood by the landslides. Warmer climate increases the risk of floods, thus making it a necessity to be prepared for such events in future. For planning a flood management scheme, we need to study how the heavy rainfall led to flooding of most regions of the state. Such an analysis can help us understand the shortcoming of our present pre-flooding and post-flooding strategies, which will be helpful for us to limit the damages from such flood events.

Study Area

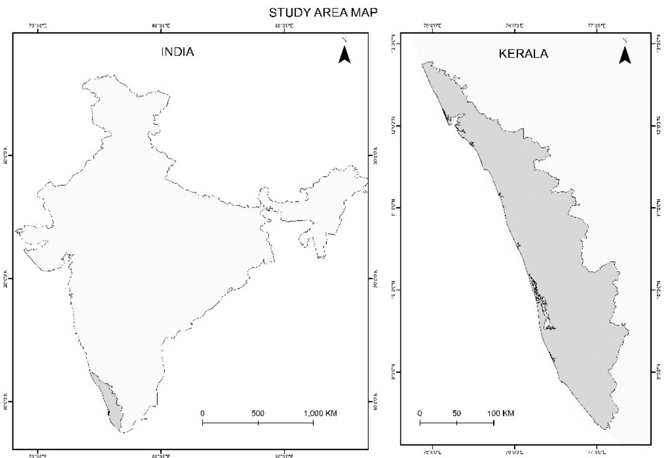
Kerala is one of the most scenic states in India that is redolent with natural beauty, water resources and many other features that have led to its reputation for beauty. It is located on the southwestern Malabar coast of India. Kerala has a total geographical area of 38,863 km, and 580 km of land is covered by water bodies. The state is divided into 14 districts with Thiruvananthapuram as its capital. The borders of Kerala are naturally beautified by Lakshadweep and the Arabian Sea to the west, Karnataka to the north and northeast, and Tamil Nadu to the east and south. The 2011 census establishes that there are about 33,387,677 inhabitants, which makes it the 13th largest Indian state by population.

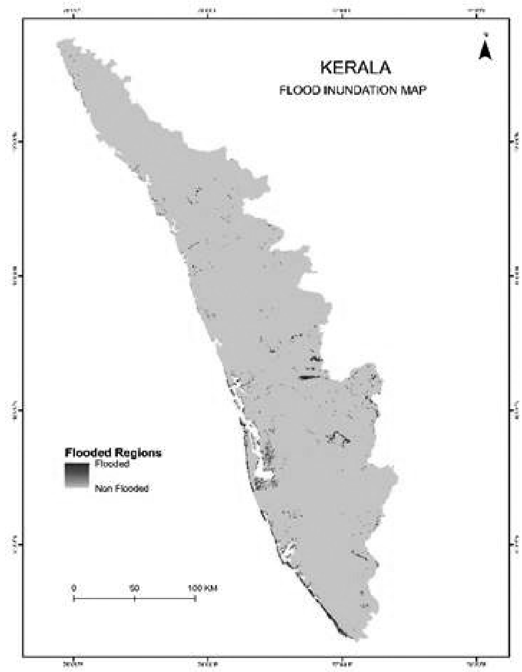
Kerala is the state that is known for its greenery due to its extraordinary climate. It has 120 to 140 rainy days per year, which makes it a wet and humid climate. In the months of June through August an average of 65 per cent of rainfall is caused by the Southwest monsoon, and the rest in September to December due to the Northeast monsoon. The pleasant climate and rainfall give this state a conducive atmosphere for farming and fisheries. The vast coastline is also a boon for the people who mainly depend on fisheries for their livelihood.

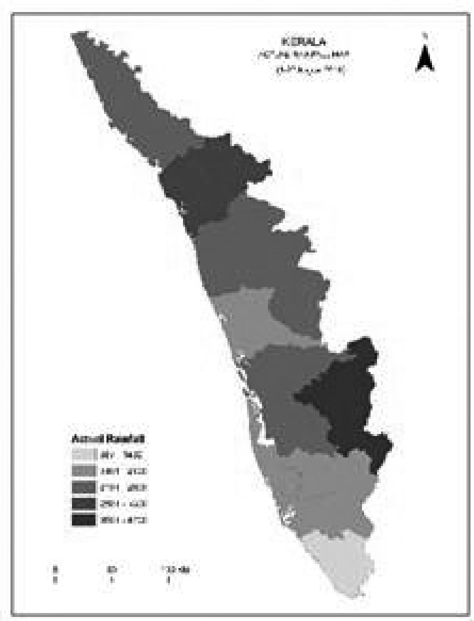
Kerala has copious biodiversity, which is concentrated and protected mostly in the Western Ghats. The benign climate in this state has also given life to many plants and trees, which can be seen as luxuriant forests.

As Kerala is divided into 14 districts, the administrative strategies are further distributed among 75 taluks, which are further divided into 1453 revenue villages for easy management of local land records, etc. Thiruvananthapuram, Kollam, Kochi, Thrissur, Kozhikode and Kannur are the six municipal corporations in Kerala.

In August 2018, Kerala was confronted with one of the worst natural disasters due its increased rainfall of 41 per cent greater than usual, which caused the state to be that submerged by impenetrable floods. The flood caused destructive loss of lives and property. The unusual amount of rainfall forced five dam gates to be opened, which had never happened in the previous 26 years of Kerala's history.







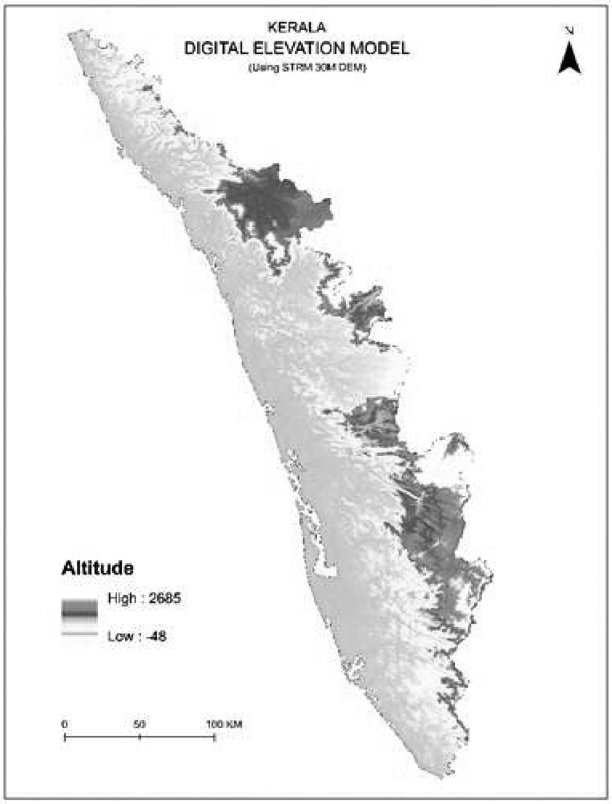
Methodology

In our study, we analyse the Kerala flood by dividing it into various phases.

Our first priority is identification of flood-affected regions in Kerala with Sentinel 1 data ingestion through ArcGIS, using the user-specified criteria from ESA Sentinel Data Hub to process flood inundation maps of the selected study area.

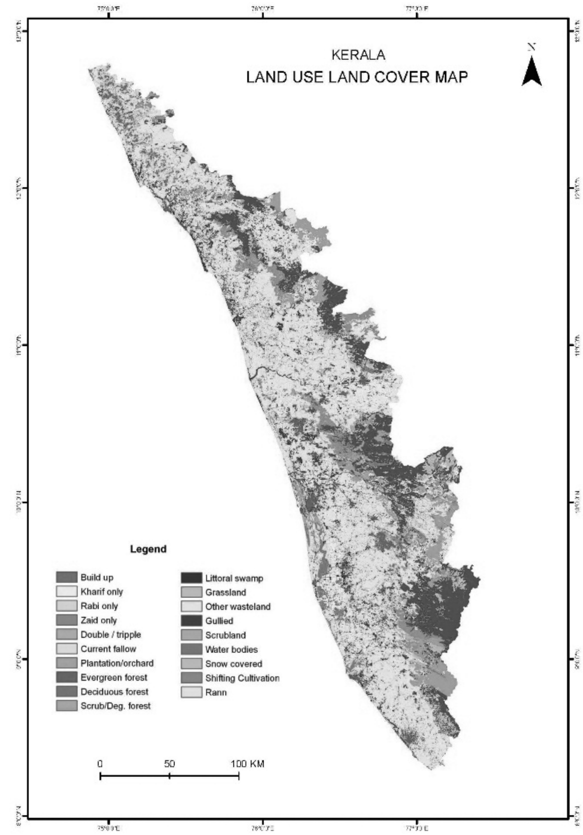
To analyse the August 2018 flooding in Kerala, daily rainfall data from June 1, 2018 to August 20, 2018 has been obtained from the India Meteorological Department. But a better understanding of the spatial distribution of Rainfall Mapping is obtained by collecting data rainfall details from 67 IMD-operated Rain Gauges of the month of August 2018 spread across the state. From a detailed analysis of data it has been found that cumulative rainfall during August 15–17, 2018 was quite significant, with more than 800 mm of rainfall at Peermade rain gauge station followed by more than 700 mm at Idukki. This data is then converted to points for plotting, and later using interpolation tools (i.e. Kriging or IDW) new raster data is created. The interpolation will smooth the transition between the points.

Relief of the land plays the second most crucial role in flooding. The steep slopes tend to reduce the amount of infiltration of water into the ground; this water can then flow quickly down to rivers as overland flow. In addition, steep slopes also cause more through flow within the soil. Both can raise river levels. Gentle slopes or flat land allows water to penetrate into the soil and increase lag times. Using SRTM 30M data we create DEM data that enables us to delineate watershed, locate major Operational Dams and analyse the slope and its direction. This is an absolute necessity for this study considering that it is analysed from a hydrological model perspective.



However, apart from rainfall, relief vegetation type and coverage play a major role, with forests intercepting more rainfall than grasses. This interception increases lag time and reduces the risk of a flood. To understand the land use patterns of the region a supervised Land Use Land Cover classification was done using the LULC 250K from Bhuvan and was later vectorised using ArcGIS. Such a classification helps us learn the land use pattern of the regions and hence is used for the final modelling.

Soil and rock type also influence what happens to precipitation or discharged water when it reaches the land. Impermeable soils and rocks such as clay or shale do not allow water to infiltrate, forcing water to run off and reducing river lag times and increasing flood risk. To understand the soil type and its water penetration properties, geomorphological mapping is extracted using QGIS from the Geomorphology (50K) 2005–2006 provided in the Bhuvan Indian Geo-Platform of ISRO.



Conclusion

This paper gives a detailed analysis of the major causes of the Kerala flood of August 2018. The main highlight is given to the hydrological structure in how the unusual heavy rainfall in the month of August caused this damage to the dams, which compelled the officials to open the gates of five dams, resulting in the mass destruction by the flood. The people of the state were alarmed by this sudden disaster, and it was not an easy task to bring back the state's beauty, the livelihoods and basic needs like shelter for the people who were rescued during this flood. Not only has the state suffered physical damages, the loss of life and property has caused greater psychological damage, and the task of bringing life back to normal is not an easy challenge for the state. Landslides were another impact of the flood which isolated areas like Wayanad and Idukki, causing massive land damage, which resulted in many deaths and many people went missing. The major flood-affected river basins were Periyar, Kambini and Puzhakal. Using Hydrological Modelling we estimated the potential flood flow in major rivers of Kerala and identified regions at risk due to the heavy rainfall-induced flooding. Flood inundation mapping methods using the topography-based index HAND and hydrodynamic modelling were used to simulate flood inundation in main river reaches. Apart from simulating the floods, we have identified several key issues and put forward suggestions to minimise these factors, thus reducing the impact of such rain-triggered floods.

The purpose of this paper is to analyse the causes of flood and give a deeper understanding of the causes of this flood. Having a correct and clear idea of what caused this can be helpful in preventing floods and taking precautions in future. Moreover, it helps us in rebuilding our state in a more preventative milieu.

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Kerala Flood 2018: Lessons for Mitigation and Management

T. I. Eldho[a] **and Sreedevi S.**[a]

ABSTRACT: India has been witnessing a large number of severe floods for the past few years and the latest one was the 2018 floods in Kerala. For effective flood management and mitigation plans, appropriate study of the flood event and hazards is required. In the month of August 2018, Kerala went through a series of disasters, all caused by once in a century rain events. As per India Meterological Department (IMD) data, Kerala received 2346.6 mm of rainfall from June 1, 2018 to August 19, 2018 in contrast to an expected 1649.5 mm of rainfall, which was about 42 per cent above the average. With such severe rainfall conditions, most of the major and medium dams were almost full by the second week of August. With further continuing of the rain, all the reservoirs were forced to release the flood water. With the continued rainfall and reservoir releases, severe flooding in 13 out of 14 districts in the state was reported during from August 14 to August 19. The disaster devastated the state with an estimated loss of nearly Rs. 30,000 crores, and about 440 lives were lost and about 1.5 million people were displaced. In order to prevent such situations from happening again, it is important that we understand the root causes of the incident and take effective measures to avoid them. In this paper, the major causes of floods, their impacts, mitigation measures and flood management issues are highlighted. An integrated flood management system can reduce the severe impacts of floods like those in Kerala in 2018.

KEYWORDS: Kerala floods 2018, flood management, mitigation, reservoir management

Introduction

Flood can be defined as a rise in water level for a short duration to a peak from which water level recedes at a slower rate (WMO, 1974). Amongst different natural calamities like cyclones, droughts and earthquakes, the maximum damage is caused due to floods around the world (WMO, 1994). It is worth noting that better early warning systems and increased preparedness resulted in a 43 per cent reduction in casualties due to floods in 2001–2010 compared to 1991–2000 (WMO, 2013). However, a recent study by Dottori et al. (2018) projected human losses due to flooding to increase by 70–80 per cent if the global mean temperature increases above 1.5°C from the pre-industrial level. Flood runoff is generated from intense rainfall as a result of intense cyclonic storms and depressions, 'break' situations in monsoon, association of El Niño and La Niña episodes or anthropogenic factors such as deforestation and man-made obstructions to free flow of river (Dhar and Nandargi, 2003).

As already reported by the Intergovernmental Panel on Climate Change (IPCC), India is the third most affected country in terms of climate-related disasters after Philippines and Cambodia (IPCC, 2013: www.ipcc-data.org). Floods are one of the most common hazards in India and about 40 million hectares of land, roughly one-eighth of the country's geographical area, is prone to floods (Gupta et al. 2003; Roy et al. 2008). In the past few years, a series of severe flooding disasters took place: the 2005 floods in Mumbai, 2008 floods in Bihar, 2012 floods in the North-eastern states, 2014 floods in

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Uttarakhand and Jammu and Kashmir, 2015 floods in Chennai, 2016 floods in Assam, 2017 floods in Gujarat, and the latest 2018 floods in Kerala. The impacts of these floods were loss of human life, property losses and economic losses. The severity and intensity of flood disasters in various parts of the country have increased especially during the past few years due to climate change (Das et al. 2009; Singh and Singh 2011).

The latest flood in 2018 seriously affected the state of Kerala in the southern part of India caused by once in a century rain events. As per India Meteorological Department (IMD) data, Kerala received 2346.6 mm of rainfall from June 1, 2018 to August 19, 2018 in contrast to an expected 1649.5 mm of rainfall, which was about 42 per cent above the average. With such severe rainfall conditions, most of the major and medium dams were almost full by the second week of August. With further continuation of the rain, all the reservoirs were forced to release the flood water. With the continued rainfall and reservoir releases, severe flooding in 13 out of 14 districts in the state was reported from August 14 to August 19, 2018. The disaster devastated the state with an estimated loss of nearly Rs. 30,000 crores, about and 440 lives were lost and about 1.5 million people were displaced. In order to prevent such situations from happening again, it is important that we understand the root causes of the incident and take effective measures to avoid them. In this paper, the major causes of floods, their impacts, mitigation measures and flood management issues are highlighted.

Analysis of Kerala Floods

Rainfall data from IMD indicates that between August 1 and 19, 2018, total rainfall in Kerala was about 758.6 mm against the average of 287.6 mm, which was 164 per cent above average. A district wise rainfall analysis in Kerala from June 1 to August 22, 2018 indicates that the departure of actual rainfall from normal was highest in Idukki (92 per cent excess) followed by Palakkad (73 per cent excess) (CWC, 2018). These districts came under the large excess category of rainfall departure as can be seen in Fig. 1. IMD data showed Peerumade (between Periyar and Pamba) and Idukki stations to have received the highest cumulative rainfall during August 15–17, 2018. Due to the severity of storms, 35 dams had to be opened to release the flood runoff.

During 1924 and 1961, Kerala witnessed heavy floods and rise in the water levels of reservoirs. However, Kerala received more rainfall in 1924 and 1961 than in 2018 between May 1 and August 21 (Mishra et al. 2018). For Pamba, Periyar and Bharathapuzha sub-basins the 2-day and 3-day rainfall depths during the August 2018 15–17, rainfall are almost comparable to the Devikulam storm of July 16–18, 1924. Seven major reservoirs, namely Idukki, Idamalayar, Kallada, Kakki, Parambikulam, Mullaperiyar and Malampuzha, have live storage capacity of more than 0.20 BCM. Volumetric analyses performed by the Central Water Commission for Periyar, Pamba, Chalakudi, Bharathapuzha and Kabini sub-basins where severe flooding occurred indicated that the dams in Kerala neither added to the flood nor helped in reduction of flood, as most of the dams were already at FRL or very close to Full Reservoir Level (FRL) on August 14, 2018, due to higher than average rainfall in the months of June and July 2018. However, early integrated reservoir management for flood protection should have reduced the intensity of flood hazards in most of the basins.

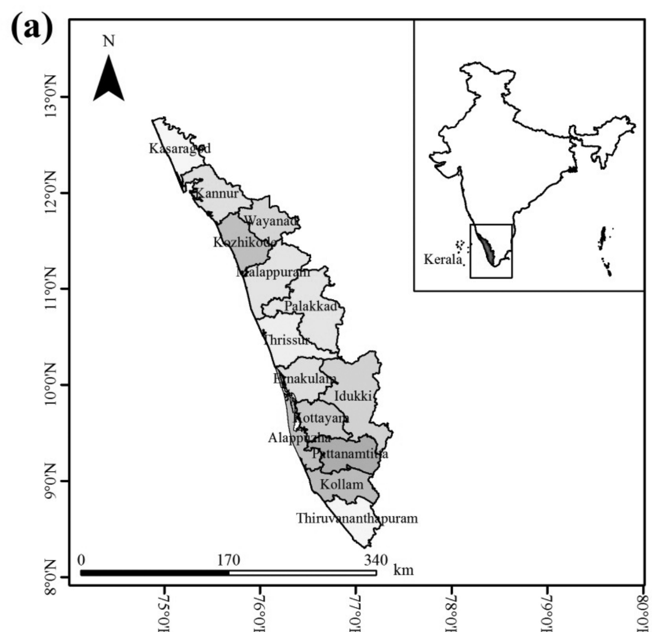

Figure 1: (a) Districts of Kerala

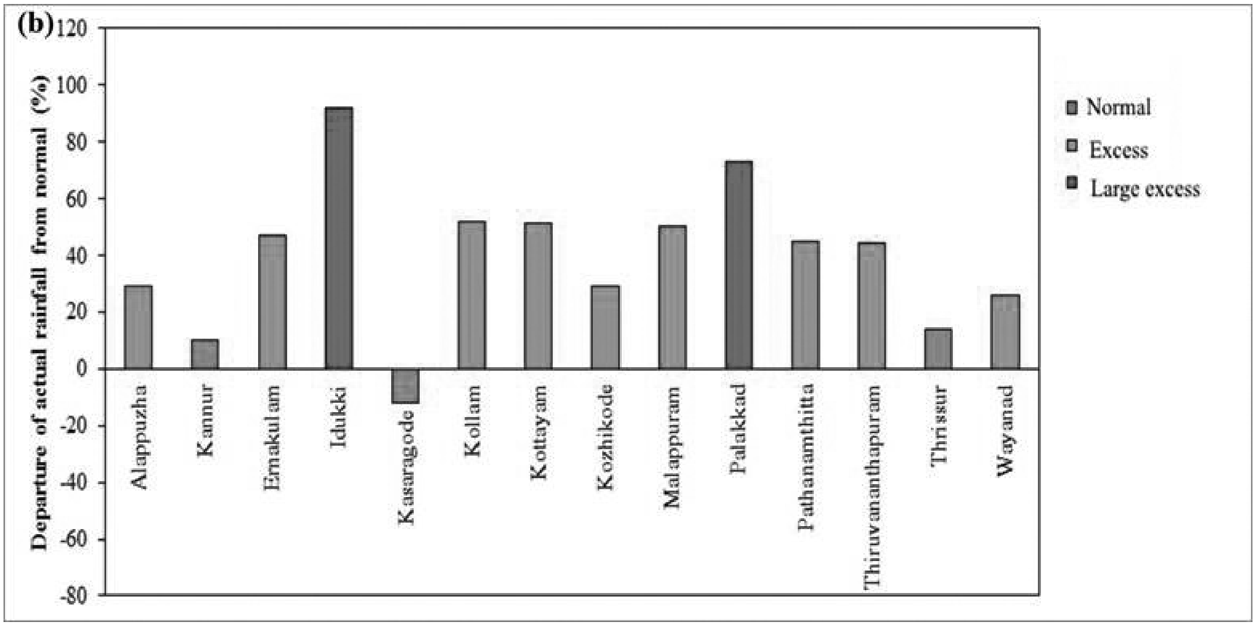

Figure 1: (b) Actual rainfall departures from normal rainfall (per cent) in the 14 districts of Kerala during the period August 1, 2018 to August 19, 2018

Causes and Effects of the Flood

Mishra et al. (2018) estimated the return period of extreme rainfall in Kerala during August 2018 using GEV (generalised extreme value) distribution and found that 1-day maximum rainfall averaged over the entire state in August 2018 had a return period of about 75 years. However, 2- and 3-day maximum rainfall had return periods of about 200 and 100 years, respectively. Based on the observed record, they found that almost all the major reservoirs were more than 90 per cent full before the heavy rain (August 14–17, 2018) and had a larger return period than what the state had witnessed. It is reported that the extreme rainfall event was caused due to formation of monsoon depressions over the Bay of Bengal and the west northwest ward movement of the depression over coastal Odisha and the surrounding area (www.imd.gov.in/pages/press_release.php dated August 23, 2018).

Detailed study to examine the role of other factors like land use/land cover change in Kerala flooding is required. A comparison of the decadal land use maps of Kerala for 1985 and 2005 provided by the National Remote Sensing Centre, India (Roy et al. 2015) is provided in Fig 2. Around 10 classes of Land use types could be identified. The notable changes in land use type from 1985 to 2005 were 79 per cent increase in built-up land, 7.65 per cent reduction in forest (which includes deciduous, evergreen, mixed and mangrove forests) and 23 per cent reduction in fallow land. The increase in impervious area reduces infiltration, thus increasing the runoff and higher flood peaks for even a short duration of low-intensity rainfall (Suriya and Mudgal, 2012). Detailed studies to assess the effect of land use change on runoff using hydrologic models need to be performed at a watershed scale.

Sudheer et al. (2018) applied the HEC-HMS model to simulate and analyse the role of dams, as well as reservoir operations, in the flood of August 2018 for the Periyar river basin. The study suggested that reservoir operations during the flooding could not have helped in avoiding the flood situation as only 16–21 per cent peak attenuation was possible by emptying the reservoir in advance, as the bulk of runoff to the flooding was also contributed by the intermediate catchments without any reservoirs to control. However, through an integrated operation of reservoirs, the flood severity could have reduced.

The Kerala flood caused the death of more than 440 people (*Gulf News*, August 30, 2018) and economic damage exceeding Rs 30,000 crore (News18, August 17, 2018). The operations of Cochin Airport were suspended for over one week. Due to floods, infrastructure facilities like buildings, highways and bridges were washed away and there was tremendous loss of agricultural land. The worst affected districts noticed were Wayanad (Kabini sub-basin), Idukki (Periyar sub-basin), Ernakulam (Periyar and Chalakudi sub-basins), Alleppey and Pathanamthitta (both in Pamba sub-basin) according to the Central Water Commission, 2018. Figure 3 shows different regions submerged due to the floods in Kerala.

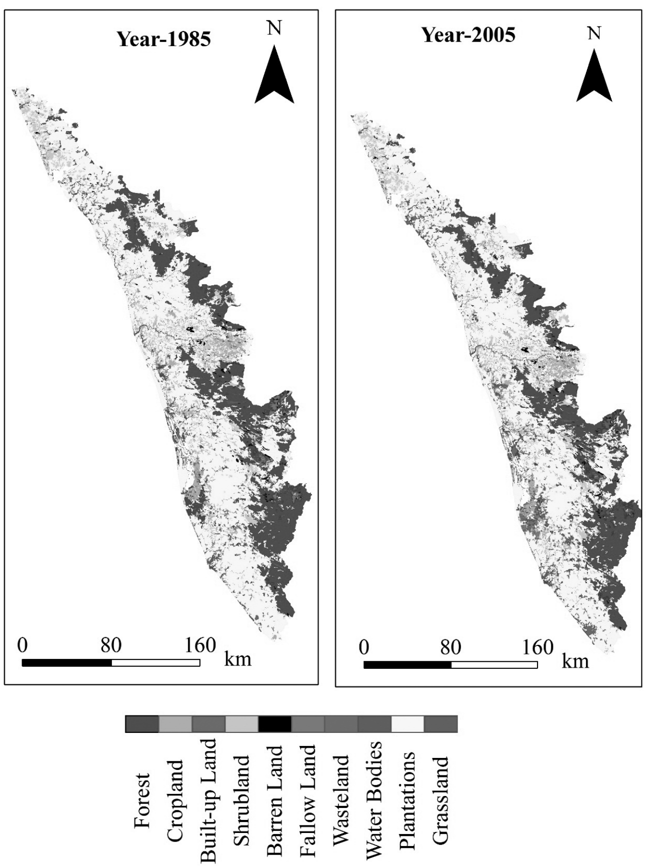

Figure 2: Land use/Land cover maps of Kerala for the years 1985 and 2005

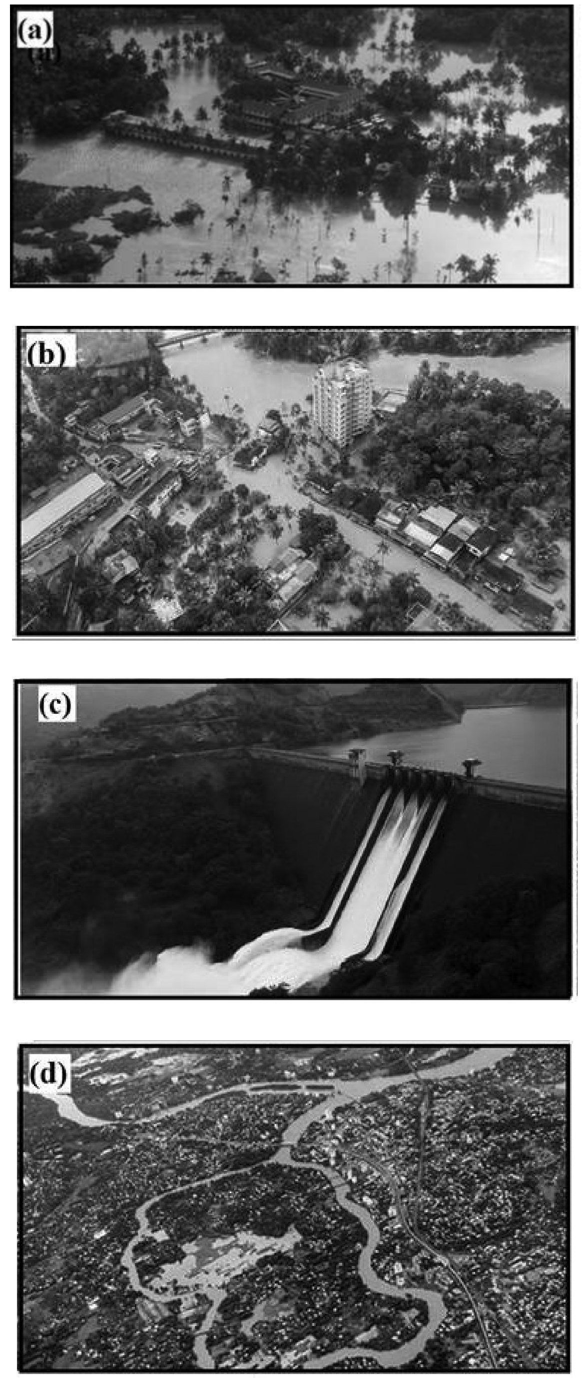

Figure 3: Photographs showing floods in different parts of Kerala in August 2018: (a) Aluva-Paravur region, (b) Near Chenganur, (c) 5 shutters of Idukki Cheruthoni dam opened during flood, (d) Aluva region (All images from Google Images: www.google.co.in)

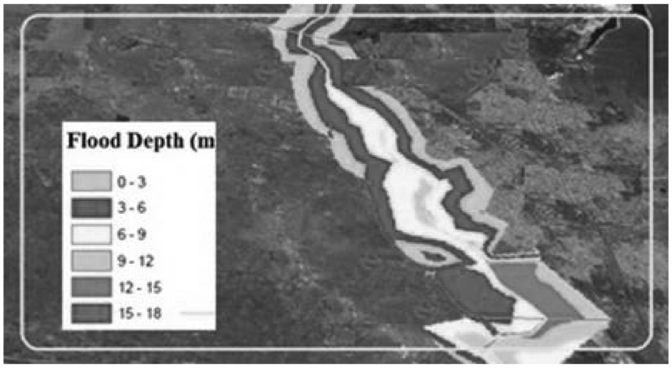

Figure 4: A typical flood depth map that can be generated using intensity duration frequency curves, rainfall return periods and hydrological modelling

Flood Management and Mitigation Measures

Computer models can be effectively utilised to prepare flood hazard maps based on return period or historical data at watershed scale. Flood vulnerability maps based on social and infrastructural factors need to be prepared. Hydraulic models such as USACE HEC-RAS, MIKE-SHE and MIKE-FLOOD are used widely to simulate the runoff response of an area to a given amount and distribution of precipitation over a defined period of time. An example of a flood depth map and hazard map that can be effectively used to identify the flood-prone areas generated by GEC-HMS-RAS software is shown in Figure 4. Further, the flood hazard and vulnerability maps can aid in better disaster management plans during flood events. There is an urgent need to review the flood management strategies and mitigation measures for all the river basins in Kerala in the context of recent floods.

Dam operation guidelines and rule curves at river basin level, for multiple extreme rainfall scenarios (including hypothetical extremes), need to be prepared. An integrated flood management system with all reservoir operation management systems is to be designed and centrally operated to deal with the type of floods observed in Kerala. A more transparent, accountable, technical and integrated mechanism to monitor, forecast and manage floods in the future has to be developed. Hydrological models must be applied for flood forecasting and real-time flood monitoring, which need to be integrated with early and real-time warning systems. Flood-related/other warnings have to be translated into easily understandable common parlance from a practical point of view. A disaster preparedness master plan for each district Local Self Government (LSG) has to be developed and enter in the public domain, to be updated once every two years. Preparation of flood and drought maps at river basin levels for multiple extreme climate scenarios such as extreme rainfall, temperature and cyclonic conditions and heat waves is crucial for future preparedness for such events.

Conclusion

In this study, an analysis of the Kerala floods in 2018 and their causes, mitigation and management is presented. A culmination of factors above normal seasonal rainfall, state-wide extreme rain, high reservoir storage, and unprecedented extreme rain in the catchments upstream to major reservoirs might have contributed to the flooding in Kerala on a large scale. The severe flooding can be attributed to the heavy rainfall received within 3 days amounting to around 414 mm from August 15–17, 2018, which forced the concerned authorities to open 35 dam gates. Despite warnings from IMD, severity of flooding could not be anticipated. Rule curves of reservoirs especially above 200 MCM need to be reviewed. The release from reservoirs played only a minor role in flood augmentation as released volume from the reservoirs was similar to inflow volumes. An integrated reservoir operation policy needs to be framed to balance flood control and other utilities such as hydropower or irrigation. Further flood mitigation and management systems are to be developed including real-time flood forecasting for the vulnerable basins.

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Evaluation of Floods in Chennai and Kerala

Manoj Pokkriyarath[a], Abhirami A.[a], Arvind M.[a] and Bishu R. R.[b]

ABSTRACT: Disasters are diversified in all aspects: they range from storms and tornadoes to earthquakes, tsunamis and cyclones. They affect a range of countries. Most of these disasters are geographically dependent. The overall response depends on many factors including the type of disaster, the types of organisations, the geography of the location, and the people involved in the rescue efforts. For example, is Japan better prepared than Nepal or Haiti to handle a disaster in terms of providing immediate relief? The overall objective was to design an evaluation method for disaster. Two natural disasters were taken as our platform, the Chennai (2015) and Kerala (2018) floods. Survey instruments were used to gather data from both the first responders and victims. ANOVA was then performed on both the data sets (Chennai and Kerala) for both victims and first responders where results were obtained within the groups and between the groups. In summary, the study shows numerous directions for improvement of relief efforts in disasters.

KEYWORDS: disasters, flood, Chennai floods, Kerala floods, ANOVA, first responders, victims, service quality

Introduction

"Disaster means a catastrophe, mishap, calamity or grave occurrence affecting any area. A disaster may arise from natural or man-made causes, or by accident or negligence. Disasters result 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 Management Act 2005). Natural disasters are complex and multifaceted events resulting from mismanaged and unmanaged risks that reflect current conditions and historical factors (Alexander 2000).

When an emergency situation such as a natural disaster develops, the first on the scene are usually police officers, fire fighters, NGOs, organisations, paramedics or emergency medical technicians (EMTs). These are the first responders, and they are trained to react quickly in emergencies. First responders have a unique perspective because they know their localities well. Moreover, during disasters, ordinary citizens have traditionally come together at disaster sites, and have helped out with the disaster relief with different degrees of effectiveness and efficiency and with varying results (Shaw & Izumi, 2014).

In this study the effect of the first responders is studied with respect to the service that they provide in first response to natural calamities, specifically in the case of floods – which may be caused by primarily natural causes, but could be accentuated by human decision-making. The study focuses on two recent floods that have occurred in India, one in Chennai and the surrounding areas in the state of Tamil Nadu in 2015 and the very recent flood in the state of Kerala in 2018. These two floods have been two of the most devastating floods that have occurred in India recently. A study on the effectiveness of the various organisations and how effective they were in providing disaster relief is attempted. The view and expectations of the victims, who in this case formed the main stakeholder of the efforts, were used in understanding how well the different organisations performed. Two sets of

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questionnaires were designed, one for the responders who helped in the immediate aftermath of the disaster, and another for the victims of the disasters.

Typically, in a disaster, we have two sets of actors. One is the group of people who are affected by the floods, whose property and lives were put in danger, and the other group is the one that came to assist. In this scenario, it is clear that the victims have certain needs to be fulfilled, with certain expectations, and certain standards that they would expect. For the group of people and organisations that are involved in the rescue efforts, they can be seen as the people who are fulfilling this need. Different organisations are involved in rescue efforts and in many cases they may be just doing the best they can and hope that they have met the need of the hour.

Methodology

In the first step we looked at the attributes that could be used to measure the effectiveness of the relief efforts. Once these attributes were identified, two sets of questions were designed, one for the victims of the flood and another for the responders, addressing each of these attributes and to measure each attribute. Once the survey questions were designed, it was sent to experts for them to critique. These experts were from both academia and from some of the target groups. Based on the experts, both the questionnaires were redesigned. The insights from these experts were most useful as they helped identify other factors that were absent in the original survey. The final questionnaire had a set of 27 questions for the victims and 66 questions for the responders. Two survey instruments were then designed and used to gather data. One survey was for victims and the other for responders. The target was to get 40 each in Chennai and 30 each in Kerala. Thus, a response of 70 * 2 = 140 survey samples was collected.

Results

An overall ANOVA (Analysis of Variance) is done for both the victims and the flood responders for which the results are discussed below.

ANOVA on flood victims

Table 1: Summary of ANOVA for Victims

ANOVA Summary Table		
S/N	**Dependent Variable**	**Location**
1	Government	NS
2	Corporate	NS
3	Military	S
4	International NGO	NS
5	Local NGO	NS
6	Religious Organisation	NS
7	Others	S
8	Satisfaction – Rescue	S
9	Satisfaction – Food	NS
10	Satisfaction – Water	NS
11	Satisfaction – Injured	NS
12	Satisfaction – Deceased	S
13	Satisfaction – Missing	S
14	Satisfaction – Medical care	NS
15	Satisfaction – Shelter	S
16	Satisfaction – Counselling	S
17	Satisfaction – Relocation	S
18	Satisfaction – Clothing	S
19	Satisfaction – Livestock	S
20	Efficiency	S

The results were tabulated and summarised in Table 1, with those factors that were deemed to be significant marked as “S” and those that did not meet the required significance at 95 per cent as “NS”. It is observed from the above table that location was significant for the following variables:

- Satisfaction with aid provided by Military
- Satisfaction with aid provided by Others
- Satisfaction with assistance provided for the Deceased
- Satisfaction with assistance provided for locating Missing people

- Satisfaction with assistance provided with respect to provision of Shelter
- Satisfaction with assistance provided with respect to Counselling
- Satisfaction with assistance provided with respect to Relocation
- Satisfaction with assistance provided with respect to Clothing
- Satisfaction with assistance provided with respect to Livestock
- Efficiency of the flood recovery team

ANOVA on responders

Table 2: ANOVA Summary for Data from Flood Rescue Responders [** Has an alpha of.056]

ANOVA Summary Table for Responders				
S/N	**Dependent Variable**	**Location**	**Organisation**	**Interaction**
1	Have you previously been involved in emergency relief operations?	S	NS	NS
2	Did you have an existing process for developing your plan of action?	NS	NS	NS
3	Did your plan of action specify guidelines or directions for your job?	NS	NS	NS
4	Was your organisation prepared fully to handle disaster relief efforts related to floods?	NS	S	NS
5	Is your organisation prepared for relief efforts in other types of disasters?	NS	NS	NS
6	Do you conduct your assessment independently?	NS	NS	NS
7	Does your organisation participate in a joint assessment?	NS	NS	NS
8	Do you rely on others to conduct the assessment?	NS	NS	NS
9	Is your organisation's assessment multidisciplinary (i.e., logistics, medical, etc.)?	NS	NS	NS
10	Do you have the necessary financial resources available when you need them?	NS	NS	NS
11	What mechanisms do you have in place to gain access to trained human resources?	NS	NS	NS
12	Do you encounter any procedural problems in procurement?	NS	NS	NS
13	Are enough trained human resources available to you?	NS	NS	NS
14	Do you use inter-agency coordination hubs?	NS	NS	NS
15	Is the team that you work with a fixed team that has been together prior to the disaster or is it an ad hoc team that was put together for this specific relief operation?	NS	NS	NS

(*Continued*)

Table 2: (Continued)

ANOVA Summary Table for Responders				
S/N	**Dependent Variable**	**Location**	**Organisation**	**Interaction**
16	Please answer the following regarding your organisation's ability to procure (purchases and donations) adequate quantities of the following commodities using the following scale. Scale: 5 = Excellent, 4 = Good, 3 = Average, 2 = Needs Development, 1 = Very Poor, 0 = None "In terms of FOOD"	NS	NS	NS
17	Please answer the following regarding your organisation's ability to procure (purchases and donations) adequate quantities of the following commodities using the following scale. Scale: 5 = Excellent, 4 = Good, 3 = Average, 2 = Needs Development, 1 = Very Poor, 0 = None "In terms of Medical"	NS	NS	NS
18	Please answer the following regarding your organisation's ability to procure (purchases and donations) adequate quantities of the following commodities using the following scale. Scale: 5 = Excellent, 4 = Good, 3 = Average, 2 = Needs Development, 1 = Very Poor, 0 = None "In terms of Vehicles"	NS	NS	NS
19	Please answer the following regarding your organisation's ability to procure (purchases and donations) adequate quantities of the following commodities using the following scale. Scale: 5 = Excellent, 4 = Good, 3 = Average, 2 = Needs Development, 1 = Very Poor, 0 = None "In terms of Others"	NS	NS	NS
20	Did they meet your organisations' specifications in terms of food?	NS	NS	NS
21	Did they meet your organisation's specifications in terms of medical?	NS	NS	NS
22	Did they meet your organisation's specifications in terms of vehicles?	S	NS	S
23	Did they meet your organisation's specifications in terms of others?	NS	NS	NS
24	Do you have problems with accessibility due to political barriers, road, sea, etc.?	NS	NS	NS
25	Please rate the quality of the following commodities as it relates to your response requirements: Scale: 5 = Excellent, 4 = Good, 3 = Average, 2 = Needs Development, 1 = Very Poor Commodity–Food	NS	NS	NS

(*Continued*)

Table 2: (Continued)

ANOVA Summary Table for Responders				
S/N	**Dependent Variable**	**Location**	**Organisation**	**Interaction**
26	Please rate the quality of the following commodities as it relates to your response requirements: Scale: 5 = Excellent, 4 = Good, 3 = Average, 2 = Needs Development, 1 = Very Poor Commodity–Medical	NS	NS	NS
27	Please rate the quality of the following commodities as it relates to your response requirements: Scale: 5 = Excellent, 4 = Good, 3 = Average, 2 = Needs Development, 1 = Very Poor Commodity–Vehicle	NS	NS	NS
28	Please rate the quality of the following commodities as it relates to your response requirements: Scale: 5 = Excellent, 4 = Good, 3 = Average, 2 = Needs Development, 1 = Very Poor Commodity–Others	NS	NS	NS
29	Please indicate the extent to which you agree or disagree with the following statements based on your experience (circle the appropriate number) (A) Humanitarianism: One should always find ways to help others less fortunate than oneself	NS	NS	NS
30	(A) Humanitarianism: It is better not to be too kind to people because kindness will only be abused	NS	S	S
31	(A) Humanitarianism: The dignity and welfare of people should be the most important concern in any society	NS	NS	NS
32	(A) Humanitarianism: People tend to pay more attention to the well-being of others than they should	NS	NS	NS
33	(A) Humanitarianism: All people who are unable to provide for their basic needs should be helped by others	NS	NS	NS
34	(A) Humanitarianism: A person should always be concerned about the well-being of others	NS	NS	NS
35	(A) Humanitarianism: I believe it is best not to get involved in taking care of other people’s needs	NS	NS	NS
36	Please indicate the extent to which you agree or disagree with the following statements based on your experience (circle the appropriate number) (B) Concern: When I see someone being taken advantage of, I feel kind of protective towards them	NS	NS	NS
37	(B) Concern: When I see someone being treated unfairly, I sometimes don’t feel very much pity for them	NS	NS	NS
38	(B) Concern: I often have tender, concerned feelings for people less fortunate than me	NS	NS	NS

(*Continued*)

Table 2: (Continued)

ANOVA Summary Table for Responders				
S/N	**Dependent Variable**	**Location**	**Organisation**	**Interaction**
39	(B) Concern: I would describe myself as a pretty soft-hearted person	NS	NS	NS
40	(B) Concern: Sometimes I don't feel sorry for other people when they are having problems	NS	NS	NS
41	(B) Concern: I am often quite touched by things that I see happen	NS	NS	NS
42	Please indicate the extent to which you agree or disagree with the following statements based on your experience (circle the appropriate number) (C) Personal distress: When I see someone who badly needs help in an emergency, I go to pieces	NS	NS	NS
43	(C) Personal distress: I sometimes feel helpless when I am in the middle of a very emotional situation	NS	NS	NS
44	(C) Personal distress: In emergency situations, I feel apprehensive and ill-at-ease	NS	NS	NS
45	(C) Personal distress: I am usually pretty effective in dealing with emergencies	NS	NS	NS
46	(C) Personal distress: Being in a tense emotional situation scares me	NS	NS	NS
47	(C) Personal distress: I tend to lose control during emergencies	NS	NS	NS
48	How satisfied are you with the effectiveness of the relief work provided during the disaster by your organisation?	NS	NS	NS
49	Do you think your organisation was efficient in providing relief during this disaster?	S	S	S
50	How efficient did you feel your organisation was in providing relief during this disaster?	NS	NS **	NS

The above table give the summary, with those factors that were deemed to be significant marked as "S" and those that did not meet the required significance at 95 per cent as "NS". Only five factors were found to be significant at 95 per cent.

- Have you previously been involved in emergency relief operations?
- Was your organisation prepared fully to handle disaster relief efforts related to floods?
- Did they meet your organisation's specifications in terms of vehicles?
- Is it better not to be too kind to people because kindness will only be abused?
- Do you think your organisation was efficient in providing relief during this disaster?

Discussion and Conclusion

Overall Chennai appears to have been better than Kerala in a number of attributes. This could be due to the fact that a) floods in Chennai was more localised and b) Chennai is a big metropolis with a high density. Kerala's floods effected the livelihood of people across much of the state and the expectation level of the people could have been much higher. With the increasing number of natural disasters, and the increasing human cost associated with each new disaster, there is little doubt that relief organisations need to be better prepared. With the absence of existing standards that are widely accepted, most organisations rely on certain guidelines and a commonsensical approach in providing relief. In this research, while attempts to identify quality of service measures were made, nothing conclusive could be identified, other than expectation gaps between the victims and the actual service provided by the flood relief organisations.

In trying to develop a model to compare the effectiveness of first responders, some metrics were identified in the results. The model identified some of the factors that were significant, and if the model can be developed further, it may be able to be used to compare the effectiveness of the first responders. This can then be used to better prepare the organisations for providing better disaster relief. However, with growth of technology, internet and social media, organisations also need to learn to embrace them in order to be more effective and be prepared.

Some of the internal factors have been identified and if organisations can look at educating and training the relief workers and others in the organisation to be able to be more empathetic as well as train them with the required skills to conduct proper relief work, the effectiveness can be increased. However, due to the nature of the organisations who end up being the first responders in a disaster scenario, this is very difficult to achieve.

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Flood Inundation Mapping of Kosi River and Probable Remedial Measures by Remote Sensing and GIS

Sampa Paik[a] and Gupinath Bhandari[a]

ABSTRACT: A flood is an overflow of water on earth surface, which is usually dry or moist. Sometimes water storage gets flushed with a large amount of water. This flushing may happen due to heavy rainfall within the area of any river basin. The precipitated water travels as surface runoff due to gravity depending on the topography of that particular river basin and goes towards the river. The river tries to carry forward the same water towards the downstream of the river. However, due to human interference, if the river bed gets uplifted at any stretch or multiple stretches, then the same river cannot carry forward the water further downstream and spills over the water on either side of the river, and inundates the land, which is called river flood. The other type may be urban flood due to lack of appropriate drainage systems. Flood can be in the form of local inundation or accumulation of runoff/discharge after heavy rain in the catchment and break of the embankment. The main causes of flood in India are: gathering of water due to localised heavy rainfall, excessive accumulation of runoff after heavy rainfall, high discharge from upper basin areas, poor drainage condition of river, and insufficient height and strength of river embankments. Floods are among the most calamitous usual disasters around the world impacting human lives, agriculture, animal husbandry and infrastructure. Predicting the flood and assessing the extent of damage can potentially help the researchers, disaster management people and policymakers to mitigate the flood-induced hazards in the downstream areas. Such studies require calibration of a hydrologic model using in situ observations for accurate prediction. In addition, use of remotely sensed satellite data serves as a viable option for supplementing the in situ observations. Kosi River in India changed its course across a width of 112km in its lower portion in Bihar in a period of about 250 years. Due to high frequency and intensity of flood, Kosi River wiped out many towns and villages inflicting heavy losses on human, cattle life and property. Due to this phenomenon, the Kosi was known as the "Sorrow of Bihar".

The present study is aimed at modelling flood using a hydrodynamic model of Kosi River basin and to assess the flood damage using land use land cover changes over a 20 km range. A Digital Elevation Model (DEM) of the study area was prepared using high-resolution Cartosat-1 imagery. River cross-sectional nodes were extracted from DEM. Remote sensing and HEC-RAS tools were used for data transformation from Cartosat-1 stereo images to inundated and damaged areas. Flood damage assessment was performed using flood inundation and land use land cover changes. An attempt has been made to discuss the probable structural and nonstructural remedial measures to reduce the losses.

KEYWORDS: flood inundation, Kosi River, HEC-RAS, remote sensing, DEM, GIS

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Introduction

Flood has always been considered as one of the normal catastrophes that is accompanied by enormous losses and damages, which affect the lives of human beings. To optimise the surrounding land, the most essential tool is to prevent the risks of flood in rivers and determine their boundaries. The flood inundation maps are one of the most fundamental and essential pieces of information required in civil engineering projects and should be taken into consideration before any investment or operational development of the projects. As the river zoning maps give valuable information, such as the depth and area of flood prevention in flood zones, it is crucial to provide the maps in the first place. The purpose of this study is to focus on the analysis of HEC-RAS and Arc-GIS in order to assess and predict the flood depth and spatial extent of flood in the Kosi river floodplain. This will help the decision-makers, particularly the concerned government's sector, and developers make a correct plan for future growth.

Data Used for the Study

The main objective of the study is to identify the damage that occurred due to flood inundation. To fulfil the set objective, water level and discharge, DEM, Google satellite images and river cross-sections are required. Required DEM data has been collected from http://bhuvan.nrsc.gov.in by Cartosat-1, which is a stereoscopic Earth observation satellite in a sun-synchronous orbit, and the first of the Cartosat series of satellites. The satellite was built, launched and maintained by the Indian Space Research Organisation. River stage and discharge data has been collected from the water resources department of the Government of Bihar.

Software Used

A set of HEC programmes (HEC-RAS and HEC-Geo RAS version 5.0.5) and Arc-GIS 10.5 were used for simulating discharge and water levels and also generating flood inundation maps.

Catchment Delineation

The approach for delineating river catchment from DEM data is based on flow direction, flow accumulation and pour point data. The process carefully determines the slope between each pixel in the DEM. In ArcMap 10.5, a data management tool is used to mosaic the DEM data tiles. Filling the DEM data, preparation of Flow Direction map, preparation of Flow Accumulation map, Raster Calculation, creation of Stream Order map, generation of Basin Flow map and Creation of Pour Point Data are the basic steps to extract the required Kosi River catchment area.

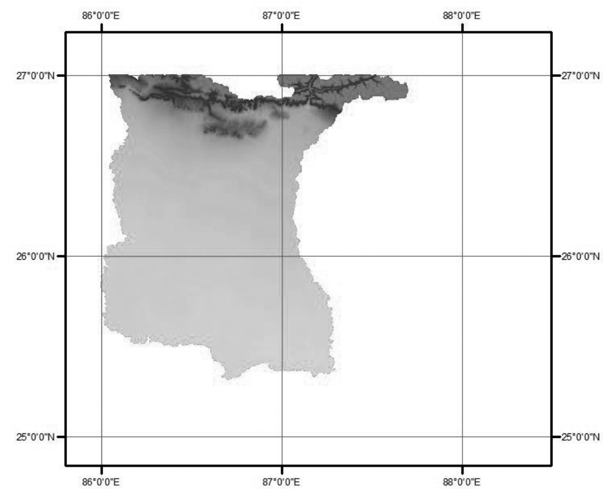

Figure 1: Kosi river catchment

Extraction of River Cross-Sections from DEM in HEC-RAS

River cross-sections are the keys inputs for hydrodynamic modelling of the river and its floodplain. In RAS-mapper, the extracted DEM file was used as an input. It will provide all the earth surface profile information in the form of elevation. Main river channel, left over bank, right over bank, flow path and required number of river cross-sections were drawn on DEM with the help of Google satellite. From DEM, 14 cross-sections (Figure 2) were extracted in 20 Km range at the downstream portion of Kosi river. Adequate number of cross-sections is critical to produce a good representation of the channel bed and floodplain, especially if sudden change in river bed elevation is recorded.

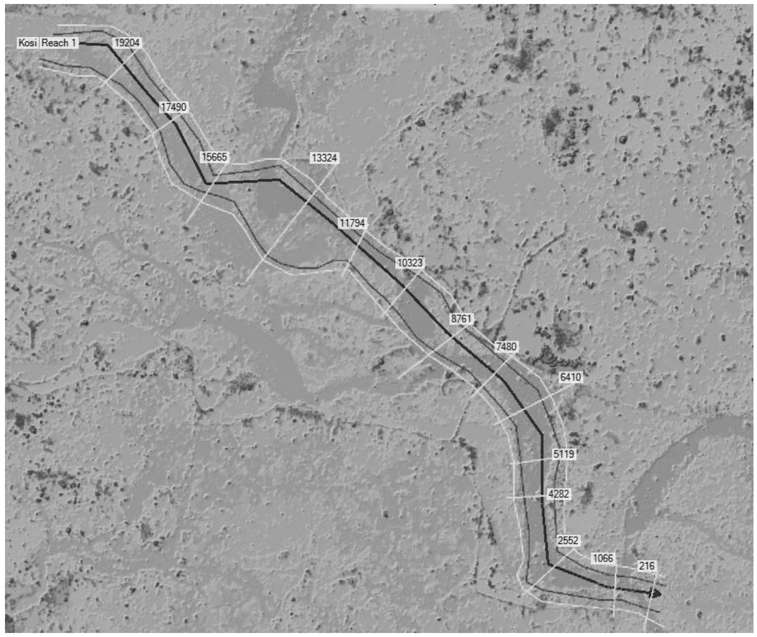

Figure 2: River channel, bank, flow path, cross-section distance

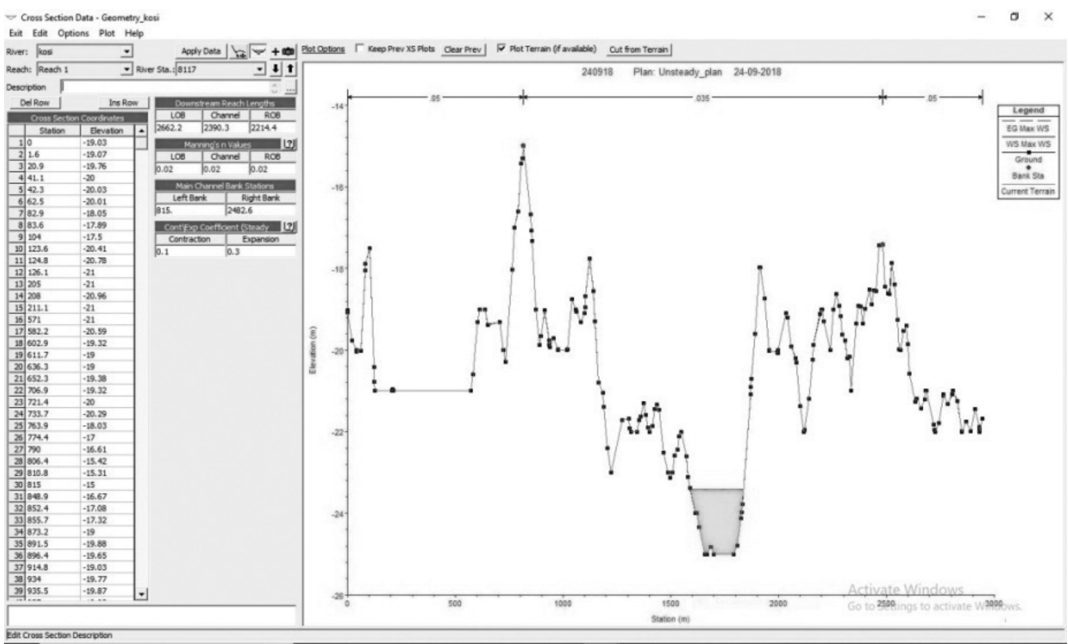

Figure 3: River cross-section

Boundary Conditions of the Model

Boundary conditions are necessary to establish the starting water surface at the upstream and downstream sections of the river system. Initial water surface is necessary for the hydraulic calculations. In addition to the boundary conditions, the initial conditions of the system are necessary at the beginning of the unsteady flow simulation. Initial conditions, in general, consist of flow and stage information at each of the cross-sections. In this study, flow hydrograph is applied as the upstream boundary condition. Models are analysed for a monsoon period of continuous 100 days duration considering unsteady flow conditions. The computation time interval of 24 hours is found to be suitable for this analysis.

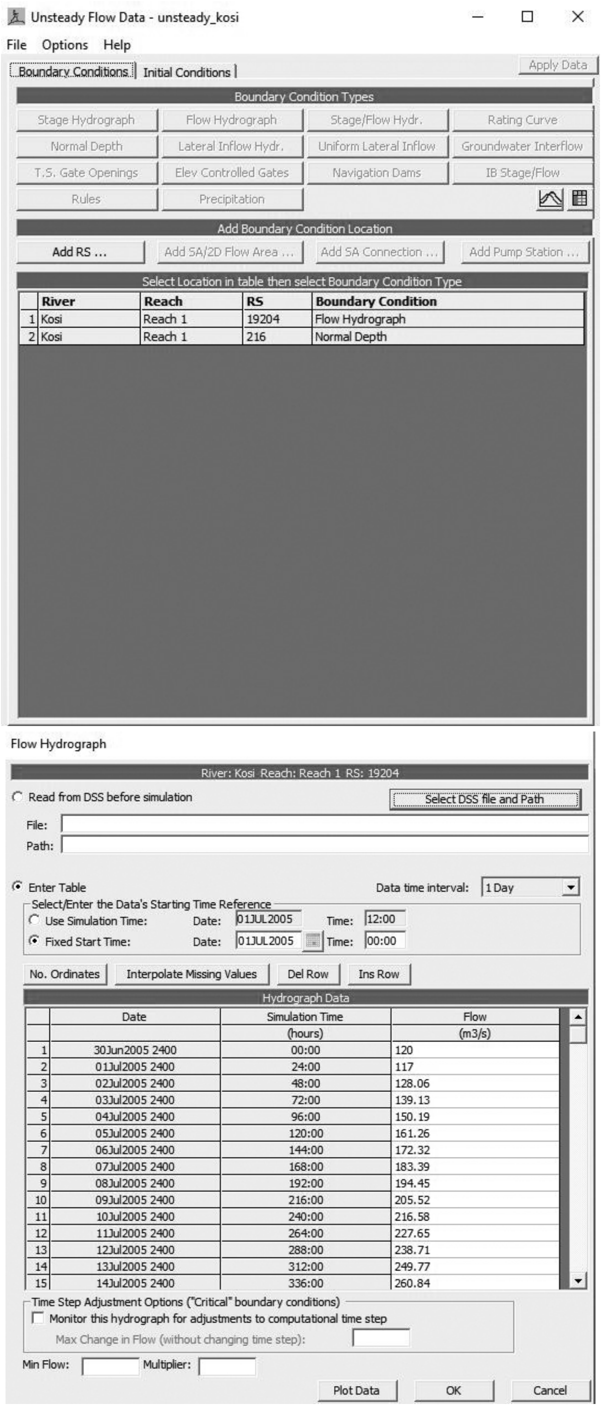

Figure 4: Boundary condition

Setting of Simulation Parameters

For unsteady flow analysis, proper adjustment of computational interval, hydrograph output interval, detailed output interval and mixed flow regime mode play important roles in flow simulation and quality of results. The hydrograph output interval is used to define at what interval the computed stage and flow hydrograph will be stored in the output file. In this study, the hydrograph output interval is set at 1 hour and the computation interval is set at 30 seconds. The detailed output interval allows writing profiles of water surface and flow at specific time intervals during the simulation. Stage and Flow Hydrographs are shown in Figure 3. The mixed flow regime is omitted in this study since no hydraulic jump is expected.

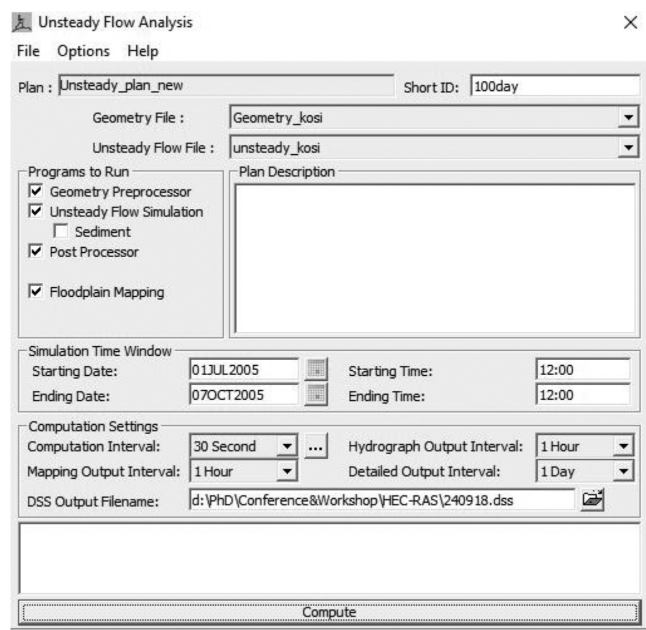

Figure 5: Simulation parameters

Flood Inundation Mapping

Hydrodynamic modelling and flood inundation mapping have been done in the geographical information systems (GIS) platform using ARC GIS 9.3 and HEC-Geo RAS software. River cross-sections are extracted from the DEM using HEC-RAS 5.0.5. These cross-sections are then exported to the hydrodynamic model of HEC-RAS. In this study, unsteady flow analysis is conducted for generation of water surface profiles. The resulting water surface profiles are exported back into the GIS for mapping of floodplain with different water levels. Flood inundation mapping and damage assessment are prepared for the year 2005. The flood inundation maps are prepared by delineating the areas subjected to inundation by floods of various magnitudes and frequencies.

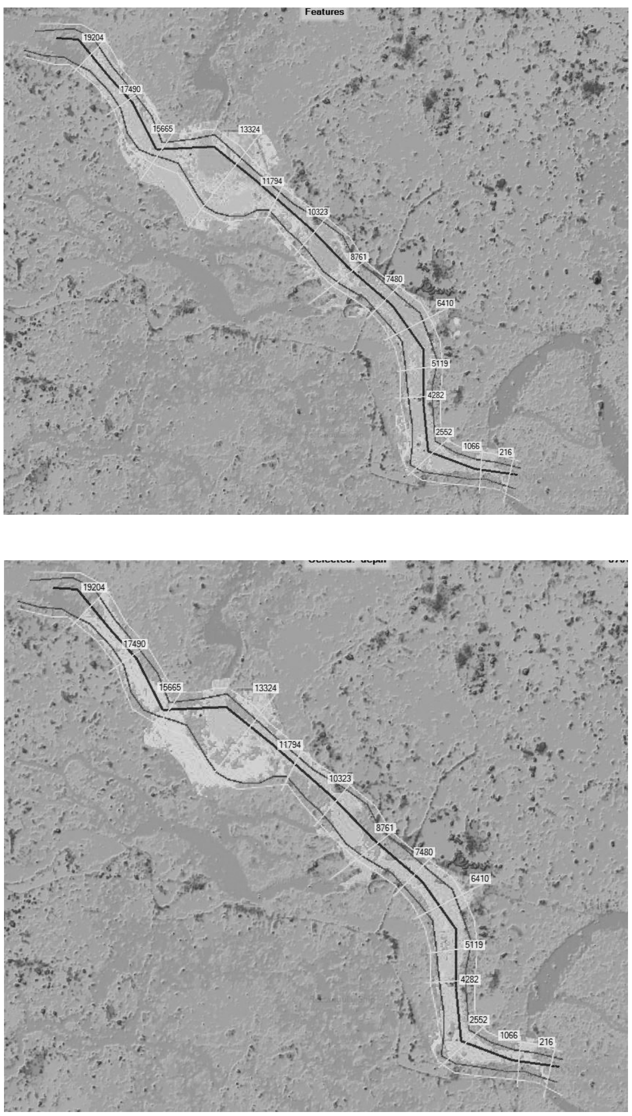

Figure 6: Flood zone map (maximum discharge and minimum discharge)

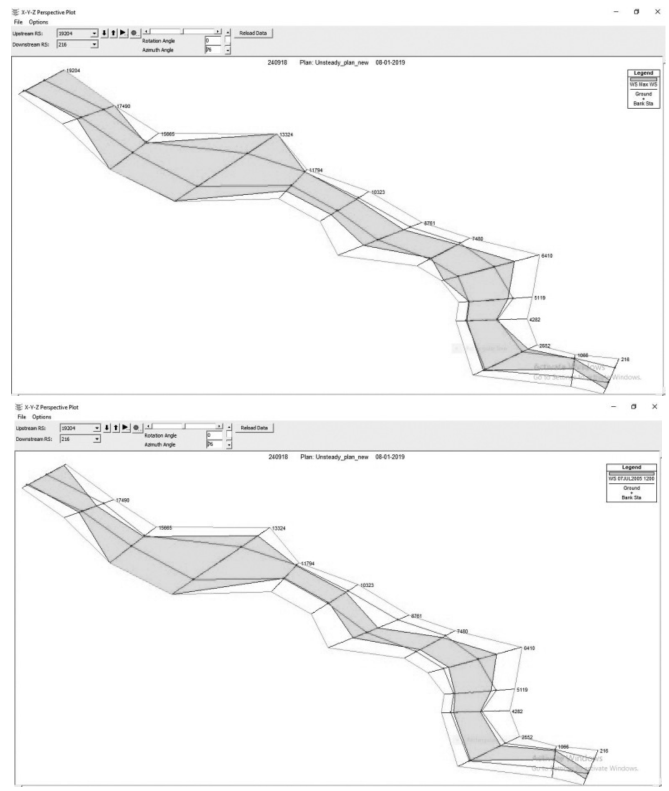

Figure 7: x-y-z Perspective plot for each cross-section (maximum discharge and minimum discharge)

Probable Remedial Measures

Different methods of flood mitigation have been applied. Floodplain management and the use of science and knowledge can reduce flood damage. Management measures to reduce flood damage can be done in two parts: structural and nonstructural measures. Structural flood management application involves damming, trenches, the diversion of river flooding, increased river discharge capacity and other physical flood mitigation structure constructions. The nonstructural flood management approach includes eliminating the destructive effects of flood without constructing physical structures, flood forecasting and warning, maintenance of retention ponds, land use planning, flood zoning, disaster services, shelters, flood fighting and post-flood healing measures.

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Disaster Relief: A Case Study on Medical Camps during the Kerala Floods 2018

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ABSTRACT: One of the key performance indicators of the health status of a country is its disaster health management. Medical health camps are of high importance to help combat health inequity. Many rural communities use medical camps to meet their health needs and receive free professional care from health care practitioners. Medical camps are an increasingly popular method of delivering health care to those who have difficulty accessing it. During August 2018, Kerala was affected by the heaviest flood in more than a century. The Kuttanad area was the most affected part of the state, because this region has the lowest altitude in India and is one of the few places in the world where farming is carried out around 1.2 to 3.0 m (4 to 10 ft) below sea level. This area is usually prone to flood, but this time it was heavily affected. Many medical camps were organised for communities which were cut off from the outside world by rising waters. This paper discusses the role and impact of such medical camps in the flood-affected areas. The data was collected from seven medical camps and from 881 responders. Data was collected through informal and formal interviews and participatory observation. Researchers were shadowing different specialists, and had the opportunity through participatory observation to see the interactions between doctors and patients. A debriefing after the consultation allowed us to receive more in-depth understanding from the doctors about each of their patients. Findings show that surprisingly 70 per cent of the patients were women. Most patients experienced skin diseases and other symptoms related to living in a very humid environment. Children experienced the common cold, fever, diarrhea and hematological disorders, which was expected. However, more surprisingly, many people also came with diseases totally unrelated to the flood such as rheumatic disorders, and many long-term diseases like diabetes, hypertension, heart disease and asthma. Observations also allowed us to notice the behaviour of the patients. Many of them came to the medical camp just for observing and they were confused on whether to attend it or not. Many patients were doubtful because the camp was conducted for free. This indicates that more communication and work at ground level is needed before medical camps are set up, in order to make them more efficient and to reach more people in need. Since the study is participatory in nature, during the disaster, there were challenges to maintain the study design. Future studies should address some of the gaps and bring about more information about the effectiveness of medical camps.

KEYWORDS: medical camp, Kerala, disaster relief, flood, diseases, safe water, health

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Introduction

Over the past few decades, there have been many proposals to make health a top priority in India (Panagariya, 2014). However, despite recent economic growth, health continues to be a major concern in rural areas of India, where health inequality has pushed them to face the dual burden of communicable and non-communicable diseases (Panagariya, 2014). According to the World Health Organisation (2012), the most common diseases in rural India are cardiovascular disease, diabetes, acute and chronic respiratory infections, malaria, cancers, diarrheal diseases and musculoskeletal disorders (WHO, 2012). The burden of disease is attributed to lack of accessible health care, high cost and quality of care received in rural areas (Panagariya, 2014). In addition, these diseases are exacerbated during natural disasters that plague rural India every year and further threaten the health security of the country. Natural disasters have known effects on physical and mental health and can lead to poverty, poor infrastructure and limited resources (Math, Nirmala & Kumar, 2015). To combat the complexity of natural disasters and their effect on an already poor health state in rural India, medical camps are usually deployed to deliver a range of health services, including vision, dental, pharmacological and general check-ups provided by health care practitioners. Medical camps are a popular method of delivering health care to those who have difficulty accessing care and can be seen as one approach to managing health during a disaster (Citrin, 2010).

According to Math, Nirmala and Kumar (2015), the "six R's" approach to disaster management is a holistic method of dealing with a disaster and includes the following concepts: readiness, response, relief, rehabilitation, recovery and resilience. Readiness is how prepared people are to respond to a disaster, response is the actual work performed and relief is the sustained rescue work. Furthermore, rehabilitation looks at follow-up measures, recovery is the return to normalcy and resilience is fostering the community to engage in disaster management (Math, Nirmala & Kumar, 2015). Medical camps fall under the concept of response since they involve taking action towards maintaining health and well-being during a natural disaster.

Gaurav Singh, ul Hasan and Kasi (2016) discussed the lack of enough research on the effectiveness of such medical camps. The paper discuss the challenges in setting up of the medical camps during the Kashmir floods of 2015. Nancy Angeline, Suguna Anbazhagan and A. Surekha (n.d.) mentioned the ineffectiveness of medical camps in bringing health care access to communities in need. Medical camps are often limited to trauma care and prevention of outbreak. This brings the need for a study on the medical camps and their effectiveness in catering for the needs of the whole community.

Study Area

Alappuzha, also known as Alleppey, is located in South Kochi, west of Kottayam, in Kerala. It has a number of rivers and lakes and is known for its popular watercraft races, backwater tourism, shorelines and marine items (Geography of Alappuzha, 2019). According to the 2011 census, the total population of the district of Alappuzha is 2,127,789 of which 1,114,647 and 1,013,142 are female and male respectively (Geography of Alappuzha, 2019).

In August 2018, Kerala was affected by record-breaking rainfall and flooding. The general elevation of the state of Kerala is less than 6m above sea level, with some parts of the area at 1 to 2 m below sea level (Central Ground Water Board, 2019). Alappuzha was heavily impacted by the floods and suffered the most damage. To help support the population, medical camps were implemented across the district to provide medical care for those in need. The purpose of this paper is to gain insight on how medical camps are established, and how efficient they are in addressing the health care needs of residents in the villages of the Alappuzha district.

Methods

As part of the Live-in-Labs® programme, students were deployed to several villages within the Alappuzha district with a team of doctors, nurses, dentists and pharmacists from the Amrita Institute of Medical Sciences in Kochi (Ramesh, Mohan, and Menon 2016). Participants in this study (sample size: n = 880) included residents who were affected by the floods and who attended the medical camps. Data was collected through informal and formal interviews and participatory observation. Students were placed with different specialists such as general physicians, optometrists and dentists, and had the opportunity through participatory observation to see the interactions between doctors and patients. Each consultation lasted approximately five minutes, and based on the disclosed symptoms and observations, patients were diagnosed with a particular illness and prescribed medication. After the consultation process, students received more in-depth data such as trends in illness and demographics from each health care professional.

Students were also placed in the pharmacy and camp management operations. This provided the students a better opportunity to be with the patients at various touch points. Students also participated in the camp organisation in helping the patients get diagnosed and get the medicines prescribed. The language barriers in speaking with the community were mitigated by creating a team of native and non-native speakers. The team also received training for conducting interviews.

The medical camps were done in spatially distributed and smaller teams of doctors and support staff. They used boats and smaller vehicles to ensure the medical facilities reached those most in need. This gave the students an opportunity to interact with people in a more comfortable environment compared to medical camps of larger size. The structure of interaction and observation was reviewed every day, based on the daily experiences. The field notes were coded later in the day. The inferences were later discussed with the medical doctors to understand the design and the results of the study. Due to the emergency situation and facilities, medical complaints were not coded following medical guidelines.

Results

Medical camp visits took place in the Alappuzha district across four days in the following villages: Kainakary, Kannadi, Era, Thalavadi, Pacha and Thakazhi. On day one, students visited four wards of Kainakary, followed by Kannadi and Era on day two. Thalavadi and Pacha villages were visited on day 3 and the last village, Thakazhi, on day 4. Table 1 shows the number of females and males who visited each medical camp during the four-day visit to the different villages. Table 2 describes the prevalence of different diseases among three different age groups: 0–18, 18–50 and 50 plus years of age.

Table 1: Statistics of Females and Males Who Attended the Medical Camps

Day	# People	# of females	# of males	% female	% male
Day 1–1st visit	103	74	29	71.8	28.1
Day 1–2nd visit	85	64	21	75.2	24.7
Day 1–3rd visit	110	70	40	63.6	36.4
Day 1–4th visit	21	16	5	76.2	23.8
Day 2	338	238	100	70.4	29.6
Day 3–visit 1	30	25	5	83.3	16.6
Day 3–visit 2	80	55	25	68.7	31.2
Day 4	113	82	31	72.5	27.4
Total	880	624	256	**70.9**	29.0

Table 2: Statistics of Diseases Diagnosed by Age Group

Age	Diseases	Total	Percentage
50 and above	• Diabetes	20	2.27
	• Joint pain	43	4.8
	• Thyroid	34	3.8
	• Hypertension	67	7.61
	• GERD (gastroesophogeal reflux disease)	80	9.09
	• Fungal infections (skin, related to water)	300	34.9
	• Cataracts	40	45.4
	• Respiratory infections	2	02
	• Diarrhea	23	2.61
	• Heart diseases	10	1.13
	• Asthma	19	2.15
	• Piles	2	0.22
	• Cancer	3	0.34
18–50	• Thyroid	43	4.88
	• Fungal infection	78	8.86
	• Joint pain	5	0.56
	• Vitamin deficiency	31	3.52
	• Myopia	27	3.06
	• Gum infection (bleeding gums)	11	1.2
	• Tooth decay	20	2.27
	• Fever	10	1.13
0–18 years old	• Fever	3	0.34
	• Diarrhea	2	0.2
	• Cough	5	0.56
	• Hematological disorder	1	0.11
	Total	880	100

Qualitative Findings

As the students were a part of the medical camp, they could see the impact that the floods had on the local residents. Many people described how their flooded living environment made it difficult for them to stay healthy and heal their physical ailments.

A lot of people were found to have respiratory problems, because smoking is prevalent among men, and affects the whole family (Nichter et al. 2015). Most men were not aware of the consequences of smoking. Students observed quite a few residents who were asking for a treatment regarding their severe coughs, but were also reluctant to consider quitting smoking.

Through participatory observation, students were able to observe the behaviour of the patients. Most beneficiaries were thankful that the camp was held close to their village. Due to the flood the primary health centre was closed, and no medicines were available locally. However, a few of the patients doubted their care. After getting the prescription from a doctor, they were seen to crosscheck with several other doctors as to whether the diagnosis was correct, and verify if the medicines properly addressed their problem. Even at the pharmacy, when they were given the medicines, they spent significant time fact checking with nurses and pharmacists on the prescriptions. A discussion with some of these patients revealed that they were doubtful because the camp was conducted for free. They also had experience of previous camps held by other NGOs, where they felt the diagnosis was not accurate and not enough medicines were available.

Discussion

Throughout the four medical camps, it was clear that more females attended the camps than their male counterparts. This could be attributed to gender. Being in the waterlogged landscapes, women have significantly reduced access to medical facilities compared to men. So medical camps are an opportunity for the women get access to medical facilities with much ease. Another factor could be that due to the flood, men working in the agricultural fields have become jobless and thus seek employment away from their families and their homes. In addition to gender differences, there were variations in the number of diseases present in the village among different age groups.

Rheumatic disorders were much more common among the adult population, whereas children experienced the common cold, fever, diarrhea and hematological disorders. A possible explanation as to why adults experience more rheumatic disorders could be attributed to heavy lifting performed in daily wage jobs as a result of limited employment in the agriculture sector due to the flood. Also, children are more likely to experience fever and diarrhea because their immune systems are immature and more susceptible to developing these conditions in flood-related situations.

Medical camps reported the visit of patients with many long-term diseases not related to the flood, such as diabetes, hypertension, heart disease and asthma. This is in line with what the WHO (2012) identified as the most common diseases in rural India. Other common diseases like malaria and musculoskeletal disorders were not found, and cancer was not prevalent in the areas visited. However, fungal infections, particularly in lower parts of the body such as legs and toes, could be associated with long exposure to contaminated water and unhealthy living environments. Furthermore, cases of skin allergies, respiratory infections and diarrhea were also reported and could also be related to unsafe water consumption and exposure.

The qualitative findings shed light on the impact of the environment on physical well-being. Waterlogging in living spaces makes it difficult for people to care for themselves and their family members because flood water has many contaminants that endanger health and prolong the recovery period. In addition, these findings also demonstrate the importance of implementing health promotion strategies, such as awareness and risk reduction, to, for example, lessen the negative impact on those who smoke on a daily basis.

Observations and data were assessed for three R's: relief, readiness and response (Veenema, Tener 2018). The multistructure interdisciplinary medical team and facilities were key in enabling the three parameters. The bigger team of around 40 medical staff ensured the relief activities were administered at a greater pace. Consultation rate was at patients per hour. The patients were provided with an opportunity to get specialised consultation prior to preliminary consultation. Saravan and Sudhakar (2017) mentioned the need for telemedicine systems in building capacity for remote health care. The medical camps were equipped with state of the art telemedicine units which have capabilities of rapid blood analyser, X ray facilities, ECG and EEG facilities. This helped the doctors to spot the patients in need of emergency care and define the treatment pathways. These efficient practices take the response and readiness factor of the medical camps to a higher benchmark. The mobile pharmacy unit was equipped to balance the consultation team.

Medical camps were also perceived as venues for dispatching lifesaving medicine. Among the respondents, many patients were observed having old medical prescriptions. Also many of respondents mentioned that they had visited other medical camps and collected medicine. Centralised storage of information on the patients and distribution of medicines would have helped in identifying the black holes in disaster medical care. The collaborative efforts from the different organisations from cultural, social and political backgrounds in organising such medical camps brings the people with needs, who are lost in the mainstream response programmes.

However, as revealed by the qualitative findings, in the event of disaster there can be many camps implemented in affected areas, from various organisations. Since their quality and supply can vary, it can affect the trust people have in such relief programmes. Hence, good communication at local level is important to ensure the most affected population are informed and turn up when a camp is held.

Limitations and Future Research

Some limitations in this study include language barriers, speed and accuracy of interpretation, as well as potential misinterpretation. During the medical camps, international students were assisted by Malayalam-speaking students to conduct conversations in the local language. Throughout the translation process, the actual meaning could have been lost or misinterpreted. In addition, the medical camps were conducted in specific areas of Alappuzha district and this limited our ability to generalise our findings and compare to other rural areas in Kerala. With regard to the qualitative findings, additional time with residents in each village would have allowed for a deeper understanding of why some residents were distrustful of the medical camps and their services. Another limitation was the lack of follow-up care with each resident who visited the medical camps. Future research should implement a database of each person attending the medical camps as it will track visitors and follow up on their progress.

One area that was not explored in great detail was the psychological effects of natural disasters on local residents. Health is a holistic concept and includes physical, social and mental well-being. Future studies should address the prevalence of mental health, its impact on health and well-being, and methods used to cope with these challenges. Overall, a more holistic approach is needed, not only regarding the health aspect but inclusive of all other factors connected to disaster management (Mohanan and Menon, 2016).

Conclusion

This paper discusses the experience of a multidisciplinary group of international students from Ryerson University, who worked alongside MSW students from Amrita University in the flooded areas of Kerala in July 2018. Health inequality is a known burden in India and the diseases attributed to the lack of proper health care are typically treated through medical camps, especially in rural parts of the country. In this paper, the importance of medical camps in areas affected by natural disasters is discussed. During the course of the four days, students, doctors, nurses and pharmacists brought the medical camp to the villages, and provided free consultations and medications to individuals and families affected by the flood. Despite the limitations in this study, students were able to assist numerous individuals who needed basic and complex health care. Medical camps were found to be efficient in the visited areas, as they addressed a large part of the population and covered all common and specific diseases. The most common long-term diseases were found to be diabetes, cardiovascular, diarrheal and respiratory diseases, which is consistent with WHO (2012) data. Disaster-specific diseases were fungal infections and skin allergies, affecting all categories of villagers. However, good communication at local level is important to ensure affected people keep trusting these kinds of relief operations, in their own interest. We hope future studies will address some of the gaps in this study and bring about more information about the effectiveness of medical camps.

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Deficiencies in Flood Damage Assessment and Possible Improvements

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ABSTRACT: Floods cause damage to property and crops, contamination of soil and water, disruption of transport and communication, and loss of human and cattle lives, and there is continuous fear, anxiety and distress in the minds of people residing in flood plains. Classification of damages is illustrated with examples.

In India, flood plain occupancy is becoming more and more costly, occasionally leading to social and economic disaster. Due to ever increasing human pressure on land, the toll exacted by flood disasters is especially heavy. This paper discusses the dilemma of flood plain occupancy.

Procedures for assessment of various types of flood damages widely differ in developed and developing countries due to (i) differing perception of flood impacts and (ii) inadequacy of data base. In India, emphasis continues to be on assessment of direct damages. This does not mean that indirect and intangible damages are insignificant. The paper highlights the significance and hence consideration of indirect and intangible damages. Examples of such damages which should not be attributed to floods are also highlighted.

Deficiencies existing in collection, reporting and analysis of flood damage data at local level, district level, state level and central level are discussed. The National Flood Commission of the Government of India (RBA 1980) made several recommendations 1980 to improve the procedure for flood damage assessment. These are highlighted in the present study. Unfortunately many of these recommendations are yet to be implemented.

Two case studies on direct and indirect flood damage in Chennai city and in Surat city are briefly reviewed to highlight the significance of indirect and intangible flood damages in urban areas.

KEYWORDS: flood plain occupancy, economic disaster, deficiencies in damage assessment, national flood commission recommendation

Introduction

Flood damages may be defined as the destruction or impairment, partial or complete, of the value of goods and services or of lives resulting from the action of flood waters and the silt and debris that they carry. These flood damages arise basically due to flood plain occupancy but the effects of flood may be felt far beyond (Frongia S et al. 2016). Assessment of flood damages is necessary to find the magnitude of the flood problem in a specific area and to plan the structural and non-structural measures which would help in mitigation of such damages (Suriya S et al. 2012). Mitigation of flood damages is the benefit of flood control projects.

The literature review shows that India suffered heavy flood damages in 1971, 1973, 1976, 1977, 1978, 1980, 1984, 1988, 1993, 1995, 2006, 2008, 2012, 2013 and 2015 (CWC 2011, Singh & Kumar 2013, Mujumdar P. P et al. 2016). Rapid climate change is causing extreme rainfall events with sharply increased frequency and unpredictability. During the month of August, 2018, 13 out of 14 districts in Kerala state were severely affected by flood due to heavy rainfall (CWC 2018).

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Dilemma of Flood Plain Occupancy

The magnitude of flood damages is generally determined by the type of development (agriculture, industries and transport network) in the flood plains. Before the population of India grew and economic activities developed, flood water spread over the flood plains, flowed back to the rivers and emptied into the sea without causing much damage. However, as human settlements started growing close to the river banks and with increased economic development activities, more and more of the flood plains got occupied leading to adverse effects of floods being felt in a significant manner by the people.

On the one hand, flood plains provide attractive locations for various human activities, notably agriculture and transportation. The flat lands in river valleys consist of fertile alluvial soils. Some of the world's great civilisations have developed along the banks of rivers such as the Tigris, the Euphrates, the Nile, the Indus, the Ganga and the Yangtze. The flat lands in the river valleys also provide transportation corridors and building sites for homes and factories. For certain activities, a riverine location is essential, such as those which are dependent on rivers for transportation or for water for processing or cooling purposes. Not surprisingly, therefore, flood plains have become the focus of a considerable portion of the world's settlements and economic activities.

Flood plain occupancy on the other hand can be costly and in some cases may lead to disaster. Once in a while the river may overflow its banks and exact a heavy toll of property damage, income loss and perhaps loss of life as well. In developing countries, since means of sustenance are already limited, the toll exacted by flood disasters is especially heavy.

Classification of Loss and Damage due to Floods

The United Nations Framework Convention on Climate Change (UNFCCC, 2012) defines loss and damages (L&D) as the actual and/or potential manifestation of impacts associated with climate change in developing countries that negatively affect human and natural systems. 'Loss' means irreversible impacts: negative impacts in relation to which reparation or restoration is impossible, such as loss of ecosystem services. 'Damages' can be recovered, meaning negative impacts for which reparation or restoration is possible, such as damage to houses and coastal mangroves (UNFCCC, 2013).

Previous studies indicate that the majority of researchers have classified loss and damage (L&D) in two groups, tangible and intangible. Furthermore, each group of L&D is split into two groups, direct and indirect, depending on the direct contact with the water. Table 1 shows classification of flood loss and damages into a) direct tangible L&D, b) indirect tangible L&D, c) direct intangible L&D and d) indirect intangible L&D. Examples of various types of L&D attributable to floods as well as those L&D which should not be attributed to floods are also highlighted in the table.

Table 1: Classification of Losses and Damages (L&D) due to Flooding

Types of Loss and Damage (L&D)	Inclusion	Exclusion (Ref: RBA 1980)
Direct Tangible L&D of goods and services that are traded in market. These arise through direct physical contact and action of flood water	Growing and pre-harvest crops; houses and household property; private property; public buildings; public utilities (railways, roads, telegraph network, electricity); loss of livestock; damage to soil due to waterlogging	Expenditure on compensation paid to flood victims, remission of land revenues, etc. should not be considered. These represent only financial transfer from Government to flood victims Cattle temporarily missing but returning later

(*Continued*)

Table 1: (Continued)

Types of Loss and Damage (L&D)	Inclusion	Exclusion (Ref: RBA 1980)
Indirect Tangible L&D (economic and traded in market). These arise from the disruptive effects of flood on normal social and economic activities both within and beyond the flooded area. The value in aggregate of the goods and services lost because of interruption to normal activities forms indirect L&D	– Loss of earning in agro-based industry and trade; – Loss of revenue to the road transport and railways due to interruption of services as a result of submersion or washing away of roads, railway lines and bridges; – Relief expenditure on medical measures, building temporary habitation facilities and rescue operations; – Loss of earning to petty shop-keepers and loss of employment to farm wage earners	Services for which annual aggregate demand will not decline due to floods (weavers, carpenters, goldsmiths, etc.) may not be considered. Similarly there may be no loss of earnings for the shop-keepers dealing in textiles and other consumer goods required occasionally
Direct intangible L&D. These include loss and damage to goods and services for which a market does not exist	Loss of archeological sites, loss of human life, people affected, damage to cultural heritage, biodiversity and ecosystem services	Accidental deaths such as those resulting from capsising of boats, house collapse due to rains, snake bites, etc. should not be attributed to flood
Indirect intangible L&D	Fear, anxiety and ill health, migration; impact on social crime, conflicts and disputes; loss of indigenous knowledge; social welfare loss due to water stress and violence against women	Fear, anxiety, conflicts due to rumours

Today's Intangibles May Become Tomorrow's Tangibles

These intangibles are being defined merely by antithesis to the tangible damages susceptible to approximate monetary evaluation. The intangibles remaining unquantified or unevaluated thus need have no other common property than that they have been excluded from the analysis either because they could not or ought not to be included. Being defined this way, today's intangibles may become tomorrow's indirect or even direct damages as satisfactory methods of quantification are evolved or when there is consensus that quantification is desirable. For example, theoreticians have suggested some ways of expressing loss of human lives in monetary terms; for example, the sum of discounted streams of income/expenditure of the dead over his expected life span may be taken as monetary value of human life.

Intangible damages may be further classified as direct intangibles and indirect intangibles.

Wherever feasible, information on intangibles should be collected as it is useful in clarifying the issues involved in planning of flood safety measures. When intangible damages are significant, socio-political considerations assume overriding importance and some flood control projects may be sanctioned even without any significant economic benefits.

Collection and Coordination of Data

The responsibility for collection, compilation and coordination of data on flood damages at present rests primarily with the Revenue Department of the State Government. The flood data is of immediate and important use to state governments in connection with revenue suspension/remission and relief administration handled by the Revenue Department. For relief administration, it is not relevant to know whether the damage that has taken place is in protected or unprotected areas and whether it is on account of over spill of the river, drainage congestion, rains or cyclones. But such considerations become important from the point of view of formulation of projects. The Revenue Department may have little interest in revising and finalising the flood damage data and in examining suitability of data for preparing flood control projects or for evaluating the effects of such projects.

Local Level: In most states, the revenue staff at the village-level have traditionally been associated with collection of data on land holdings, crop areas, crop yields, prices, etc. These officials are familiar with the layout of the concerned villages and are in a position to make an intelligent guess about the extent of flooding and crop losses.

District Level: Data relating to public property including roads, buildings, canals, embankments, tubewells and so on, is generally collected by the different departments responsible for construction and maintenance of such property. Data collected at the village and block levels is processed, scrutinised and consolidated at the district level.

State Level: At the State level, the work of compilation and processing the damage data is undertaken by the Directorate of Economics and Statistics.

National Level: Damage data at the national level is compiled by the Central Water Commission under the Ministry of Water Resources.

Present Methodology of Flood Damage Assessment

Procedures for flood damage assessment widely differ in developed and developing countries. This difference is mainly due to (i) differing perception of flood impacts and (ii) inadequacy of data base. In India, emphasis at present is on assessment of direct damages. Method of assessment is based on complete enumeration. Procedure for assessment of loss and damages as being followed in India is briefly described below.

Crop Damages

The Government of India has recommended two farms for reporting flood damage at village and block/Tehsil level as shown in Tables 2 and 3. However, these have not yet been adopted in some cases. The current practice is to consider the crop damage to be the total loss of output. Crop damage is affected by the particular stage of growth of the crop at the time of the flood, the period of inundation and the possibility of revival of the crop after the flood. The more correct assessment of the crop damage would be in terms of the infructuous expenditure incurred an inputs, labor, seeds and loss of yield (Tables 2 and 3).

While converting the crop damage into monetary terms, the crop yields should be based on crop cutting experiments carried out on a scientific basis in the flood-affected and the neighbouring areas. With respect to prices, the price that a farmer would have obtained if their produce were not lost due to floods should be used in finding monetary value of loss.

Table 2: Proforma I for Reporting Flood Damage at the Village Level Statement of Flood Damage for the Year

Village....................... Tehsil/Block.............................. Sub-division............... Dist............ State..............	
Crop area affected (hects)	Crop yield O/H

(*Continued*)

Table 2: (Continued)

Total Area Affected Hects.	Population Affected	Crop Stage at the Time of Flooding (Crop-wise)	Total Crop Area	Crop Area Completely Damaged	Area Re-sown/ Replanted	Area Partially Affectd	Partially Affected Crop	Replanted Crop	Normally Expected Yield*	Total Value of Crop Damage Rs.
1	2	3	4	5	6	7	8	9	10	11
Houses damaged Number		Lives lost Value (000. Rs.)		Cattle loss Number		Total Number		Value (000 Rs.) (000 Rs.)		
12	13	14	15	16	17					

* Specify in terms of tillering stage or pre-flowering stage and average yield for the preceding five years.

Table 3: Proformae I for Reporting Flood Damage at the Block/Tehsil Statement of Flood Damage for the Year

Village...................... Tehsil/Block.............................. Sub-Division............... Dist............ State..............

Blocks/ Distt.	Total Area Affected (000 Ha)	Population Affected (000)	Damage to Crops		Damage to Houses		Human Lives Lost	Cattle Number	Loss Value (000 Rs)	Damage to Public Utilities (000 Rs)	Total Damage (000 Rs)
			Area (000 Ha)	Value (000 Rs)	Number	Value (000 Rs.)					
1	2	3	4	5	6	7	8	9	10	11	12

Damage to Private Houses

Floods cause physical damages to private houses and assets. These are direct damages caused by flood. A systematic procedure is followed in collecting figures relating to house damages. Houses are classified according to physical characteristics such as hut, kutcha and pukka houses. However, no data is collected on damage to household goods. House damages need to be checked and verified by senior-level officers in order to ensure that there was no inflation or over-reporting of such damages. For the purpose of converting the physical damages into monetary terms, the cost of repair of replacement of the damaged property has to be realistically estimated.

Loss of Life

Only numerical loss of human lives and livestock is reported. Accidental deaths such as those resulting from capsising of boats, house collapse due to rains, snake bites, etc. should not be attributed to flood damage.

Damage to Public Property

In developing countries such as India, government-sponsored development works have been increasing and therefore proportion of damages to government properties to total damages has also been increasing. Damage to public property is assessed by the respective departments on the basis of estimated cost of repairs. Since damage data is collected by various agencies, sometimes there is lack of coordination leading to data gap. Often due to paucity of funds, repairs are not necessarily carried out in the same financial year. The method of assessment leaves scope for double and multiple counting of the same damage in case of a subsequent flooding. Regular operation and maintenance cost of the public property do not form part of flood damage as such cost would have been incurred otherwise also if no flood damage occurred .

Indirect Damage

In the past, damage caused by cessation of normal economic activities on account of floods was completely ignored in the flood damage assessment. The Report of Rashtriya Barh Ayog (RBA 1980) states that *such losses are likely to be more important in an industrial economy such as the U.S.A.'s rather than in an agricultural economy like India's.* This may not be true now considering rapid urbanisation in flood plains.

Disruption of transport network during flood invariably affects economic activity in towns and villages. Even a normal flood may cut off the transport link to a large number of villages located in the flood plains of Gang a basin. Even the indirect damages that depend on agricultural activities need to be assessed on a priority basis. These would include losses to agro-based industries which depend on local supplies of raw materials, labourers and other inputs, and both farm and non-farm wage incomes, of petty shopkeepers, etc.

The flood damage data from 1953 to 2016 has been finalised by the Central Water Commission (CWC 2018). Table 2 shows long-term average loss and damages over the period from 1953 to 2016. Data in the table illustrates that only direct tangible and intangible damages are given importance in the existing procedure for flood damage assessment.

The Centre for Research on the Epidemiology of Disasters (CRED) in Belgium maintains The International Disaster Database (https://www.emdat.be/emdat_db). Flood-related data for India has been compiled and graphically depicted in Fig. 1.

There has been a progressive rise in flood disaster over the last five decades in India. Analysis shows decadal economic loss has increased from USD 14.66 billion in 2001–2010 to USD 36.04 billion in 2011–2018. This rapid rise is due to the most devastating floods that took place in just the last six years, namely the Assam flood (2012), Uttarakhand flood (2013), Jammu Kashmir flood (2014), Chennai flood (2015), Bihar and Mumbai floods (2017) and Kerala flood (2018).

The graph in Fig. 1 shows the decadal trend of flood with gross damage of life and economy in India.

Table 2: Long-Term Average Loss and Damages (L&D) due to Floods in India (1953–2016)

S. No	Item	Unit	Average Annual L&D	Maximum Annual L&D	Year of Max L&D
1	Area affected	mha.	7.192	17.500	1978
2	Population affected	million	31.879	70.450	1978
3	Human lives lost	Nos	1648	11316	1977
4	Cattle lost	Nos	94104	618248	1979
5	Cropped area affected	mha	3.923	12.299	2005
6	Damage to the crops	Rs in crore	1598.026	17043.984	2015
7	House damaged	nos (million)	1241642	3959191	2015
8	Damage to houses	Rs in crore	693.599	10809.795	2009
9	Damage to public utilities	Rs in crore	3120.784	38937.843	2013

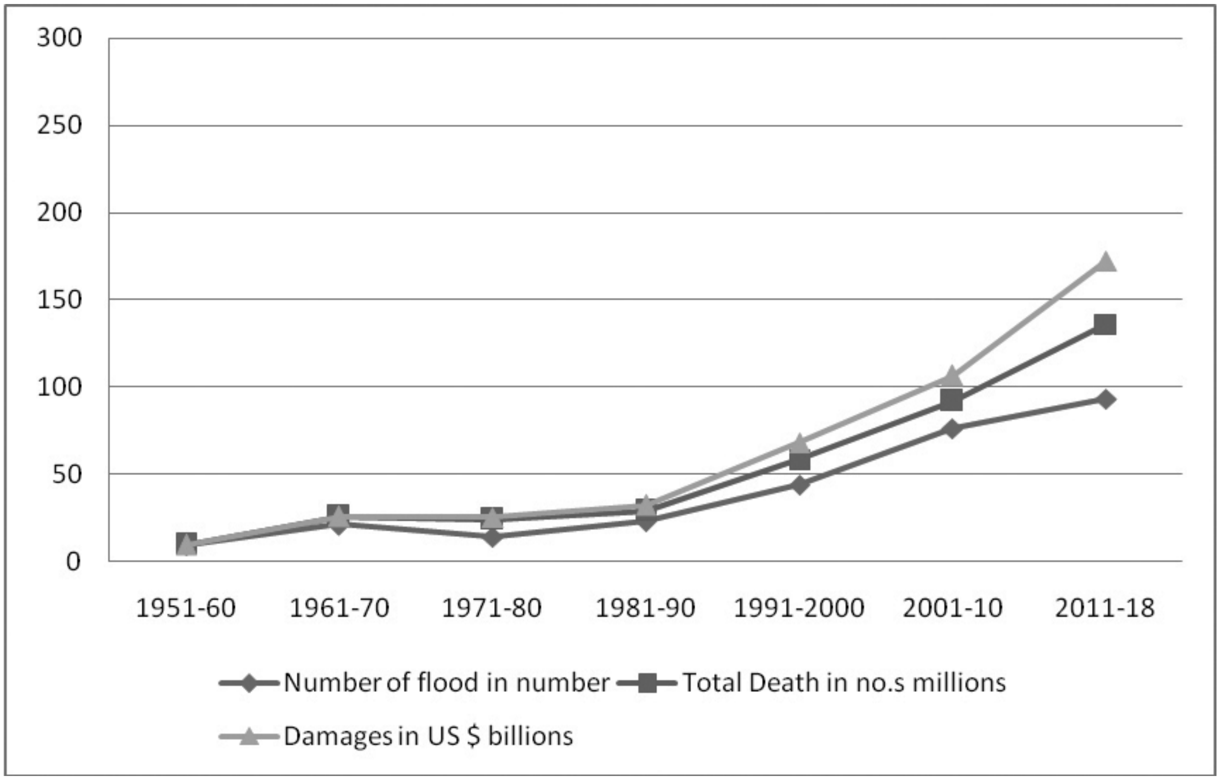

Figure 1: Decadal increase in flood events, flood damages and lives lost (Data source: EM DAT 2018)

Deficiencies in Present Methodology

Rashtriya Barh Ayog made numerous useful recommendations to improve methodology of flood damage assessment. Most of these recommendations have not been given requisite attention by some of the state governments. Flood damage statistics continue to be prepared in the manner that they have been prepared in previous decades and the desired improved methodology has not come about so far. The state governments placed greater emphasis on the efficient administration of relief measures and the entire administrative unit in the flood-affected area is geared to do rescue and relief operations.

Therefore, much time of the local authorities is taken up in reaching the flooded areas and arranging and giving relief to the affected population. The following are some of the deficiencies existing in the present procedure of flood damage assessment.

- The village-level records are not available as the states have not yet adopted the proforma prescribed by the Central Government (Tables 1 and 2). Accuracy of the statistics depends upon the first and initial report made at the village-level.
- Estimates of damaged crop area are not reported crop wise/crop areas reshown or replanted after the floods.
- Average crop yield is based on judgement of local officials, resulting in diversity of figures. Similarly, yields of partially affected and reshown/replanted crops are not estimated.
- There is considerable diversity in case of prices of various crops, where procurement prices, farm harvest prices, wholesale market prices or some other prices are used for monetary evaluation of crop losses.
- The present method for assessing the monetary damage to houses is based on judgement of local officials. Although these figures are checked and verified by senior officers, no systematic method for estimating cost of repair of different categories of houses is followed. This results in diversity and inaccuracy.
- Assessment of damage to household assets is not being done.

- The loss of cattle is not reassessed after the flood is over and many cattle reported lost may return home.
- Village-level officials are burdened with pressure of work due to high-priority relief and rescue operations besides their normal work. It is difficult for them to collect correct information by complete enumeration method.
- At higher level very little checking of village-level reports is done due to a variety of reasons.
- Present methodology is confined to assessment of only direct damages. Indirect damages and intangibles are not assessed at all.

Assessment of Flood Damage in Surat City

Government agencies in India have been computing the cost of a disaster to seek financial aid from national government and various donor agencies. These cost estimates largely focus on direct economic and non-economic L&D indicators (Prabhakar et al., 2015). Sekhar C et al. (2015) conducted a case study on calculation of economic and non-economic loss and damage (L&D) to textile-weaving businesses in Surat from the 2006 flood. This study highlights the relevance of inclusion of indirect economic L&D in the post-disaster cost estimation.

Surat city is famous for its textile and diamond industries hub situated in the western part of the Indian state of Gujarat. The whole city is located on the banks of the River Tapi along with ports on the Arabian Sea. All of the sample businesses were severely affected by the 2006 flood. Long recovery period has had an indirect economic impact on the weaving businesses, and has welfare implications for workers in terms of loss of wages, impacts on migration and remittances or potential for social conflict. Because of this, labour shortages were cited as a major problem during the post-flood scenario.

The direct economic L&D comprised repair cost of buildings and machinery; privation of finished goods, raw materials, furniture and IT equipment; and damage to documents, vehicles and other different damage (e.g. repairing electricity connection). The indirect economic loss was computed on the basis of number of repossession days for every working day multiplied by its net revenue per day – this is the amount of income each business could have earned, if the flood had not come down.

The core loss and damage of a textile unit was around INR 1.51 million, of which INR 0.98 million was due to direct loss and damage, and average indirect loss and damage and compensation were INR 1 million and INR 0.47 million, respectively. The calculation of indirect economic L&D is equally important but is generally overlooked by the government agencies while doing post-disaster impact cost estimation, and henceforth, this study urges that future damage cost assessment should include it; otherwise the true economic L&D is being underestimated.

The authors caution that the findings of this study should be read with some caveats. The low number of sample businesses involved in this case study could have led to sample bias while intangible costs, spill-over impacts and impacts on the regional economy have not been captured. In this study intangible losses caused by the flood have been neglected from computations (like social impacts, trust between business owners and labourers, social welfare impact on family members of industrial workers due to loss of wages).

Assessment of Flood Damage in Chennai City

The destructive floods in Chennai city and additional parts of Tamil Nadu during November 2015 claimed more than 400 lives and were responsible for devastating damages. Mujumdar P. P et al. (2016) carried out a rapid assessment of L&D. This report contains data and information received through newspapers, news magazines, TV reports, some government documents, website pages and other voluntary approachable sources. A physical field visit was carried out by the team on March 16, 2016, to get first-hand data and information on the flooded areas of the city. This rapid assessment report highlights the significance of indirect and intangible damages as mentioned below.

The Industrial Estate Manufacturing Association (IEMA) representing the micro, small and medium enterprise (MSME) units have wanted timely relief to get the crippled firms back on their feet. Approximately 20,000 units across the State were hit by the deluge according to their estimates, leading to a loss of Rs 1,40,000 million (Indian Express 2015).

Around 1.5 lakh street vendors in Chennai suffered massive losses after the floods, with many losing their homes and their businesses. A survey of 304 street vendors at the Koyambedu market and in T Nagar was undertaken by the federation along with the Tamil Nadu forum for crèche and child care services (TN FORCES). It was found that the vendors lost one month of their business because of the rains. Each of them lost between Rs. 10,000 and Rs. 20,000 worth of goods in the floods (*The Hindu* 2015).

Conclusion

Flood plains provide attractive locations for various human attributes. Human pressure on flood plains is increasing and at the same time flood loss and damages (direct, indirect and intangibles) are also increasing due to dense occupation of flood plains. In economic analysis, usually direct damages are considered in India. This does not indicate that indirect and intangible damages are insignificant. In some cases, indirect and intangible may be more significant than direct damages. It is therefore necessary to identify and analyse all such loss and damages. Procedures to collect the data and analyse flood damages are discussed. Several deficiencies exist in collection and analysis of data. The report of the National Flood Commission (Rashtriya Barh Ayog March 1980) of the government of India contains useful reference material on flood damages and then assessment procedure.

Case studies on flood damage computation in Surat city and Chennai city highlight consideration of indirect L&D in flood damage assessment in urban areas.

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A Review of Urban Flood Occurrence and Flood Mitigation Measures

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ABSTRACT: Rainfall is a major element of the water cycle and is responsible for depositing most of the fresh water on the Earth. It provides appropriate conditions for many types of ecosystems but when it falls beyond the limit it causes disastrous situations. Flooding has become the convective disaster event annually producing the most fatalities. Unplanned urbanisation, increase in the population, inadequate flood response mechanism, incompatibility of weather stations and inappropriate engineering practices are some of the main causes of flood occurrence. Some of the major factors on which flood occurrence is dependent are change in forest cover, land use/land cover, climatic conditions and urbanisation. Flood events can have overwhelming social, psychological and economic effects like fatalities and refugees, damage to cropped land and economic damage. Flood mitigation is an important aspect to reduce the frequency and occurrence of flood. Therefore, this paper presents a review of major problems causing flood and medium- and long-term mitigation measures to be taken. Various methods have been proposed for reducing frequency and occurrence of flood, out of which image processing and GIS applications can be more effective and suitable. In India proper flood mitigation has been a serious issue and preventive measures are not compatible, so use of image processing and GIS application can be a better solution for flood analysis and mitigation for the Indian scenario.

KEYWORDS: urban flood, GIS application

Introduction

Water occurs in nature practically everywhere in one form or another, but a very small part of that water is available as fresh water. Most fresh water deposits are due to rainfall, which provides appropriate conditions for many types of ecosystems, but when it falls beyond the limit it causes disastrous situations. Sometimes the helpful servant becomes our most furious rival, and during severe storms and floods it can bring disasters and destruction, causing great devastation and catastrophes. Floods are disasters which are seasonal and strike the pocket of the country during a certain period of the year with high frequency (Pande, 2010). Due to climatic variability and anthropogenic changes, floods have increased lately in several regions worldwide and the resulting impact from floods is often harmful (Saud, 2010). The mechanism which produces the flood is the function of frequency magnitude difference of largest flood and more frequent flood (Saud, 2010). Migration of people to urban from rural areas causes rise in population and urbanisation. Urbanisation is the major cause of change in hydraulic and hydrologic processes, loss of existing drainage capacity and flooding in urban regions (Zope et al. 2016). Due to anthropogenic changes like chaotic urban development beside watercourses and at the exit down stream where human settlements have been newly constructed without considering any past vulnerability assessment for natural hazards, the harmful consequences have raised to maximum (Saud, 2010). The developments in any major urban region need to be accompanied by a sufficient water supply scheme and storm-water and wastewater disposal

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systems by analysing extreme events of rainfall (Gupta, 2007). The increased frequency of heavy rainfall coinciding with tidal variation in coastal regions like India has caused floods in many urban cities such as Mumbai and Chennai (Zope et al. 2016).

Flood Scenario

World Flood Scenario

Floods are probably the world's most widespread, recurring, frequent and disastrous natural hazards. Many of the extremely populated cities in the developing world that are situated on the coast, for example, Dhaka, Bangkok, Mumbai and Jakarta, are highly vulnerable to urban flooding (Gupta, 2007). In Bangkok, integration of information from rain-gauges, hydrologic forecasting systems and radar for flood forecasting systems have been implemented in real-time (Gupta, 2007). Due to changes in climatic conditions and mainly increase in the intensity of rainfall, Saudi Arabia has become a perfect example for natural hazard and lately it has become a region under natural risk (Saud, 2010). A statistical overview for Saudi Arabia between 1982 and 2005 shows that average recurrence of flood hazard is about 7 times/year, epidemic hazard is 4 times/year and lastly dust storms 1 time/year and the average economic harm value may go beyond 19 million UD dollars/year (Saud, 2010). In Germany two major flood events have demonstrated that a European high-income country can also be severely hit by riverine floods. The river flooding of the Elbe, Danube and some of their tributaries caused 21 fatalities and economic damage of more than 11 billion euros in 2002 and eight fatalities and economic damage of around 8 billion euros in 2013 (Osberghaus, 2015). Jakarta has experience flood in 61 sites during the rainy season of 1992 which increased to 90 sites in 1996 and further increased to 159 sites in 2002. Also there was major flooding in 2013, 2014 and 2015 (van der Schrier et al. 2017). Such flooding events might become recurrent due to impacts of climate and land use change (Asdak and Supian, 2018). In a time period of six years (1989–1994), out of all disasters in the USA 80 per cent were flood-related and caused property damage of average four billion dollar annually (Knebl et al. 2005).

Indian Scenario

As per the statistics nearly 1/8th of Indian's geographical area or around 40 million hectares is flood-prone, out of which about eight million hectares of area is affected due to floods yearly having 3.55 million hectares area as cropped land. Floods have claimed an average 1595 lives and 94,772; ovestock yearly and around 1.2 million houses have been affected by floods alone. India is one of the most highly flood-affected nations, standing second in the globe after China and accounts for 1/5th of the international fatality count due to floods (Santosh Kumar, Arun Sahdeo, 2007) (Bhattacharjee and Behera, 2017). Forest regeneration and protection are of high significance and will restrict flood occurrence and protect human lives and properties. The findings suggest that in India forest cover has an inverse relationship with flood frequency (Bhattacharjee and Behera, 2017). Climate change will cause 10–15 per cent increase in monsoon rainfall in many regions of India, and at the same time decline of 5–25 per cent in rainfall in drought-prone regions of central India and a high decline in winter precipitation in northern India are also projected (Revi, 2008).

Causes of Flood

One of the main reasons behind the occurrence of is rapid urbanisation, which causes change in land use patterns owing to construction of urban infrastructures and changes in storm drainage networks (Gupta, 2007). Unplanned and rapid urbanisation causes deforestation, blocks the water channels, fills up the water-bodies, etc. (Sarmah and Das, 2018). Another reason is that the flood-prone regions receive high-intensity precipitation from the monsoons. The implementation of structural mitigation is difficult due to constraints of space and resources (Gupta, 2007). For some coastal cities intensive reclamation of the spaces between the islands was done being reclaimed land below high tide level and most detention ponds have been lost, which increased runoff by 2 to 3 times (Gupta, 2007). Siltation and uncontrolled dumping of solid waste causes blockage in the natural water channel and this coupled with rapid urbanisation and absence of integrated drainage network causes flood (Sarmah and Das, 2018). Some other factors combine to turn flood hazards into disasters, including intense meteorological events in highly vulnerable areas, where excessive development in human activities like exploitation of resources and land use changes is a for exposure to hazard (Sarmah and Das, 2018). Flood might be occurring in the four steps of mechanism which are 1) heavy rainfall for short duration of time, 2) sudden increase in the discharge of seasonal drains, 3) channel of these drains is unable to handle the discharge and 4) channel overflow causes flood (Pande, 2010).

Factors Affecting Flood Occurrence

Land Use/Land Cover

The relocation or migration of people from rural to urban areas has led to rapid land use/land cover changes to fulfil the population's requirements, and thus there is great increase in urban areas in the developing countries all over the globe (Zope et al. 2016). The land use/land cover change is influenced by humans trying to meet different needs such as residential, agricultural, mining, industrial and other infrastructural amenities and is a key concern associated with the sustainable and economic growth of a region (Zope et al. 2016). The change in land use/land cover causes increase in peak runoff and runoff quantity marginally. The rise in peak runoff and runoff quantity is marginally varied by 10.4 per cent and 12.2 per cent for the 2-year return period and 3.0 per cent and 4.45 per cent for the 100-year return period respectively (Zope et al. 2016). Thus urbanisation and change in land use/land cover increases urban flooding and also increases the vulnerability of the people to floods, and this condition has worsened in current times due to climate change (Sarmah and Das, 2018). For monitoring of change in land use/land cover, satellite images applying remote sensing have proved to be the most effective and efficient tool (Zope et al. 2016).

Climate Change

Recent disasters are becoming highly complex and climate change poses a larger potential risk for adverse impacts (Tran et al. 2009). The frequency and intensity of current hazard and probability of extreme events is increasing due to climate change with the emergence of new hazards like sea-level rise and new vulnerability. In the next 50 years the urban population will likely grow by around 500 million. The likely changes that climate change will be bringing in precipitation and extreme rainfall, temperature, river and inland flooding and drought, storm surges/storms/coastal flooding, environmental health risks and sea-level rise will put urban populations at most risk (Revi, 2008). The key changes in the precipitation pattern happening due to climate change will additionally boost the flood risk (Zope et al. 2016).

Forest Cover Change

Out of all environmental resources, forests are one of the most essential ones in the ecosystems. Apart from providing direct use values such as food, timber and fuel, forests supply numerous environmental services including carbon sequestration, nutrient cycling, watershed protection, climate regulation, pollution control, prevention of adverse effects of storms, flood mitigation, regulation of runoffs, infiltration and river discharge groundwater recharge and prevention of landslides and soil erosion. It has been seen that the rise in stress of population in coastal regions has caused extensive change in forest cover, which is responsible for frequent floods and consequential fatalities and loss of properties. Destruction of forest cover can make human habitation, various natural resources and ecosystem more susceptible to varying climatic conditions in the form of severe weather events such as floods and associated natural disasters. It has been observed that forest does reduce the frequency and severity of flood hazard by trapping water during heavy rainfall, reducing the runoff rate and also improving the soil moisture content. A study done on 56 developing nations has shown that flood frequency reduces with increase in natural forest cover and increases with rise in non-natural forest cover. It has been argued that forest cover might not appreciably reduce the peak runoff during intense events but could effectively reduce the volume of runoff, more recurrent floods and severe storms. On the other hand, emperical studies have found that forest cover is responsible for soil erosion. A study in China showed that soil erosion caused decrease in capacity of reservoirs, which was responsible for rise in water level and ultimately caused flood. A similar study in southern Thailand showed that due to loss of forest cover evapo-transpiration has been reduced, which increased the runoff and caused occurrence of flood event. It has also been seen that intense precipitation does not essentially result in increased incidence of flood, but forest cover change might be the major cause of the same (Bhattacharjee and Behera, 2017).

Effect of Flood

Extreme weather conditions took Mumbai underwater in 2005. For the first time in history most of the city services were shut for almost 5 days. The city was totally disconnected from the whole country. Many people lost their lives in the city and economic life came to a halt due to a combination of poor preparedness, institutional failure and high vulnerability of the poor (Revi, 2008). At least 419 people and 16,000 cattle were killed due to landslides and flood in Mumbai, as well as an additional 216 due to flood-related disease. Over 30000 vehicles and 100000 commercial and residential establishments were damaged (Gupta, 2007). In the 2009 flood event of Jeddah city, Saudi Arabia, the fatality count was more than 100 and many villages were entirely drifted by the effect of large quantities of running water and sediment (Saud, 2010). In the flash flood of Uttarakhand in 2013 more than nine million people were affected and the worst impacted districts were Bageshwar, Chamoli, Pithoragarh, Rudraprayag and Uttarkashi. Around 169 people died and 4021 were reported missing (assumed to be dead), 11,091 livestock were lost, about 4200 villages were affected and 2,513 houses were completely damaged (Arlikatti et al. 2018).

Flood Mitigation

Flooding has become a severe storm-related incident yearly producing the maximum fatalities, but the systems implemented to reduce fatalities from cyclones like public preparedness, forecasts and warning have improved since 1990 but systems for flood have shown less progress. Flood occurrence cannot be totally stopped but by taking certain positive actions we can significantly reduce their impacts. Reduction of disaster-induced losses becomes the focal point of the strategy for disaster management if disaster cannot be averted (Pande, 2010). The impacts of flood are found to be harmful due to high intensity of rainfall as well as lack of mitigation measures (Saud, 2010). The major task in flood mitigation is not only just to forecast the happening of incidents, which is difficult itself, but to predict the magnitude of events (Pande, 2010). The non-structural mitigation measures such as flood warning and flood proofing have been found to be effective in flood damage reduction as implemented in Dhaka city (Gupta, 2007).

Objective of Flood Mitigation

Flood causes huge harm to property and life and disturbance to infrastructure. Hence, for national development activities of the country flood management plays a vital role (Santosh Kumar, Arun Sahdeo, 2007). The entire elimination of storm flood is neither achievable nor possible, so flood management seeks to avoid the fury and destruction caused by storm floods and mitigate the effects of flood (Arlikatti et al. 2018).

Methods of Flood Mitigation

There are various methods through which flood mitigation can be done. According to the area of the study, climatic conditions, topography of the region and severity of the flood, the method for the mitigation can be adopted. Investing in updating and revising the policy at all levels of administration firstly from the state to district level and then to the village-level is essential. Also structure of operation will clearly define roles, responsibilities and goals created through disaster exercise (Arlikatti et al. 2018). The risk of flooding cannot be totally eliminated by using public flood safety. Hence, protective actions at domestic level to reduce the damage due to flood plays an important role in modern flood hazard management (Osberghaus, 2015). Also building up the knowledge about the flood and awareness within the public by using educational materials plays a vital role in flood mitigation. Sometimes the public need to be reminded about past hazard events and related damages to encourage them to take protective measures (Arlikatti et al. 2018). For the Jeddah region in Saudi Arabia flood mitigation has been done in three steps: firstly identification of extent of denudated region and to study the spatial distribution of flooded zones. Then delineation of the watershed where the flood has taken place, which will give us an idea about key influencing factors, which is helpful for future arrangement and flood hazard management, and finally to propose a flood control system in the region. It is not possible to identify and study flood-prone and flood-affected areas directly from the ground integration, and therefore space techniques have been utilised successfully in the Jeddah region. The natural drainage network and catchment area in the form of GIS will help in performing data integration and also can assist in modifying geospatial data when needed. For data collection work, new techniques like space tools and GIS can be used which are capable of extracting information and data and also analysing the data for easier understanding (Saud, 2010). Local knowledge is essential for flood risk management which can be extracted from hazard maps. Maps in the GIS form are superior to conventional hazard maps and integration of local knowledge into the process of GIS mapping provides realistic ideas and data for flood management strategies (Tran et al. 2009). The GIS-based applications can be used to study river bathymetry and integrate the bathymetry with the topography of the surrounding region to create integrated terrain of the river (Merwade et al. 2008).

Conclusion

The fatalities due to flooding have increased to maximum worldwide in the last few years. Flood disasters are not only affecting the developing countries like India and China but also developed countries like the USA and many European countries. Among all the developing countries in the world India is the second highest affected country by flood hazard. Some of the causes behind flood occurrence are unplanned urbanisation, reclamation of land, loss of detention ponds and uncontrolled dumping of solid waste. Also climate change, land use/land cover change and forest cover change are some of the factors which affect the occurrence of flood events. Since flood hazard is causing the maximum casualties, social and economic harm to the region as compared to other disasters, the mitigation of flood becomes an important consideration for the policy of disaster management plans of the country. In India many structural and non-structural mitigation measures are taken under consideration like delineation of watershed, identification of flood-prone areas, updating and revising policy at all administrative levels and public awareness. But the GIS technique has not been used often for urban flood occurrence and mitigation, and there have been no mitigation studies for floods in small cities or the regions beside the metropolitan cities. The GIS technique and remote sensing can prove more effective and efficient as they cover mapping like contour, land use/land cover and topography. It is most advance technique since it reduces effort, optimises time and resources and is also easier to operate. Floods can highly affect the small cities since there have been no precautionary measures taken, and therefore, for small cities and low-intensity floods, attention should be given to reduce the frequency and intensity of flood occurrence.

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Urban Flood Risk Analysis, Its Impacts and Mitigation Measures for Urban Flooding

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ABSTRACT: Urban flooding is a developing worry because of expanding densification of metropolitan regions, changes in land use, and climate change. In the last two decades, India has experienced urban flood disasters, from the overflowing of rivers to the inundation of core cities. It leads to the submerging of residential and commercial neighbourhoods and various infrastructures that brings a halt in the working of the city. Disasters like flooding have changed their dimensions in urban zones as urbanisation prompts created catchments which expands the flood peak from 1.8 to 8 times and flood volumes by up to six times. Subsequently, flooding happens rapidly because of quicker stream times and urban areas are focuses of monetary activities with crucial infrastructure which should be protected at all times. The degree of damage from these calamities has expanded over time in the urban regions on account of increased rainfall runoff volume and because of more prominent exposure of individuals and resources as a result of centralisation of assets. Regardless, it is clear that the characteristic dimension of "exposure and diverse risk" degrees of flood hazard attributes shift the urban flood nature from city to city. With the end goal to have the capacity to measure the present and potential flood hazard, comprehension of the causes of urban flooding, vulnerability and exposure is compulsory. These might be viewed as causing and impacting variables of flood risk, which might be specific to a given region.

Flood risk analysis is more intricate in urban areas than that in provincial territories given their firmly packed structures, various types of land uses and an expansive number of flood control works and drainage systems. Crosswise over India, in recent decades, numerous cities have encountered urban floods. In this paper, the author studies urban flood events within India in the past with comparative study of major cities. This paper portrays why it is critical to think about urban flood situations and what the requirement for this examination is. It features the sorts and reasons for the confined flooding and its effect and outcomes. The study concludes with the human and economic losses due to urban flooding events and appropriate measures required to be taken to mitigate these events.

KEYWORDS: urban flooding, rainfall-runoff, vulnerability, exposure, land use, climate change

Introduction

Expanding patterns of urban flooding is a universal phenomenon and represents an extraordinary challenge to urban researchers, planners, geographers, etc. the world over. Urban flood will occur in a generally brief timeframe and can immerse a territory in a few feet of water in a very short period. Even though the volume of water to be dealt with isn't as severe as a flash flood of a streaming framework, the property damages and indirect cost-related misfortunes are critical as surface water overflow is controlled and overseen by people in a stable world as this urban flooding happens in profoundly populated regions. As the Environment

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Agency's sustainable development unit stated in June 2001: "Significant floods that have just occurred on an average in 100 years, may now begin to happen every 10 or 20 years. The flood season may turn out to be longer, and there will be urban flooding in spots where there has never been any" (Ahmed Z., Rao, Reddy & Raj, 2013).

Urban flooding is unlike rural flooding as urbanisation prompts created catchments which expand the flood peak from 1.8 to 8 times and flood volumes by up to 6 times (India N. G., 2010). Subsequently, flooding happens rapidly because of quicker stream times, and urban zones are centres of economic activities with vital infrastructure which needs to be protected at all times (Rafiq, Ahmed, Ahmad & Khan, 2016).

Flood is impacted by different factors: precipitation, river overflow and tidal-flood, geography, the proportion of flood control, and changes due to infrastructural development. A few floods develop and release continuously, while others can arise in only a couple of minutes and retreat rapidly, for example, flash flood (Rafiq, Ahmed, Ahmad & Khan, 2016 and Brown, Chanson, Mcintosh & Chanson, 2011). Urban flooding is caused by substantial precipitation overpowering drainage capacity. It has enormous monetary and social effects. These are probably going to increase if no progressions are made to the administration of urban drainage. Urban floods are an incredibly unsettling influence on everyday life in the city. Streets can be blocked leading to individuals not being able go to work or to schools. The financial harms are high but the quantity of setbacks is typically exceptionally constrained, on account of the idea of the flood (Aggarwal, Rafique, Rajesh & Ahmed, 2016).

Urban floods can be classified as floods because of substantial local precipitation, floods because of waterway overbank stream and floods because of high tides or storm floods. Floods because of nearby substantial precipitation are caused by inadequate or poor drainage. Floods because of waterway overbank stream happen when stream level transcends waterway banks. Excessive stream levels are regularly caused by high runoff from upstream and backwater impact of high tides at the waterway mouth. Development of urban communities in floodplains diminishes capacity and blocks floodway in the floodplains causing flood damage. Flood barriers in urban areas might be ruptured because of high flood levels and cause serious flood damages. Urban communities in seaside zones are ordinarily situated in low-lying territories where waste is troublesome without pumping. High tides or storm floods can hamper flood drainage to the ocean and cause delayed flooding with contaminated flood water and medical issues in urban communities. Impacts of climate change increase all the more overwhelming precipitation and severe and frequent flooding, which are increasingly hard to predict (Perry, Canziani & Palutikof, 2007).

Urban Flood Risk

Reasons for floods are natural factors, human factors or a combination of natural and human factors. The risk is the probability of loss and can be expressed as (Arya, Karanth & Agarwal, n.d.):

$$Risk = Vulnerability \times Hazard$$

Flood hazard relies upon flood sizes, for example, flood depth, speed and duration. The vulnerability might be characterised as the conditions dictated by physical, social, monetary and ecological components which increase the powerlessness of a community to the effect of hazards. At the point when flood waters physically encroach on individuals and infrastructure, the vulnerability of individuals and infrastructure is conclusive for the level of harm and damage. Impacts because of urban floods are critical as far as economic losses, both direct and indirect. This is because of high density of population, large impervious areas, clogging of drainage frameworks, high financial estimations of properties and infrastructure and so forth. The impacts of urban floods can be physical, economic, social and environmental. Both direct and indirect essential potential misfortunes can be counteracted through better land use planning, which additionally affects the potential secondary losses. Better flood emergency responses instruments help diminish potential secondary losses. While in rural regions the harms because of floods are for the most part comparable as far as loss of agricultural production (Tingsanchali, 2011).

Damages in an urban setting are progressively intricate. Notwithstanding the vulnerability, the magnitude of the damage relies upon the flood type particularly related to depth, flow speed and duration. One of the significant factors for the rise in urban flood damages is essentially the expanding population and resources that are physically presented to floods in urban communities. Urban communities in many nations are developing quickly. Relocation from country territories to urban communities has prompted uncontrolled urban sprawl with expanding human settlements, modern development and infrastructure improvement. Regularly, urban development in the floodplain extends over some floodways, thus reducing its flood drainage capacity.

Factors Responsible for Urban Flooding

A progression of storms moving over a similar region can cause areal flash flooding. A muddy flood is delivered by a gathering of overflow created on cropland. Sediment is then disengaged by overflow and conveyed as suspended issue or bed stack. Muddy overflow is more probably recognised when it achieves occupied territories.

Most of the sewerage and drainage network of various cities becomes old, and its condition is obscure. They can't adapt to the volume of water or are obstructed by trash and by non-biodegradable plastic packs. Sewers overflow because of illegal connections, and the sewer framework can't adapt to the expanded volumes. As new advancements make already porous progress, the measure of water running off the surface into channels and sewers increases drastically. Developments infringe floodplains, hindering floodways and causing loss of natural flood storage. Advancement and redevelopment to higher-density land arrives by high land costs. The extent of impermeable ground in existing developments is expanding as individuals build patios and pave over front gardens. Expanded impenetrable zones, for example, streets, rooftops and paving, because of expanding development densities implies more runoffs (Singh & Singh, 2011). Some of the significant hydrological effects of urbanisation are: (1) increase in water demand, often exceeding the available natural resources; (2) expanded wastewater, troubling waterways and lakes and endangering the environment; (3) decreased infiltration and (4) diminished groundwater recharge, expanded utilisation of groundwater, and declining base stream of streams. As indicated by natural hydrological phenomena, because of expanded impenetrable area precipitation reacts rapidly, creating higher peak flows in the waste channels.

Although these influences are very diverse, they generally tend to create more serious flood hazards by accentuation flood peaks. Thus flood hazards in the built environment have to be seen as the consequence of natural and human-made factors.

Climate change is the other large-scale global pattern clearly affecting flood risk significantly. The modifications in meteorological examples which are related to a warmer atmosphere are conceivably drivers of expanded flooding, with its associated direct and indirect impacts. Observed and projected patterns of climate change could have an increased effect on existing flood risk, for example:

- Gradual increase in the sea level rise due to global warming is one of the factors causing increased flood frequencies and damage in coastal areas.
- Change in climate leads to change in rainfall patterns that could lead to more intense, frequent and higher-level floods.
- Changing the frequency and duration of drought events guides groundwater extraction and land subsidence, which compounds the impact of sea level rise.
- An increasing frequency of storms leads to more frequent sea floods.

According to climate scientists, as shown by the Intergovernmental Panel on Climate Change, an increase in extreme weather is consistent with a warming climate. Although individual extreme weather events cannot be attributed to climate change, they can increase the chance of some of those events happening.

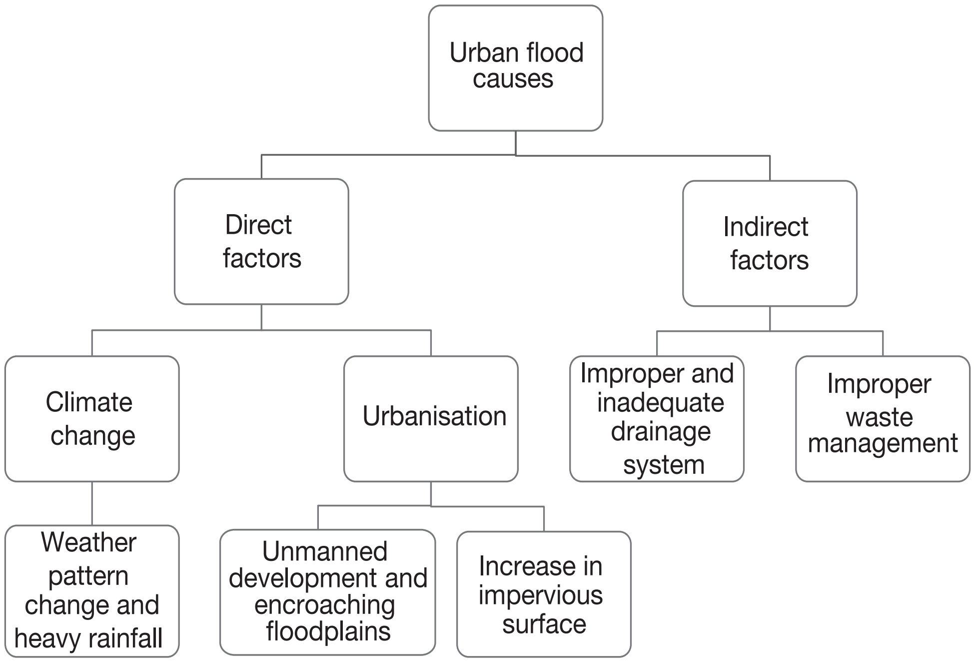


Figure 1: Urban flooding factors

Impacts of Urban Flooding

Urban floods have extensive effects especially as far as economic losses both direct and indirect. Flood risk is a component of exposure of the population and the economic activities alongside the vulnerability of social and economic components. The effect of such floods on the lives and livelihoods of individuals, a component of their vulnerability, should be comprehended (Ahmed, Rao & Reddy, "Integrated Storm Water Management-An Approach for Urban Flooding in Hyderabad," 2016). Urban floods result in stagnation of water on streets, railroad tracks and in few cases even at airplane terminals on account of the lack of tempest water drainage limit. These outcomes in traffic influxes and traffic preoccupations bringing about the loss of worker hours and ultimately economic loss. In the event of substantial rainstorms, air traffic gets disrupted. Media transmission gets disturbed, and upkeep of supply of basic products becomes a challenge. As communications are disturbed industrial creation gets hampered. Costs of fundamental commodities shoot up. Amid and after urban floods the urgent task is the restoration of damaged roads, railway tracks, damaged structures and recovery of occupants from low-lying regions and collapsed buildings. Damages of assets are noteworthy in warehouses and buildings because of flooding by storm and sewage water. Transient articles add to economic misfortune. Mishaps and fire because of a shortcircuit are likewise common. Thus there is a great deal of economic pressure for alleviation measures. There is a psychological worry as protected return of relatives isn't guaranteed. Schools and universities get shut. Removal of the population in low-lying regions and crumbled structures, for the most part, meets with firm opposition. An interruption in the supply of necessary wares incorporating power supply results in agitation and water bodies get polluted (Ganaie, Hashia & Kalota, 2013). Waste disposal gets hampered because of traffic interruption. The stagnation of water, contamination of consumable water and gathering of waste at dustbins result in plagues/epidemics. Mishaps because of open pits and sewer vents covered up under amassed water adds to issue. As traffic gets upset, it is difficult to get medicinal help (Rafiq, Ahmed, Ahmad & Khan, 2016). Based upon the above factors, the damages due to urban flood can be categorised as:

- Physical Damages
- Economic Damages
- Environmental Damages

Apart from exposure and vulnerability, the magnitude of the damage also depends on the flood type related to water quantity and quality, flow velocity, depth and sediment load. But in rural areas damages directly reflect the loss of agricultural land and its production. But damages in urban areas are more complex. They can be categorised as primary, secondary and tertiary damages; see Figure 2.

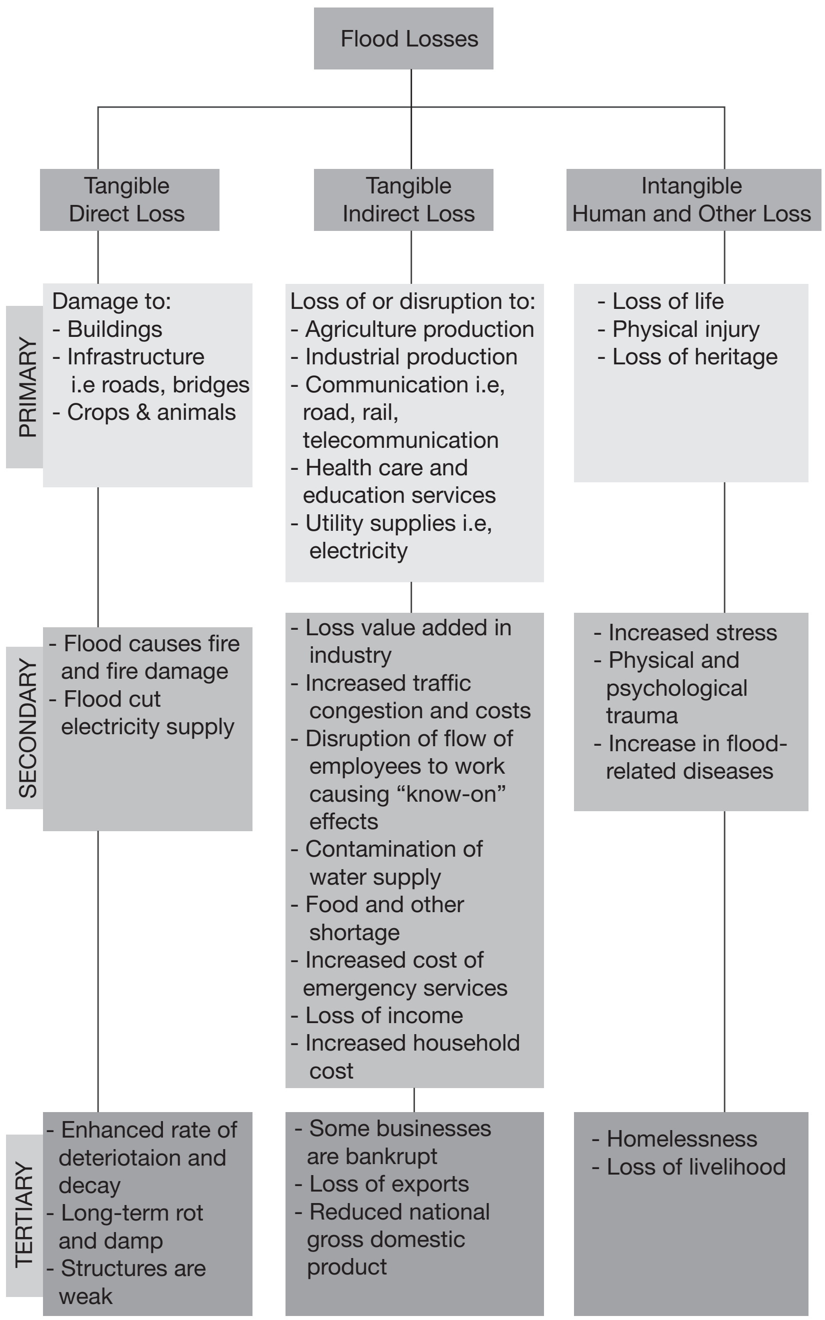


Figure 2: Flood losses

Case Studies

In order to understand the phenomenon of urban floods in India comprehensively, case studies of various major cities are being done. The studies include the cases of Mumbai 2005, Hyderabad 2008, Chennai 2016 and Kerala 2018. The Mumbai floods in July 2005 ended up being an eye-opener for the Government of India. The reasons for urban flooding are unique and so are the procedures to manage them. The NDMA (National Disaster Management Authority) has for the first time addressed urban flooding as a different catastrophe, delinking it from floods. NDMA initiated its endeavours to define the Flood Guidelines in 2006 and released them in 2008. Indeed, even while the Flood Rules were under planning, efforts started to detail these Urban Flood Guidelines in August 2007 (India N. G., 2010).

The case studies include the impact related to human and property losses, findings/reasons of devasting loss and finally mitigation measures taken to deal with urban flooding.

Mumbai Floods, 2005

Mumbai is a coastal city and the financial capital of India and also the capital city of the Indian state of Maharashtra. Being a low-lying and coastal area it gets flooded almost every year. The heaviest of these floods was seen on July 26, 2005. Floods in Mumbai are said to be caused by heavy rains accompanied by high tides but these are not only the reasons that contribute to the floods every year; various other reasons accompanied are responsible for the massive flooding in Mumbai (Kadave, 2016).

The July 26, 2005, occasion has been termed 'overwhelming' (>200 mm/day according to the criteria for precipitation arrangement of IMD, India Meteorological Department), the most grounded rain at any point recorded in India. Serious urban floods were accounted for from 10 urban communities, and Mumbai was most exceedingly worst affected. The Santa Cruz observatory at Mumbai air terminal recorded 944 mm over 24 hours completing 08:30 h on July 27, 2006, while the Colaba observatory recorded 74mm of rain (Rafiq, Ahmed, Ahmad & Khan, 2016).

Over 60 per cent of Mumbai was inundated to various degrees on July 26, 2005. The IMD was not ready to issue direction early in this event. Despite the fact that there was considerable precipitation in the northern rural areas, the IMD was not proficient in screening the precipitation and issuing warnings continuously. This has been attributed to the nonattendance of front line adapt like tipping compartment rain measure with the IMD and IMD has only two rain gauge in city. These are scrutinised just at 08:30 step by step. The basic drivers of flooding in Mumbai were low ground levels, low level of outfalls, buildup of channels/ nallas, rundown channels, impediments of utilities, encroachment along channels/nallas, ghettos along outfalls, urbanisation, loss of holding lakes, waste dumping in SWDs/nallas predominantly in ghettos and augmentation in overflow coefficient (Kadave, 2016).

The extraordinary precipitation event of 994 mm on July 26, 2005 has been an activity for Mumbai, and it has exhibited the dangers of brisk progression in urban areas. This event has led to Mumbai setting up a fundamentally enhanced response framework reliant on consistent precipitation at 27 areas in the city to manage repeeats of related events later on.

A study titled "The Brihanmumbai Stormwater Disposal System (BRIMSTOWAD-II)" with plan precipitation intensity of 100 mm/h has been used to reexamine the previous BRIMSTOWAD survey (1993) which depended on structure precipitation intensity of 50 mm/h. The results of this examination are expected to suggest different structural, non-structural and pumping alternatives for Mumbai city. Under the present worldwide economy, where important call centres and other financial organisations are situated in urban communities of the developing world, interruption in one city has impacts for overall business; henceforth, we can't ignore flooding in any city as being only a local phenomenon. The Mumbai experience would be valuable for arranging response methods for other considerable urban networks to adjust to practically identical events later on.

Table 1: History of Floods in Hyderabad

Details	February 1908	August 2000	August 2008
Rainfall	430mm	240.5mm	237mm
Human loss	1500	26	-
Population affected	600000	200000	150000
Property loss/worth	80000 homes	35693 homes, 135 lakhs	49.2 lakhs

Hyderabad Flood, 2008

Hyderabad city, State capital of Telangana, lies along the banks of the Musi river. The city is surrounded by lakes, hills, forests and rock formations. The city has experienced floods for several decades and experienced flood in September 1908, August 2000 and August 2008. Property loss and human lives lost in these floods are shown below in Table 1. The current water drainage limit of Hyderabad is to deal with 12 mm/hour precipitation. Obstructed channels, unapproved encroachments of Musi river beds and development along stream banks that block natural drains further lessen stormwater drainage limit of the urban capacities (Ahmed Z., Rao, Reddy & Raj, 2013).

After becoming the capital of the state of Andhra Pradesh in 1956, Hyderabad encountered a massive scale of migration from coastal front territories, Rayalseema and different parts of Telangana district. Poverty was the fundamental factor for that rural to urban movement in search of the employment opportunities made by the quick development that occurred mainly in the 1990s. After the establishment of Greater Hyderabad Municipal Corporation (GHMC), Hyderabad transformed into the second larger city in India, with a spread of 7000 sq. km and a massive movement of migration put pressure on shelter and infrastructure services. Urban development plans were not able to adapt the population, and unauthorised settlements happened wherever the land was accessible. This heedless development had its impressive effect on the systems, at whatever point there is high precipitation, which caused immersion of the low-lying territories as a result of the exceptional geography of the city and enveloping zones. The drainage network couldn't exhaust the overflow of the storms enough to avert immersion. The normal experience has been that the surplus water immersed a couple of zones of the developed zone, and surges in a few sections of the city, damaging public and private property.

In Hyderabad, settlements were coming up in low-lying zones, regularly infringing over seepage channels, and encroachment in the quick upper catchments of the hilly urban area has likewise caused severe flooding. Urbanisation in Hyderabad prompts increase in impenetrable zones which, thus, altogether expanded the rate of spillover, bringing about overpowering of a planned limit of the stormwater drainage framework.

Chennai Floods, 2015

Chennai city is the capital of the state of Tamil Nadu, on the eastern coast of South India where three conduits/rivers wind through it, Adyar River, Cooum River and Buckingham Canal. Chennai is the fourth largest metropolitan city in India having a population 47 lakhs with a density of 26,903 persons/sq.km and development rate of 13 per cent. Chennai, having a plain landscape, is bordered by the Bay of Bengal in the east with an average rise 6.7m from the MSL (Mean Sea Level). Chennai experiences an extensive portion of its precipitation between October and December related to depressions and cyclones. Average yearly precipitation is around 1200 mm–1300 mm originating from the ocean side (Lavanya, 2012).

The Adhyar waterway assembles surplus from around 450 tanks in its catchments, beside surges from the Chembarambakkam tank. Today, the numbers of waterbodies in Chennai have been decreased to 46 due to development. The city geography is of levelled topography and deficiencies of characteristic slant stop unhindered runoff. This is an imperative clarification behind enhancement a working arrangement for stormwater waste. Chennai's corporation has made and kept up a tempest water depletion arrangement of 855 km in the city (Rafiq, Ahmed, Ahmad & Khan, 2016 and Gupta & Nair, 2010). Records show disastrous flooding in Chennai in 1943, 1976, 1985, 2002, 2004, 2005, 2006, 2007 and 2015.

Erratic town planning, choked channels, improper waste management and the destruction of natural mangroves, woods and fields are major factors leading to flood hazard in Chennai. The continuous rain from the upper east tempest from November to December 2015 played a major role in the city's inundation. The 2015 Chennai surge has been attributed to the El Nino phenomenon (Express, 2019). The low-pressure zone was integrated and slowly strengthened into a deep depression on of November 8, 2015, because of which there was extremely significant continuous rainfall in the city and other districts of Tamil Nadu on the northern side.

Kerala Floods, 2018

Kerala is an Indian state on the southwestern Malabar Coast. In August 2018, severe floods affected Kerala, due to unusually high rainfall during the monsoon season. It was declared a level-3 calamity or calamity of severe nature as per the Government of India. Apart from high precipitation, Kerala floods have become more severe because of human factors like increase in impervious surface, destruction of Western Ghats (deforestation), improper planning and faulty management of dams. For the first time, 35 out of the 54 dams were opened which led to overflow of natural drains within the state. All the 5 gates of the Idukki (Cherurhoni) Dam in Kerala were opened, underlining just how severe the conditions were in the coastal state that had witnessed constant heavy rain and flooding. This was the first time in history that all the gates of that dam had been opened. The dam was sending approximately 6 lakh litres of water flooding down the Periyar river every second (*Today*, 2019).

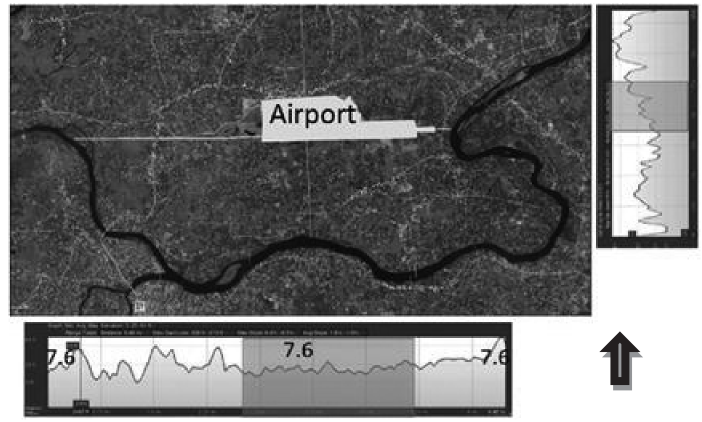


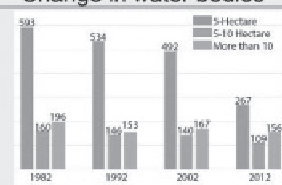
Figure 3: Kochi Airport analysis

Urban floods are living declarations of the contention between urban development and climate-related vulnerabilities (Basak, Goswami & Palanichamy, 2018). A case of this was the shutting down of Cochin International Airport for about 14 when flood waters from the swollen waterway ruptured the fringe dividers and overflowed the runway (India T. o., 2018). The world's first solar-controlled airport lost roughly 20 per cent of its sun-powered boards due to damage. Altogether, a loss of USD 35 million was brought about because of damage to the airplane terminal (*Times*, 2018). The airport is almost 420 metres from the Periyar waterway, situated on the floodplains of the stream. Any development over stream floodplains is constantly vulnerable to flooding. At the point when the Periyar waterway is in spate, the airplane terminal's drainage framework, which releases into the Chengalthodu creek, is endangered, and there is an invert stream of water along the rivulet and drainage channels into the air terminal. The elevation investigation in Fig. 3 demonstrates that the airplane terminal and the stream are nearly on a similar dimension, and zones towards the north are at a higher rise. This implies that in case of overwhelming precipitation, stormwater from the north depletes towards the airplane terminal (Basak, Goswami & Palanichamy, 2018).

Observations from Case Studies

PARAMETER		MUMBAI-2005	HYDERABAD-2008	CHENNAI-2015	KERALA-2018
		CASE STUDY			
Time		July, 2005	Aug, 2008	Nov, 2015	Aug, 2018
Rainfall	Normal	250 MM	145 MM	708 MM	98.5 MM
	Flood-Actual	944 MM - 277%	237 MM - 64%	1612 MM - 128%	352 MM - 257%
Impact	Human	Loss - 500 & Affected - 1.5 lakh	Loss - 14 & Affected - 1.5 lakh	Loss - 422 & Affected - 18 lakh	Loss - 483 & Affected - 10.28 lakh
	Financial Loss	550 crore	49.5 crore	14000 crore	19500 crore
	Infra. Damage	Buildings: 52K residential loss, 40K commercial loss Transpo-rtation: 52 local trains, 900 BEST buses, 51K other modes		1.01 lakh buildings damaged 3.82 lakh hectares of crops damaged 9800 crore of roads damaged	Buildings: 42K hect crop damage Transpo-rtation: 10Kkm of road damage; Kochi airport & metro closure - loss of 300cr
Findings	Rainfall	Heavy rainfall & rising sea level	Heavy rainfall & more 40mm/hr events	Heavy rainfall & cold pool	Heavy rainfall & compund effect
	Urbanisation	Year / Green / Builtup / Wetland 1950 / 60% / 12% / 28% 1975 / 54% / 24% / 22% 2000 / 30% / 52% / 18%	Change in water bodies (chart below)	Year / Dense vegetat. / Builtup / Wetland 1975 / 19.5% / 17% / 13% 2000 / 15.7% / 26% / 7.7% 2007 / 11.2% / 31% / 6%	Year / Builtup / Forest / Wetland 2005 / 9% / 57% / 33% 2012 / 22% / 48% / 29% Destroying Western Ghats and CC
	Drainage	Faultering drainage system Incapable SWD		Inadequacy of SWD system Improper management	Inadequate efficiency of drain-43% 12 catchment efficiency - 25%
	Construction	Change in path of mithi river Bandra-Worli sea link		Increase in impervious surfaces Death of water bodies	Change in path of periyar river Reduction of natural drain width

Mitigation Measure	MUMBAI-2005	HYDERABAD-2008	CHENNAI-2015	KERALA-2018
	Increase capacity of SWD-BRIMSTOWAD	Managing urban-runoff: At household level	Increase efficiency of SWD	Operational Flood Managment: NDMA 3R approach - Rescue, Recoup, Rehabilitation
	Storm Water Pumping Stations at the SWD outfalls	Managing urban-runoff: Controlling impacts from existing & new development	City river conservation project	Funds allocated for damaged roads and infrastructure
			Flood alleviation scheme	
	Bores along with the storm water drains	Managing urban-runoff: At structured level	Incorporation of master plan with metro plan for SWD	Funds allocated for damaged roads and infrastructure
		Policy Level: No const. near water bodies		
	Planting and preserving of mangroves	Policy Level: Awareness of TP laws& regulatory measures to protect environment	Funds under JNNURM for engineering operation	



Conclusion

Urban flooding is a noteworthy risk to the livelihood of individuals as a result of quick urbanisation that prompts impermeability of surface and change in climate resulting precipitation. Thus, urban flooding is a significant issue in urban areas, and its degree of harm is entirely reliant on the degree of their own vulnerability. In any case, urban flooding is significantly caused because of anthropogenic exercises, so a multidimensional methodology is required to mitigate this issue. In this paper, it is stated that the volumes produced because of impenetrable regions of the ground in an urban area can surpass the limit of the existing waste system. Some of the mitigation measures which reduce the impacts of urban flooding are:

- An incorporated methodology joining watershed and land use with advancement arranging, designing measures, flood preparedness and emergency management ought to be received for controlling urban floods.
- New engineering methods, for example, pervious passages, pervious parking areas to minimise the surface runoff and maintaining of stormwater channels, including desilting before rainstorm and utilisation of permeable development material for pavements and construction of drainage network, should be used with proper planning and adequacy.
- Safe and secure regions for groundwater recharge like detention pond and use of conjunctive administration to improve groundwater capacity should be provided: use of surface water for groundwater infiltration could enhance flood management by diminishing peak streams, protecting lakes/water bodies from encroachment and clearing existing infringements by the urban nearby bodies and also protecting from encroaching the natural drains and drainage networks at discharge.
- The public ought to be taught about the dangers associated with unlawful developments on or along nallas and tank territories and they ought to be encouraged to abandon the vulnerable region. The government ought to think about the movement for the needy individuals in some different zones. On the off chance that this does not work out, the harsher choice of pulverisation of the structures must be considered.
- Hazard mapping of the areas of the city ought to be done to assess the vulnerability, identified with urban surges, utilising GIS Technology, and construction of drainage network should be done with proper planning and adequacy.

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II Cyclone and Coastal Zone Regulations

Tropical Cyclone Heat Potential and Intensification of Tropical Cyclones

Vijendra B. Sambhalwar[a]

ABSTRACT: The increase in temperature across the sea surface is significantly measured in the form of Sea Surface Temperature (SST) and for many decades it was the major factor for the prediction of cyclone and related events. Several studies show that SST is not the only factor which is representing the heat content measurement for cyclones and intensity prediction. It is known that from the Mean Sea Level, both in upper strata up to certain limits and in to the depth, the temperature decreases. New studies on the cyclone genesis revealed the importance the temperature holds by the water layer structure which is measured in the form of energy, termed as Tropical Cyclone Heat Potential (TCHP). Results of the study by Mainelli et al. 2008, show that for a large sample of Atlantic storms, the TCHP variations have a small but positive impact on the intensity forecasts. The purpose of this paper is to study the climatology related to the TCHP and the cyclone intensification using case studies and spatial modelling. The study done by Lin et al. 2013, explains the intensification of cyclone followed by sudden landfall resulting in severe destruction of property and life of the people due to the killer Cyclone Nargis (2009).

KEYWORDS: SST, TCHP, tropical cyclone, intensification

Introduction

The atmospheric structure has its own properties and conditions for climatic and weather circulation, which involves the ocean as well as atmospheric parameters. In the tropics the thermal contrast between land and ocean generates a large-scale upward motion of wind with rising over relatively warmer continents and sinking over oceans. The resulting pattern is titled as Walker circulation, where the loop formed over oceans circulates to the land. The raising branch of Walker circulation is often associated with convection-induced rainfall and the sinking branch is suppressed by the rainfall. In orderly episodes, the trade winds are flowing from the eastern to western direction in the Pacific and Atlantic Oceans. The low atmospheric pressure develops over the western Pacific Ocean and high pressure is maintained across the eastern Pacific Ocean surface and the eastern winds help with this. Thus the increase in temperature is observed in the deep layer on the western side of the Pacific Ocean. These rises in temperature of the fluids across the oceans are directed by the Coriolis effect.

Eastern trade winds flow from east to west along with the rotation of Earth nearly throughout the year, which is one of the contributors to the generation of the weather phenomenon. The reverse phenomenon of winds flow from west to east occurs over the Indian Ocean which is called Monsoon. Along with the neutral Walker circulation over the Pacific Ocean the same event occurs in the Indian Ocean which results the monsoon and related activities (Fig. 1). The precipitation due to monsoon covers nearly all the countries and regions surrounded by the Indian Ocean.

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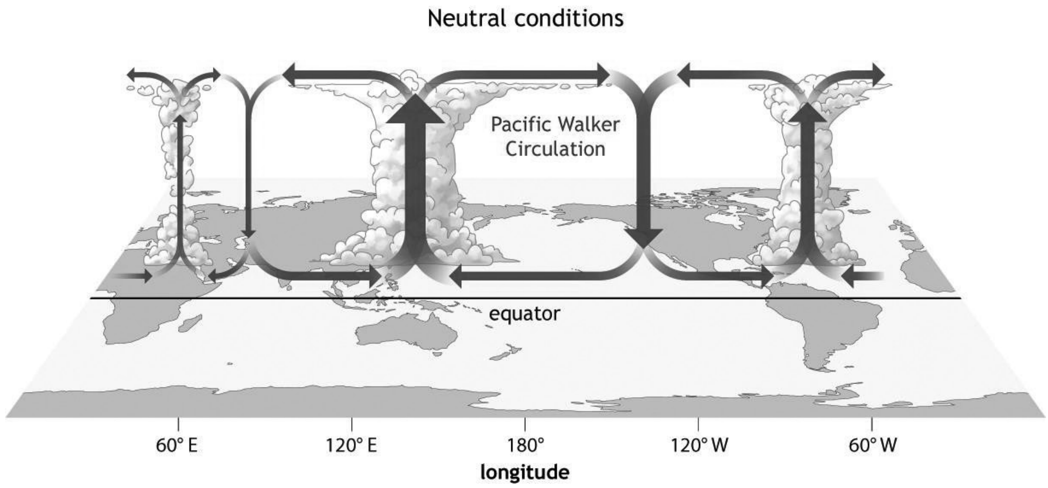

Figure 1: Pacific Walker circulation in neutral condition (Source: NOAA)

Tropical Cyclones

The tropical cyclone, also called typhoon (western Pacific Ocean coast, China, Japan, Philippines) or hurricane (North Atlantic and eastern Pacific Ocean), is an intense circular storm that originates over warm tropical oceans and is characterised by low atmospheric pressure, high winds and heavy rain. It draws energy from the sea surface and maintains its strength as long as it remains over warm water. Accompanying these strong winds, the torrential rains and the devastating phenomenon of the storm surge (an elevation of the sea surface that can reach 6 metres above normal levels) becomes one of the most dangerous natural hazards in tropical and subtropical areas of the world. These tropical cyclones are the major drivers of the atmospheric action transferring the heat over the cooler region which brings life in the form of nutrients to the marine ecosystem (Joseph A. Zehnder, n.d.). Formation of the tropical cyclone follows the condition related to the atmosphere and ocean:

- Sufficient ocean thermal energy
- Enhanced mid-troposphere relative humidity
- Conditional instability
- Enhanced lower troposphere relative vorticity
- Minimum weak vertical shear and
- Displacement at least 5 degrees away from the equator (Gray, 1968).

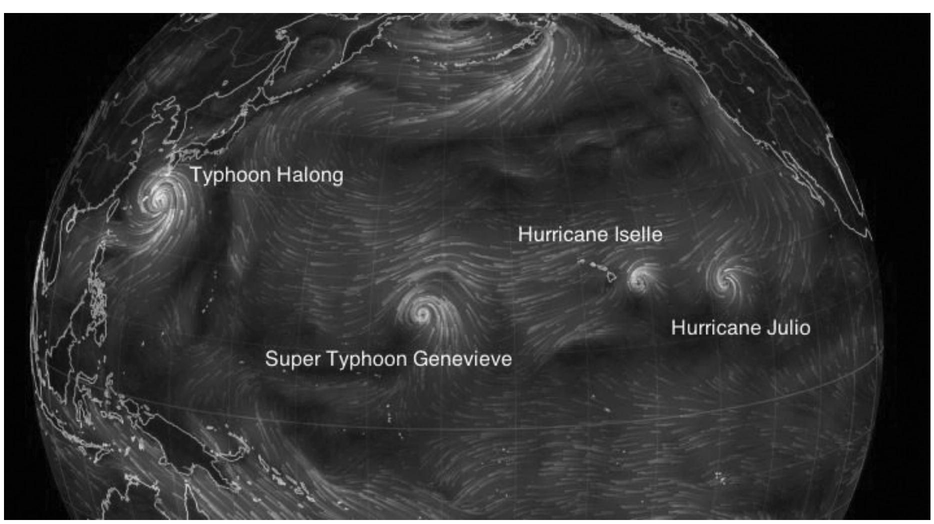

Figure 2: Tropical cyclones over Pacific Ocean (Source: Global Wind Map/VOX)

In the cyclone genesis, the atmospheric conditions contribution is compulsory. Along with them the role of the thermal energy or the temperature of the ocean surface and the layers is also important. For the formation of the cyclone the temperature should be more than or equal to 25–26°C. The thermal energy needed for hurricanes and monsoons comes from the upper layers of the oceans, but not from the thin layer represented by sea surface temperature (SST) alone (Sharma and Mm, 2014).

TCHP

In the 20th century the increase in temperature was significantly measured in the form of SST and for many decades was the major factor for the prediction of cyclone. Several studies show that SST is not the only factor which is representing the heat content measurement. It is known that from the Mean Sea Level (MSL), both in upper strata up to certain limits and in depths, the temperature decreases. New studies on the cyclone genesis revealed the importance the temperature holds in the water layer structure which is measured in the form of energy, termed as Ocean Heat Content (OHC).

The OHC, also known as the Upper Ocean Heat Content (UOHC) or Tropical Cyclone Heat Potential (TCHP), which is defined as an integrated vertical temperature from surface to depth of 26°C isotherm (Maneesha et al. 2015) or the integrated heat content excess per unit area relative to the 26°C isotherm, integrated from the depth of the 26°C isotherm to the surface, was chosen because it combines the upper-ocean and SST information into a single parameter (Mainelli et al. 2008).

Examples of the utility of TCHP data information for category 5 hurricanes (Isabel, Ivan, Emily, Katrina, Rita, and Wilma from the 2003–05 hurricane seasons) are presented from the paper of Mainelli et al. 2008. Results show that for a large sample of Atlantic storms, the TCHP variations have a small but positive impact on the intensity forecasts. National Hurricane Center (NHC) forecasters utilised the TCHP analyses for Hurricane Ivan on a number of occasions. In the 1500 UTC discussion product from September 8, 2004, the forecaster stated, “Thereafter the hurricane will be over the northwestern Caribbean Sea where there is high oceanic heat content and lower shear. So, Ivan is expected to intensify before reaching Cuba. Ivan had just entered the Caribbean at the time of this forecast and was already a category 4 hurricane”. Thus, the forecaster recognised the role that the high TCHP would play in maintaining or further increasing the intensity. The NHC discussion products for Isabel did not mention the TCHP analyses but did consider the SST field. The Isabel case highlights the fact that the TCHP is one of several factors that can affect intensity changes (Mainelli et al. 2008).

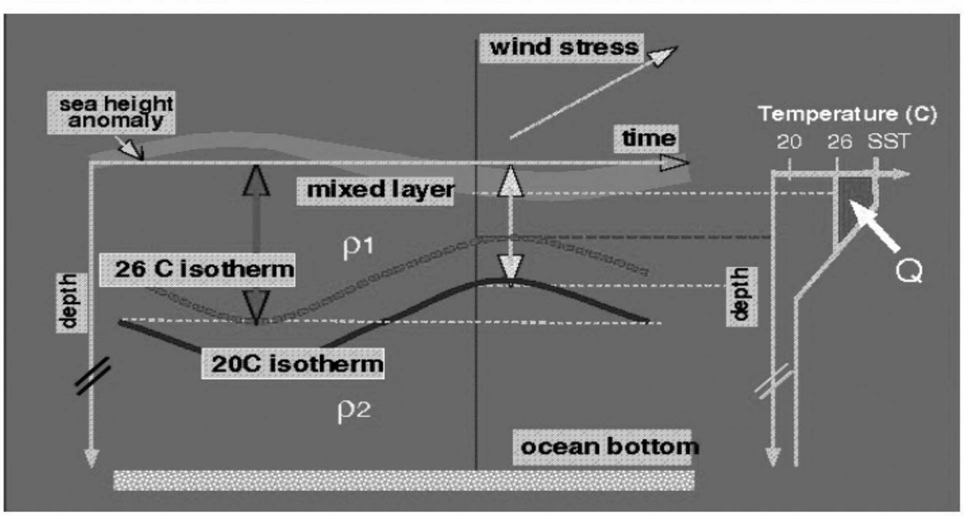

Figure 3: D26 isotherm and ocean layer (Source: NOAA)

Data and Methods

Tropical cyclone forecasting is one of the toughest of its type. The involvement of the multiple parameters of the climate and atmosphere makes the whole system highly complex. There are multiple models provided by the different agencies in the world for the cyclone track forecasting and the methods, which can be predicted over 6 hr intervals to 72 hr. But the involvement of the multiple factors and the sudden changes in the system of the ocean water makes prediction more difficult. The material and the data were collected according to the objectives of the study. The data consisted of the primary and secondary data products as well as the reports.

Primary Data

Data on Earth/field coordinates of the tropical cyclone for the cyclone track is collected from the JTWC as well as the NOAA satellites and the information branch of the NOAA. JTWC is the warning centre of the US government and joint venture of US naval and the US air force, responsible for giving warnings about tropical cyclones by using various satellites, aircraft and ocean devices and their data products. Specifically, the data from satellites which is specifically injected into the polar orbit of the Earth like the MODIS (Moderate Resolution Imaging Spectroradiometer) sensor onboard TERRA (EOA) and AQUA series satellites and GOES (Geostationary Operational Environmental Satellite system) of the geostationary satellite. The nodal agencies like NASA and NOAA are responsible for the operation and the data regulation of these satellites.

Secondary Data

SST, SHA, D26 isotherm, TCHP and the secondary data are collected from the NOAA/AOML Physical Oceanographic Division and the ECMWF data archive respectively. ECMWF works along with the WMO and uses the system of the more than 90 satellites of European nations and the European Union (EU) along with the aircraft and oceanographic devices like the bouyon. The NOAA uses similar methods with their own models and data from the huge system of satellites and the oceanographic devices and systems like XBT. The IMD uses the INSAT satellite system data and other data for forecasting and generating the reports and to issue the warnings.

The TCHP (UOHC) parameter can be calculated from the equation provided by Mainelli et al. 2008; Goni and Trinanes, 2003; Goni et al. 2009 and Maneesha et al. 2015. The equation is

$$TCHP = \rho * Cp \int_{0}^{D26} (\overline{T} - 26)dz \tag{1}$$

Where ρ is the density of water column above 26°C isotherm, Cp is the specific heat of seawater at constant pressure, $\overline{T}$ is the average temperature of two consecutive layers of a depth increment dZ and D26 is the depth of the 26°C isotherm (Sarma et al. 1990); (Sadhuram et al. 2004).

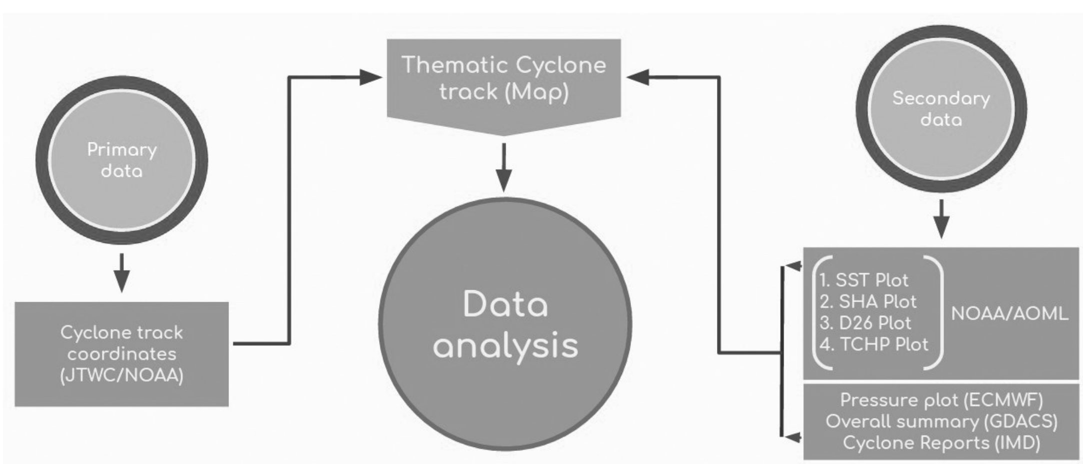

Figure 4: Methodology followed

Tools

ArcGIS software, Google Earth were used for the generation of the track of the cyclones by using the collected primary data. The products from these softwares were processed and used for the analysis and the resulting processes.

Methodology

The methodology followed is as shown in Figure 4. Primary as well as secondary data was collected from the different archives of the data providers, processed by using the softwares, followed by analysing the data for the study.

Results and Discussion

SST, SHA and D26

Cyclone Gaja

Figure 5 shows that the SST remains higher than 27°C over the period. The SHA does not show that much variation from the regular phenomenon. The SHA varies between 10 cm in between in the initial phase, which decreases to -10 cm also. Contrary to the SHA the isotherm column of the ocean layer follows the depth of more than 100 m in the initial phase and more than 75 m in the remaining phase, specifically after crossing the Indian peninsula.

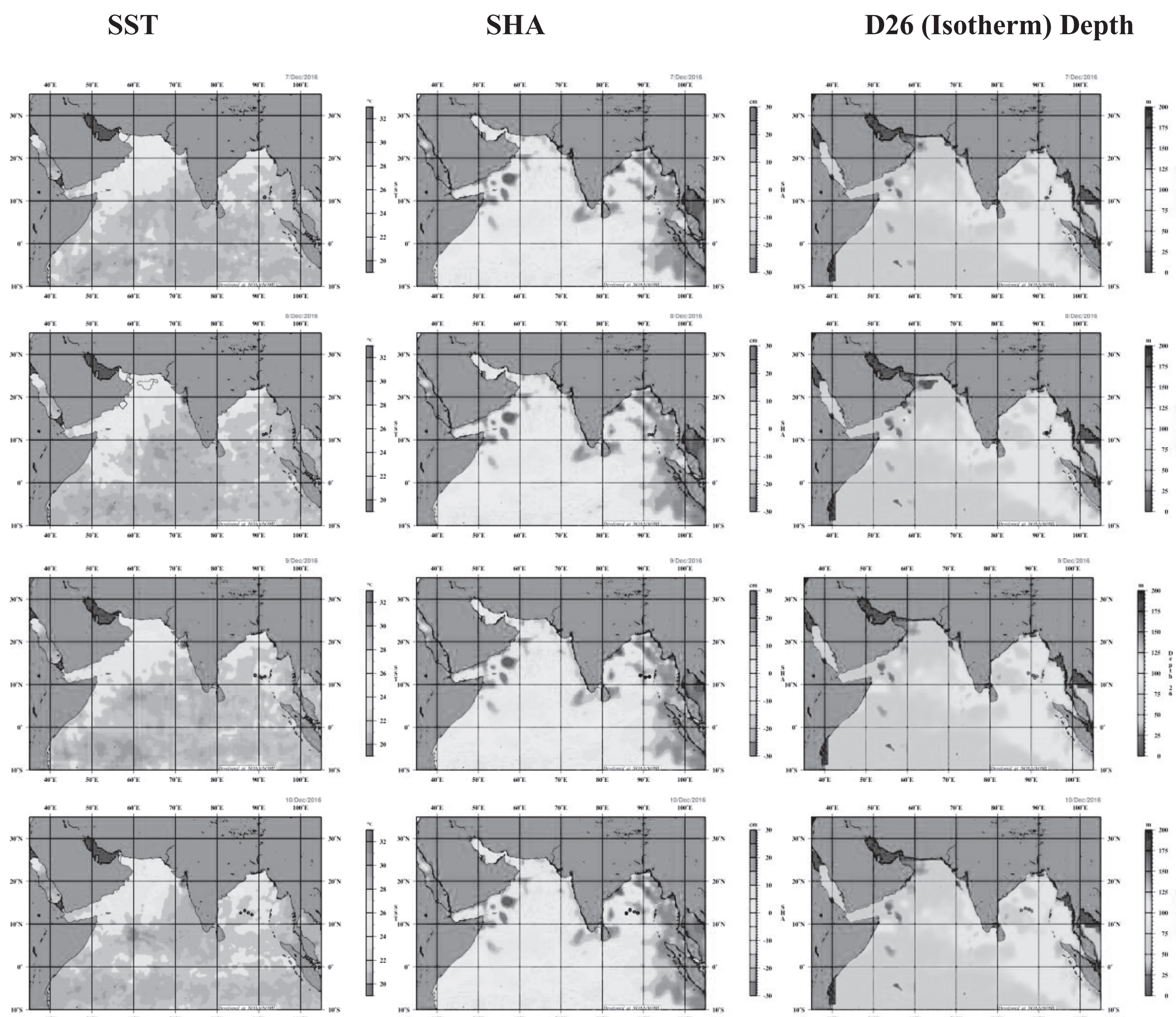

Figure 5: Daily mean SST, SHA and D26 isotherm plots from Nov 10 to Nov 15, 2018 (Source: NOAA/AOML)

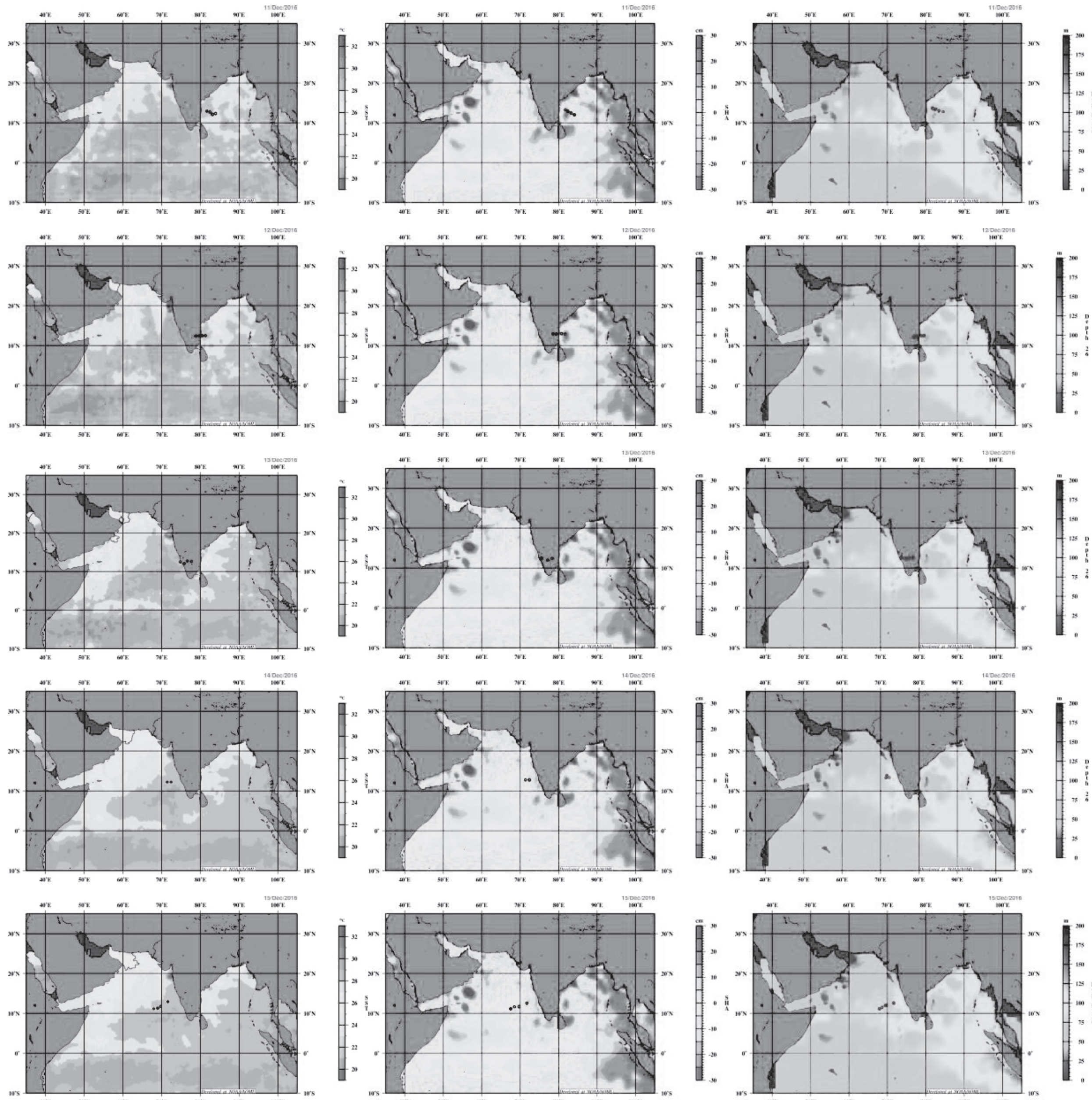

Figure 5: (Continued)

Cyclone Ockhi

Cyclone Ockhi follows the path from the region where the temperature was observed at more than 27°C. On the other hand, except for the initial phase observations in SHA, it does not show much variation. But the D26 isotherm remains more than 50 m between November 29 and December 5 and reaches more than 125 m in depth.

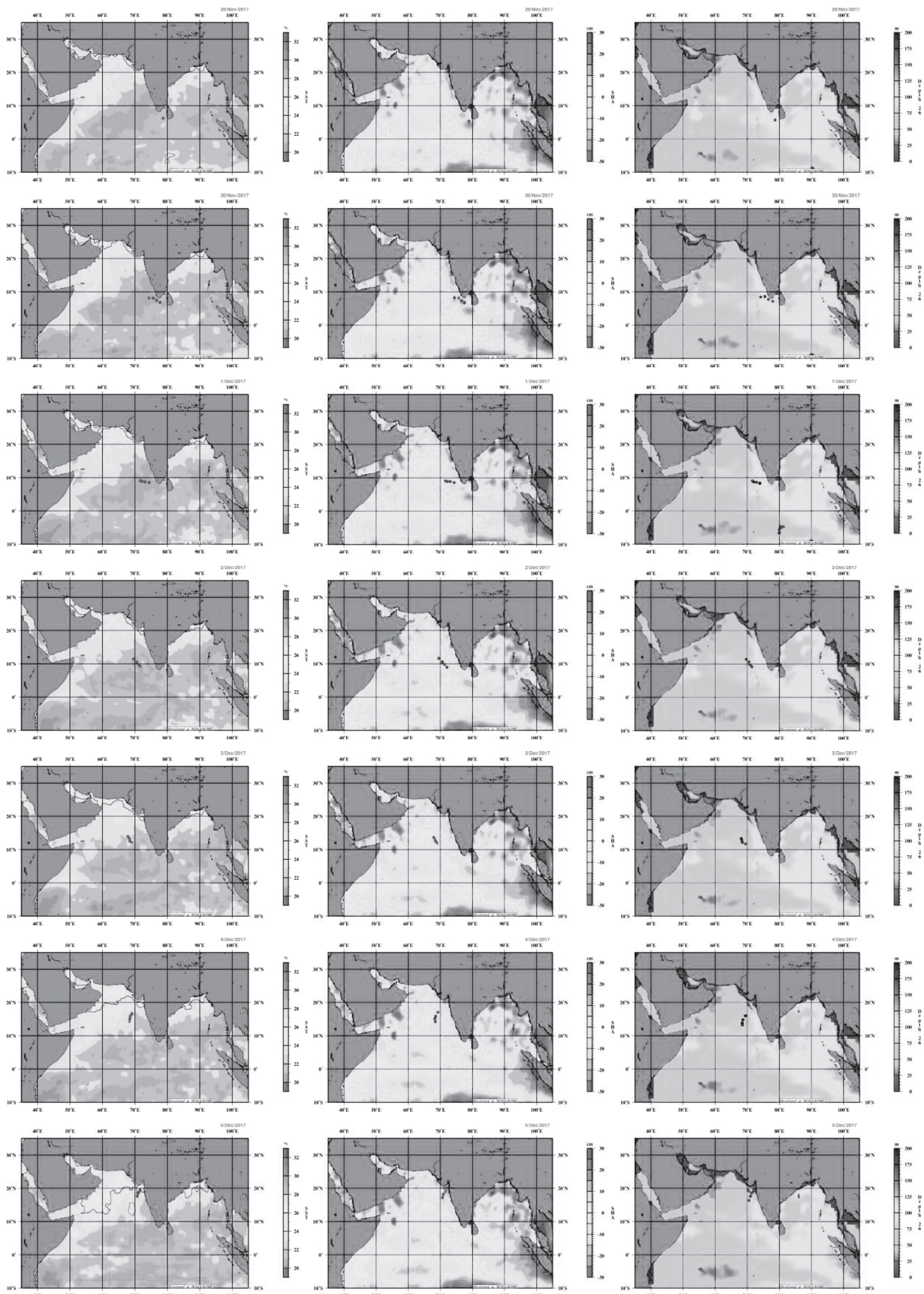

Figure 6: Daily mean SST, SHA and D26 isotherm plots from Nov 29 to Dec 5, 2017 (Source: NOAA/AOML)

Cyclone Vardah

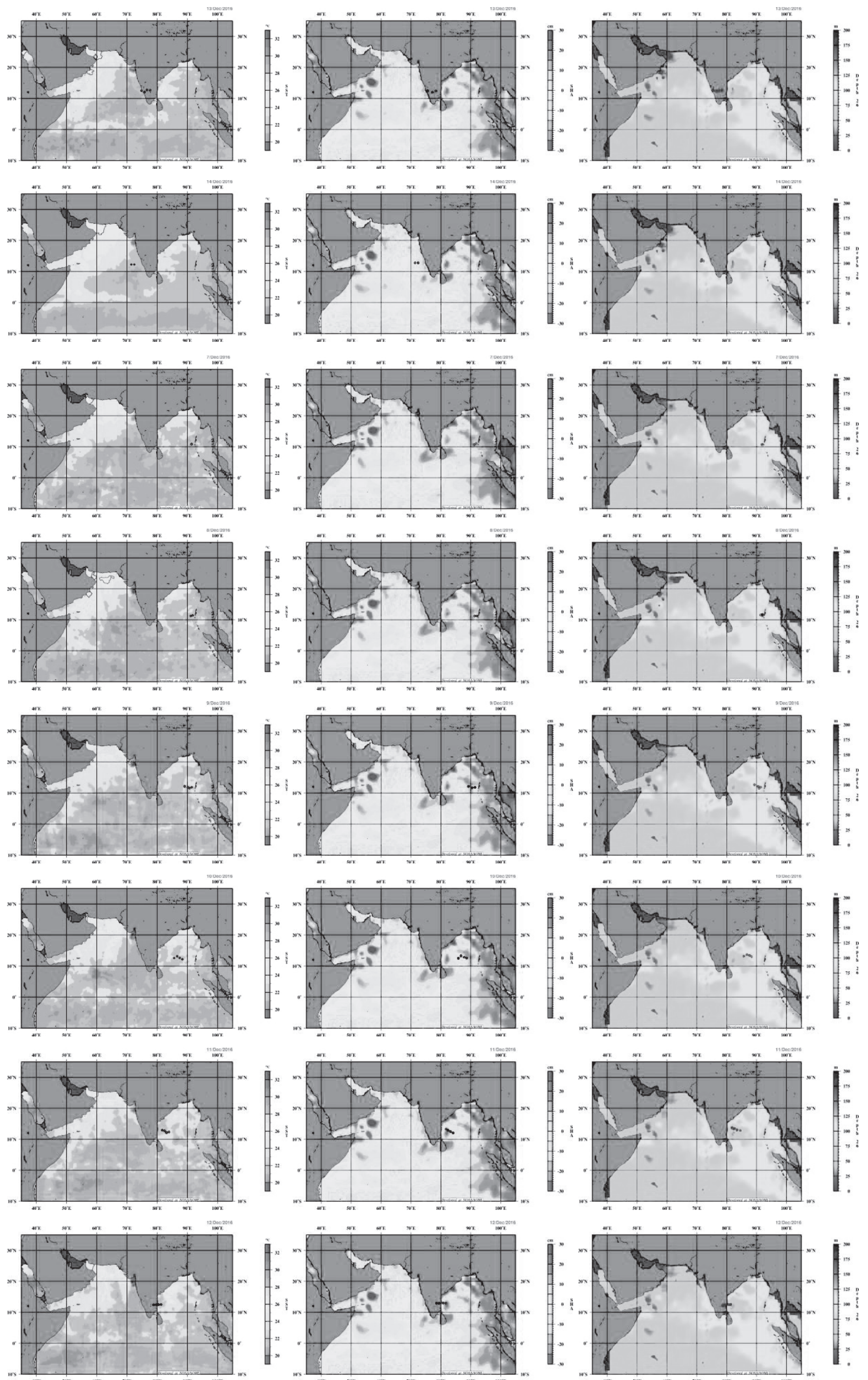

Figure 7: Daily mean SST, SHA and D26 isotherm plots from Dec 7 to Dec 14, 2016 (Source: NOAA/AOML)

The region with more than 27°C SST was the path for Cyclone Vardah. In contrast, SHA does not show positive changes on most days. And D26 isotherm remains more than 50 m and shows the depth at more than 100 m in the initial and dissipating phases.

TCHP

Cyclone Gaja

TCHP for Cyclone Gaja for its whole active period remained at more than 50 kJ/cm^2. On November 13, 2018, the plot shows the favourable conditions for the dissipation, whereas suddenly the TCHP increases from <50 kJ/cm^2 to the previous condition of more than 50 kJ/cm^2 and intensifies. But in contrast there was not much change observed which could trigger further intensification. Only the November 14 TCHP provided sufficient energy to further move.

Cyclone Ockhi

Cyclone Ockhi gathered speed between December 2 and 3, 2018. As the plots show, the energy remained at more than 60 kJ/cm^2. When the speed decreased only then does the TCHP show lowering to 40 kJ/cm^2.

Cyclone Vardah

Cyclone Vardah moved on the path where the TCHP remained at more than 40 kJ/cm^2, which is sufficient to move and further intensify the cyclone (Maneesha et al. 2015). On the other hand, the cyclone peaked in speed on December 10 and 11, 2016 and then made landfall on the Indian Peninsula.

TCHP and Intensification of the Cyclone on Track

As per Maneesha et al. 2015, in the Bay of Bengal (North Indian Ocean), the threshold value for the genesis and intensification is 40 kJ/cm^2, which is observed in all three cases of Cyclones Gaja, Ockhi and Vardah. Cyclone Gaja intensified on November 13, 2018 and then made landfall. Cyclone Ockhi intensified to a speed of 185 kmph and 139 kmph between December 2 and 3, 2017, where the TCHP was observed at more than threshold. And Cyclone Vardah intensified to the 139 kmph of category and followed the landfall. At where also the TCHP observed more than the threshold.

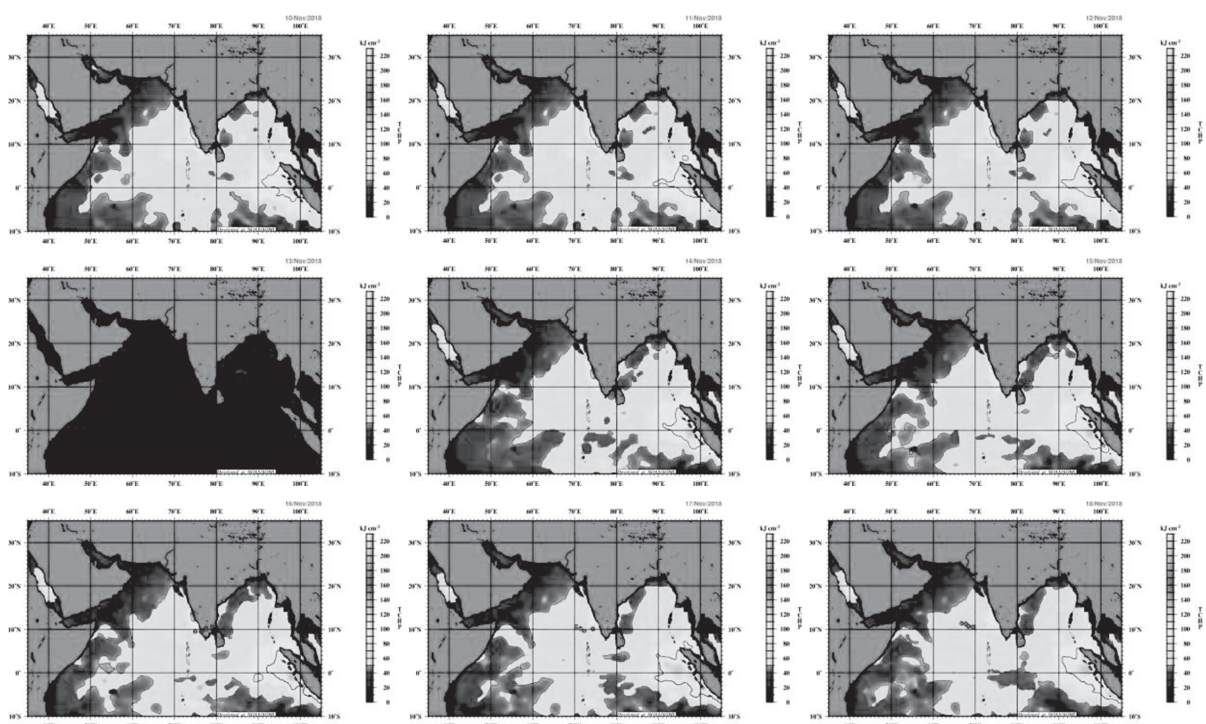

Figure 8: Daily mean TCHP plots from Nov 11 to Nov 18, 2018 (Source: NOAA/AOML)

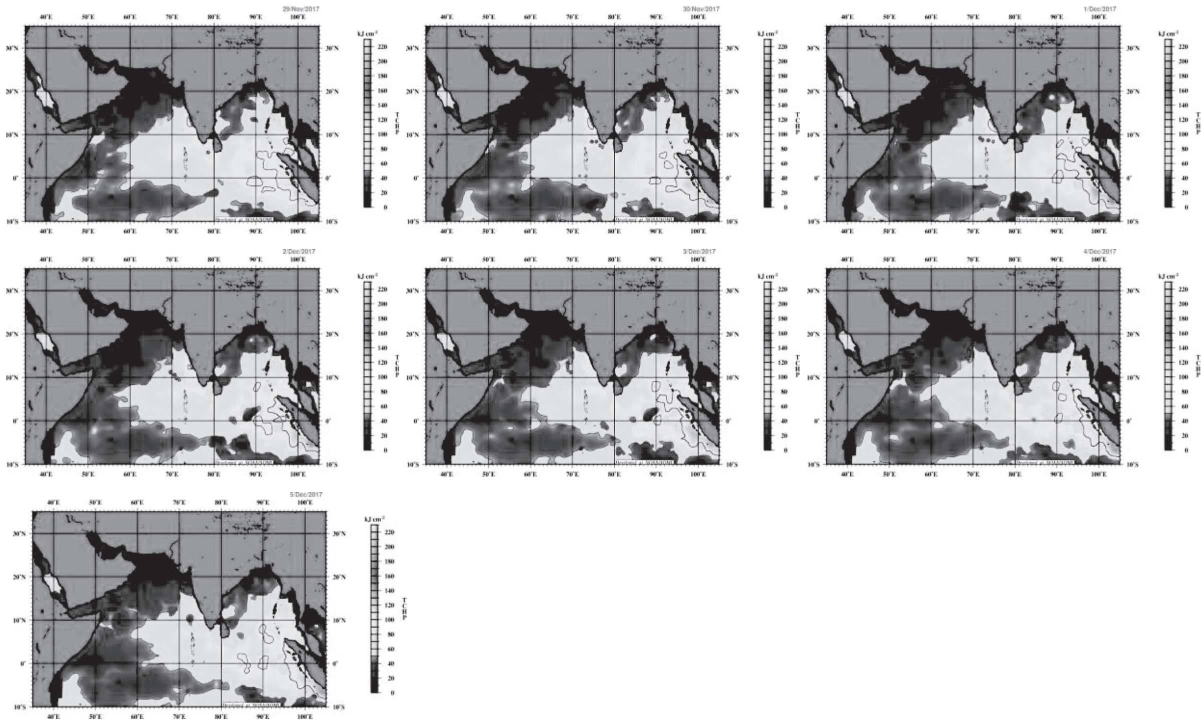

Figure 9: Daily mean TCHP plots from Nov 29 to Dec 5, 2017 (Source: NOAA/AOML)

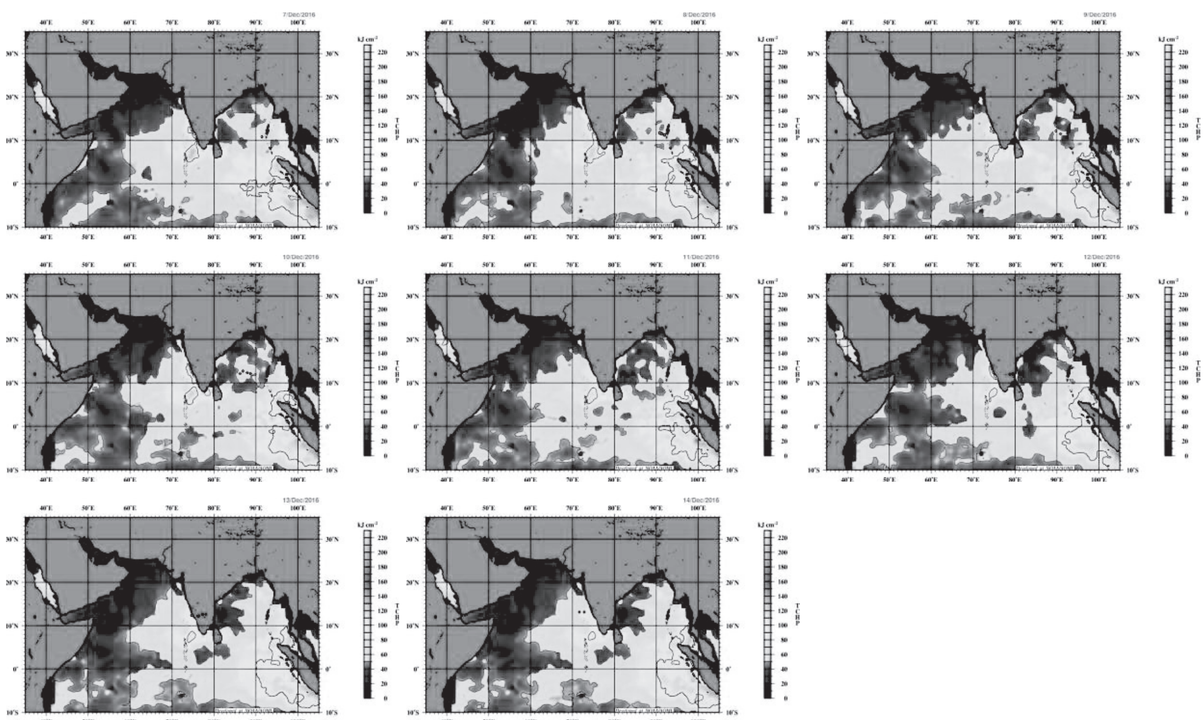

Figure 10: Daily mean TCHP plots from Dec 7 to Dec 14, 2016 (Source: NOAA/AOML)

Conclusion

In this study the TCHP parameter and its role in the intensification of the cyclone was found to be positive. From the above case studies it was determined that Cyclone Gaja (2018), Cyclone Ockhi (2017) and Cyclone Vardah (2016) followed the path where the TCHP threshold was observed at 40 kJ/cm^2. But the SST and the related variables were not as influenced by the TCHP.

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Understanding Coastal Erosion and Human Well-being: A Study of Mousuni Island, West Bengal

Sharanya Chattopadhyay[a]

ABSTRACT: When the term "disaster" is mentioned in any context, we promptly think about rapid onset disasters; but in recent years with the overarching threat of climate change, sea level rise and coastal erosion have become one of the most impactful phenomena. An assessment of the Indian coastal areas using satellite data of 1989–1991 and 2004–2006 frames shows that around 45.5 per cent of the areas is undergoing erosion. The population exposed to such coastal slow onset disasters is facing loss and damage in a multifaceted way. Predominantly poverty and vulnerability are used synonymously, but the fact is that economic factors are not sufficient to fathom the severity of the damage. To ensure an efficient policy framework to combat such disasters it has become crucial to understand and capture the inter-linkage of human well-being and coastal slow onset disaster. The universe of this present study is a coastal island of the Indian Sundarbans, West Bengal, which is undergoing land loss and related damages. This paper addresses the plight of these vulnerable people facing extensive erosion induced land loss and embankment breach; this study relies upon the various key factors of human well-being as identified by the researcher in the field, such as material living standards, infrastructure, healthcare, education, political participation and governance, and environment (present and future conditions). Predominantly using household survey methods and a few in-depth interviews, this study tries to capture the existing condition of the abovementioned key factors. The research findings include intriguing details of the abovementioned objectives and provide ample insight into how the responses vary across different respondent groups.

KEYWORDS: erosion, embankment, objective well-being, subjective well-being, perception

Introduction

The Disaster Management Act (2005) of the Government of India defines disaster as "a catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or man-made cause, 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". Any literature related to disaster categorises all the disasters into two groups depending on their pattern of occurrence, that is, rapid onset disaster and slow onset disaster. Interestingly, whenever the term "disaster" is mentioned in any context, we promptly think about rapid onset disasters; thus, the extent of attention received by rapid onset disasters (cyclones, floods, etc.) is much higher than that received by slow onset disasters. In recent years, with the overarching threat of climate change, extreme rapid onset events such as increasing intensity and frequency of cyclones

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or erratic heavy precipitation have caught ample attention worldwide. But climate change also triggers sea level rise (SLR), salinisation, increased temperature and coastal erosion, all of which are by nature slow onset events. As these events happen slowly over a long period of time, the rate of impact is slower and they appear less calamitous than rapid onset extreme events. In 2012, the United Nations Framework Convention on Climate Change (UNFCCC) stated that there lies a synergistic interaction between rapid onset and slow onset events that leads to manifold increase in the risk of loss and damage. Thus, to combat this mutually reinforcing cycle of damage and destruction, it is equally important to understand the different ways slow onset disasters affect communities and society at large.

India has a long coastal stretch, bordered by the Bay of Bengal in the east and south-east, the Arabian Sea in the west and south-west, and the Indian Ocean in the south; this long stretch is inhabited by around 18.8 crore (about 15.5 per cent of the national population) people in the mainland and 4.4 lakh people in the island territories (Census 2011). An assessment of the Indian coastal areas using satellite data of 1989–1991 and 2004–2006 frames shows that around 45.5 per cent of the coastal areas are undergoing erosion. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (2007) states with "very high confidence" that coasts will be exposed to increasing risks, including coastal erosion, over coming decades due to climate change and sea level rise. All those people residing in coastal India are exposed to slow onset events, such as sea-level rise, erosion and salinisation. Existing literature has examined the human impact of rapid onset disasters; but the human impact of slow onset events such as sea level rise and induced coastal erosion is yet to be explored.

Understanding Human Well-being

There are many "damaged societies" around the world who are already experiencing water and food shortages, poverty, lack of access to energy, extreme weather, regime failure, etc. Coupled with all these factors, slow onset disasters lead to a situation where a "tipping point" (a point where a series of small changes or incidents becomes significant enough to cause a larger, more important change) is often crossed. Often poverty and vulnerability are used synonymously, but the impact of such events cannot be fathomed only in terms of economic status. Understanding human well-being is a complex task because the literature available on this issue is enormous and includes various disciplines of thoughts. Highly noted in this field, the capability approach by Amartya Sen (1999) contains three basic concepts: functionings, capabilities and agency. Functionings are the valuable activities or physical state that a person might value doing or being, such as a healthy body, being safe, being educated, having a good job, and being able to move and visit people. Capabilities refer to the freedoms one has to do these valuable activities or reach these valuable states; capabilities reflect the freedom of one individual to choose from possible livings. Sen distinguished this opportunity aspect of freedom (capabilities) from the process aspect. Agency is the ability to pursue goals that an individual values. Income, expenditure and assets are not adequate in assessing well-being of people, simply because heterogeneity, environmental factors, social structure, etc. are very crucial factors in people's lives. Well-being is a state of being with others, where human needs are met, where one can act meaningfully to pursue one's goals and where one enjoys a satisfactory quality of life. There are two major dimensions of human well-being: objective well-being and subjective well-being. Objective well-being deals with external factors, such as material living standards and quality of life, whereas subjective well-being deals with people's own evaluation of well-being and general life satisfaction. There are eight key factors of human well-being as identified by the Commission on the Measurement of Economic Performance and Social Progress that is, material living standards (income, consumption and asset), health, education, personal activities including work, political participation and governance, social connections and relationships, environment (present and future conditions) and insecurity (economic as well as physical). But as threats and their manifestation in a particular area depend on various factors, there might be variations in the pattern or variability of the indicators. Not only is this a quantifiable parameter, but people's perception about their way of life is an instrumental factor in framing the policies.

The Indian Sundarbans Delta Region

The Indian Sundarbans Delta (ISD) is spread over about 9630 km^2 between 21˚40'04"N and 22˚09'21"N latitude, and 88˚01'56"E and 89˚06'01"E longitude. This is the smaller and western part of the complete Sundarbans delta; around 60 per cent of the delta region comes under the administrative boundary of Bangladesh. The Indian Sundarbans is an immense archipelago situated between the vast Bay of Bengal in the south and the fertile plains of Bengal in the north. This archipelago, created by the confluence of the rivers Ganges, Meghna, Brahmaputra and their innumerable distributaries, is the world's largest mangrove delta and a world heritage site. Always in the headlines for the breathtaking natural beauty of the mangroves and the numerous flora and fauna (including Royal Bengal tigers, crocodiles and sharks), this place is also home to over 4.4 million people. Struggling for their survival in this underdeveloped area, mostly because of the geographical constraints and the ill effects of flooding as well as natural disasters, the inhabitants are now facing the increasing impacts of climate change. The low-lying coastal plains, which get submerged daily during high tide and resurface during ebb, became habitable only after the construction of embankments. In the Sundarban area, sea level rise, erosion, extreme weather events and resulting embankment breach have become very common phenomena. The communities exposed to such slow onset disasters are facing loss and damage in a multifaceted way. To ensure an efficient policy framework to combat such disasters, it's important to visualise how human well-being is compromised. It has become crucial to understand and capture the inter-linkage of human well-being and coastal slow onset disaster as well as the lived lives and specificities of the daily life experiences of the exposed community.

In the sheer absence of literature that assesses the linkage between slow onset disasters and human well-being, it has become imperative to look into this matter in the developing countries. This study attempts to explore various dimensions of human well-being in coastal stretches of the Indian Sundarbans taking into account varied indicators. Variables representing a wide range of societal domains, education, health, social relations and living conditions have been incorporated in the study. It also takes into account subjective perception of life, that is, satisfaction with facilities/services, personal relations, public safety, etc. The objectives of the study are as follows:

- To capture the differential perception of the community regarding the threat
- To identify the factors affecting well-being of the exposed community facing the coastal erosion and embankment breach in coastal Sundarbans

Area of Study

Detailed study was conducted in two villages of an island of the Indian Sundarbans which are administratively under Namkhana Block of South 24 Paraganas District. The selected island, namely Mousuni Island, is a small island in the south-western part of the Indian Sundarbans. It covers an area of about 26 km^2. The island is encircled by the Muriganga or Battala River in the west and north-west, Chinai River (earlier known as Pitt's Creek) in the east and Bay of Bengal in the south. The island consists of four revenue mouzas, namely, Mousuni, Bagdanga, Kusumtala and Baliara (moving from North to South). As the western parts of Kusumtala and Baliara village are eroding at an alarming rate, these two villages were specifically chosen for this study.

Average elevation of the islands of the Sundarbans from average sea level is not much higher. The average elevation of Mousuni Island from mean sea level is 3.9 metres. This whole area is tide-dominated; peripheral areas of this island get inundated during high tide. Due to heavy siltation at the riverbed, in many areas once saline water engulfs the land, it doesn't recede easily.

Thus, any rise in sea level has a tremendous impact on the lives of the islanders. The impact is basically twofold. Firstly, both homestead land and agricultural lands are lost to the sea, putting more pressure on highly populated small islands as well as on lower capability population. Secondly, the land lost to the sea is difficult to reclaim for agriculture in the near future, since salinity destroys the productivity of the soil. Therefore, even a small rise in the sea level is a calamity for people on low-lying land fronting the sea. According to eminent river scientist Dr Kalyan Rudra, the accumulation of silts in Kolkata port increased four times between 1999 and 2003 after the commission of the Farakka Dam. Greater amounts of silts are accumulating upstream of the Farakka Dam, while downstream, water from Farakka Dam is less silt laden, thus causing more erosion. As the Sundarbans (both the Indian and Bangladesh Sundarbans) are situated at the sea mouth of the Ganga-Bramhaputra-Meghna delta (i.e. downstream from the Farakka Dam) they are facing the maximum erosion (Rudra 2018). This combined with sea level rises due to worldwide climate change has a crucial impact on the rapid land erosion in the Sundarbans (Rudra 2018). During 1990–2000, relative mean sea level in the western part of the Bay of Bengal adjoining Mousuni Island was rising at 3.14 mm/year; the global estimate of sea level rise was between 0.5 and 3 mm per year. But during 2000 to 2008, the relative mean sea level rise data of the Sundarbans, also from the Sagar Island observatory, showed the rate to be 12 mm/year (Hazra et al. 2002).

Table 1: Demographic Data of the Two Study Villages

Name of the Village	Kusumtala	Baliara
Total household	1289	1746
Total population	5663	8672
Total no. of males	2898	4358
Total no. of females	2765	4314
Total no. of literates	4373	5957
Total no. of workers	2042	2717
Total no. of non-workers	3621	5955

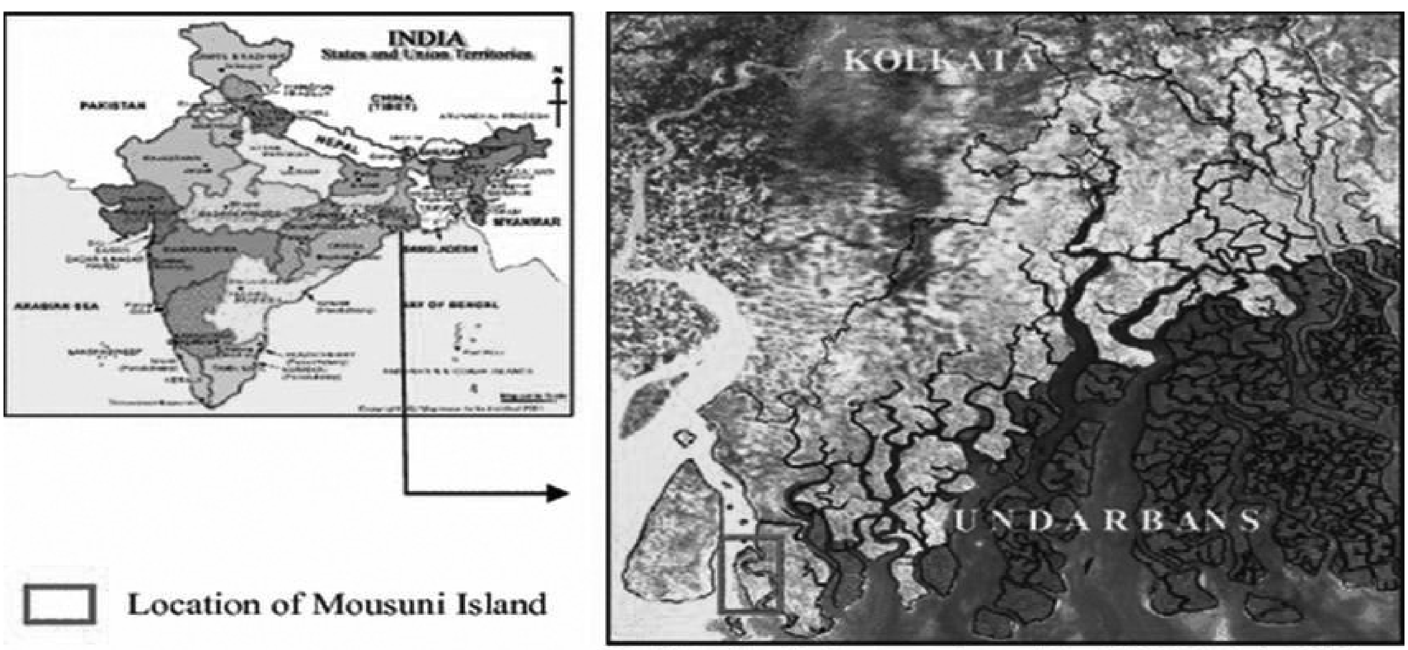

Figure 1: Location of study area

Data and Methodology

In this particular study, a mixed method research design was employed to gain enough insight for achievement of the desired objectives. Within this, an exploratory sequential research design was employed. Initially after interacting with the respondents various factors influencing well-being were identified and at the later stage quantitative data was collected. For analysing the perception of threat amongst the islanders, in-depth interviews were conducted. Through household questionnaire, field data was collected during June and July 2018. For assessment of objective well-being, data regarding material living standards (income, consumption and assets), health, education, personal activities including work, political participation and governance and environment (present and future conditions) has been obtained. For assessment of subjective well-being, perceptions were noted on the basis of a Likert scale. A total of 75 islanders were chosen on the basis of stratified random sampling. The stratifications were done on the basis of distance of the households from the shoreline/embankment.

Results

Before moving into discussion about objective as well as subjective well-being, a few field observations should be mentioned. Well-being is highly contextual and it is embedded in the environmental specifications. Historically, embankments have been an integral part of the lives of the islanders; embankments are the only protective barrier between the mighty waves and the settlements of the islands. The most striking notion was that on Mousuni Island, the embankment becomes non-existent as one moves from north to south along the western coastline. Along the North-western side of the island (Bagdanga Mouza) concrete embankment is present (block pitching). In Kusumtala village, earlier earthen embankment with bamboo fence and GeoTube sacs filled with sand were present. Even now along the coastline some remnants of damaged embankment are visible; bamboo logs are lodged along the coastline. But in Baliara village, embankment is non-existent.

Assessment of differential perceptions of the islanders on threat:

Flood is commonly known as *Bonya* or *Baan* in the local Bengali language. Flood on Mousuni Island as well as the Sundarban region comes under the broader category of coastal flooding, but the reality of coastal flooding in this region is understandably different from that of "Flood Disaster". In the absence of a protective embankment, in Baliara village, saline water from the Bay of Bengal engulfs parts of the village during "*Jowar*" or high tide. Sometimes it inundates a very small area of the coastal side of the village and very few families adjacent to the embankments are affected by the saline water intrusion. Sometimes, if there is an embankment breach, it inundates only a few "*bighas*" of agricultural land or resources close to the breached embankment.

It is said that flood happens mainly during the monsoon season, but in reality, it does not have any specific season and time on these coastal islands. If the embankment is unable to stop the strong tidal waves during the year, they breach the embankment and create floods.

Monsoon is the most vulnerable season for breaching of embankment. Most incidents of the flood happen during the months of mid-*Shrabon* (August) to *Kali Pujo Kotal* (October). Mousuni Island as well as the Sundarban region experience semi-diurnal tides (i.e. two almost equal high tides and two low tides in a day). The height of the tides changes every day and it becomes highest or lowest in a two-week cycle in a month. In Bengali, Spring tides are called *Bhara Kotal* or *Kotal*. The height of the tidal level in the Sundarbans becomes higher during the first moon (*Pratipad Tithi*) to third moon (*Tritiya Tithi*). The tidal water fails to return to sea during the brief duration between low tides and high tides because of the network of the rivers in this area. If there is any embankment breach, then the saline water that enters the village during high tide gets stagnant. Thus, according to the respondents, saline water inundation during the months of June to October is a common phenomenon. The total amount of destruction due to saline water inundation is small compared to any major "flood disaster", but the conditions of the affected families are not different from the impacts of the latter.

The term “risk” can be defined as the likelihood of an undesirable state of reality (adverse effects) that may occur as a result of natural events or anthropogenic activities. The perception of the community/individual varies according to not only the isolated phenomenon of climatic change or hazard, but also their levels of exposure to the disaster and their understanding of and interaction with the environment. The types of hazards and climate change factors (sea level rise, erratic rainfall, rapid coastal erosion, land loss, saline water ingress and regular flooding during high tide) the islanders of the Sundarbans are facing in their daily lives are not happening suddenly. There is barely any “suddenness” in the said phenomena. In the context of the Sundarbans, in the absence of any other alternatives, the islanders are living with the hazards over generations. Thus, it won’t be an exaggeration to say that the islanders are not exposed to the hazard; they are being introduced to it from the very beginning of their existence. Erosion, landloss and flooding have been intrinsically textured in the daily lives of the islanders.

Identifying factors affecting well-being in the coastal regions:

In the absence of a standard framework for assessment of factors affecting well-being in the coastal regions, initially a pilot study was done to identify the various factors influencing well-being. Based on the qualitative data obtained during this phase, the below-mentioned factors were identified. Many of the indicators match those of the study “Multidimensional Well-being: An Index of Quality of Life in a Developing Economy” by Haq and Zia (2013).

a. Indicators of objective well-being:

- Material living standards
  - Annual income of the households
  - Monthly expenditure of the households
  - Assets (no. of different livestock, landholdings, etc.)
- Education
  - Literacy rate age 15+: Ability to read a newspaper and to write a simple letter
  - Percentage of females who completed primary level or higher education level
  - Percentage of males who completed primary level or higher education level
- Health
  - Percentage of children who received full immunization course
  - Percentage of women who received prenatal consultation (from qualified doctors or nurses)
  - Percentage of women having safe delivery
  - Percentage of households who can reach nearest health care unit within 30 min
  - Percentage of households having nutritional deficiency
- Living conditions
  - Percentage of households having access to safe drinking water
  - Percentage of households having sanitary toilets
  - Percentage of households having access to electricity
  - Percentage of households using gas or kerosene oil as fuel used for cooking
  - Types of houses (kaccha, semi-kachha or pakka)
  - Percentage of houses having road connectivity
- Employment opportunities
  - Livelihoods dependent on riverine resources
  - Livelihoods dependent on economic/social resources
- Political voice and governance
  - Voting rights
  - Participation in decision-making
  - Governmental assistance
- Environment
  - Number of floods per year
  - Number of cyclones per year
  - Percentage of households to lose land
- Emergency services:
  - Access to disaster shelters
  - Access to relief

Table 2: Five-point Likert Scale used for Assessment of Subjective Well-being

Five-point Likert Scale				
-2	-1	0	1	2
Not at all satisfied	Slightly satisfied	Moderately satisfied	Very satisfied	Extremely satisfied

Table 3: Indicators of Subjective Well-being and Responses Based on Gender of the Respondents

Indicators in Terms of Satisfaction	-2		-1		0		1		2	
	M	F	M	F	M	F	M	F	M	F
Education	25 %	15 %	35 %	30 %	30 %	50 %	10 %	5 %	-	-
Healthcare	40 %	55 %	30 %	35 %	30 %	10 %	-	-	-	-
PWD	20 %	15 %	20 %	15 %	30 %	40 %	30 %	30 %	-	-
Employment	35 %	20 %	30 %	40 %	25 %	30 %	10 %	10 %	-	-
Public safety	10 %	20 %	25 %	25 %	40 %	30 %	25 %	25 %	-	-
Warning system	20 %	30 %	30 %	25 %	20 %	21 %	30 %	24 %	-	-
Way of life	40 %	20 %	22 %	40 %	28 %	32 %	10 %	8 %	-	-
Personal relationships	20 %	43 %	32 %	20 %	23 %	20 %	25 %	17 %	-	-
Aspirations	44 %	40 %	16 %	16 %	16 %	44 %	24 %	-	-	-

Assessment of human well-being must consider both objective and subjective dimensions of the well-being aspect. Thus, different indicators of life have been incorporated in this study; use of objective and subjective measures is crucial to get a holistic picture. Rigid restriction to objective indicators considerably narrows the perspective, whereas little bit of flexibility helps in exploring the topic.

b. Indicators for subjective well-being:

- Satisfaction with education facilities
- Satisfaction with healthcare infrastructure
- Satisfaction with activities of Public Works Department (PWD)
- Satisfaction with available employment opportunities
- Satisfaction with public safety measures
- Satisfaction with early warning system
- Satisfaction with way of life
- Satisfaction with personal relationships
- Achievement of aspirations

All these abovementioned indicators were measured on the basis of a 5-point Likert scale. Named after the inventor psychologist Rensis Likert, the Likert scale is a rating scale used in research to assess people's attitude towards certain topics.

Preferences and perceptions towards certain topics change across genders. To understand if attitude of male and female respondents towards a particular topic varies, the responses were sorted on the basis of gender.

The responses were mostly in the category of "moderately satisfied" (58 per cent), followed by "not at all satisfied" (57 per cent). Interestingly, none of the respondents were extremely satisfied with the different parameters. It is alarming that 55 per cent of the women were not at all satisfied with the healthcare infrastructure, probably because they face maximum trouble during pregnancy and gynecological issues. The average time taken to reach effective health facilities is more than 1.5 hours on these islands. During storms, cyclonic disturbances and low tides, the ferry service comes to a halt. This phenomenon makes the situation much more disturbing. Again in the case of personal relations, 43 per cent of women were not at all satisfied, due to the extensive out-migration problems.

As women are left behind when men of the households migrate, invariably the social fabric changes. Often men come back with lots of addictions; this pattern creates chaos in the rural society. A considerable percentage of elderly people of the villages narrated the increase in the incidents of domestic violence when the migrant men come back to villages in their respective houses. Even though the roads, water supply and electricity is a major problem in this region, 70 per cent of the total respondents (including men and women) were “moderately satisfied” and 60 per cent of the total respondents (including men and women) were “very satisfied”. This phenomenon can be explained in terms of historical backwardness. There was no initiative from the administration earlier for development of these facilities, but in recent years, there is a noticeable initiative for road construction, piped water supply and electricity. These visible initiatives are triggering a sense of hopefulness and satisfaction among the islanders. Among the male respondents, 40 per cent stated extreme dissatisfaction about their way of life. The respondents reported about the sheer lack of opportunity and freedom of choice in this study area. Livelihood diversifications of the islanders also revolve around natural resources; Ellis (2000) rightly stated that the reasons that individuals and households pursue diversification as a livelihood strategy are often divided into two overarching considerations, which are necessity and choice. Necessity refers to involuntary and desperate reasons for diversifying (land loss, environmental deterioration drought, floods, civil war). Choice, by contrast, refers to voluntary and proactive reasons for diversifying. In the context of the islanders, the diversification is not a proactive decision; by nature it is highly reactive. Thus, it is a form of “distress diversification”; it is the last resort for the islanders rather than a lucrative alternative livelihood, leading to further marginalisation. Depending on the location of the households and social relations the spread of warning and information varies. As there is no particular centre for dissemination of climatic warnings, people are dependent on the community and media. Access to media is also highly skewed on this island.

Apart from these highly subjective perceptions of well-being, human well-being has been captured objectively as well. Table 4 depicts the various indicators chosen to represent the multidimensional objective well-being and the variability in terms of the distance from the shoreline. The convergence of subjective and objective well-being can give an idea of how in a particular setting these two types of well-beings operate together.

Table 4: Indicators of Objective Well-being

Indicators	Maximum		Minimum	
	<500 mtr	>500 mtr	<500 mtr	>500 mtr
Annual income	90,000/-	2,00,000/-	30,000/-	80,000/-
Monthly expenditure	7,000/-	15,000/-	2000/-	6,000/-
Landholding	0	3 bigha	0	0
Livestock				
Poultry birds	0	4	0	0
Cows	0	1	0	0
Goats	0	2	0	0
Literacy I5+	60 %	87 %	42 %	85 %
Percentage of females in primary education	67 %	85 %	50 %	70 %

(*Continued*)

Table 4: (Continued)

Indicators	Maximum		Minimum	
	<500 mtr	>500 mtr	<500 mtr	>500 mtr
Percentage of males in primary education	75 %	89 %	70 %	85 %
Full immunisation	44 %	65 %	30 %	50 %
Prenatal care	30 %	46 %	18 %	35 %
Safe delivery	40 %	60 %	23 %	51 %
Healthcare within 30 min	20 %	28 %	10 %	20 %
Nutritional deficiency	68 %	56 %	47 %	39 %
Safe drinking water	24 %	45 %	10 %	37 %
Sanitary toilets	7 %	21 %	0 %	15 %
Electricity	0 %	18 %	0 %	6 %
Source of fuel				
Kerosene stove	5 %	40 %	0 %	25 %
Fuelwood	95 %	60 %	100 %	75 %
Types of house				
Kaccha	80 %	50 %	75 %	40 %
Semi-pakka	25 %	45 %	20 %	41 %
Pakka	0 %	19 %	0 %	5 %
Road connectivity	10 %	60 %	0 %	50 %
Dependency on riverine resources	90 %	75 %	80 %	60 %
Dependency on economic/social resources	20 %	40 %	10 %	25 %
Voting rights	100 %	100 %	95 %	99 %
Political participation	36 %	54 %	10 %	23 %
Government assistance	28 %	35 %	15 %	27 %
Land loss	68 %	27 %	35 %	20 %
Access to shelters	60 %	74 %	48 %	67 %
Access to relief	64 %	70 %	50 %	65 %

Discussion

The percentages in Table 4 depict the horrible condition of basic necessities in the lives of the islanders. There are some significant observations from the field data; all these observations can be vital in formulation of policies and further probing into the matter.

- The average annual income of respondents <500 mtr varies greatly from that of the respondents >500 mtr. Monthly expenditure follows the same pattern. The people living in the close vicinity of the shoreline have very few alternative options for livelihood.

- Landholding of islanders staying within 500 mtr from the shoreline is nil. Due to rapid erosion and saline water ingress, land loss is a common phenomenon here.
- None of the islanders within 500 mtr own livestock. The respondents stated that rearing and maintenance of animals have been impossible for them due to erosion and repeated relocation issues. Thus, rearing farm animals is not much of a potential livelihood option.
- Healthcare infrastructure is indeed very poor on this island. The reason behind utter dissatisfaction of women with healthcare services can be well understood from the low percentages of children having full immunisation as well as low percentages of women having prenatal care and safe delivery option. The absence of a proper well-equipped healthcare facility within the villages/near the villages compels the islanders to travel longer for treatment.
- Safe drinking water supply, electricity and sanitary toilets are not widely available yet, though initiatives are being taken by administration and people are quite satisfied with the progress.
- Most of the houses are kachha mud houses and these are highly vulnerable to saline water intrusion. Saline water damages the mud walls and causes weakening of the physical structure. Apart from that, during coastal surges loss of property is a common phenomenon.
- The majority of the population are entirely dependent on fuelwood for cooking. During monsoon and storm surges availability of fuelwood is a major problem.
- Within 500 mtr from the shoreline, there is no proper road. Thus access to these areas is difficult even for people from the central part of the same island. These areas in turn remain neglected. In case of any emergency, the unavailability of road is an issue of grave concern.
- An average of 85 per cent of the respondents within 500 mtr from the shoreline are dependent on riverine resources (such as fish, crab and prawn seedlings). This dependency has a twofold impact; it leads to biodiversity loss due to overexploitation and it’s not a safe and sustainable option for living.
- Dependency on other forms of economic/social resources is very low in the study area. It leads to increased vulnerability of the exposed community to climatic shocks and stresses.
- Even though most of the respondents have voting rights, political participation is low. They are not very involved in local level decision-making.
- A large section of the coastal population is continuously battling with land loss. 68 per cent of the population within 500 mtr from shoreline reported that their homestead land is lost. The sea is rising and it is slowly engulfing the land mass.
- Medium access to shelters and access to relief was reported from the field. The exact reasons behind that require further probing.

Conclusion

All the indicators of objective and subjective well-being point to a simple understanding, that the factor behind the disruption of well-being in a particular location is highly site specific. There is no shortcut to measure well-being as well as the relation between well-being and slow-onset disasters. The community of coastal Mousuni Island of the Indian Sundarbans is continuously facing the brunt of sea level rise and erosion induced land loss. It is highly debatable if this problems can be termed as shocks; the nature of the hazard and its interaction with people show that it is more of a “stress” for the community rather than a “shock”. In the absence of a clear understanding about the multidimensional impacts of slow onset disasters and their effect on different well-being indicators, there is no integrated approach to tackle the situation. As the stresses of this eco-region are not rapid onset disaster, the plight of these people is not taken care of. They are a constantly retreating race. In spite of several limitations, such as time constraint, climatic fluctuations, onset of monsoon and lack of transport facilities, this study tries to provide insight about the factors affecting well-being of people on this island. Further probing and quantification is needed for formulation of a policy recommendation.

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Vulnerability Assessment and Restoration of Cyclone-Damaged Trees in GITAM University Campus at Visakhapatnam

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ABSTRACT: Trees shrubs and ground covers play an important role in improving environmental quality, modifying microclimates and in reducing the urban heat island effect in cities. However in coastal climates which are prone to severe cyclonic storms, trees are vulnerable to various types of damage from extreme winds.

Over the years various species of trees and shrubs have been introduced in the GITAM University campus making it a green and eco-friendly campus. The severe cyclonic storm which struck the city of Visakhapatnam on October 12, 2014, caused immense damage to the green cover of GITAM University. In order to assess the vulnerability of the different types of trees in the campus to various types of damage caused by cyclonic storms a damage assessment has been carried out. Four principal ways in which most of the trees suffered damage, namely defoliation, uprooting and wind throw, damage to co-dominant stems and salt spray damage have been identified. During the post-disaster stage, debris clearance and efforts to restore many of the damaged trees have been successfully carried out. The study has thrown light on the various ways that trees respond to cyclonic winds and shows how pre-cyclone precautions and post-cyclone restoration efforts can increase the resilience of trees to severe cyclones.

KEYWORDS: uprooting, salt spray damage, co-dominant stems, wind-resistant trees, restoration of trees

Introduction

The picturesque and serene campus of Gitam University is located adjacent to the Rushikonda Hill along the Visakha–Bheemli coastal corridor just a kilometre away from the sea. Spread over an area of more than 100 acres, the campus is home to a large number of indigenous and exotic species of trees, shrubs and groundcovers. On October 12, 2014, the Very Severe Cyclone Hudhud with wind speeds exceeding 180 km/hour made its landfall at Kalilashgiri, located close to the GITAM University and caused immense damage to several of its buildings and infrastructure. Extensive damage was inflicted to the vegetation of the campus by the cyclonic winds. Many trees were completely uprooted or suffered from loss of foliage or breakage of stems.

A damage assessment has been carried out by the author to understand the different ways that trees fail in the face of strong winds. The study has helped in identifying the vulnerability and resilience of various trees, shrubs and palms to cyclonic storms. Post-disaster, quick clearance of debris and careful restoration of many storm damaged trees have helped in reviving and saving many storm damaged trees. Lessons learned from this study can help in taking proper pre-disaster preparedness measures and make efforts to reduce the vulnerability of trees to damage from future storms.

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(a) (b)

Figure 1: (a) Small leaved *Dalbergia sisoo* tree near Shirdi Temple, GITAM campus. (b) Defoliated *Azadirachta indica* (Neem) tree behind the School of Architecture, GITAM campus.

Types of Damage

Trees, palms and shrubs in the GITAM campus have been affected by Hudhud in several ways. Salt damage to roots and leaves, wind damage to trunks and branches and loss of leaf tissue are the most common ailments that have been observed in the aftermath of the cyclonic storm. The most common form of tree damage in the GITAM University campus was defoliation, uprooting, followed by snapped trunks and broken branches and discoloration and salt burn salt to the leaves of different species of trees vulnerable to salt spray damage.

Defoliation

In the face of strong cyclonic winds one strategy adopted by trees with small leaves is to shed their leaves and at times even sacrifice some stems to reduce the wind stress on their main branches. When the leaves are lost, trees also lose the ability for adequate photosynthesis. However defoliated trees should not be discarded under the assumption that they are dead as gradually they tend to refoliate. In the Nightingale Park in the GITAM campus many Tectona grandis trees with large leaves which did not shed their leaves ended up getting uprooted whereas trees such as *Azadirachta indica* (Neem) and *Samanea saman* (Rain Tree) which shed their leaves remained intact.

Terminalia cattappa trees (Fig. 2a) and *Araucaria heterophylla* trees (Fig. 2b) with their tapered branches which allowed the wind to pass did not suffer much damage unlike other trees in their vicinity such as *Greviella robusta* which got completely uprooted. *Terminalia catappa* trees were the first to refoliate after the cyclonic storm.

Fig. 2(a) shows a refoliated *Terminalia catappa* tree in front of the Bheema's Canteen in the campus. The tree suffered minimal structural damage as the layered branches of the tree allow high-velocity winds to pass through. Fig. 2(b) shows Araucaria trees (tall trees with a columnar habit) behind the Vishveshwaraiyya Building which suffered minimal damage under strong wind conditions which *Greviella robusta* trees in their vicinity, which are tall trees with a dense crown and brittle wood, were completely uprooted during the storm. These trees have been subsequently restored.

(a) (b)

Figure 2: (a) Refoliated *Terminalia catappa* tree (b) Araucaria trees with stable architecture

Salt Spray Damage

Salt damage from flooding and ocean water carried on the wind can infiltrate the soil and affect tree nutrition and water absorption. Salt displaces the nutrients trees need to survive, and excessive salt causes soil aggregates to break down, affecting aeration and water uptake. Salt in the soil will actually pull moisture out of the roots, causing root desiccation. According to Appleton et al. (1990), the most frequently seen symptoms from direct salt deposition on above ground tree parts are delayed bud break, reduced leaf size, desiccation of leaf margin and tips, premature defoliation, premature fall coloration, bud and stem kill or dieback and reduced shoot growth. Sinclair et al. (2007) have reported instances of salt spray damage on plants 80 km from the Atlantic Ocean with most of the damage usually occurring within approximately 300 m of the ocean.

In the wake of Hudhud salt spray damage has been observed in the following plant species in the GITAM campus: *Mimumsops elengi, Tecoma castinifolia, Acacia auriculformis, Callophylum ionophyllum Polyalthia longifolia, Ficus elastic and Bauhinea blackeana* trees, and mostly in shrubs such as Aralia (bush) and *Graptophyllum pictum* among others. Trees and shrubs which showed high tolerance to salt spray include *Thespesia populnea, Terminalia cattapa, Nerium oleander and Cassia biflora* (Mohan, 2004).

(a) (b) (c)

Figure 5: (a) Salt spray damage to *Tecoma castanifolia* trees (b) leaves of *Mimumsops elengi* trees affected by salt spray (c) salt spray damage to Aralia bush shrubs

(a) (b)

Figure 6: (a) Leaves of *Ionophyllum callophylum* before Hudhud (b) salt spray damaged leaves of *Ionophyllum callophylum* post-Hudhud

Seigendorf (1984) recommends washing the foliage and branches of trees affected by salt spray with a stream of water every third day. Mulching (a simple process of using garden leftovers such as leaves, grass clippings and shredded trees to cover any bare soil) may be used to prevent the growth of weeds and subsequent build up of salt in the soil, prevent evaporation and retain moisture at the root zone mulching in the garden. Rainfall occurring in the wake of a cyclonic storm is also effective in mitigating the adverse effects of salt spray damage.

Wind Throw

Wind throw, uprooting or blowdown of trees refers to trees uprooted or broken by wind. Breakage of the tree trunk instead of uprooting is sometimes referred to as windsnap. Windthrow is a result of failure of the root system. Soil type and condition can decrease the wind requirement for windthrow significantly. Very sandy soil lets go more easily than substantial loam, and waterlogged clay soils break up more easily. Uprooting usually occurs when soils are wet and the tree's roots are unable to securely anchor themselves in the soil. Hence the tree tends to have shallow roots which makes the tree vulnerable to uprooting.

Slender, top heavy tall trees with shallow roots such as *Sweitenia mahagoni, Greviella robusta, Spathodea campanulata* trees in the Gitam Campus became prime candidates for wind throw during Hudhud. According to David R. Foster, Director Harvard Forest at Harvard University, taller trees are more susceptible to wind throw as the tree trunk acts as a lever and so the force applied to the roots and trunks increases with height. Foster also explains that tree species vary in characteristics that influence their susceptibility to breakage and uprooting: the strength of their wood (controls breakage), the depth and strength of their roots (controls uprooting) and the shape of their crowns (branch arrangement) determines how much wind they intercept.

Strong, deep-rooted trees may not collapse during a storm, but the limbs of the tree in the canopy can get broken. Poor structure in the crown will result in limb breakage, splitting and tearing. Under the stress of high-velocity winds brittle trees drop their branches or split apart. Some brittle trees in the campus that have lost major limbs in the cyclonic storm are: *Acacia auriculformis, Pongamia pinnata, Greviella robusta, Calistemon lanceolatus, Eucalyptus* species, *Dalbergia sissoo and Spathodea campanulata*. Species with shallow root systems that have been found to be vulnerable to wind throw include *Peltorphorum* spp., *Thespesia populnea, Albezia lebbek, Sweitenia mahagoni, Dalbergia sisso* among others.

(a) (b)

Figure 4: (a) Uprooted *Spathodea campanulata* tree in front of the School of Architecture (b) uprooted *Calistemon lanceolatus* tree in the garden in Kokila Sadan

According to Seigendorf (1984) the greatest measure to reduce breakage and wind throw of trees involves pruning which reduces the surface area of a tree allowing more wind to pass through. Pruning should allow 10–25 per cent of sunlight to pass through small and young trees and 25–45 per cent through large trees. Further Seigendorf suggests that greater movement of wind through the crown can be facilitated by thinning limbs so that the remaining ones have a spacing of 16–18 inches. Trees with columnar habits are less amenable to pruning. By removing small branches from the outer edges of trees with dense canopies they can be made more wind resistant.

(a) (b)

Figure 3: (a) Damaged Peltophorum trees with codominant stems (b) damaged eucalyptus tree showing bark inclusion

(a) (b)

Figure 7: (a) Leaning *Pongamia pinnata* tree in NTR Park (b) *Pongamia pinnata* tree with broken stem near School of Architecture

Damage to Codominant Stems

Trees with a single dominant stem such as *Ionophyllum callophyllum, Aurucarea hetrophylla* among others have withstood the cyclonic storm with minimal damage whereas trees with codominant stems such as *Peltophorum* spp., *Greviella robusta, Spathodea campanulata*, *Eucalyptus* spp. *Pongamia pinnata* among others have suffered extensive damage such as snapping of their trunks and breakage of stems. The term “codominant stems” is used to describe two or more main stems (or “leaders”) that are about the same diameter and emerge from the same location on the main trunk (Smiley, 2003). Trees can split apart because of the bark inclusion in the union where the two codominant stems are joined.

Codominant stems tend to fail much more often than others, especially in storms. Included bark forms in the junctions of codominant stems where there is a narrow angle union. A “V” union is much more likely to fail than a “U” union as stems with a V union compress bark between them, which results in little physical connection between them. Fig. 3(a) shows damaged codominant stems of Peltophorum trees along the road in front of the Ganesh temple in GITAM University and Fig. 3(b) shows bark inclusion in a damaged Eucalyptus tree in front of the indoor stadium in the campus. Trees with bark inclusions can be braced together with rods (right) and cables. This helps prevent the trunks from separating from each other when confronted with strong winds. Structural pruning is another method of preventing the impact of this defect. When major parts of the trunk of a tree with codominant branches are damaged, then it may have to be removed as a last resort.

Vulnerability Analysis of Trees to Storm Damage

After analysing the various ways that different trees have responded to the cyclonic storm an attempt has been made to understand the vulnerability or resilience of different trees in the campus to cyclonic winds. Further studies on damage to trees in various parks, residential localities and the Andhra University Campus in Visakhapatnam by the author have shown similar damage has occurred to trees along the coastal corridor.

Trees that are most vulnerable to storm damage and have little chances of survival include trees that have a split trunk, heavily leaning trees, have more than half of their crown missing and have severed or cut roots. Tall, older trees with severed roots are more vulnerable than younger medium height trees. Among the palms in the campus it is seen that top heavy palms such as *Caryota urens* and *Cocos nucifera* are vulnerable to uprooting and breakage of stems whereas palms with streamlined trunks such as *Hyphorbe lagenicaulis* (Champagne palm) and *Veitchia merreli* have shown a high degree of resilience. Table 1 summarises the vulnerability/resilience of trees and palms in the GITAM University campus.

Table 1: Vulnerability/Resilience of Trees and Palms in GITAM Campus, Visakhapatnam

Botanical Name	Vulnerability/Resilience
Spathodea campanulata	Vulnerable to uprooting, defoliation and breakage of stems
Bauhinea variegata	Vulnerable to salt spray damage and uprooting
Peltophorum pteracarpum	Vulnerable to snapping codominant stems, uprooting
Callophyllum ionophyllum	Vulnerable to damage by salt spray but wind resistant
Pongamia pinnata	Mature trees prone to breakage of codominant stems
Delonix regia	Brittle bark. Susceptible to loss of canopy and stems
Dalbergia sisoo	Vulnerable to uprooting, defoliates quickly
Tecoma castanifolia	Not salt spray resistant but quick to recover
Sweitenia mahagoni	Shallow roots, top heavy. Vulnerable to uprooting
Mimumsops elengi	Wind resistant but vulnerable to salt spray damage
Terminalia catappa	Highly wind resistant, refoliates fast recovery after cyclone
Greviella robusta	Slender, top heavy. Vulnerable to uprooting
Tectona grandis	Mature trees sometimes get uprooted as it does not defoliate
Eucalyptus spp.	Easily uprooted and can damage adjacent buildings
Azadrachta indica	Defoliation without branch breakage. Highly resilient
Bambusa vulgaris	Highly resilient, wind resistant
Ficus benjamina	Vulnerable to salt spray damage. Wind resistant
Acacia auriculformis	Easily uprooted, brittle stems. Vulnerable to uprooting
Polyalthia longifolia	Leaves vulnerable to salt spray damage. Recovers in time
Nerium oleander	High resistance to wind and salt spray tolerance
Cassia biflora	High resistance to wind and salt spray damage
Araucaria heterophylla	Stable, pyramidal symmetrical form. Wind and salt resistant
Caryota urens	Top heavy. Highly vulnerable to uprooting
Bambusa vulgaris	High wind resistance when planted in groups
Pisonia alba	Vulnerable to breakage of codominant stems
Hyphorbe lagenicaulis	Aerodynamic form. Wind resistant and resilient to salt damage
Bismarck nobilis	Top heavy. Suffers moderate damage under high winds
Areca catechu	Wind resistant but vulnerable to moderate salt spray damage
Veitchia merelli	Highly resistant to damage from wind and salt spray
Cocos nucifera	Top heavy. Fronds damaged but standing

Post-disaster Debris Clearance

In the aftermath of Cyclone Hudhud the campus was completely strewn with the debris of uprooted trees, broken stems of trees and other windblown debris which blocked many roads and blocked the entry into buildings. Debris not collected can cause damage if it becomes airborne, and it can also block drainage catch basins and cause flooding. Concerted efforts by the university authorities, students volunteers from the NSS wings of various schools and departments of the university, the teaching and non-teaching staff helped in clearing the large amount of debris that had accumulated in the wake of the cyclonic storm. Fig. 8(a) shows an inspection being carried out for assessing the different types of debris that required clearing. Since most of the debris deposited made many of the roads inaccessible, the roads had to be swept and the debris stored at a point by the side of the roads (see Fig. 8(b)).

Since many large codominant stems snapped during the storm, these branches had to be cut down to manageable sizes for loading in the disposal trucks as shown in Fig. 9(a). Tree canopies had to be cleaned of broken limbs. Carpenters and skilled personnel were engaged in removing broken stems and branches from trees as these have the potential for injuring passers-by and should be removed immediately in the aftermath of a storm. The broken branches being removed from a Peltophorum tree is shown in Fig. 9(b). Debris being loaded in trucks for disposal is shown in Fig. 10(b).

(a)

(b)

Figure 8: (a) An inspection of the debris to be cleared (b) removing debris from roads by NSS volunteers of GITAM University

(a)

(b)

Figure 9: (a) Cutting of large broken stems prior to disposal (b) removing broken stems from codominant branches of a Peltophorum tree

(a) (b)

Figure 10: (a) and (b) loading debris in trucks for disposal

Conservation of Cyclone Damaged Trees

Not all trees uprooted trees uprooted in a storm can be saved, but in certain cases it is possible to restore the tree by replanting it. Also at times trees have better chances of survival if they blow over rather than break up. This is seen in the case of the four *Greviella robusta* (Silver Oak) trees in the rear open space behind the Vishveshwariah Building in the campus. The tall slender Silver Oak trees, with shallow roots were completely uprooted by the storm whereas other trees with codominant stems such as *Pongamia pinnata* in the vicinity suffered from breakage of the main stems. Restoration efforts have helped in saving these uprooted trees.

For reestablishing the uprooted Greviella trees, the roots of the trees were kept moist to encourage the formation of new roots. Next holes were excavated to accommodate roots. Torn or jagged roots were cut and the trees were pulled up as straight as possible and the sites were backfilled with soil and water and the trees were straightened and staked. Watering was done three times a week for the replanted trees. After a period of six months the stakes were removed. The uprooted Greviella trees are shown in Fig. 11a. Staking of the Greviella tree is shown in Fig. 11(b) and Fig. 11(c) shows the fully restored Greviella trees with the stakes removed.

(a) (b) (c)

Figure 11: (a) Uprooted *Greviella robusta* trees (b) staking of a *Greviella robusta* tree (c) restored Greviella tree with stakes removed

(a) (b)

Figure 12: (a) and (b) Lifting and staking of a fully uprooted *Sweitenia mahagoni* tree in Ganesh Park

Many tall, top heavy, slender *Sweitenia mahagoni* trees in the NTR Park and Ganesh Park in the campus suffered from extensive damage from the cyclonic winds. Many were uprooted and others suffered from twisting of the main stem and broken branches. Most of the uprooted trees in these two parks have been restored. Straightening and staking of a Mahogany tree in the Ganesh Park are shown in Fig. 12(a) and 12(b) respectively.

Many single-stemmed *Callyphyllum ionophyllum* trees that were exposed to the strong cyclonic winds despite not getting uprooted got defoliated and their leaves exhibited signs of salt spray damage. Staked *Callophyllum ionophyllum* trees behind the School of Architecture are shown in Fig. 13(a). However many trees of the Eucalyptus trees suffered from uprooting and breakage of codominant stems (Fig. 13(b)).

(a) (b)

Figure 13: (a) Staked *Ionophyllum callophylum* trees (b) staked Eucalyptus trees

Conclusion

Cyclonic storms can be predicted in advance through early warning systems. Hence pre-disaster preparedness measures such as denutting of coconut trees, pruning the foliage and stems of codominant trees can help in reducing the damage to trees in the event of a cyclonic storm. Trees with well-spaced framework along a single dominant trunk and that are salt resistant fare better in cyclones. Post-disaster operations such as quick removal of debris and broken and hanging stems from damaged trees help prevent potential hazards. Pre-disaster and post-disaster assessment damage to trees coupled with structural pruning and suitable conservation measures would help in making landscapes safe, resilient and sustainable.

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Human Behavioural Features and Disaster Resilience: An Analysis Based on Cases of Cyclone Survivors in Odisha

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ABSTRACT: The degree of human behaviour, before or during natural disasters, depends upon the damage capacity and the damage caused to the community. The resilient psychological confidence of the people helps the community people to take proper preparedness which can minimise the risks. This is reflected in the form of confidence to face any other disasters in future. There is seen a psychological fear among the people when similar conditions from the past, such as still wind circulation, creation of low pressure in sea and temperature fluctuation, are observed by the people. Proper forecasting helps a lot in reducing the level of hysterical behaviour by the victims. Proper preparedness, awareness among community people, accuracy in forecasting and technological interventions are among a few factors which led to control of hysterical behaviour by the citizens during the last Odisha Cyclone. The level of paranoia of the victims are determined by various stages of human behaviour, like shocking stage, suggestive stage and recovery stages; and the behaviour of victims of previous cyclones like Phailin, Hudhud and Titli has been determined by normal and abnormal behaviour of the victims which will be elaborately dealt with in the paper. To test the assumption, a comprehensive compilation of case studies (10 cases) are conducted in four coastal blocks in Paradip areas of Jagatsingpur district, with help from a corporate, i.e. Paradeep Phosphates Limited. The study will be purely qualitative in nature. This empirical case-based study has also revealed how corporate intervention helps in reducing the level of psychological trepidation of the victims. The full study also suggests a model where corporate social responsibility, preparedness and psychological aspects of victims are taken together for a better solution.

KEYWORDS: paranormal behaviour of cyclone survivors, cyclone preparedness, corporate social responsibility

Introduction

Natural disasters are notable for their global frequency and diversity, capable of generating both physical and psychological effects on the human populace of the world. It has endangered human lives and caused severe human sufferings. Since time immemorial, the human species has been subjected to countless death, destruction and devastation authored by various natural catastrophes. Be it a cyclone, typhoon or hurricane, each of these brute forces of Mother Nature is capable of wreaking havoc in the human settlement as well as wiping out cities from the face of the earth. They leave in their wake a trail of death, destruction and despair. These colossus monsters of "Mother Nature" have always been instrumental in aggravating human suffering to an unimaginable extent. The historicity of natural disasters depicts a very heart-wrenching scene of chaos, pandemonium, deaths and destruction. Whether the destruction of Helike, once bustling city of ancient Greece by a gigantic tsunami, or the gradual drying of the once fertile, the Mediterranean region,

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each one of them can be attributed to the dance of destruction played by some of these rogue natural catastrophes.

The human trauma that is caused by these natural calamities is sometimes inexplicable and heart-rending. The population which somehow escapes the clutches of death during these disasters is left with post-traumatic stress disorder (PTSD) by losing their near and dear ones. This leads to serious social disorganisation as well as disorientation. According to a report by the United Nations International Strategy for Disaster Reduction (UNISDR), the worldwide reported economic losses from various natural catastrophes such as earthquakes, hurricanes, and other climate-related disasters cost nearly $2.9 trillion during the last two decades.

Even though the human race seems to be a puppet in the hands of the vagaries of nature, it possesses this inherent and proven ability to rise up again from the ashes of destruction like a phoenix and rebuild itself in a stronger manner which can withstand the ravages of times. Charles Darwin in his magnum opus, *On the Origin of Species*, propounded this evolutionary theory of “Natural Selection” which basically refers to the survival of the species that is better adapted to for the immediate local environment as well as any sort of hostile change in the natural environment. In Darwinian terms the phrase is best understood as “survival of the form that will leave the most copies of itself in successive generations”.

Therefore it becomes important for *Homo Sapiens* (human beings) to enhance their adaptability to any kind of unfavourable as well as hostile change in the natural environment so as to mitigate the impediment to the growth and development of human civilisation.

The very survival of humans thus depends upon the dexterity of resilience shown towards the change in natural environment. Resilience refers to the ability of individuals, socities and socio-economic systems to cope with the sudden impact of natural catastrophes and to restore as quickly as possible their ability to function and their capacity to act.

The concept of human resilience is relatively new in the context of disaster reduction. It is characterised by resistance and flexibility and aims at quickly returning life to normal. However, it would be a mistake to see resilience merely in terms of resistance and vulnerability. This is because the ability to respond flexibly is a precondition for quickly restoring normal conditions after a disaster. It would also be short-sighted to see resilience simply as an emergency response system, because the crucial criterion for resilient systems is that they are able to restore all key functions as quickly as possible.

As the popular saying goes on, “Hell hath no fury like a woman scorned” (*The Mourning Bride* by William Congreve), it’s better for us not to provoke “Mother Nature” through increasing human interferences in natural processes which might cost us dearly in the upcoming future.

There is no denying the fact that natural disasters have been detrimental to the growth and prosperity of human civilisation, yet it throws a plethora of challenges to the human race, so as to better equip itself to fight back and strive for sustainable development without abusing and causing much damages to the nature.

The objectives of this empirical case-based study are to establish the relationship between various stakeholders of the society such as civil societies, corporates, self-help groups (SHGs), government bodies and other groups in mitigating the devastating effects of natural catastrophes especially tropical cyclones. It also reveals the corporate social responsibility (CSR) activities carried out by corporate bodies mainly PPL to bring back normalcy in people’s lives after the disaster.

Description

The state of Odisha lies in between the latitudes 17.780N and 22.730N and between longitudes 81.37E and 87.53E. It is the 9th largest state by area and 11th largest state by population. It has a coastline of 485 kilometres or 301 miles.

Since its inception, during the British period, the state of Odisha has been a mute spectator to a gamut of natural catastrophes predominantly by the tropical cyclones that are originated in the Bay of Bengal. Since 1990, a total number of five tropical cyclones have affected the state of Odisha:

- 1999 Odisha Cyclone
- Cyclone Phailin (2013)
- Cyclone Hudhud (2014)

- Cyclone Helen (2013)
- 2004 Myanmar Cyclone

To start with the 1999 Odisha Cyclone (IMD designation BOB 06, JTWC designation 05B), it was the strongest recorded tropical cyclone in the North Indian Ocean and the most destructive one in the region. The 1999 Odisha Cyclone organised into a tropical depression in the Andaman Sea on October 25, though its origins could be traced back to an area of convection in the Sulu Sea four days prior. The disturbance gradually gained momentum as it took a north-westerly path, reaching cyclonic storm strength the next day. Taking advantage of highly favourable conditions, the storm quickly intensified, attaining super cyclonic storm intensity on October 28, before peaking on the next day with winds of 260 km/h (160 mph) and a record-low pressure of 912 mbar (hPa; 26.93 inHg). The storm was able to sustain this intensity as it made landfall on Odisha on October 29. The cyclone steadily weakened due to persistent land interaction and dry air, remaining quasi-stationary for two days before slowly drifting offshore as a much weaker system; the storm dissipated on November 4 over the Bay of Bengal. Although its major effects were felt in a localised area of India, the outer fringes of the super cyclone impacted Myanmar and Bangladesh. Ten people were killed in the former, while two were killed in the latter by the storm's rain bands. The storm was the most severe to strike Odisha in the 20th century, wreaking havoc in the state and adjacent areas with high storm surge, powerful winds and torrential rainfall. The storm's impacts exacerbated the damage caused by a very severe cyclone that struck the same region less than two weeks earlier. The 5–6 m (16–20 ft) surge brought water up to 35 km (20 mi) inland, carrying along with it coastal debris and inundating towns and villages. The surge combined with heavy rains produced widespread flooding, damaging around 1.6 million homes and causing rivers to breach 20,005 flood embankments. The storm's effects destroyed numerous crops, including sugarcane, rice and other Rabi crop harvests. Although estimates of the death toll varied significantly at times suggesting 30,000 fatalities, the Government of India enumerated 9887 fatalities in the country, of which a majority were caused by storm surge; over 8000 deaths occurred in Jagatsinghpur. The total damage cost of the destruction wrought by the super cyclone amounted to US$4.44 billion.

According to the data released by the Government of Odisha, the official death toll was 9893, but there were difficulties in making accurate estimates and local people insisted that the final death count was much higher. All the villages along the seacoast in Ersama block of Jagatsinghpur district were washed away. The exact number of casualties is still not clear and debatable. The coastal farming communities were among the worst-hit population by the ravages of the cyclone – it saturated more than 1 million hectares of cropland under salty water and killed more than 406,000 livestock. Millions of people who earned their living on the land were left homeless and without a means to make their ends meet. The cyclone struck just three weeks before the harvest and almost all the plantations in this mostly agricultural community such as paddy fields, sugar cane and vegetable crops were destroyed. About 11 million people, nearly a third of the state's demography of 35 million, were estimated by the UN agencies to be directly affected, having lost their shelter, crops, livestock and livelihoods.

Table 1: Districts with Maximum Human Casualties (OSC 1999)

District	Human Casualties	Population Affected		
		Total	Rural	Urban
Jagatsinghpur	8119	13,62,760	15,99,295	64,117
Cuttack	471	24,17,048	18,47,923	5,69,125
Kendrapara	469	13,70,000	13,03,200	75,800
Puri	303	15,63,000	13,70,000	1,93,000

Source: Gupta, M. C., "Odisha Super Cyclone 1999", National Center for Disaster Management

Table 2: Districts with Maximum Washed Away Houses (OSC 1999)

Name of District	Fully Washed Houses
Jagatsinghpur	12,124
Balasore	11,483
Kendrapara	276
Mayurbhanj	262

Source: Gupta, M. C., "Orissa Super Cyclone 1999", National Center for Disaster Management

Table 3: Districts with Damaged Boats and Nets (OSC 1999)

District	Boats	Nets
Chilika Lake	7560	11,599
Jagatsinghpur	6988	16,271
Kendrapara	6354	8905
Puri	3181	7945

Source: Gupta, M. C., "Orissa Super Cyclone 1999", National Center for Disaster Management

Table 4: Districts with Maximum Number of School Damaged (OSC 1999)

Name of Districts	No. of School Damaged	
	Primary School	High School
Jajpur	2115	208
Ganjam	1972	315
Cuttack	1617	424
Balasore	1288	152
Jagatsinghpur	1111	275

Source: Gupta, M. C., "Orissa Super Cyclone 1999", National Center for Disaster Management

Other sectors which were badly affected by OSC were:

Agriculture Sector: The 1999 Odisha cyclone has completely ruined the agricultural base and logistics in the affected areas of Odisha. In coastal belts, due to high tidal waves the standing crops were damaged, affecting 1.5 million families, and the worst-affected districts were Jagatsinghpur, Cuttack, Kendrapada and Puri.

Loss of Livestock: More than 0.4 million cattle were killed by the super cyclone. The number of cattle death was reported highest in Jagatsinghpur (highest), Kendrapara, Cuttack, Khudra and Puri.

Infrastructure: Complete collapse of communication networks and the surface communication was badly affected due to damage to the road and rail networks. The water supply system and irrigation infrastructure were adversely affected. Drinking water sources were either destroyed or contaminated by the rotting carcasses and aggravated the already vulnerable state of the populace.

Research Institutes: The super cyclone severely affected research institutes and facilities in the coastal belt of the state.

Community-Based Disaster Preparedness (CBDP) Model in Odisha

As a result of the Pilot Project of Odisha Disaster Management, a local disaster management (preparedness and mitigation) system was installed within the 10 blocks from the block level to the gram panchayat and village levels. Increased level of appreciation, especially with case stories of successful disaster preparedness activities in the June 2001 floods and November 2002 cyclone threat, increased demand for the replication of the preparedness and mitigation activities in other blocks within the coverage districts of the project and for the other districts in Odisha.

Local and Community-Based Disaster Preparedness and Mitigation Process

- Training of trainers and orientation on block and panchayat disaster management plans
- Formation of block and gram panchayat disaster management committees, working plans and training of task forces
- Selection and training of volunteers from each village in CBDP and mitigation and community contingency planning (preparedness and mitigation measures)

- Hazard vulnerability and resources mapping discussion, formulation of CCP and approval by the village's palli sabha
- Formation and training of village response groups/ task forces
- Finalisation and approval of the GP and block disaster management plans
- Mock drills, plan implementation and social mobilisation at various levels
- Review and update of plans and continuing improvement of CBDP and mitigation

Diagrammatic Representation of CBDM

Various community-based disaster management (CBDM) experiences have shown that when villagers know what to do and how to protect themselves (especially after the experience of a major devastating disaster such as the Super Cyclone of 1999 and Floods in 2001 and Phailin 2013), they are able to continue and sustain the process.

Research Methodology

Research is based on empirical study and a few observations were made to develop this case. Selection of the test fields was made on the basis of severity of the previous cyclones and degree of cyclone vulnerability.

Vulnerability and Selection of Place of Study

Vulnerability

Odisha is a state on the eastern seaboard of India, located between $17^{0}49'$ and $22^{0}36'$ North latitudes and between $81^{0}36'$ and $87^{0}18'$ East longitudes. It spreads over an area of 155,707 sq km and is broadly divided into four geographical regions, i.e. Northern Plateau, Central River Basins, Eastern Hills and Coastal Plains. It has a 480 km coastline. Its population was 42 million as per the 2011 census. Administratively, the state is divided into 30 districts, 58 sub-divisions, 314 blocks (administrative units in descending order of geographical area and population) and 103 urban local bodies. The average density of population comes to 236 per sq km with significantly higher density in the coastal areas compared to the interior parts.

Odisha is vulnerable to multiple disasters. Due to its sub-tropical littoral location, the state is prone to tropical cyclones, storm surges and tsunamis. Its densely populated coastal plains are the alluvial deposits of its river systems. The rivers in these areas with heavy loads of silt have very little carrying capacity, resulting in frequent floods, only to be compounded by breached embankments. Though a large part of the state comes under Earthquake Risk Zone-II (Low Damage Risk Zone), the Brahmani-Mahanadi graben and their deltaic areas come under Earthquake Risk Zone-III (Moderate Damage Risk Zone) covering 43 out of the 103 urban local bodies of the state. Besides these natural hazards, human-induced disasters such as accidents, stampedes and fire, vector-borne disasters such as epidemics, animal diseases and pest attacks and industrial/chemical disasters add to human suffering.

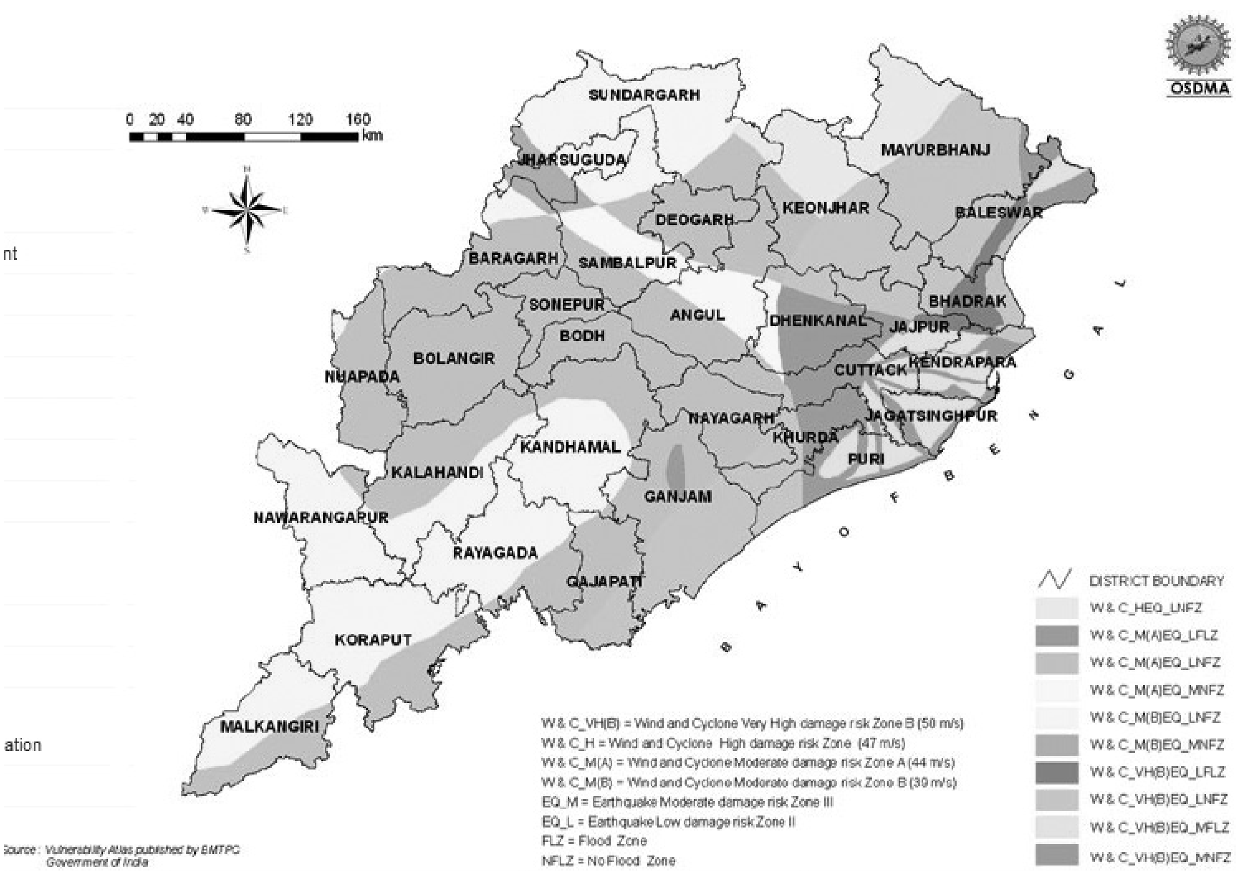
Selection of Place of Study

The multi-hazard map of Odisha demonstrates the vulnerability of Odisha. This converging nature of the hazardous zone played an important role in selecting the district for our study. This decision was coupled with the Odisha Super Cyclone.

Jagatsinghpur District was selected for our study. To be more precise, the blocks were Kujang, Ersama and Balikuda.

The selection was supported by various factors such as the following:

- Landfall point of Odisha Super Cyclone was between Ersama and Balikuda (south-west of Paradeep).
- Paradeep is an industrial area with major industries in that region making the region vulnerable to industrial disasters.
- It is the zone which has overlapped disaster possibilities due to cyclone, flood, moderate earthquake, tsunami and others due to sea.
- Scope to get to see the development of people in major industrial zone.



Multi-hazard Map of Odisha

PPL's Corporate Social Responsibility

As a responsible corporate citizen, PPL is committed to improving the quality of life in the communities around. PPL recognises avowed responsibility of being a catalyst in the socio-economic change process, through niche interventions that supplement the government's efforts in different sectors.

PPL believes that prosperity needs to be shared. Being proactive and conscious of our obligations marks our efforts in addressing inclusive growth – reaching out through innovative community-based interventions. With a lens of inclusiveness, a strategy that enables participation of key stakeholders, a proactive approach, and a long-term vision of transformation, we work within socio-legal frameworks, in a time-intensive, process-driven manner.

Activities of PPL could be categorised under various headings such as the following:

- **Peripheral Activities:** These encompass programmes and interventions for rural upliftment. A contribution to the welfare of inmates of the Nivedita Ashram orphanage, a community hall with attached toilets, a park for public use, repairing old hospital buildings and providing facilities are just small examples of outreach work.
- **Health:** Various camps concerning general issues of the population were conducted. These included free health camps and diabetes camps.
- **Education:** As part of the community outreach activities, 425 school kits containing water bottles, stationery boxes, notebooks, drawing and painting material and tiffin boxes and so on were distributed

in four primary schools in the neighbourhood of the plant site. The kits were distributed to school children in the presence of local dignitaries.

- **Community:** Child Centric Panchayat Initiative is a unique programme under the CSR framework where children are at the centre of development; each intervention and activity rationalises the benefit for children as primary stakeholders. No society can think of meaningful development without addressing appropriate development of children and women; “invest in children” is the credo and “ensure participation” is the guiding principle. This sharpens the focus while directing the effort for inclusive development.
- **Navratna Krishi Vikas Project:** The project is a mission towards ensuring wholistic agricultural development of villages adopted by PPL. The project started in Odisha and Chhattisgarh in 2005–06 and now has successfully added two more states, Bihar and Jharkhand. In a span of five years, PPL has demonstrated initiatives in 269 villages and has shown villagers the path to development by way of practically demonstrating complete agronomic solutions to farmers. Apart from the efforts stated above, the project aims at giving additional income to farmers through income-generating schemes like cultivation of tissue culture banana, hybrid papaya, pineapple, mushroom, apiary, fisheries, vermicompost, poultry, duckery and other schemes suitable to the area.

Santara Village

Our first visit was at Santare village which is situated in Kujung block. For our assistance, there was the NGO partner of PPL called FIDR. Mr Parshuram Behera was the village coordinator who assisted us in having our interaction with the villagers. We had an interaction with a group of people who were an eyewitness to the devastation carried out by the super cyclone. Our discussion started with our introduction followed by their introductions. We were having this conversation in a temple compound.

Case 1

Mr Parshuram Behera initiated the discussion by telling us that at the time of Super Cyclone temple was the only pucca building in the village. He narrated the incident as:

> *On 28th October all the animals became erratic and came to this place for shelter. We couldn’t understand anything, but we realised it the very next day. Then we understood that animals did get a prior sense of situations like this. From that time till today many pucca houses have been constructed.*

Case 2

Mr Upendra Nath Mishra narrated his bitter experience during Odisha Super Cyclone.

He said, “Cyclone[s] like this have never occurred and will never occur also. The destruction created by it can never be compensated for us. We have lost our family members, savings of our lifetime and property. I have seen the dead bodies floating all over, the distinction between humans and animals was gone as both of them were lying side by side. I cannot forget that odour coming from the rotting flesh of the dead bodies. That seven feet wave took everything with it.”

He wrote a poem describing that situation of super cyclone. He was visibly in tears while narrating the poem. The description was beautiful in terms of making us visualise the actual conditions. The highlight of the poem was that even during that terrible time few people resorted to stealing things belonging to others; a man cut the hand of a dead body in order to take out a jewellery. These gory depictions of incidents which actually took place during that time were really appalling.

Case 3

The worst part of the super cyclone was that there was an absence of preparedness told by Mr Bichtra Behera. No flashing of news on televisions; no prior warning was announced by the Government. Due to lack of preparatory measures they didn’t get food for a week. He further added that this cyclone was beyond their imagination. Cyclone is a normal phenomenon of a coastal area and they are familiar with it as well, but they have never thought of something like this. During the cyclone this area got totally disconnected from the rest of the world and thus relief materials could not reach on time.

He also told us about the relief supplies that they received at that time were through the aerial droppings made by the Indian Air Force. It was a packet containing blanket, mosquito net, torch, food (dry food items) and emergency medicines. But the major problem was its proper distribution among the populace. PPL also came forward to help the community as part of its CSR. Even today PPL is also working for the upgradation of the sanitation system of the village by constructing household toilets. A school safety plan has also been implemented for preparing as well as sensitising children for such situations.

Today this village is vulnerable in terms of having disasters related to factories because of three nearby major gas depots belonging to Indian Oil, PPL and IFFCO.

We also posed questions on insurance practices and found that people are now well aware of insurance products. But it was low considering the size of the community.

We also managed to get a copy of school-based disaster reduction plans.

Taking all these information we concluded our discussion and thanked them for having their precious time.

Mangarajpur Village

Our second visit was held at Mangarajpur Village of the same block. Here we saw a Multipurpose Cyclone Shelter (MPCS) that has been made by Odisha State Disaster Management Authority (OSDMA) and this building was built as per the instructions given by the NDMA. This actually helps in protecting the vulnerable populace from various types of natural disasters in which the most important ones are cyclones and floods. Its maximum capacity was 2000. Currently only one MPCS is present for every five villages.

Case 4

Our respondent Mr Ravindra Nath Mahapatra, Sarpanch of the village, told us that this MPCS was constructed after the 1999 cyclone. Today villagers look after this building. In order to prepare the village for such disastrous situations a village rescue committee has been set up. This committee has 50 members and has been trained for three different purposes like rescue, first aid and asset keeping. This is a very good example which shows that disasters bring development and awareness.

Explaining the situation during the cyclone he told us about the removal of debris, which took almost two months. Skeletons were lying on the trees. Even after 15 long years of the cyclone, the scenes are still unforgettable and heart-wrenching. During super cyclone whosoever came forward to help others ended up as dead or injured. The sea water has adversely affected the sources of drinking water like hand pumps and wells in terms of both quality and quantity.

He also brought the topic of cutting of the mangrove forests to our attention which was a major cause for bringing sea water into the nearby human settlements. Industrialisation is another reason. According to him, it’s good to have industries as it provides employment to millions, but they cannot afford the damages caused to the natural environment.

Another key person Mr NandKishore Das gave his views regarding the worst condition of livestock. They also need care and protection. For their safety a similar building is also required. Livestock was equally affected as human beings.

With all these information we concluded our discussion by thanking them. Then we moved towards our next destination.

Rayat Village

Our third visit of the day was at Rayat village of the same block. We had a group discussion which we started by giving our introduction. We came to know the condition of this village was same that time as the other villages, but it got affected in other ways also.

Case 5

One of the key persons of the village Mr Nuisingh Senapati told us that after the cyclone flood came. The flood brought acidic water from the industries with it as a result of which their agricultural fields got destroyed. Even today fruiting does not occur in the coconut trees which came in contact with the acidic water. Most of the big trees were uprooted by the cyclone. Even if few survived they became fruitless due to flood having acidic water. The proximity of the villages to the industries proved to be a bane for them.

People were badly affected by skin diseases, malaria and UTI. Due to its connectivity with the city the relief materials were able to reach them. Sanitation was a major issue for them. The school building served as a shelter for the villagers during the cyclone.

PPL is helping the villagers in constructing the household toilets under its sanitation project. The status of community ownership is good as people are well aware of its usefulness. We saw the hand pumps were constructed on height in order to avoid contamination due to flood. Evacuation is important during such disasters and it was pointed out by another key person of the village, Mr Babaji Sahoo. He said that many lives would have been saved if evacuation had taken place on time. This village does not have MPCS in such a case evacuation is the only option.

With this we ended our discussion and thanked them for giving us the important information. Then we left for the next village.

Baghadia Village

Our last visit of the day was held at Baghadia village of the same block. This is a complete fishermen community village. There are about 212 households. Fishing is the main occupation of this village. A fishermen cooperative has been established known as Siji Sewa Swawaya Committee.

Case 6

Our key respondent Mr Kumar Bar Behera told us about the condition of the village during the cyclone. Since fishing was the main occupation of the village, due to cyclone followed by the flood, it had destroyed their lives. It took almost a year or more in restarting their work. Till that time they were jobless, homeless and hopeless. Their nets and boats were heavily damaged. They had received Rs 500 for net repairing and Rs 700 for boat repairing.

There was no pucca building in this village at the time of the cyclone. They didn't have any place to keep their boats and nets, as told by Mr Arjun Behera. Today they have pucca building so the problem of shelter is manageable, but they need a place to keep their boats and nets safe.

During our interaction we came to know that no village-level committee had been formed in this village. The relief materials also did not reach on time. They had stopped prawn cultivation due to industrialisation and because of the construction of the check dams.

With this interaction we ended our visit of the day. We thanked them for their hospitality and warm behaviour. They have enriched our minds with new information which would be helpful for us in understanding disaster and its implications and above all the ways for managing it in a better way.

Balituta Village

The second day of our visit was at Balituta village of Ersama block. Ersama was one of the worst-affected villages during Super Cyclone 1999.

Case 7

Mr Gauri Hari Mohanty has helped us by giving information about the condition of the village during the cyclone. He said a cyclone with such a great intensity was beyond the imagination of the people. It was Thursday when the cyclone hit the village. Cyclone was about to come, they could know that as the sky had turned red, wind had stopped blowing and temperature had increased. These were the indigenous signals which helped them in predicting cyclones. About 10 feet high tide came up and took everything with it.

A tributary of Mahanadi called Mahanga flows through this village. He told us that he could never forget the scene where about 50–60 dead bodies were floating on this river. The bodies were swollen after absorbing water. It was hard to identify the faces. If the cyclone had come at night then it would have been even more difficult for them to save their lives.

No such early warning came due to which they were not prepared. There was no food storage with them. They were completely dependent on relief materials. The condition of sanitation was also very bad. About 1000 houses have been damaged, 10,000 people got affected and about 1000 had died.

Case 8

Another respondent Mr Sameer Ranjan Das helped us by telling us that a village called Sankha under Padampur Gram Panchayat had been completely washed away. There was no one alive after the cyclone.

Seacoast is about 7 km away from this village, even then about 7 feet height of water column came.

Talking about the relief work he told us that the government paid Rs 75,000 per dead person in a family. Pucca houses have been constructed by the government which falls under the Indira Awas Yojna. PPL, TATA, Laxmi Narayan Trust, World Vision and Ram Krishan Mission all came forward to help by constructing pucca houses in the villages. This block was adopted by the Maharashtra Government and thus aid came from there.

This village was also suffering from a lack of connectivity from the city and thus relief materials were not reaching on time. Debris clearance took about a month in the village. The village still suffers from transportation problems.

He further added that at the time of Super Cyclone 1999 the predication, preparedness and evacuation was zero which led them to suffer this much. He also pointed out the cutting up of the mangrove forest. Laying stress on forestation he said that trees can save lives since we cut them so we suffered.

With all these information we concluded our discussion by thanking them for the time that they have given us. Then we moved for our next visit.

Nuagaon Village

Our next visit was at Nuagaon village which is situated in the same block. This village is the only village forming Gram Panchayat due to its large population residing in the village.

Case 9

Here Mr Tamil Pradhan was our key person. He has his own organisation known as Anchalik Surakhsha Sanganthan.

He started by saying that this village was saved because it was at higher elevation. The destruction took place, but the villagers came forward and managed to help themselves. With the help of sand-filled bags the water invading the village was prevented and the road was repaired which helped in connecting their village with the city. It almost took two to three days to complete the work.

At the time of the cyclone only 32 houses were pucca houses out of 1200 households consisting about 6000 population in 1999. There was no awareness among people regarding the food storage or keeping their documents safe. It is Super Cyclone 1999 which has taught them all this. Now villagers are aware of such a situation. The major issue of this village after the cyclone is health and sanitation. Many died due to diseases.

He talked about the intervention of PRIs in managing such situations. He said that “awareness is the key through which we can execute any plan”. It is necessary to have awareness among people regarding these situations. MPCS is in the village which is being maintained by the villagers.

Then we also had a discussion with the Anganwadi workers and CDBO.

Case 10

Mrs Nirupama told us about the difference in the situation that has come if we compare the situation during Super Cyclone and Phailin. Now the government is very active regarding disaster management in the state. The prediction, preparedness and evacuation were far better during Phailin.

Anganwadi workers are also given training for creating awareness among people. Food security during disaster is one of the major focused areas of the government. Thus special arrangements have been made for pregnant women and children up to three years of age. She showed the food packet which is distributed to every pregnant lady (Yellow packets) and women having children up to three years of age. These food packets are being made by an SHG. The SHG which is involved in making these food packets is Ganga Devi. Thus disaster has been nicely linked with livelihood and gender.

This information has provided us a comparative study between the cyclones. The way that the Odisha Government handled the situation is worth appreciating. The comparative analysis made us understand that awareness plays such a big role in managing a disaster situation. Being a disaster management student it becomes very important for us to understand these dimensions.

With all this we ended our discussion by thanking them for the precious time and information that they have shared with us.

Discussion

Psychological: The fear of cyclones was evident and the memory seemed to be still fresh in the minds of the people. The impact depends upon the damages caused to the community. During the discussion Phailin was never given any priority since everyone was prepared and the damage to life was almost zero. This was reflected in the form of confidence to face any other disaster. Hence the villages required psychological rehabilitation programmes to prevent the impact being carried by the next generation.

There was fear among people when the condition of low pressure, depressions and temperature fluctuation were observed. Despite the fact that various radars are installed, the degree of accuracy of the Indian Meteorological Department has increased.

Lack of Financial Institutions: The presence of financial institutions was found to be negligible. During our visit, only SBI and PNB kiosks were present. So there was a need to bring financial literacy among the villagers to use financial institutions for their contingency.

Insurance: There was an increased demand for insurance products, but when compared to the size of the community, it was negligible. Hence there is a wide scope for insurance and a better way of disaster preparedness.

Community Participation: Community participation according to us was more in Nuagaon. Reason for this conclusion: During our visit to MPCS the condition of the toilets and rooms were in a dilapidated condition. The responsibility for the maintenance was of the officials. But the condition at Nuagaon was far better along with the training sessions and the awareness level among the women groups was quite high. It had SHG and there were sanitation and livelihood interventions in the villages by companies like PPL added to their competence.

The SHG at Nuagaon was well versed with the strategies for mother and child care. This was missing in the nearby regions.

SHG plays a vital role in bringing awareness among the most vulnerable group of the society, i.e women and children.

Awareness: Awareness about disaster management was found to be quite high among the masses. The importance of communication channels like roads and telecommunication devices was primary. Awareness for forest was observed and its need is being felt. But due to industrial intervention people are also getting to know about the hazards which are present in the region.

School-Based Disaster Reduction Plan: Schools in the villages were found to have a good infrastructure. This followed the guidelines of School-Based Disaster Risk Reduction.

Sanitation: Sanitation and other intervention by PPL was appreciable. This ensured control over the diseases caused due to unhygienic sanitation conditions, reducing the impact which could be caused after a disaster.

Lack of Strategic Interventions: The interventions of PPL and the reputation were found to be far better than the other organisations in the villages. Still the interventions were more philanthropic in nature and increased the dependency of the people on the organisation to intervene.

SHG Model Adopted Was Multifunctional: The SHG functioning performed activities including disaster preparedness and livelihood generation, such as in Nuagaon.

Need of Infrastructure: There is a need to build more cyclone shelters which would result in both direct and indirect benefits. There is a need to build more Multipurpose Cyclone Shelters.

Negative Impact of Support and Other Government Programmes: During disaster the support and other relief activities are the only ways to bring back life to mainstream. But the negative impact could be observed in the long run where people take initiative to build basic requirements. For instance, building concrete houses and others will bring other basic requirements. There is lack of coordination when it comes to bringing any change for preparing a self-dependant sustainable model in terms of financial inclusion. Maintenance which should be taken by the community seemed to be ignored. As they passed the responsibility of maintaining MPCS to the government officials. Even today people seemed to be relaxed by being very sure there is no need to have a developed model which must need the least dependence on external relief, ignoring the fact that disasters need proper and advanced health and education system to tackle it by awareness and also recovery from the impact in minimum time.

Table 5: Summary of Observations

	Name of Respondents	Issues Highlighted
Case 1	Mr Parshuram Behera (Santara village)	– Animal behaviour – Need of pucca houses
Case 2	Mr Upendra Nath Mishra (Santara Village)	– Psychological impact – Inhuman behaviour by some as illustrated by respondent. Taking jewellery from dead bodies – Narration of incidence brought tears
Case 3	Mr Bichtra Behera (Santara village)	– Lack of distribution channel during disaster – Village lies near Indian oil, PPL and IFFCO – Vulnerable to chemical disaster – School-based disaster reduction plan – Increase in non-life insurance
Case 4	Mr Ravindra Nath Mahapatra Mr Nand Kishore Das (Mangarajpur village)	– Maintenance of MPCS – Debris clearance took 2 months – After 15 years the cyclone is still unforgettable – Tube wells were affected – No provision for livestock safety
Case 5	Mr. Nuisingh Senapati Mr Babaji Sahoo (Rayat village)	– Flood followed cyclone which made soil acidic – Impact is seen even today where trees do not bear fruits – More MPCS should be constructed
Case 6	Mr. Kumar Bar Behera Mr. Arjun Behera (Baghadia village)	– It took almost a year for fisherman community to get into mainstream – Compensation provided was inadequate (i.e Rs 1200 for net and boat repairing) – Stopped prawn cultivation
Case 7	Mr Gauri Hari Mohanty (Balituta village)	– Strength of cyclone was underestimated – It was worse due to rivers flowing nearby – Villages were completely washed away
Case 8	Mr Sameer Rajan Das (Balituta village)	– Compensation of Rs 75,000 was provided – Houses were built by organisations like Tata and Laxmi Narayan Trust – Need for mangrove forests was realised.
Case 9	Mr Tamil Pradhan (age 35 years) (Nuagaon)	– Responsible to manage post-disaster situation in the village – His preparedness plans and awareness was visible in village
Case 10	Mrs Nirupama (32 years) (Nuagaon)	– Integration of preparedness to SHG – Preparation of food packets – Linking disaster with livelihood and gender

Conclusion

It is found that even after the passage of 18 years people still have not forgotten the agony and deep mental pain that resulted out of the large-scale destruction carried out by the super cyclone of 1999. As a matter of fact they still give importance to the super cyclone of 1999 vis-à-vis other high-intensity cyclones like Phailin which hit coastal Odisha in the near past. It also revealed the loopholes in the distribution channel of relief materials among the populace. Lack of proper infrastructure, sanitation systems and early warning measures resulted in countless deaths and loss of property which could have been avoided. It also shows the resilience and indomitable spirit of the coastal communities to tackle such hostilities in an effective way in the future. This study also shows the role and responsibilities of the corporates, government agencies and other stakeholders of the society in tackling the unfavourable conditions during and after the cyclone.

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Role of Multipurpose Cyclone Shelter as a Disaster-Resilient Infrastructure in Digha Dadanpatrabar Coastal Belt, West Bengal

Sripurna Kanjilal[a] and Gupinath Bhandari[a]

ABSTRACT: Cyclones are among the most common catastrophes in the coastal belt. Cyclones and subsequent storm surges, affect the people living in the coastal areas. Climate change is aggravating these hazards, making the coastal belts even more vulnerable, and prone to devastating cyclones and storm surges. In the present study the coastal stretch between Digha and Dadanpatrabar of West Bengal, India, has been considered as the study area, which comes under Ramnagar-I and II community development blocks of Purba Medinipur District. In the eastern part of this coastal stretch, in Mandarmani–Dadanpatrabar, fishermen and small-scale farmers reside along the coast. They usually dwell within 200 m from the high tide line in small mud huts with thatched roofs or semi-pucca houses with roofs of mud tiles or asbestos, which in most cases are unable to withstand the high velocity winds. Under the Pradhan Mantri Relief Fund (PMRF) scheme and National Cyclone Risk Mitigation Project (NCRMP) assisted by the World Bank, several Multipurpose Cyclone Shelters (MPCS) have been constructed in this district, while some are still under construction. The present study focuses on assessing the capacity of each existing Multipurpose Cyclone Shelter. The available space per person in each MPCS has been evaluated and compared to the provisions. It is observed that the existing cyclone shelters are unable to cater to the needs of the population (Census Report, 2011) seeking shelter. There is inadequate maintenance of the shelter during non-disaster period. This study puts forward recommendations for better utilisation and improvement including the appropriate planning and stability of the MPCS building.

KEYWORDS: cyclone shelter, climate change, vulnerability, coastal community, inundation

Introduction

Cyclones are a frequent natural calamity faced by the people living in the coastal areas of India. Cyclonic situations set up in the Bay of Bengal almost every year during the months of April–May and September–December (Department, 2009). The high velocity cyclonic winds are accompanied by tidal waves, storm surges and torrential rainfall. People who reside within a distance of 10 km from the sea coast are generally the worst affected by inundation that varies between 2.5 and 5 metre approximately and lasts for about five to six days (Department, 2009). Climate change and its resultant sea-level rise can significantly increase the vulnerability of the coastal population (NDMA, 2009). Multipurpose Cyclone Shelters (MPCS) are one of the most important structural measures, taken by the government of India to deal with the devastating cyclones and subsequent storm surges in reducing the loss of lives. The Construction of cyclone shelters has been a worldwide proven measure of preparedness. The construction and maintenance of cyclone shelters have become a source of local motivation for preparedness in India as well (GoI, 2006). A cyclone shelter is a community building, built on an elevated land to ensure the safety of the local people from

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the cyclones and associated storm surges (Rahman & Islam). Cyclone shelters serve as immediate and temporary refuge to the local people and their livestock when any disaster hits (Haider & Ahmed, 2014). West Bengal has a long coastline of about 220 km across its three coastal districts, namely North 24 Parganas, South 24 Parganas and Purba Medinipur (Environment, 2018). Under the Pradhan Mantri Relief Fund (PMRF) scheme and National Cyclone Risk Mitigation Project (NCRMP) assisted by the World Bank, several MPCS have been constructed in this district, while some are still under construction.

Study Area

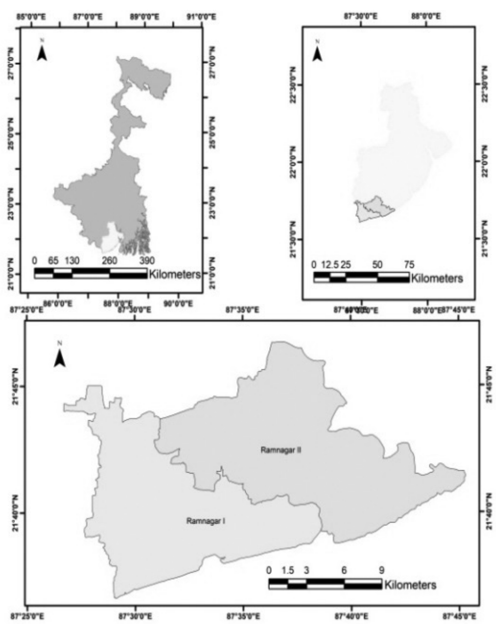

Figure 1: Study area

West Bengal has been identified as Category I among 13 cyclone-prone states and union territories (UTs) in India, based on the frequency of occurrence of cyclones, its vulnerability and size of the vulnerable population (Haider & Ahmed, 2014). The area of interest for this study extends from Udaypur sea beach (21^{0} 36″ 40′ N, 87^{0} 29″ E) to Dakshin Purushottampur (21° 41’ 22.89” N, 87° 45’ 17.47” E) that come under Ramnagar-I and Ramnagar-II community development blocks. This coastal stretch has important fishing harbours like Shankarpur and Dadanpatrabar, which are inhabited by small-scale farmers and local fishermen residing within 200 m of the high tide line, while on the other hand, it has one of India’s most popular tourist spots, Digha-Mandarmani. This highly populous coastal belt is vulnerable to tropical cyclones and associated storm surges, which poses potential threat to the people living in this area.

Objectives of the Study

On an average five to six cyclones develop in the Bay of Bengal and the Arabian Sea and out of which two to three are usually severe. Fishermen and small-scale farmers reside near the coast, in small mud huts which are in most cases unable to withstand the high velocity winds. Cyclones are also associated with storm surges that inundate a few kilometres of land. These local people often take refuge in the Multipurpose Cyclone Shelters in the disaster periods. The use and maintenance of cyclone shelters during the rest of the year or non-disaster periods are equally important as huge investments are made to erect these shelters (NDMA, 2009). The main objectives for the present study are:

- To understand the functioning and the maintenance of the existing MPCS
- To assess the connectivity of each existing MPCS with the neighbouring villages in Ramnagar-I and II
- To calculate the available space per person in each MPCS, compared to the provisions given by the government

Data Set and Methodology

The main focus of this paper is to understand the facilities provided in a cyclone shelter and their present conditions. For this the cyclone shelters of the two blocks have been visited. Household survey and talks with the local people have provided insights about the situations during cyclone hazards, how the local administrative body operate during the crisis periods, what was the situation in the cyclone shelters during the disaster periods and so on. The local government offices have provided data about the different constructional specifications of the cyclone shelters.

SRTM DEM data set 2014 has been used to acquire the elevation of land. The road networks are collected from the ISGP website.

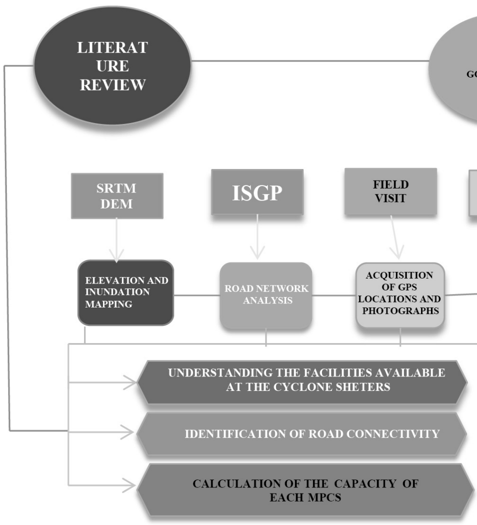

Figure 2: Methodology

Results and Discussion

Location and Number of Cyclone Shelters

According to the UNDP guidelines, coastal states are advised to carry out a survey within 10 km bandwidth from the coast. The cyclone shelters are advised to be located on the available high elevated lands. In absence of available elevated area, the structure may be elevated through construction of a mound or shelter be built on stilt (NDMA, 2009). In Ramnagar I community development block, maximum number of cyclone shelters are situated within 3 kms (Fig. 3) while the furthest being about 7 kms away from the coast. In Ramnagar II two shelters are 0.5 kms from the coast while the furthest is about 8 kms from the coast. Studies have shown that unless a cyclone shelter is within 1.5 km of a house, it may be too distant. The local people, afraid of theft, postpone their withdrawal to the shelter (Rahman & Islam). At times conveyances are provided by the local government to relocate the vulnerable people to the shelters, but in most cases the villagers have to walk along with their belongings to the nearest cyclone shelters. Most of them are built at an elevation of 6–15 metres but not equitably distributed among the entire coastal stretch. The cyclone shelter should ultimately become a “community asset/ resource” such that it will have a broader impact on the livelihood of the villages. Hence, it is appropriate to locate the cyclone shelters inside or near the villages. Ultimately, the idea is to assure their regular use during the normal period as well. Such sustainable use should also generate required finances to supplement proper maintenance of the structure (GoI, 2006).

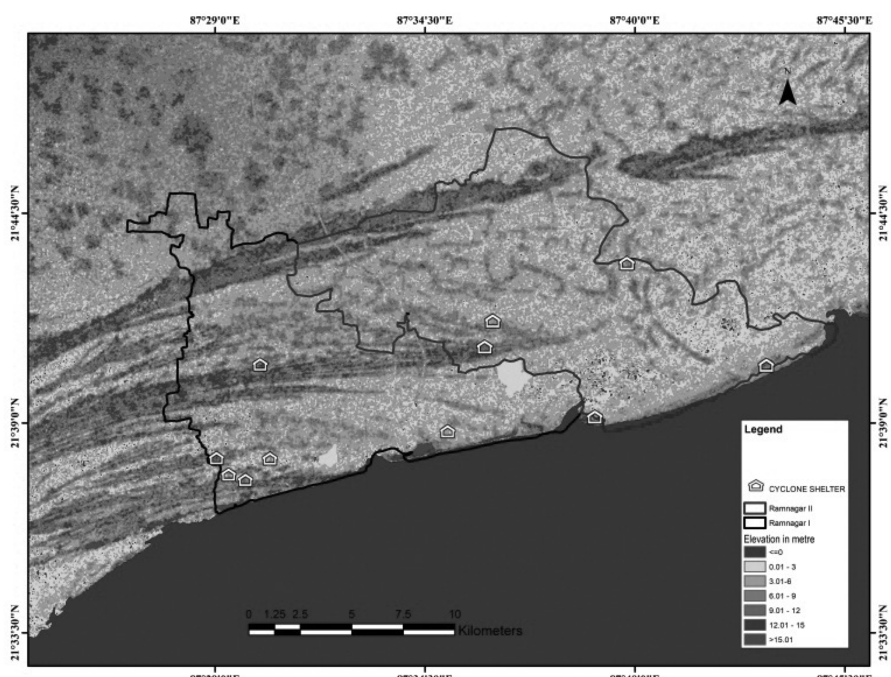

Figure 3: Location of the Multipurpose Cyclone Shelters

Facilities Available in the MPCS

The cyclone shelters are concrete structures that are able to withstand wind speed of more than 65 km/h. Under guidelines provided by the government, the buildings are two storied with or without stilt depending on the level of storm surge. Depending on the top soil conditions in coastal areas, pile foundations are preferred. However, suitable type of foundations should be considered based on local conditions and soil strata (GoI, 2006). The plinth height of 1.5 m will be used for stilt with the height varying from 2.5 m to 4.5 m if the storm surge level is more than 1.5 m and less than 4.5 m. In all cases, the floor level of a shelter will be at least 0.5 m above the possible maximum surge level. Ramp with a slope of 1:8 for easy access to the cyclone shelter for aged and children are to be provided (NDMA, 2009). The UNDP guidelines state that providing bunkers with resting facilities for small children and elderly/sick persons and storage shelf facilities in every room and veranda for accommodating the personal belongings of the occupants is necessary (GoI, 2006). The shelters are said to be equipped with two toilets for boys and two toilets for girls, in addition six urinals may also be provided for boys. These will also serve the needs of the shelter in emergencies. The size of each toilet should be minimum 9 sq ft, preferably 12 sq ft (GoI, 2006). Septic tanks should be provided. Tanks should be properly sealed and roof sufficiently elevated so as to prevent inundation during flooding (GoI, 2006). Figure 4 (a) shows a complete view of an MPCS. The cyclone shelters are built on a raised plinth. Ramp (b) is provided for easy access of elderly people and differently abled people who can easily enter the shelters on wheelchairs. There are two halls on each floor. According to the government rules, the rooms should be provided with bunkers for old people and children, but there is no trace of any bunkers or storage shelves in the MPCS of Ramnagar I and Ramnagar II community development blocks. There are community kitchens (g) in each MPCS; people take refuge in the shelters for about two to three days or until the water has receded. In such cases cooking meals for the people is very important. No kitchen utensils or provisions for gas have been noticed in any of the cyclone shelters in the two blocks. Two toilets separate for men and women are available (d, e, f). Lacking maintenance, the toilets are dirty and missing taps. There are only two toilets on each floor for each boys and girls which are clearly not sufficient for the number of people that will take shelter during the emergency. No separate toilets for the differently abled people have been seen. There are storage areas available in the shelters (h) for keeping supply like emergency kits, medication and grocery but have no supplies stored and in many shelters they are dumped with garbage. Cyclone shelters also provide shelter for cattle. Some villagers usually own cows, goats, pigs, hens, chickens and other domesticated animals that are also under threat during severe cyclones and sea water inundation. The shelters have specific areas to provide protection to these animals.

Figure 4: A look inside an MPCS, photographs taken by the author, 2018

Sustainable Use of the MPCS

The use of a shelter during non-disaster periods leads to its better maintenance, more successfully serving in emergencies. Regular use also provides economic justification for the investment (GoI, 2006). The primary use of the cyclone shelter is to protect people from natural hazards such as flood, cyclone and tsunami and act as a relief camp during other disasters (NDMA, 2009). The cyclone shelter should ultimately become a “community asset/resource” such that it will have a broader impact on the livelihood of the villages. Hence, it is appropriate to locate the cyclone shelters inside or near the villages. Ultimately, the idea is to assure their regular use during the normal period as well. Such sustainable use should also generate required finances to supplement proper maintenance of the structure (GoI, 2006). The cyclone shelters are often used as training camps, election booths, health camps, community gatherings and meetings. But using them as schools or offices is prohibited as the shelters are to be evacuated immediately in case of a cyclone warning. In Ramnagar I block one of the cyclone shelters is being used to manufacture bicycles (Fig. 5) for a local government scheme which is violating the basic norms as relocating huge amount of goods and parts of bicycles is not a very easy task considering disaster situations, whereas as in Ramnagar II most of the cyclone shelters remain vacant with almost no maintenance. The toilets are dirty, the sinks have missing taps, with no water supply, and garbage is dumped in the areas which are meant for storage of supplies that are required during a natural calamity.

Figure 5: Use of the cyclone shelters during normal periods

Capacity of Each MPCS

On average, about 50–60 per cent of the total population of vulnerable locations use cyclone shelters during emergencies (GoI, 2006). Each cyclone shelter has 900 sq. space per floor. According to the governmental provisions (UNDP-Disaster Risk Mitigation, MHA) 2 sq ft standing space is allotted per person in a cyclone shelter (GoI, 2006). So, 900/2 = 450 and each MPCS having three floors may cater to 450x3 = 1350 persons per MPCS. But 450 people in one room will cause suffocation and people may need to be in the shelter more than 24 hours; in that case the allotted space per person is not sufficient. Therefore, 2 feet x 5 feet area should be allotted per person which indicates 900/(2x5) = 90 people per floor. Three floors can accommodate 270 people approximately. Hence the capacity of each MPCS is around 270–300 persons. The existing MPCS facilities are not equitably distributed among the vulnerable areas.

Road Connectivity

Road connectivity of the MPCS to the neighbouring villages is important, not only to reach the shelter in the shortest time possible but also to seek medical help. The coastal tract of Ramnagar II is mostly inhabited by local fishermen and small-scale farmers. Extensive aqua-cultural ponds, salt pans and mudflats are present parallel to the coast which makes it difficult to construct more roads and thus portray low road connectivity (Fig. 6), whereas the western Ramnagar I block is a famous tourist spot; Digha, visited by lakhs of tourists every year, has a well-connected road network. The road connectivity reduces as we go landward which is contrasting to the values in Ramnagar II. It has to be noted that the condition of the roads in Ramnagar II should be given more importance here. Keeping the roads accessible throughout the year especially during the monsoon season when the cyclones are most likely is the essential task. By surveying the local residents it has been known that at times the local administrative body provides conveyance, but at most times the villagers have to walk to the shelter along with their belongings and livestock. So a well-connected road network and at the same time well-maintained accessible roads in those hostile situations are of equal importance.

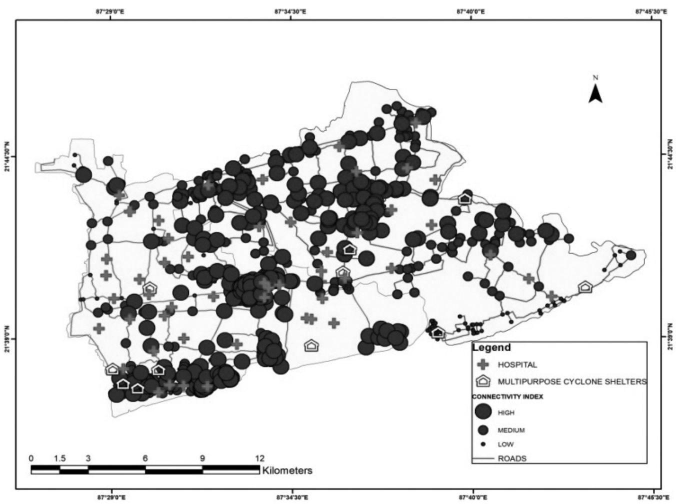

Figure 6: Road connectivity

Conclusion

It is observed that the cyclone shelters are not equitably distributed throughout the blocks. The cyclone shelters have provisions of various basic amenities like kitchen and toilets, but they are not functional in many cases due to lack of maintenance. There is a lack of awareness among the people and people are often reluctant to move to the shelters due to unavailability of conveyance. Each MPCS is supposed to cater to 50–60 per cent of the surrounding vulnerable population according to the governmental guidelines, but in reality each shelter can hold only up to 300 people and is not sufficient for the huge amount of the vulnerable population seeking refuge. The shelters are connected by roads. Higher road connectivity is seen in the northern parts of the blocks but lower connectivity near the beach. Due to the availability of mudflats in Ramnagar II block, the roads may not be possible to increase, but it has to be maintained so that they are accessible during times of natural calamity.

Acknowledgements

I owe deep gratitude to my research guide, who has guided me all along. I am thankful to the BDMO of Ramnagar I and Ramnagar II CD blocks for helping me with the necessary data. I also thank my fellow research scholars for their encouragement and support. Lastly I am grateful to my parents who are my source of inspiration.

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Changes in Coastal Regulation Zone Rules and Their Impacts on Coastal Areas with a Focus on Mangroves: A Case Study from the East Coast of India

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ABSTRACT: Coastal Regulation Zone (CRZ) rules are formed to protect the coastal zone and regulate development in coastal areas and have been amended several times over the years. The draft 2018 CRZ notification relaxed the rules, opening up fragile coastal areas to real estate development. Many environmentalists are sceptical about the reduction of CRZ limits on land along tidally influenced bodies from 100 to 50 metres, or the width of the creek, or whichever is less. This study analyses the changes in CRZ rules over the period of 30 years and attempts to understand the effects of those changes on the coastal environment with a special focus on mangroves. West Godavari district of Andhra Pradesh on the east coast of India with a 17 km coastline is considered for spatially analysing the changes in CRZ in accordance with the 2018 draft CRZ notification with the help of technologies like Remote Sensing and Geographical Information System (GIS). A large area which is under No Development Zone will go under Development Zone due to the extensive changes in rules. Comparative analysis of land-use change in mangroves for the period 2010–2018 in the selected area reveals that there has been a considerable reduction in the mangroves. The study clearly shows the threat to 'Ecologically Sensitive Areas' such as mangroves due to anthropogenic activities. The 2018 CRZ rules instead of strengthening the protection to sensitive coastal areas are promoting developmental activities in fragile coastal areas.

KEYWORDS: coastal regulation zone rules, mangroves, 2018 draft notification, aquaculture

Introduction

Coastal areas are commonly defined as the interaction areas between land and sea and are diverse in form and function. The coast of India which is about 7516 km (MoEF) comprises diverse habitats and ecosystems such as mangroves, mudflats, estuaries, lagoons, backwaters, creeks and coral reefs. Coastal areas are at the forefront of development and there has been tremendous pressure for the development of urban settlements, ports, aquaculture and fisheries (Mohanty et al., 2008). The population living within 100 km of coastline is estimated to be 2.07 billion in 1994 which is 37 per cent of the total world population (Cohen et al., 1997). Increasing population, technological advancement, competition for coastal resources and other developments led to serious environmental

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changes, making it a concern for the public and governments (Panigrahi & Mohanty, 2012). There are efforts to protect the coastal areas since 1991 in the form of laws and regulations.

Increased awareness about the ecological and economic value of coastal areas led to the promulgation of the first Coastal Regulation Zone (CRZ) notification on February 19, 1991, by the Ministry of Environment and Forest (MoEF), Government of India, under the Environment (Protection) Act, 1986 (MoEF, The Environment (Protection) Act Notification, 1991 – Coastal Zone Regulations S.O. 114 (E), 1991). The rules have been iterated twice till date in 1991 and 2011 and modified and amended several times. The Ministry of Environment, Forest and Climate Change (MoEFCC) has proposed a new draft CRZ notification in 2018 to replace the existing framework based on the recommendations of the Shailesh Nayak Committee. This paper focuses on how the proposed 2018 CRZ framework addresses the coastal issues and safeguard fragile ecosystems.

The aim of the study is to analyse the changes in CRZ rules and their effect on coastal areas, especially mangrove areas. Mangroves act as natural barriers to extreme climate impacts and protect vulnerable coastline and communities from destructive events such as storms, tsunamis and coastal erosion (Kerr & Baird, 2007). Mangroves can protect the coast from heavy gales and minimise the damage caused due to natural disasters such as cyclones (Sankar, 2018). The West Godavari district of Andhra Pradesh with a coastline of 17 km is chosen for the analysis. West Godavari is one of the 13 districts in the state of Andhra Pradesh and is separated from East Godavari district by River Godavari on the east and River Tammileru separates it from Krishna district on the west. The area of interest, mangrove CRZ-I zone, lies near *Vemuladeevi* settlement, in *Narsapuram* Mandal of West Godavari district next to an estuary, the place where Godavari river meets the sea.

The study seeks to identify the changes in mangroves over the period 2010–2018 and evaluate if the recent 2018 CRZ rules could address the issues faced by sensitive coastal areas. Mangrove areas come under CRZ-1 A which are 'Ecologically Sensitive Areas' and play a significant role in maintaining the integrity of the coast. Mangroves are one of the world's major threatened tropical environments and at least 35 per cent of mangroves have been lost since the 1980s (Valiela et al., 2001). In this study, the Coastal Zone Management Plan (CZMP) of West Godavari district was used to delineate the required CRZ. Land-use change analysis of the area over the years 2010–2018 was carried out to understand the predominant changes in land-use around mangrove areas.

Aquaculture is an economically well-established industry in many southern Indian states and there has been tremendous pressure on the coastal zone. Thousands of acres of land in Andhra Pradesh have been converted into aquaculture ponds in the past years (Supreme Court, 1996). Aquaculture has contributed to the degradation of mangroves in the east coast of India (Hein, 2018). The Supreme Court in 1996 banned the intensive non-traditional shrimp aquaculture in CRZ area. The ruling says that agriculture lands/salt pan lands/mangroves/wetlands/forest lands/land for village common purposes cannot be converted into shrimp culture ponds. Coastal aquaculture which is gradually taking over mangrove areas is observed and addressed in the paper.

Coastal Regulation Zone Rules (1991–2018)

The term 'coastal area' broadly refers to the geographical area along the coast, while the term 'coastal zone' refers to the geographic area defined for coastal management by enabling legislation (FAO, 1998).

A notification was issued in 1991 by the Ministry of Environment and Forest, Government of India, under the Environmental Protection Act of 1986 for framing the CRZ rules, to restrict setting up and expansion of industries, operations or processes and so on in the said CRZ. As per the notification the coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters which are tidal influenced (in the landward side) up to 500 m from the High Tide Line (HTL) and the land between the Low Tide Line (LTL) and the HTL are declared CRZ. The coastal stretches within 500 m of HTL on landward side are classified into four sub-zones, namely, CRZ-I (ecologically sensitive areas), CRZ-II (developed/urban areas), CRZ-III (undeveloped/rural areas) and CRZ-IV (coastal stretches of Andaman and Nicobar Islands, Lakshadweep and small islands), to regulate developmental activities (MoEF, 1991). The original notification has been amended 25 times between 1991 and 2009 due to the socio-economic pressure in the coastal zone and other inadequacies in the notification (Panigrahi & Mohanty, 2012).

MoEF issued CRZ-2011 notification in supersession of 1991 notification after careful consideration of suggestions made by the public, with an objective to ensure the livelihood of fisher and other local communities, to conserve and protect the coastal environment and to promote sustainable development considering the dangers of natural hazards (MoEF, 2011). The classification of CRZ into four zones continued the same in 2011 notification but with modifications in CRZ-IV. There is significant change in 2011 notification compared to its predecessor.

The 2011 notification required the demarcation of HTL and the demarcation process got completed as recently as 2017, and then 2018 draft CRZ notification admits the demarcation of HTL by National Centre for Sustainable Coastal Management (NCSCM), Chennai. The 2011 notification also required the demarcation of Ecologically Sensitive Areas (ESAs) and hazard line and those remain incomplete till date. The 2011 notification required the coastal states and UTs to prepare CZMPs with the demarcation of different CRZ categories which has not been completed. The 2011 notification has not been effective and has gone under 12 amendments, without proper public consultation (Menon et al. 2015; Chouhan et al., 2016).

MoEFCC in supersession of CRZ notification 2011 released the draft 2018 CRZ notification. The draft classified the CRZ areas into seven categories as compared to the earlier five of 2011 (see Fig. 1). The draft hosts a lot of changes, the major being the reduction of CRZ limits from 100 m (or the width of the creek, whichever is less) to 50 m (or the width of the creek, whichever is less) along the tidally influenced bodies. Another major change includes the reduction of no development zone (NDZ) for areas where population density is more than 2161 per sq km from 200 m to 50 m (MoEFCC, 2018). Environmentalists across the country raised objections to the draft 2018 CRZ notification, saying that it has diluted the norms and favoured builders while exposing the eco-sensitive areas (Chacko, 2018; Dhar, 2018).

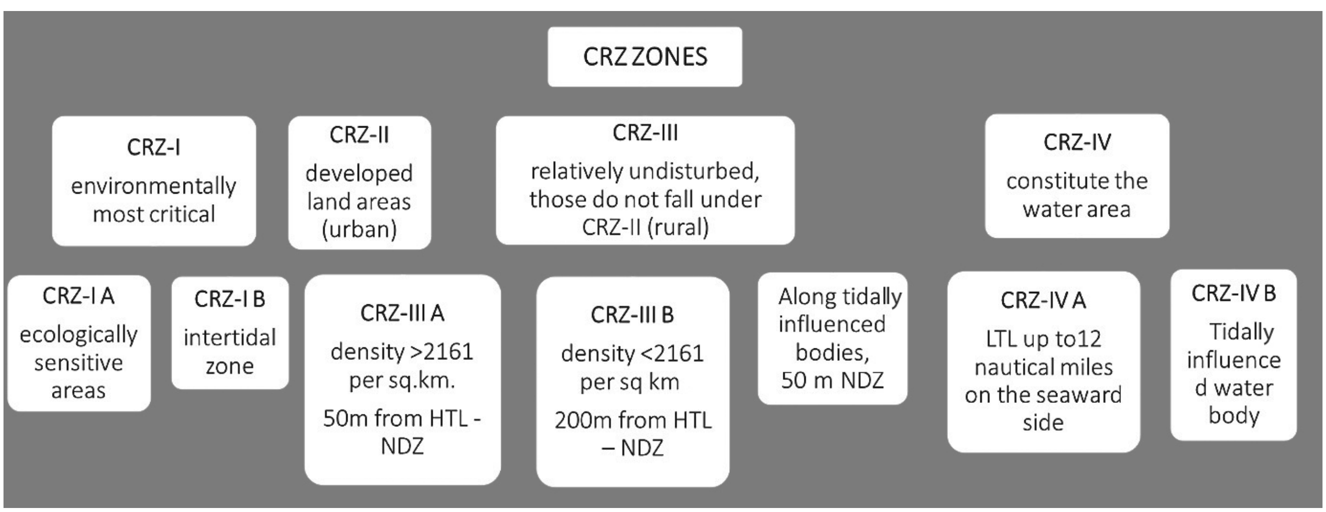

Figure 1: CRZ classification as per 2018 draft notification

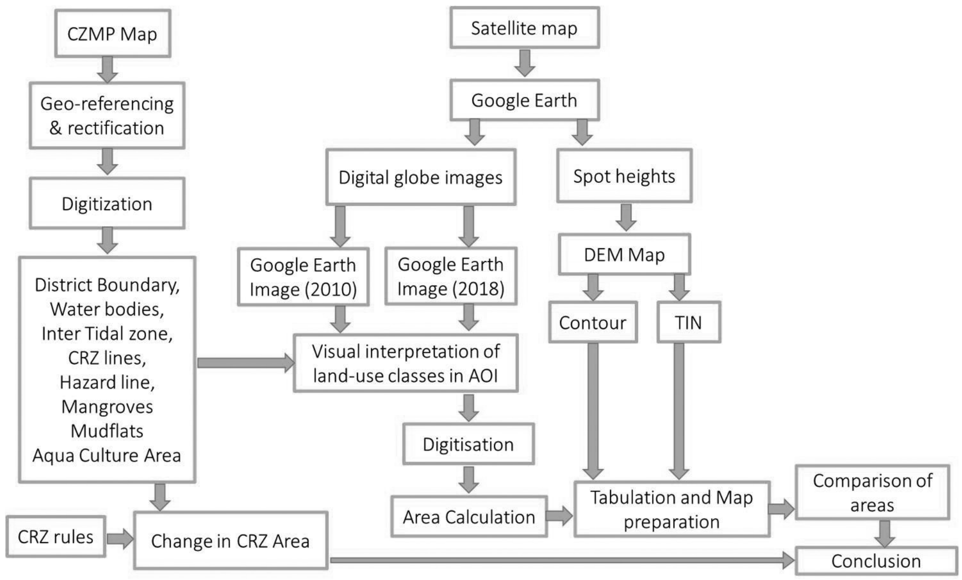

Figure 2: Methodology flowchart

Data and Methodology

The draft Coastal Zone Management Plan of West Godavari district prepared in accordance with the CRZ notification 2011 by National Centre for Sustainable Coastal Management was used to delineate various Coastal Regulation Zones and other details. The georeferenced and rectified output of CZMP was used in the preparation of coastal area map of West Godavari with all CRZ. The layers delineated from CZMP map include district boundary, water bodies, intertidal zone, CRZ lines, hazard line and various Coastal Regulation Zones like mangroves, mudflats and aqua-culture areas.

Google Earth images of the years 2010 and 2018 were selected and used for comparison of land-use change for the selected area, which is the landward side of an estuary and contains ecologically sensitive areas. ArcGIS was used to digitise the high resolution Google Earth images and extraction of land-use categories: aquaculture, mangroves, mangroves within aquaculture, built-up and other (vegetation, agriculture and grasslands). Land-use maps were prepared and the geographical area in each land-use category was calculated for time series comparison in ArcMap. The area under each category is compared and analysed for determining the changes that have taken place in the study area between 2011 and 2018.

For further detailed analysis, the changes in land-use of the mangrove areas over the period of 2011–2018 are analysed and compared with the new CZMP map. Based on the analysis, inferences are drawn on the 2018 CRZ draft notification and its effect on coastal areas, especially mangroves.

Results and Discussion

Changes in No Development Zone (As per 2018 Notification) in the Context of West Godavari District

Coastal Regulation Zone Notification, 2011, stated that ‘area up to 200mts from HTL on the landward side in case of seafront and 100mts (or width of the creek whichever is less) along tidal influenced bodies is to be earmarked as No Development Zone (NDZ)’. The 2018 draft CRZ notification reduced the 100 m along tidally influenced bodies to 50 m (or width of the creek whichever is less) from HTL and the NDZ for CRZ-IIIA will be 50 m instead of 200 m. The draft notification allows some types of construction in CRZ-II zone as well (MoEFFCC, 2018).

Figure 3 shows the Coastal Regulation Zones of West Godavari district of Andhra Pradesh along its 17 km coastline. As per 2011 rules, approximately 4.019 sq km of land is NDZ along tidally influenced bodies under CRZ-III which will directly drop to 2.0095 sq km of

NDZ along tidally influenced bodies as per 2018 rules. In this paper, the area calculation was limited to the CRZ within the 3 km stretch from HTL on the landward side. The total area going into the hands of real estate developers and builders will rise greatly if the NDZ area all along the tidally influenced bodies is calculated.

These changes in the 2018 CRZ notification make the coast more vulnerable to development. The mangroves in the private areas will not require a buffer zone anymore as per new rules. All these changes can further influence the destruction of ecologically sensitive areas such as mangroves.

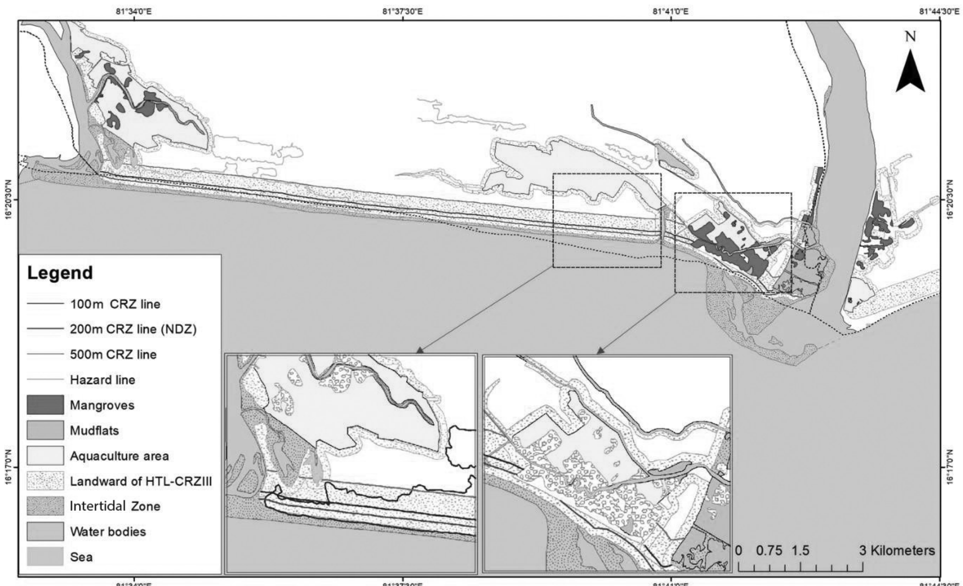

Figure 3: Coastal Regulation Zones of West Godavari district (till 3 km from HTL) (source: modified from CZMP map)

Land-Use Comparison and Change Analysis

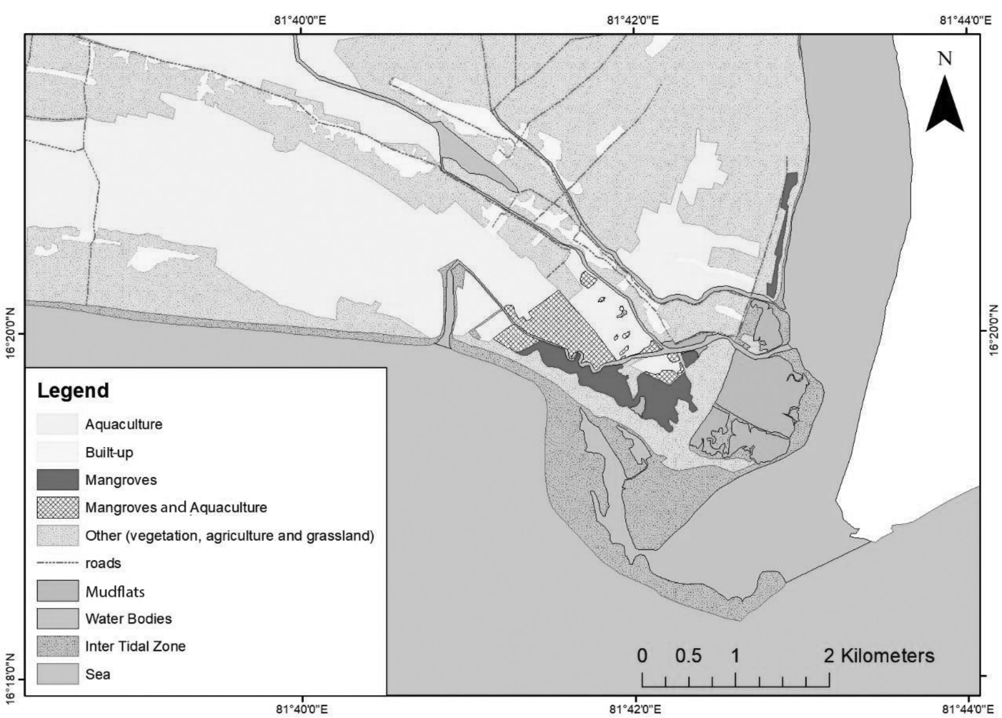

Figure 4: Land-use of Coastal Regulation Zones and neighbouring areas as per 2010 satellite data

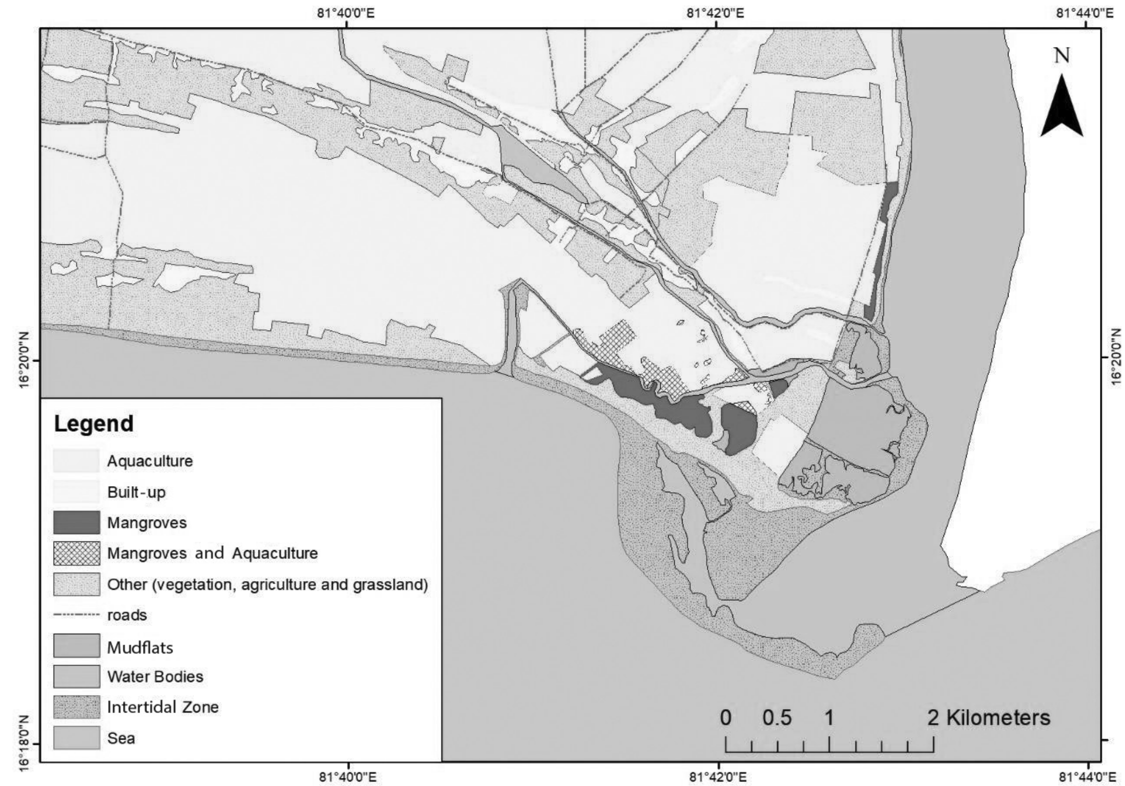

Figure 5: Land-use of Coastal Regulation Zones and neighbouring areas as per 2018 satellite data

Table 1: Comparison of Land-Use in 2010 and 2018

S. No.	Land-Use Category	Area (in sq km)		Area (in %)		Difference in Area (in %)
		2010	2018	2010	2018	
1	Aquaculture	10.437	15.76	38.398	57.982	+19.584
2	Built-up	1.467	1.695	5.397	6.236	+0.839
3	Mangroves	0.6505	0.533	2.39	1.960	-0.43
4	Mangroves within aquaculture	0.556	0.2779	2.046	1.022	-1.024
5	Other (agriculture, vegetation and grasslands)	14.07	9.127	51.765	33.579	-18.186

Land-use maps of the study area for the years 2010 and 2018 are represented in Figs. 4 and 5, respectively. The map contains the land-use of CRZ and the surrounding areas as per 2010 and 2018 satellite data. The area covered under each of the five land-use categories is tabulated, as shown in Table 1.

Analysis of land-use revealed that there has been a considerable shift in the land-use characteristics of the study area over the decade. There has been a massive increase in the aquaculture area from 38.39 per cent to 57.98 per cent in 2018 which could be due to commercial reasons. Aquaculture dominates the area at the expense of vegetated areas and ecologically sensitive areas like mangroves. Mangroves cover reduced from 2.39 per cent in 2010 to 1.96 per cent in 2018 which is due to an increase in aquaculture. Land-use named 'Mangroves within aquaculture' is the area where mangroves are found inside aquaculture ponds. The 'Mangroves within aquaculture' reduced from 2.04 per cent to 1.02 per cent which is due to be periodic removal of mangroves from aquaculture ponds. The threat to ESAs such as mangroves due to anthropogenic activities is clearly seen.

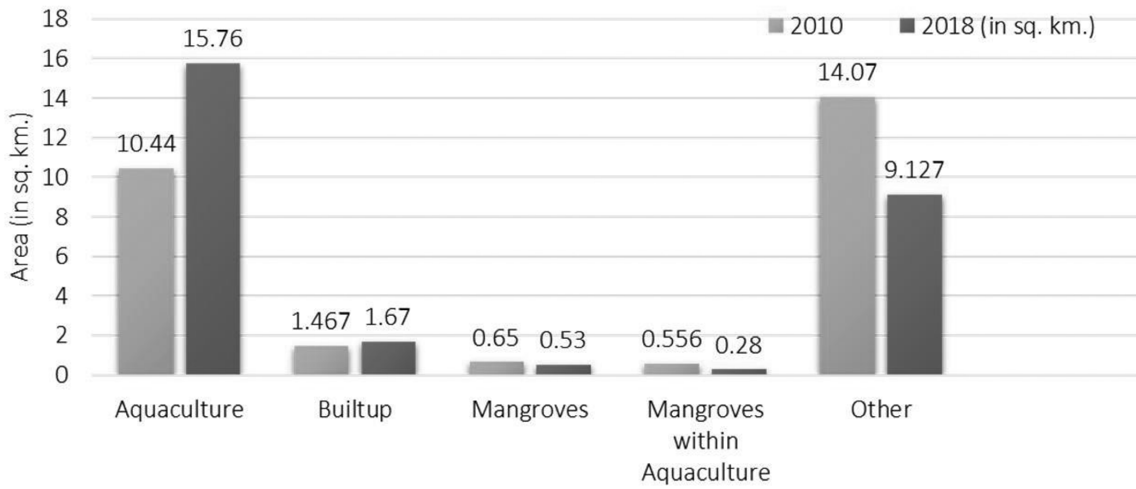

Figure 6: Graph depicting the land-use change in the study area from 2010 to 2018

Depletion of Mangroves in the Study Area

Anthropogenic activates have led to the reduction in the mangrove cover in the study area. Reclamation of mudflats and vegetated areas caused significant changes in the morphology of area and in the process, mangroves have also been damaged. Strategic removal of mangroves for intensive aquaculture was observed during the field visits.

Coastal Zone Management Plan of West Godavari district with reference to the CRZ notification 2011 has been prepared indicating various Coastal Zone Management Zones (APCZMA, 2018). Mangrove areas identified in the CZMP map includes the mangroves present inside aquaculture ponds as well. The geometrical patterns of mangrove areas in CZMP map in the study area instead of organic boundaries explain it and were confirmed during field visits. The CZMP should not have designated the sparse and very low dense mangroves which grow inside aquaculture ponds as mangroves. The mangroves present inside aquaculture ponds are being removed periodically to facilitate aquaculture. The strategic removal of mangroves for aquaculture can be understood from the change in land-use of mangrove cover between 2010 and 2018 (see Fig. 7). As much as 0.4 sq km of mangroves got reduced in the past decade just in the study area due to aquaculture (see Table 2). As shown in Fig. 8, field visits in December 2018 showed the presence of aquaculture in mangroves and mudflat areas. Strong bunds around ponds were constructed to restrict the growth of mangroves. The mangroves in the tidally influenced water bodies have been cleared as well.

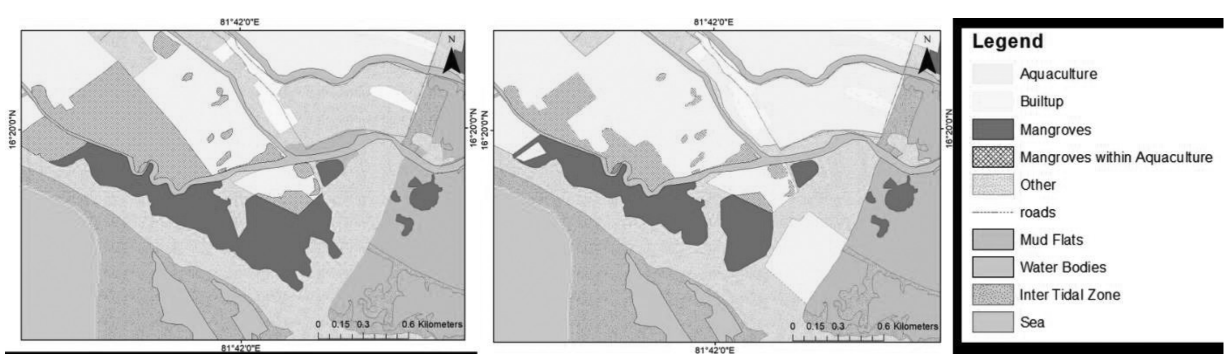

Figure 7: Mangroves cover as per 2010 satellite data (left) and 2018 satellite data (right)

Table 2: Mangrove Area Comparison between 2010 and 2018

	Area in Sq Km		
	As per CZMP	As per 2010 Satellite Data	As per 2018 Satellite Data
Mangroves	1.47	0.65	0.53
Mangroves within aquaculture		0.556	0.278
Total	1.47	1.206	0.808 (33 % reduction from 2010)

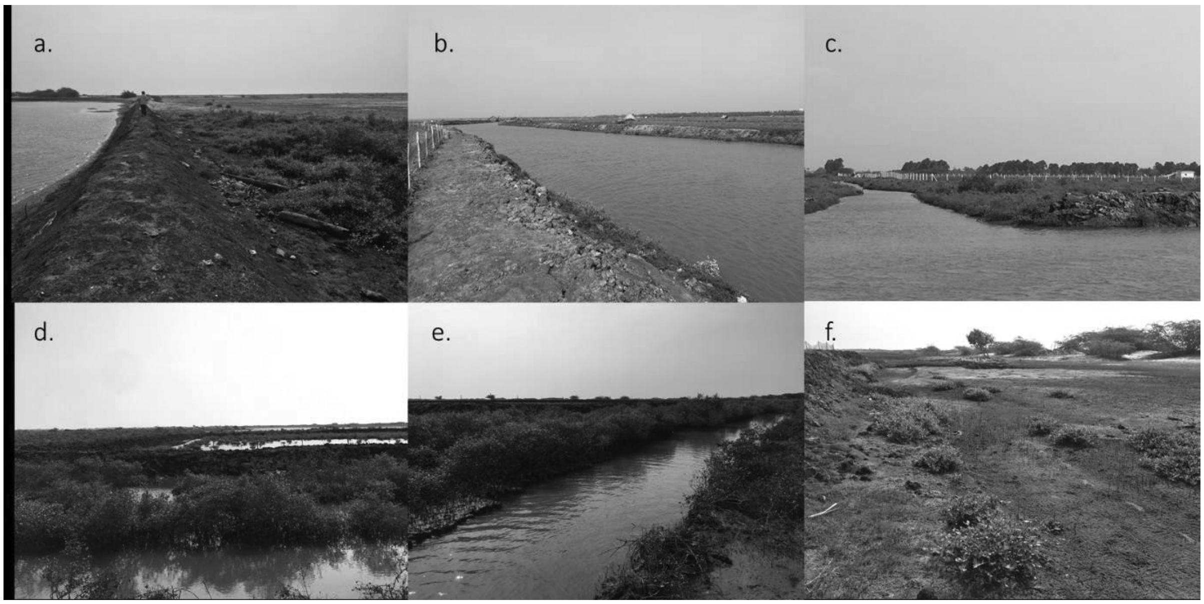

Figure 8: (a) Anthropogenic obstructions to the growth of mangroves; (b) mangroves on either side of water body are cleared for aquaculture bunds; (c) large area was cleared of mangroves for aquaculture/construction activity; (d) large aquaculture pond amidst mangroves; (e) tidally influenced water bodies are cleared of mangroves to facilitate water for aquaculture ponds;(f) spare and very low dense mangroves

The extent of development in ESA needs to be regulated. The 2018 draft CRZ notification by changing the extent of NDZ around tidally influenced bodies is bringing the construction activities much closer to the sensitive areas. The rules instead of protecting the sensitive coastal areas are promoting developmental activities in fragile coastal areas. The 2018 CRZ notification diluted rules by removing the requirement of buffer zones for mangrove areas in private land.

Conclusion

Enormous pressure is being exerted on the coastal ecosystem from unregulated anthropogenic activities. Extensive changes in coastal protection rules are further opening coastal areas for major developmental activities. The 2018 draft rather than addressing the weaknesses of the 2011 notification has further weakened the existing coastal safeguards. The changes show adverse effects on ecologically sensitive areas like mangroves. Mangroves reduce the risk from several hazards and their importance in coastal defence and disaster risk reduction should be acknowledged by coastal zone managers and policymakers.

Mangroves in the study area are depleting due to strategic removal to facilitate aquaculture which can be clearly understood from the land-use change analysis. The draft CZMP of the district do not corroborate well with the actual extent of mangroves for their respective times. Mangrove forests have been reducing at alarming rates which will be further affected drastically due to the changes in CRZ rules. The new diluted CRZ rules are accelerating the loss of mangroves and other sensitive ecosystems, thereby damaging the coastal environment and not serving the purpose of CRZ rules.

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Impact of Coastal Regulation Zone Violation on the Coastal Environment

Souvik Chatterjee[a] and Gupinath Bhandari[a]

ABSTRACT: Coastal zones are being exploited by different stakeholders; unprotected and unregulated development of coastal zones are increasing the vulnerability of the local population. India has a coastline of about 7500 km; to protect these vast coastal stretches from unregulated developmental activities and to provide safeguard to the fishing communities, Coastal Regulation Zone (CRZ) was implemented in 1991 and subsequent amendments came on the same. Coastal zones have been classified into some zones based on their development, vulnerability and economic and ecological importance. Still, parts of coastal zones are being violated. The coastal stretch of Digha–Udaypur and Mandarmani–Dakshin Purushottampur of Purba Medinipur district of West Bengal, India, are among them. This paper has focused on identifying the violated activities within CRZ of these two sectors of coastal zones of West Bengal, and it also studies how these violations are actually increasing the fragileness and vulnerability. Findings revealed that Mandarmani–Dakshin Purushottampur stretch is more violated and the condition is more threatening than Digha being a rural area, and coping capacity in the inhabited people is lower. Digha sector is one of the main urban sea resorts of West Bengal and is well protected though the scenic beauty and accessibility of the beach have been totally destroyed. Erosion is the main problem in both the stretches, but salinisation of groundwater, loss of coastal ecosystem and lowering of frontal dunes are increasing. Proper study and management of these two fragile coastal zones are of utmost importance to protect these zones from environmental hazards.

KEYWORDS: coastal regulation zones, vulneribility, fishing communities, developmental activities, environmental hazards

Introduction

Coastal zone (CZ) can be defined as “extending from the coastal plains to the outer edge of the continental shelves, approximately matching the region that has been alternately flooded and exposed during the sea level fluctuations of the late Quaternary period” (Pernetta & Milliman, 1995). Coastal zone is always at the forefront of civilisation and has been by far the most exploited geomorphic unit of the Earth (Panigrahi & Mohanty, 2012). The coastal zone in most countries is under severe and increasing pressure from rapid urbanisation, pollution, tourism development, over-exploitation of coastal resources (specially biological resources) and continued development in hazard-prone areas (Nanda, Mukhargee, & Bhattacharya, 2001). India has a coastline of about 7516 km and 4198 islands are spread along the main coast of Andaman, Nicobar and Lakshadweep group (Panigrahi & Mohanty, 2012). This vast CZ is under tremendous pressure by ever increasing population in the coastal regions and by developmental activities. To protect the environment of this long CZ and to provide security to the livelihood community, a safeguard was provided by the Ministry of Environment and Forest (MoEF) by the name of Coastal Regulation Zone (CRZ) in the year 1991 (S.O.114(E), dated February 19). After several amendments to the main notification, and reports submitted by different committees, a whole new regulation was introduced in 2011 (S.O.19(E) dated January 6). Now in February 2018

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we have noticed a new draft of Coastal Regulation Zone notification which is going to supersede the regulation of 2011.

The main objectives of these CRZ notifications are to protect the coastal environment from unregulated developmental activities and to ensure livelihood security of the coastal communities.

The coastal environment is by far the most fragile system in the world due to sea level rise, increasing tropical cyclones, storm surge, saltwater intrusion and so on, and mostly in the developing countries like India, coastal marginal areas are inhabited by the peoples amongst the lowest income groups except some urbanised areas like Mumbai which in turn increases the vulnerability due to less resilience and durability to cope up with the environmental or social hazards. It is important to understand how the CRZ regulation has actually been implemented in the coastal areas to provide safeguard to these marginal peoples from any type of hazardous situation. Panigrahi and Mohanty (2012) have shown the strength, weakness, opportunity and threat of the CZ regulation. This paper focuses on understanding the effectiveness of CRZ in protecting the coastal environment and coastal communities. The main objectives of this paper are to find out the violating activities within the CRZ areas and to understand the negative impacts of violation of CRZ on the coastal environment.

Study Area

Coastal stretches of Digha – Udaypur and Mandarmani – Dakshin Purushottampur have been selected for the present study. Both these coastal stretches are located in the coastal belt of Purba Medinipur District of West Bengal, India, at the northern tip of the Bay of Bengal (Fig. 1). Digha–Udaypur stretch comprises Old Digha, New Digha and Udaypur (Digha township) and it is the largest sea resort of West Bengal. Digha township started developing as a tourist destination immediately after independence when Sir John Frank Smith (an English businessman) convinced the then chief minister of West Bengal Dr Bidhan Chandra Roy to develop this place as a beach resort (Digha Sankarpur Development Authority, Urban Development Department, Govt. of West Bengal, 2018). Tourism is the main source of revenue generation in Digha township.

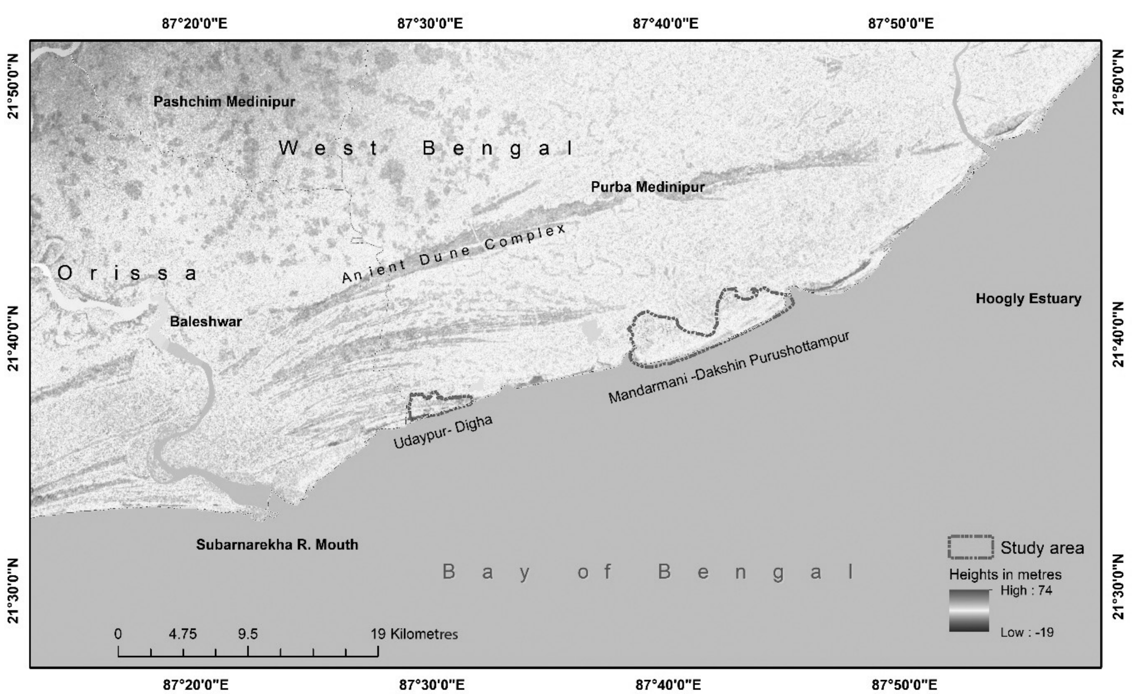

Figure 1: Location of the study area

On the other hand Mandarmani–Dakshin Purushottampur coastal stretch is comprised of six villages: Mandarmani, Silampur, Sonamui, Dadanpatra, Mania and Dakshin Purushottampur. This coastal stretch is mainly inhabited by coastal marginal people with fishing and agriculture as their main economic activities.

Dataset and Methodology

Identification of violating activities within CRZ starts with the classification of the coastal stretches of the study area according to the CRZ classification scheme of 1991 (MoEF, 1991) and the Coastal Zone Management Plan (CZMP) of West Bengal, 1996.

Preparation of basemap: Survey of India (SoI) Open Series Map (OSMs) no. 73O/6, 73O/10 and 73O/14 have been collected and georeferenced into World Geodetic System 1984 (WGS 84) for vertical referencing and into Universal Transverse Mercator Projection and zone 45 North (UTM45N) for horizontal referencing. These toposheets were merged after georeferencing.

Delineation of High Tide Line (HTL): It is the first step of classification of the coastal stretches according to CRZ norms. High Tide Line is the line on the land up to which the highest water line reaches during the spring tide (MoEF, 1991). In practice past HTL can be identified from satellite images on the basis of geomorphic characteristics, e.g. seaward limits of frontal dunes, backshore vegetation and marginal embankment. It is desirable that the time and date of pass (DoP) of the image should correspond with the spring tidal condition for a better understanding of the inundation level (Bandyopadhyay, 2007). For that the Landsat 5 Thematic Mapper (TM) data of October 23, 1991, has been used due to fulfilment of the required criteria. The time and DoP of the image and corresponding tidal condition of the nearest Tide Gauging station at Sagar Island have been provided in Table 1. TM image then georeferenced using GCPs from the already prepared basemap. After georectification, Modified Normalised Difference Water Index (MNDWI) of Xu (2006) has been carried out for identification of land–water boundary. The MNDWI can be expressed as follows:

$$MNDWI = \frac{Green - MIR}{Green + MIR} \quad \text{after XU (2006)}$$

Then the HTL has been delineated demarketing the permanent vegetation line (wherever available) and the land–water boundary identified from MNDWI image.

The HTL of 2018 has been identified from the field survey using handheld GPS receiver and following the dune toe of the frontal dune as the dune toe represents the HTL of that year, and wherever dune is not available permanent vegetation line or seawall line has been followed as seawall represents the permanent water line until the embankment is breached by wave action.

Table 1: Details of Satellite Images and Tidal Condition

Used Satellite Images				Tidal Information (Sagar Station)			
Time (GMT)/ DoP	Path/ Row	Sensor Id./ Satellite Id.	Remarks	Time (IST)/Date		Height	
				High Tide	Low Tide	High Tide	Low Tide
04:01:42/ October 23, 1991	139/45	TM/Landsat 5	Used for HTL verification	8:52 p.m./ October 22, 1991	3:16 a.m./ October 23, 1991	5.28 m	1.19 m
03:58:36/ February 25, 1991	139/45	TM/Landsat 5	Used for LULC classification	9:03 a.m./ October 23, 1991	3:25 p.m./ October 23, 1991	5.15 m	0.94 m
04:37:43/ January 2, 2018	139/45	OLI/Landsat 8	Used for LULC classification				

Source of satellite images: earthexplorer.usgs.gov; source of tidal data: tides.mobilegeographics.com

Preparation of CRZ map: Based on the annexure-I of CRZ notification of 1991 (MoEF, 1991), and following the West Bengal Coastal Zone Management Plan of 1996 (WBCZMP96), the coastal stretch of Digha–Udaypur and Mandarmani–Dakshin Purushottampur have been classified. In the WBCZMP96, sectors A-1, B-5, F-1, F-2, H-1 and N of Digha Development have been classified as CRZ-III and the sectors B-1, B-2, B-3, B-4, B-7, C-5, E, E-3 have been classified as CRZ-II for already being developed. On the other hand, all the six villages of the Mandarmani–Dakshin Purushottampur stretch have been classified as CRZ-III. It is to be noted that in the CZMP of 1996 it was recommended by the MoEF to the West Bengal Coastal Zone Management Authority (WBCZMA) that in Digha–Sankarpur area the frontal dune should be classified as CRZ-I and the area after dune up to 500 m if any should be classified as CRZ-II or III as per the regulation. Following these information coastal zones of the study area have been classified (Fig. 2).

Land-Use and Land-Cover (LULC) change detection: Landsat 5 TM image of February 25, 1991, and Landsat 8 Operational Land Imager (OLI) image of January 2, 2018, have been collected and georeferenced using GCPs from the basemap; both of these images were cloud free and for that no atmospheric correction has been carried out. Normalised Difference Vegetation Index (NDVI) of both these years have been computed to detect the change in vegetation cover in the CRZ area. The formula of NDVI is as follows:

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

Maximum likelihood image classifier algorithm has been used for unsupervised LULC classification of the years 1991 and 2018 to identify the change in land-use and land-cover classes within the coastal zone.

LULC classes have been validated using topographic sheets (for 1991) and high-resolution sentinel image (for 2018). True colour and standard false colour composite images have also been used for detecting land-use features manually.

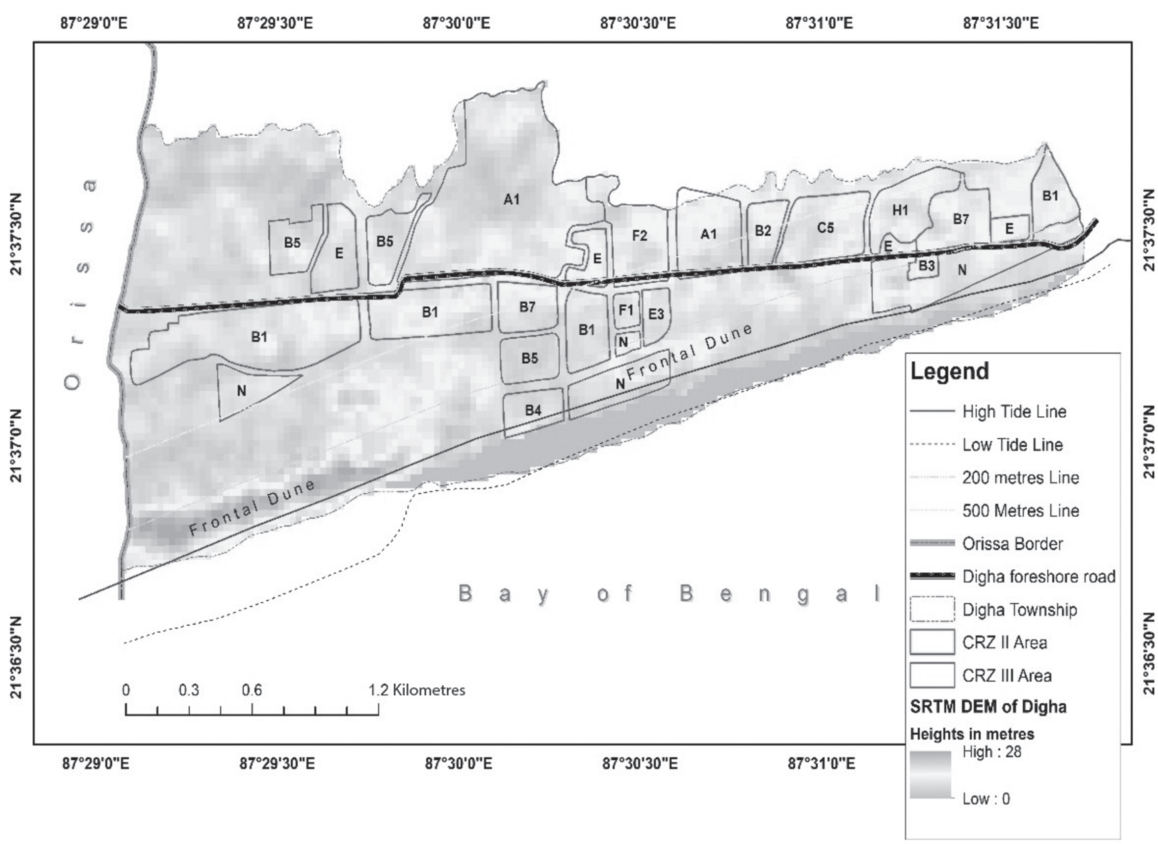

Figure 2: (A) CRZ map of Digha–Udaypur sector

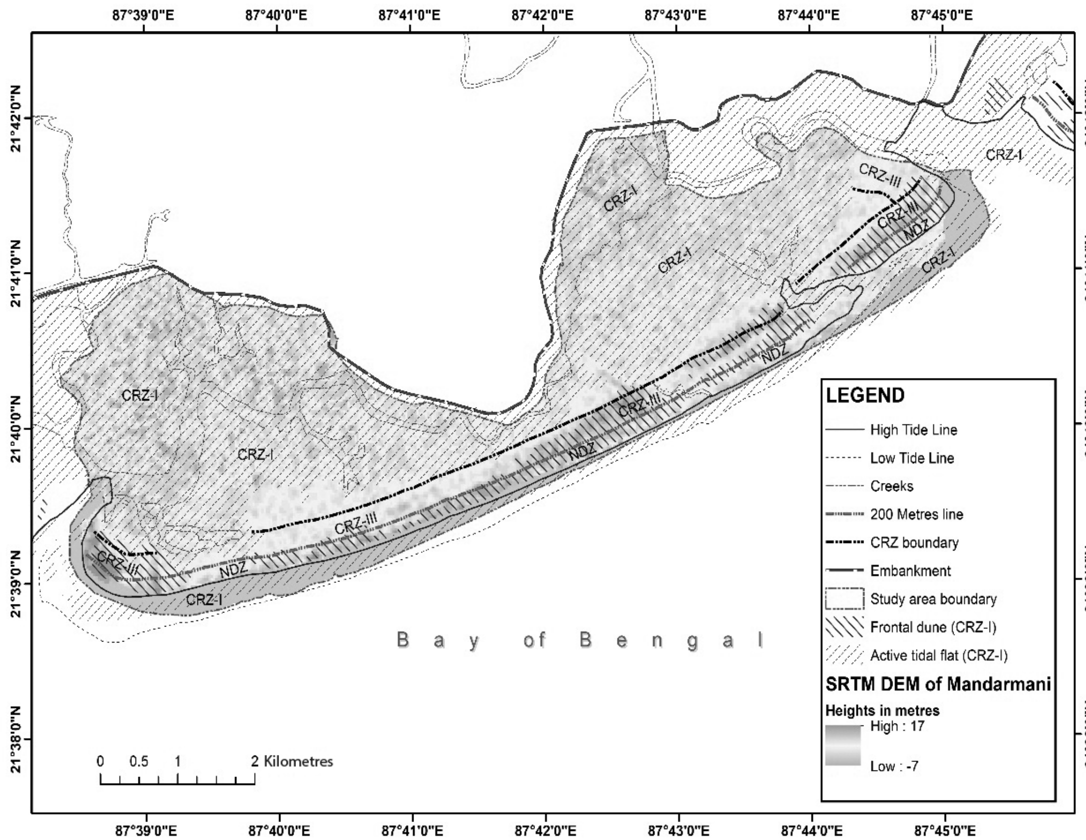

Figure 2: (B) CRZ map of Mandarmani–Dakshin Purushottampur sector

Identification of violating activities within CRZ: in the CRZ notification of 1991 some activities were prohibited and some are regulated based on the classification of coastal zones, e.g. any type of construction activities within 200 m from HTL were prohibited in CRZ-III and from 200 m up to 500 m from HTL the construction were subjected to some terms and conditions. Any new construction on the seaward side of the authorised structures is prohibited in CRZ-II areas. Thus non-implementation of such regulations can be considered as violation of the CRZ notification. Nandakumar and Muralikrishna (1998) have provided a checklist in appendix-II, for mapping violations in CRZ. For mapping the violation 200 m × 200 m grids have been constructed for both the stretches, and based on the checklist and alteration of coastal zones, a number have been assigned to every grid. Then the coastal stretches have been classified according to the violations.

Results and Discussion

CRZ Map of the Study Area

Non-availability of a basic CRZ map of the study area reduces the implementation efficiency of CRZ notification. It is important to prepare a map before identifying violation. Coastal zone of the eastern part of Digha, i.e. from 87° 30' E to 87° 32' E. (from Youth Hostel to Hotel Sea Hawk) has been classified as CRZ-II, and the western part of Youth Hostel has been classified as CRZ-III (Coastal Zone Management Plan of West Bengal, 1996), but as per the direction by MoEF to the WBCZMA some sectors, e.g. B-1, B-2, B-3, B-4, B-7, C-5, E and E-3 come under CRZ-II, and other sectors, e.g. A-1, B-5, F-1, F-2, H-1 and N, come under CRZ-III, here the direction by MoEF has been followed. The Digha Township is situated on the older dune complex, which has become the beachfront dune complex due to migration of dunes (Coastal Zone Management Plan of West Bengal, 1996), and according to the direction provided by the MoEF, frontal dune areas of Digha–Sankarpur should be classified as CRZ-I where no developmental activities are permitted. To understand the frontal dune areas, CRZ map has been superimposed on SRTM DEM (Fig. 2). The majority of the Old Digha township comes under CRZ-I if direction is maintained. A shore parallel sea wall was present in the full stretch of Digha since 1970 for protection of the Digha township from erosion. The area from sea wall to Low Tide Line (LTL) has been classified as CRZ-I.

Coastal areas of Mandarmani–Dakshin Purushottampur have been classified as CRZ-III. In Fig. 2, 200 m line and 500 m line are representing the NDZ and CRZ-III areas respectively. The area between HTL and LTL has been classified as CRZ-I – here also a frontal dune complex exists, which should be considered as CRZ-I. Between the main land and the shorefront dune, there exists a semi-active tidal flat, in 1972 toposheet (73O/10); this area is pointed as remains flooded during the months July–November, and this area should be classified as CRZ-I due to its geomorphic and ecological importance, but no mentions have been given in the WBCZMP of 1996. This stretch is actually a barrier sand island, where tidal water used to enter from both sides of the island and due to tidal asymmetry sand was deposited in the middle part of the creek and the island got connected with the main land and the creek remained open on both sides.

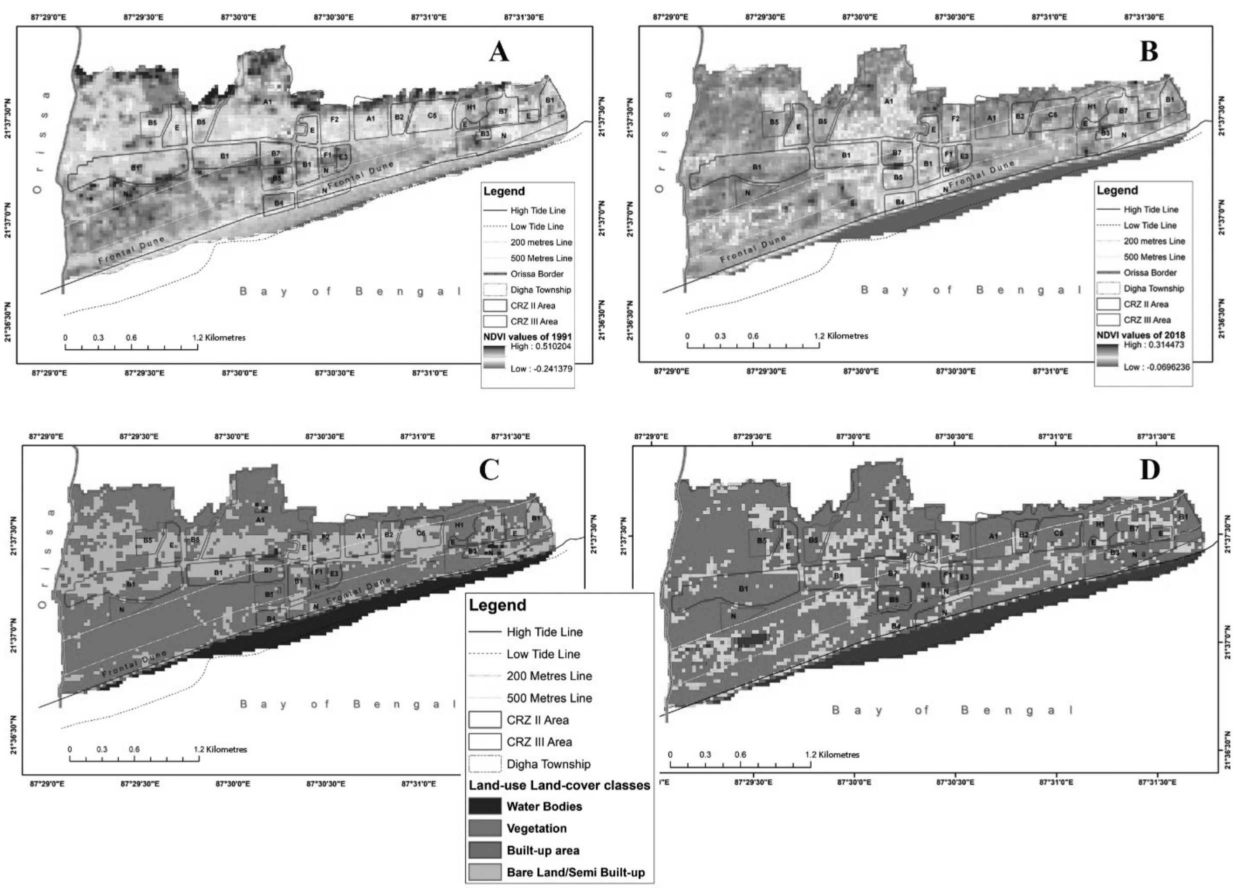

Figure 3: (A) NDVI image of Digha, 1991, (B) NDVI image of Digha, 2018, (C) LULC map of Digha, 1991, (D) LULC image of Digha, 2018

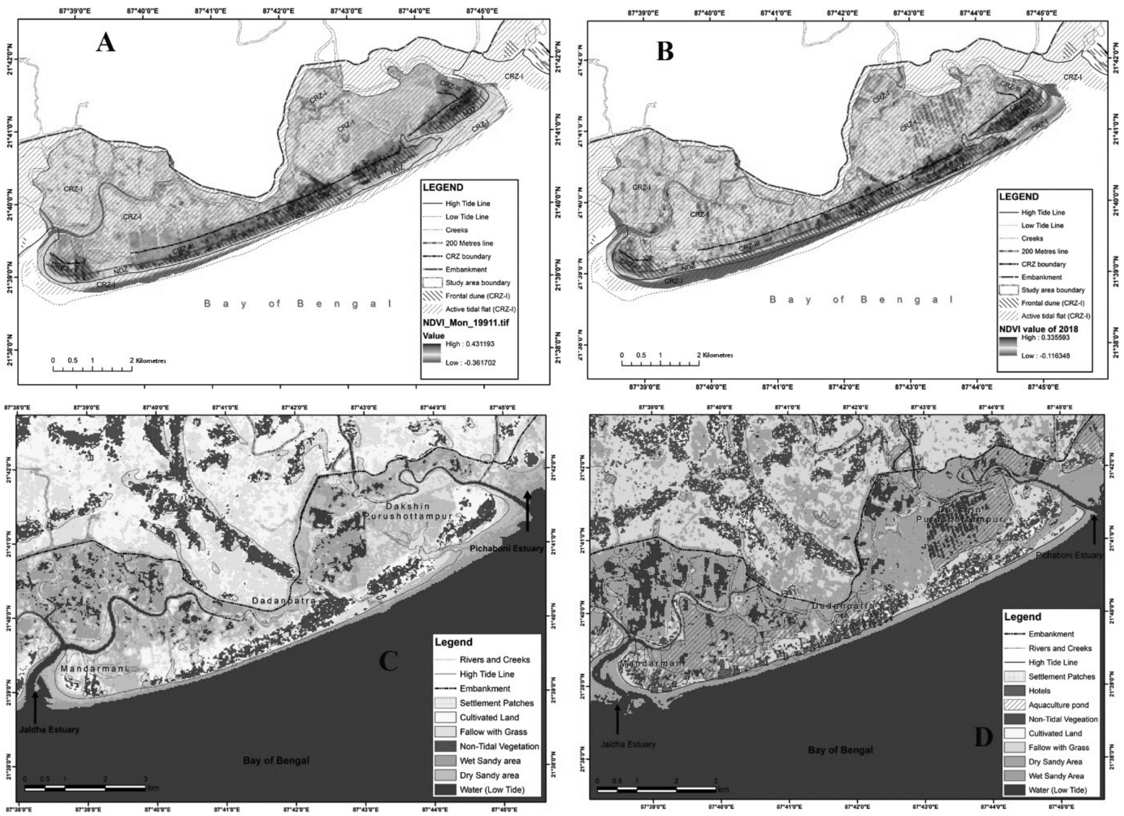

Figure 4: NDVI image and LULC map of Mandarmani–Dakshin Purushottampur, (A) NDVI image of 1991, (B) NDVI image of 2018, (C) LULC map of 1991, (D) LULC map of 2018

Land-Use and Land-Cover Change

NDVI image and LULC map of 1991 and 2018 for the study area have been prepared to identify the changes in the CRZ areas; CRZ map has been superimposed on the NDVI images and LULC maps. It can be observed that greenery has reduced from frontal dune in the middle and eastern parts of Digha township (Fig.3) and has been converted into built-up area. The majority of the loss can be observed in the New Digha township. Bare lands which were actually the dune top areas have been converted into built-up areas; some greenery have increased between New Digha and Old Digha and the western part of New Digha due to plantation of Casuarina.

In the coastal stretch of Mandarmani–Dakshin Purushottampur the majority of the vegetation loss can be observed in the middle and western parts especially between Mandarmani and Dadanpatra, vegetation loss is due to erosion of frontal dune and conversion of land into built-up area and flattening of sand dunes (Fig. 4). Loss of vegetation can also be observed in the active tidal flat area between main land and frontal dune due to coversion of saltmarshes to aquaculture pond. A spit has developed in the eastern part on the mouth of Pichaboni river. Agricultural land has also been reduced due to many factors, such as conversion of agricultural land into aquaculture pond, salinisation and development of hotels and resorts.

Violation of CRZ Area

For identification of violated areas the coastal stretches have been converted into 200 m × 200 m grids and number has been assigned to each grid on the basis of checklist survey, and land-use land-cover changes. Grids with no violation assigned a score '0', grids with violation in CRZ-II have been assigned '1', grids with violation in CRZ-III behind 200 m from HTL assigned '2', grids with violation in NDZ of CRZ-III have been assigned '3' and those grids with violation in CRZ-I have been assigned a score '4'. In this violation mapping only the seafront areas have been selected; CRZ areas along the creeks have not been considered.

In Digha stretch the majority of the violation can be observed in Old Digha and New Digha sectors, and between these two there exists a zone of no violation; mainly the violation of CRZ-III and II is present in these sectors except some areas of New Digha where violation of CRZ-I is observed. The main violation activities are construction of hotels, flattening of sand dune, extraction of groundwater, dumping of waste materials, development of parking lots in seafront areas, aquaculture ponds and fisheries. The majority of the development of this major tourist destination has been done at the cost of environment. All the hotels, clubs, offices and fisheries have been developed by converting active tidal lands and migrating sand dunes.

In the case of Mandarmani–Dakshin Purushottampur the scenario is more eye-opening – hotels are situated within the intertidal zone, violations are more in CRZ-I areas and frontal dunes have totally been destroyed by the construction activities. Hotels are directly disposing their untreated sewage in the sea. Driving on the beach, construction of lamp posts, newly construction of sea wall and exposition of boulders to protect the hotels have totally violated the CRZ regulations. And the violation is concentrated between Dadanpatra and Mandarmani. The eastern part, that is, Mania and Dakshin Purushottampur, is less violated and construction can not be observed here, but conversion of active tidal areas along the creeks into aquaculture ponds is the main violating activity.

Vulnerability Due to Violation

Coastal zone of Digha is the zone of erosion, and severe dune migration is affecting the Digha township and adjacent Gangadharpur village. The existence of Atili village is no more in the area as it was shown in the SOI toposheet of 1968 edition, due to migration of dune (Chakraborty, 1995). Digha losts 37.23, 193.01, 35.66 and 8.3 hectares of land between 1912–16 and 1931–32, 1931–32 and 1968–70, 1968–70 and 2001, and 2001 and 2008 respectively (Bandyopadhyay, Mukherjee, & Pahari, 2009). The construction of sea dikes in 1972–82 along the 3.7 km stretch of Digha has reduced the horizontal erosion, but as stated by Niyogi (1970), one metre lowering of beach would cause 75 m recession of coast to restore the equilibrium in profile. But due to contruction of sea walls horizontal erosion has been arrested; in the work of Bandyopadhyay, Mukherjee and Pahari (2009) it is mentioned that the dike of Old Digha has arrested 200 m coastal retreat, but the beach lowering has increased the slope so much that the horizontal gap between the alignment of highest HWL and lowest LWL now measures few metres, whereas the unprotected sector of Gangadharpur amounts to a normal 250 m.

Lowering of beach is also prominent in the violated areas of the Mandarmani–Dakshin Purushottampur sector. Exposition of palaeo-mud in the result of beach lowering. In Fig. 6, it can be observed that Profile A which is located in Mandarmani near Digante Resorts is about 250 m wide which is not protected by sea dike and frontal dune is present up to the HTL, whereas the protected area near Hotel Sonar Bangla Resorts has lowered down and the width of the beach is 50 m less than the 1 km away unprotected beach. Overtopping of sea dikes every fortnight during the monsoon season is very common in both the coastal stretches; on July 15, 2018, sudden high tide wave overtopped the sea dikes in Mandarmani and flooded a large area. Progressing seawater reaches Mandarmani Coastal Police station which is situated 600 m inland from the HTL.

Contruction of hotels and conversion of vegetated land area are harming frontal dune in two ways: first, construction activity materialised by flatening the sand dune and, second, removal of vegetation cover reducing the sand to be trapped by the vegetation cover this also loosening the dune to get eroded by wave and wind. Hotels and resorts are disposing their waste directly into sea and seawater is getting polluted which in turn reduces fish catch and also the biodiversity of beach. Due to lowering of dunes majority of the time water remains on the beach and this is changing the habitat pattern of living organisms, e.g. some large crabs live near the HTL which remains submerged for a very short time, and when water retreats they move out of their burrows and collect food from distant low shore areas, but due to lowering of beaches these crabs have been removed from the majority of the stretch and can be seen in the easter part of the sector near Dakshin Purushottampur where the pollution is less and their natural habitat pattern is maintained.

Conversion of low-lying active tidal flats into aquaculture pond is also causing geo-environmental hazards. Reclamation of active tidal flats is paralysing the area from getting matured in height, and these areas are remaining below High Water Level and can be submerged with rise in sea level. These areas are also breeding and spawning ground for many marine and brackish water species, and due to reclamation, these species are under great threat.

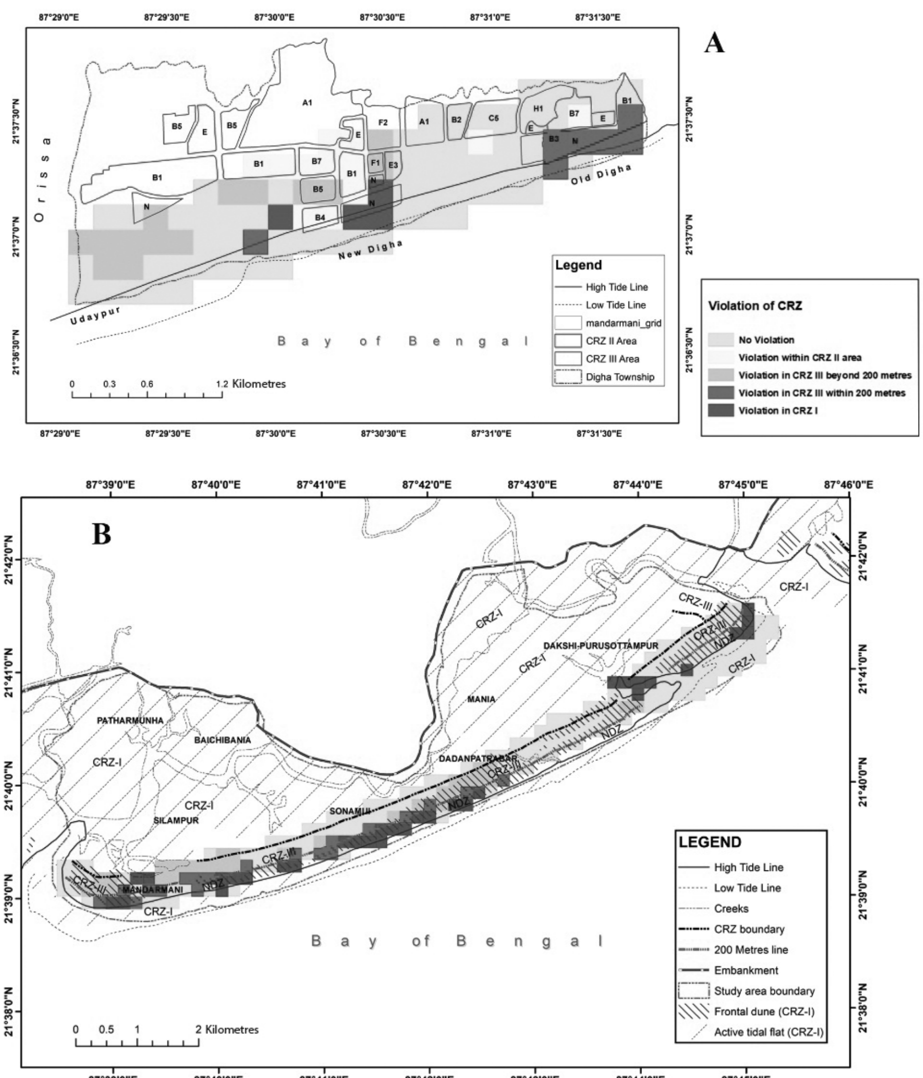

Figure 5: (A) Violation of CRZ notification along the coast of Digha–Udaypur, (B) violation of CRZ notification along the coast of Mandarmani–Dakshin Purushottampur

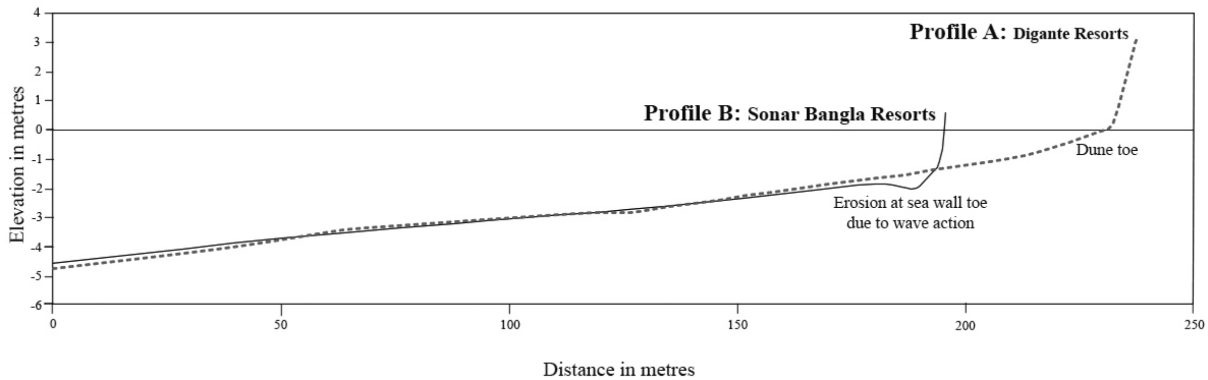

Figure 6: Beach profiles of Mandarmani, (A) profile near Sonar Bangla Resorts, protection wall is present, (B) profile near Digante Resorts, natural dune protecting the coast as a barrier. Source: Primary survey in July 2018

Conclusion

The situation of Mandarmani–Dakshin Purushottampur stretch is much more threatening than Digha. Digha was built up in the 1950s, but construction in Mandarmani started after 2005–06 and the first sea resort in Mandarmani developed in 2001. The Mandarmani–Dakshin Purushottampur is mainly inhabited by fisherfolk and agricultural communities; majority of the hotel owners live in Kolkata or outside of the area; any type of disastrous event will cause the life and property of these inhabited poor people, the resilience to cope up with any situation is less among them. Awareness and major initiatives by the local and national bodies are essential to cope up this situation. Polluters pay policy should be strictly implemented. Proper sewage treatment facility and place for dumping the waste materials should be installed in the Mandarmani area. National Green Tribunal has filed a case against these hotels. No new construction has taken place in the last two to three years except for some parks and facilities by the state government. Erosion in Digha has been reduced after construction of sea dike, but lowering of beach has resulted in the narrowing of beach and very short time exposition of beach during low tide. Waves have become dissipative to reflective in low tide and high tidal scenarios respectively. Construction of groyen on the western side of Digha Mohona has resulted accretion; proper study on sediment movement and sediment budgeting should be done for proper beach nourishment and protection. Three main variables, that is, sediment input by the rivers and sediment reworking by wave and tide governs the coastal morphodynamics (Bandyopadhyay, 2007); it is assumed that due to less sediment input by Subarnarekha river and due to construction of dams in upper catchment area and the east-directed natural drift during the monsoons (June–September) are the main cause of erosion. But the main threat is climate change and resulted sea level rise, increasing frequency of tropical cyclones and earthquake-induced tsunami. A severe cyclonic storm can cause catastrophe as the system is already vulnerable. Proper management and proper implementation of CRZ is essential.

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Bangladesh Coastal Zone: A Legal Analysis

N. Nabila Hoque[a]

ABSTRACT: The paper examines the scenario of coastal zone policies in Bangladesh and is a comprehensive desk-based research paper. The coastal zone of Bangladesh covers 19 southern districts with a total land area of 47,201 square kilometres. The lives and livelihoods of the people in the coastal zone are also adversely affected and disrupted by various other simulated and naturally occurring disasters which have decelerated expansion of development in the said regions. The Sundarbans provides sustainable livelihoods to millions of people in the vicinity of the site and acts as a shelter belt to protect the people from storms, cyclones, tidal surges, seawater seepage and intrusion. The coastal metropolitans consist of the main port city, commercial capital and Export Processing Zones.

Bangladesh is more than often defenseless to climate change. The coast region of the country specifically is famous for its vulnerabilities and natural disasters. Sea level rise, storms, cyclones, drought, erosion, landslides, flooding and salinisation are already displacing large numbers of people. The multiple purposes to address the liabilities and prospects of the coastal zones, eco-friendly commercial activities and other sustainable use of natural resources have been considered. The three main components found were coastal zone policy, coastal development strategy and priority investment programme.

All of the policies have clear implications for coastal development, but in most cases do not have specific sections on coastal areas and often fail to capture the distinctive combinations of vulnerabilities and opportunities that characterise the coast. Therefore, in order to ensure more effective implementation of ultimate policy goals, the policies need to be reviewed and updated.

KEYWORDS: climate change, coastal zone policy, legal analysis coastal development, strategy

Introduction

The coastal zone of Bangladesh covers 19 southern districts with a total land area of 47,201 square kilometres (sq km). Bangladesh's coastal region covers about 20 per cent of the nation's total land area and more than 30 per cent of the country's cultivable lands. The Bay of Bengal is the largest among 64 bays in the world and an estimated 1.4 billion people live along its coastline in Bangladesh, India, Thailand and Myanmar. The coastal area of Bangladesh is full of natural resources and consists of extremely versatile ecosystems, for instance, the world's largest single tract of mangroves (the Sundarbans), the world's longest beach (the Cox's Bazar), coral reefs, dunes, wetlands and so on. Nevertheless, the said region is often the victim of Mother Nature's wrath in forms of disasters such as tropical storms, storm surges and frequent downpour. The lives and livelihoods of the people in the coastal zone are also adversely affected and disrupted by various other simulated and naturally occurring disasters, i.e. water and soil salinity, numerous forms of pollution, land erosion, elevated arsenic content in land water, water sorting, climate change risks and so on which have decelerated expansion of development in the said regions.

Importance of Coastal Zone

Bangladesh is an agriculture-based nation and the livelihood of the people of the coastal region is also dependent on agricultural crops, mainly rice. A number

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of aspects affect the usage of land for agriculture in the coastal regions, namely, flooding, drainage congestion, physiography, soil salinity and lack of irrigation facilities. Soil salinity is distinctly high during the summer or dry season; thus, the harvesting season is restricted to the monsoon or rainy season. Aquaculture is one of the most dominating source of income for the people of the coastal zone. The *Exclusive Economic Zone* (EEZ) in the Bay of Bengal also supports marine fisheries, mainly shrimp farming. It has been predicted that the national development will soon be influenced mainly by the coastal fisheries resources.

Covering about 6017 sq km and situated in the southwest corner of Bangladesh, the Sundarbans is the largest mangrove forest in the world. The Sundarbans is a blessing for Bangladesh and has huge multidimensional use for the local people and also for the nation. The Sundarbans provides sustainable livelihoods for millions of people in the vicinity of the site and acts as a shelter belt to protect the people from storms, cyclones, tidal surges, seawater seepage and intrusion. The area provides livelihood in certain seasons for a large number of people living in small villages surrounding the property, working variously as wood-cutters, fishermen, honey gatherers, leaves and grass gatherers and so on. The trees in the forest were very slowly diminishing and one of the primary reasons for deforestation was for the purpose of expanding agricultural land. Population growth and economic pressure are two prominent factors leading to the large-scale clearing of forests. In order to remedy the situation the Forest Department in 1964 took active steps to achieve afforestation in coastal areas. Initially the plantation was done to increase the mangrove shelterbelt which later stretched to government land under the social forestry programme.

Industrial areas: The metropolitans, such as, Chittagong and Khulna, and many other cities are situated alongside the coast. Apart from being the second largest city in the country, Chittagong is the main port city and also a commercial capital. There are Export Processing Zone (EPZ), the industrial belts in both Khulna and Chittagong. Along with ship-breaking yards on the coast of Chittagong. According to a report in an English daily, Chittagong generates 40 per cent of the country's industrial output, 80 per cent of its international trade and 50 per cent of its government revenue. Approximately 30 million people of Bangladesh are directly dependent on oceanic fisheries and sea-based commercial transports for their livelihoods.

Tourism: Most of Bangladesh's present tourist attractions are located in coastal areas. Bangladesh is working towards a sustainable marine tourism industry that will contribute to coastal community development and poverty reduction as well as protect marine ecosystem and biodiversity. The country offers the rare beauty of sunrise and sunset from the same location in fascinating Kuakata, the beauty of the Sundarbans, the home of Bengal Tigers, the world's longest sea beach in Cox's Bazar and many more attractions. Coastal tourism is contributing to the economy and the people of the coastal regions. The government is taking measures for the development of the tourism sector and efficient management.

Environmentally important: The coastal zone possesses several ecosystems that have important conservation value. These ecosystems are biodiversity hot spots, but planned management is yet to be initiated. Recognising the gradual depletion of ecosystems and the ecological importance of the flora and fauna, Bangladesh has identified protected areas in the form of national parks, game reserves, wildlife and fish sanctuaries, world heritage sites, marine reserves and ecologically critical areas. There are three wildlife sanctuaries in the Sundarbans and all of them were established in 1977 under the Bangladesh Wildlife (Preservation) (Amendment) Act, 1974, having first been gazetted as forest reserves in 1878. Along with the Forest Act, 1927, the Bangladesh Wildlife (Preservation) (Amendment) Act, 1974, controls activities such as entry, movement, fishing, hunting and extraction of forest produce.

Problems of Coastal Zone

Bangladesh is more than often defenceless to climate change. Its low altitude, high population density and insufficient groundwork altogether work adversely for the nation. The coast region of the country specifically is famous for vulnerabilities and natural disasters. Among them land accretion and erosion in the coastal region generate socio-economic abnormalities and concerns. While erosion forces dislocation of individuals, land seizure and unlawful settlement are predominant in areas where the coast is accreting. Bangladesh frequently experiences cyclones and storm surges which leads to extensive destruction to life and property. The shallow mainland and uniform coastal land aggravate the cyclonic storm surges. Defence from repeated storm surges is an imperative concern in land management.

Displaced people: Sea level rise, storms, cyclones, drought, erosion, landslides, flooding and salinisation are already displacing a large number of people. It has been estimated that by 2050, one in every seven people in Bangladesh will be displaced by climate change. Up to 18 million people may have to move because of sea level rise alone. Approximately 28 per cent of the population of Bangladesh lives on the coast, where the primary driver of displacement is tidal flooding caused by sea level rise. By 2050, with a projected 50 cm rise in sea level, Bangladesh may lose approximately 11 per cent of its land, affecting an estimated 15 million people living in its low-lying coastal region.

The progression of salinisation has worsened by increasing sea levels. The backbone of Bangladesh's economy is agriculture which is being severely affected and harvests spoiled by increasing salinity are especially in danger from the consequential soil degradation. As a result many areas have already been a victim of huge harvest losses and substantial decrease in value. Additionally the coastal regions are also suffering growing frequency and severity of tropical storms, which cause loss of human life, damage to houses, property and infrastructure, and disruption of agriculture and other livelihoods. In 2016 there were four cyclones, namely, Roanu, Kyant, Nada and Vardah – in the Bay of Bengal, although generally there is just one.

Impacts on women: We live in a society where women and children are the most vulnerable group. During disaster, this vulnerability increases. Though disaster itself does not discriminate, the socially constructed role of women makes them more vulnerable during the said circumstances. The women of Bangladesh are among the first to face the impacts of climate change, and their suffering is disproportionate. Life after a disaster is difficult, and the threshold of difficulty increases by many folds for women refugees due to many causes, like their vulnerability, mental attitude, physical attributes and other social issues. Women who migrate are often at risk of human trafficking. It has been observed that the number of Bangladeshi women being trafficked to brothels is rising.

Legal Framework

Natural disasters have made coastal land-use management an important aspect of national development. Hence, coastal land-use management is one of the key features in national coastal development policy and strategy. In 1999 Bangladesh government adopted the Integrated Coastal Zone Management activity policy. The policy's multiple purposes to address the liabilities and prospects of the coastal zones, eco-friendly commercial activities and other sustainable use of natural resources have been taken into consideration. The three main components were a coastal zone policy, a coastal development strategy and a priority investment programme.

The Priority Investment Programme, 2004, was introduced for the following purposes:

- Mitigation of natural disasters, safety and protection
- Environment management – defence and rejuvenation of the environment
- Water resources management
- Enhancing rural livelihoods and sustainable economic opportunities for coastal people
- Productive economic activities, intensive growth of tourism and fisheries sector
- Infrastructure development
- Social development including health and nutrition, education, water and sanitation

The Ministry of Water Resources formulated the Coastal Zone Policy, published in the official gazette in March 2005. The main objectives of the Coastal Zone Policy 2005 were as follows:

- Reduction of coastal vulnerabilities and improvement of surviving mechanism
- Improving the livelihood of the seaside community by ensuring their basic needs
- Guaranteeing the optimal usage and sustainable management of coastal resources

- Creating an empowering institutional environment
- Advancement of gender equality through women's progression
- Conservation and enrichment of endangered ecosystems

The Coastal Development Strategy (2006) was made to organise synchronised priority actions and preparations for their execution via choosing planned priorities and setting targets. The main priorities of the Coastal Development Strategy (2006) were:

- Ensuring clean and safe water availability
- Protection from human-induced and natural hazards
- Improving use of coastal lands
- Stimulating economic growth
- Sustainable management of natural resources
- Betterment of coastal livelihood, especially women's
- Environmental conservation
- Empowerment via knowledge management
- Assisting institutional environment

Other legislation and policies associated with coastal zone management of Bangladesh primarily comprise, policies and legislation for the management of coastal forests and trees, policies and legislation for the management of coastal land, policies and legislation for the management of coastal water, and finally policies and legislation for the management of coastal fisheries.

The Forest Policy, 1994, highlights the formation of plantations on all recently accreted lands in the coastal zones. It is dedicated to preserving the resources and ecosystems of the Sundarbans. Safeguarding the nation against natural disasters is the primary objective of the National Environment Policy, 1992. It concentrates on the conservation of ecological equilibrium and sustainable development. On the subject of coastal forest, the Coastal Area Policy, 2005, has a comparable assurance. It usually underlines sustainable development in the coastal zone and, hence, straightaway supports the formation of coastal plantations and preservation of prevailing coastal forests and conservation of coastal habitations.

As per the Land-Use Policy, 2001, generally the coastal "Char Land" is at first given to the Forestry Department for 20 years. During the said period, mangrove forests are planted as portion of the coastal defence system. As accretion progresses, the land behind the mangrove belt is converted into agricultural land for settlement. Thus, the government also has a limited scale land settlement programme. People who have lost their land due to erosion are given priority in the allocation of such said land. The Environment Policy, 1992, stimulates usage of land depending on the ecosystem predominant in various regions of the country. It highlights that efforts ought to be reinforced for land recovery, erosion defence, soil fertility and decrease of soil salinity and/or alkalinity. The said policy also indicates reassigning of newly accreted land to the Forestry Department on a priority basis to stabilise and defend the land from erosion.

The Forestry Policy, 1994, declares that "effective measures will be taken for afforestation in the newly accreted char in the coastal areas, as it protects soil and reduces the velocity and intensity of cyclones, tornados and tidal bores". The aforesaid further assists to stabilise newly accreted land. The National Water Policy, 1999, proposes undertaking surveys and enquiries of the problem of riverbank erosion, developing and executing master plans for river training and erosion control, and planning and executing systems for retrieval of land from the sea and rivers.

The National Policy for Safe Water Supply and Sanitation, 1998, suggests that every single village should have a pond specifically set aside only for drinking water. The said pond is also to be secured from contamination and surface runoff. The waterlogging problem has produced extensive dissatisfaction amongst the people. The Development Strategy of the National Water Management Policy, 2001, reflects upon it with primary importance to rationalise coastal embankment systems on the basis of environmental audit. Last but not least the policies and legislation for the management of coastal fishers are the Fisheries Marine Fisheries Ordinance, 1983, and National Fish Policy, 1998. These are two of the main policies on marine fisheries for Bangladesh.

Conclusion and Recommendations

All of these policies have clear implications for coastal development, but in most cases do not have specific sections on coastal areas and often fail to capture the distinctive combinations of vulnerabilities and opportunities that characterise the coast. The policies have been developed for all concerned institutions to put their efforts together for the development of the coastal zone of Bangladesh. Though systematising their actions in the coastal zone and expanding the foundation for a firm synchronisation mechanism. Nevertheless, a lot of improvement is still required for sustainable development of the coastal zone. The policies were more or less adopted with an ultimate aim to generate circumstances in which poverty will be reduced and the livelihoods of the coastal communities will develop. Unfortunately the coastal zone has suffered from various practical management-related difficulties that have led to lower than expected economic revenues and more than predicted environmental damage.

Therefore, in order to ensure more effective implementation of ultimate policy goals, the policies need to be reviewed and updated. An efficient system for monitoring and impact assessment of policy implementation needs to be developed. Ensured stakeholder participation in policy formulation is of vital importance. Good management practices need to be followed at all times in order to ensure adequate policy implementation. The policies must include specifically detailed contingency plans for coping with disasters along with guidelines on how such plan is to be effectively made. The mitigation plan of the problems is also required to be included in the said policies.

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Assessing Vulnerability of Coastal Communities to Climate-Induced Hazards: The Case of Kerala, India

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ABSTRACT: The coastal villages of Kerala spanning nine districts with a coastal belt of 590 kilometres have been primarily prone to climate-induced hazards of varying patterns and intensity. In Kerala, the vulnerability is exacerbated due to high density of population, social and economic disparity, differential infrastructure and services, and so on. However, there have been few attempts to investigate the underlying factors and pathways through which vulnerability of coastal communities is constructed. Hence this research aims to identify and assess the driving factors, which expose the coastal communities to constant risks due to various climate-induced hazards. This is achieved by building a Composite Vulnerability Index and mapping the vulnerability of various coastal districts in terms of their performance on the index. Comprehending existing literature on vulnerability research as well as relevant secondary data, the study consolidates various proxies of socio-economic and community development of the Kerala coastal community under four major sources of vulnerability, such as (1) demographic variables, (2) occupational variables, (3) built infrastructures and (4) lifeline support services. The study then attempts to build the composite index by aggregating and normalising the performance of various indicators under the identified sources of vulnerability. The vulnerability mapping demonstrates that vulnerability significantly varies across the nine coastal districts. As the vulnerability index developed tries to capture a comprehensive scale of vulnerability including many indicators of development, this study helps to identify and examine potential factors that contributed to the vulnerability in each district. This would help to propose context-specific interventions and strategies to combat the negative impacts of climate change leading to sustainable adaptation to the changing climatic pattern. Additionally in the context of varying geography and variation in the nature and pattern of development along coastal districts of Kerala, this study sheds light on the need to consider location-specific vulnerability sources with higher priority for minimising risk of coastal communities during frequent natural hazards.

KEYWORDS: natural hazards, coastal community vulnerability, vulnerability assessment, composite vulnerability index

Introduction

The coastal population is at risk due to increased frequency and intensity of climate-induced natural hazards globally. In India the fishermen community spanning for almost 7500 km long densely populated and low-lying coastline is directly exposed to deleterious effects of climate impacts such as cyclone, flood, drought, sea level rise and temperature and rainfall variability. A study by Intergovernmental

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Panel on Climate Change (IPCC) points out that the vulnerability of a region depends to a great extent on its wealth and that the level of poverty of the community limits their capacity to adapt to the climate impacts (IPCC, 2000). Moreover, literature on climate change impacts and vulnerability studies indicated that countries, regions, economic sectors and social groups differ in their degree of vulnerability to climate change (Bohle et al., 1994). Additionally, it is recognised that impacts, adaptive capacity and vulnerability will vary even within a region (IPCC, 2001).

Coastal regions are geographically important as well as vital domains in terms of economy and biology. 60 per cent of the world's 39 metropolises with a population of over 5 million are located within 100 km of the coast, including 12 of the world's 16 cities with populations greater than 10 million (IPCC 2001). In developing countries, such as India where approximately 20 per cent of its population live in coastal areas (TERI, 2008), coastal communities are highly vulnerable and are in the front line of the detrimental effects of the changing climate. Vulnerability is a condition wherein the internal ability or lack thereof to cope, recover and adapt to climate stress (Kasperson et al., 2003). Coastal vulnerability describes the susceptibility of the natural system and of coastal societies (persons, groups or communities) towards coastal hazards. Though the natural hazards occur regionally, their pattern and scale of impacts vary locally based on the inherent susceptibility.

Kerala is one of the major coastal states of the country with a coastline of 590 km. The coastal area of Kerala comprises nine districts, distributed across 222 fishing villages and is considered as one of the important centres for fisheries-related activities in the entire north-western Arabian Sea. The coastal stretch of the state recently experienced various natural hazards such as Tsunami 2004, Okhi cyclone 2017 and the flood 2018. The coastal belt of Kerala is one of the most densely populated regions in the country, which adds to its vulnerability. Additionally a study by Praveen et al. (2013) revealed that sea level rise due to a coastal hazard may result in pronounced inundation of coastal stretches with low backshore elevation. However, there have been few attempts to investigate the underlying factors and pathways through which vulnerability of coastal community is constructed.

This paper attempts to construct a picture of socio-economic context of vulnerability by focusing on indicators that measure both the state of development of the region and its capacity to respond to the impending natural hazards.

Literature Review

This section provides an overview of literature on vulnerability of coastal zones due to impending climate change largely based on studies on developing countries. An attempt is also made to comprehend various driving factors of vulnerability in terms of socio-economic and infrastructure development. Coastal zones throughout the world have historically been among the most heavily exploited areas because of their rich resources. In coastal nations more than half of the population lives in coastal areas, and migration from inland areas to the coast is increasing. Climate change has posed new threats to many of the coastal areas. The problems of the coastal zone are unique due to the high density of population, loss of land due to coastal erosion and mining of beach sand for industrial purposes, drastic morphological and shoreline changes due to shore structures like harbour breakwaters (Sachin et al. 2014). The coastal community is the only sector that periodically loses dwelling places due to erosion. The destruction of natural habitats in the form of reclamation of wetlands, cutting of mangroves and dumping of industrial and urban wastes worsens the plight of the coastal communities (Sachin et al. 2014).

In developing countries, such as India where approximately 20 per cent of its population live in coastal areas (TERI, 2008), consequently climate change could represent additional stress on ecological and socio-economic systems of the coastal community that are already facing tremendous pressures due to rapid urbanisation, industrialisation and economic development. India, the second largest producer of fish, is contributing about 5.43 per cent of the global fish production and thus providing livelihood to 14 million people in the country (Das et al., 2014).

Vulnerability has emerged as a central concept for understanding the impacts of climate change and natural hazards, in order to develop adequate risk management strategies. Kasperson et al. (2003) defined vulnerability as a condition wherein the internal ability or lack thereof of the community to cope, recover and adapt to climate stress. Further, coastal vulnerability describes the susceptibility of the natural system and of coastal societies (persons, groups or communities) towards coastal hazards. Assessing coastal vulnerability is an important prerequisite to identify the areas of high risk, factors contributing to the risk and the ways to reduce the risk (Brooks, 2005). Studies on vulnerability of coastal community have been largely based on vulnerability indices constructed using multiple indicators. Within the UNFCCC, indicators of vulnerability have been defined that can be used to study vulnerability and adaptive capacity and identify areas (countries or regions) that are vulnerable. Vulnerability is often reflected in the condition of the economic system as well as the socio-economic characteristics of the population living in that system.

Many researchers have adopted index-based approach to address the socio-economic status of the coastal communities. For instance, Kumar (2003) constructed a coastal vulnerability index by hypothesising vulnerability as a function of the impact of the climate change on the community as well as their resistance and resilience to the impacts experienced. Vijayakumaran (2008) approximated direct scores made for 39 factors under seven dimensions based on the information obtained from the villages. Szlafsztein and Sterr (2007) formulated an index combining a number of separate variables that reflect natural and socio-economic characteristics that contribute to coastal vulnerability due to natural hazards. In the context of the present paper, vulnerability is defined as the fishers inherent inability, or lack, to cope with or recover from and adapt to climate stress.

Characteristics of the Coastal Community in Kerala, India

Kerala is one of the major coastal states of India with a coastline of 590 km distributed across 222 fishing villages and 187 landing centres. In Kerala about 40 per cent of the people live within 25 km nearer to the coast and hence the major economic activity of the state takes place within this area. Moreover the coastal zone also has density of population of more than 2500 persons per sq km which is much higher than the average density of India 1099 (Marine fisheries census 2010). The map showing the coastal districts of Kerala is given in Fig. 1.

The major livelihood of the coastal community is fishing and allied activities with people involved in the primary and secondary sectors amounting to around 2.1 lakhs. There are nine coastal districts in Kerala: Thiruvananthapuram, Kollam, Alappuzha, Ernakulam, Thrissur, Malappuram, Kozhikode, Kannur and Kasaragod. Many geophysical processes like coastal erosion, storm surges, coastal flooding, tsunamis and sea level rise pose hazards to these people. The intensity of each of these processes is likely to increase under changing scenarios of global climate change. A study by Praveen et al. (2013) revealed that sea level rise due to a coastal hazard may result in pronounced inundation of coastal stretches with low backshore elevation. About 370 Km of Kerala coast is subject to coastal erosion of various magnitudes due to one or more or combination of several factors like early onslaught of monsoon and subsequent high and steep waves and geological factors, sea level rise, turbulent zones near Lakshadweep and laterite cliff erosion. The erosion tendencies may increase with human activities such as urbanisation, construction of dams, prevention of soil erosion in the midland and high land belts, development of harbours.

With a dependency of 118,937 families on fish and fishery-based industries and almost 55 per cent of families falling below the poverty line, the coastal communities of Kerala is more prone to suffer from the adverse effects of climate change. The socio-economic condition of the fisherfolk in the state is pitiable when compared to the general section of the population. In Kerala the high density of population, social and economic differences, as well as differences in the quality of built structures, exacerbate the vulnerability of coastal community leading to constant risk to hazards. Many artisanal fishers are extremely poor and are often socially and politically marginalised with limited access to healthcare, education and other public services. Lack of proper infrastructure facilities cause these regions and communities to live in relative isolation from the mainstream.

Figure 1: Coastal districts of Kerala

Materials and Methods

In this section, the methodology adopted for the construction of the index of vulnerability for the coastal districts of Kerala is presented. A study by Intergovernmental Panel on Climate Change (IPCC) points out that the vulnerability of a region depends to a great extent on its wealth and that poverty limits adaptive capabilities (IPCC, 2000). Further, they argue that socio-economic systems typically are more vulnerable in developing countries where economic and institutional circumstances are less favourable

The vulnerability index, measured here, tries to capture a more comprehensive scale of vulnerability. This is done by including many indicators that serve as proxies to look at different aspects of vulnerability. In particular the study considered four different sources of vulnerability, such as (1) demographic variables, (2) occupational variables, (3) built infrastructures and (4) lifeline support services which are trivial in determining the overall vulnerability of an area.

In this study, the possible sources of vulnerability for each of the nine coastal districts were identified followed by identification of sub-indicators for each source of vulnerability. A composite coastal vulnerability index is thus developed focusing on indicators that measure the socio-economic and development status of the region as the major drivers of vulnerability. Figure 2 presents the sources of vulnerability as well as their indicators under consideration of the current research.

The methodology used to calculate the vulnerability index follows the basic approach developed by IPCC by taking the geometric mean of the various proxies after standardising them. Since it was extremely time intensive, expensive and cumbersome to carry out the survey in the entire state, these parameters were obtained as secondary data from the Marine Fisheries Census (2010) published by Ministry of Agriculture, Government of India, New Delhi and Indian Council of Agricultural Research. The procedure followed to construct the vulnerability index for the different coastal districts has been described below.

- Step 1: Calculate a dimension index of each of the indicators for a district (X_1) by standardising the sub-indicators of each source of vulnerability using the formula.
  Dimension Index = (Actual X_1 – Minimum X_1)/(Maximum X_1 – Minimum X_1)

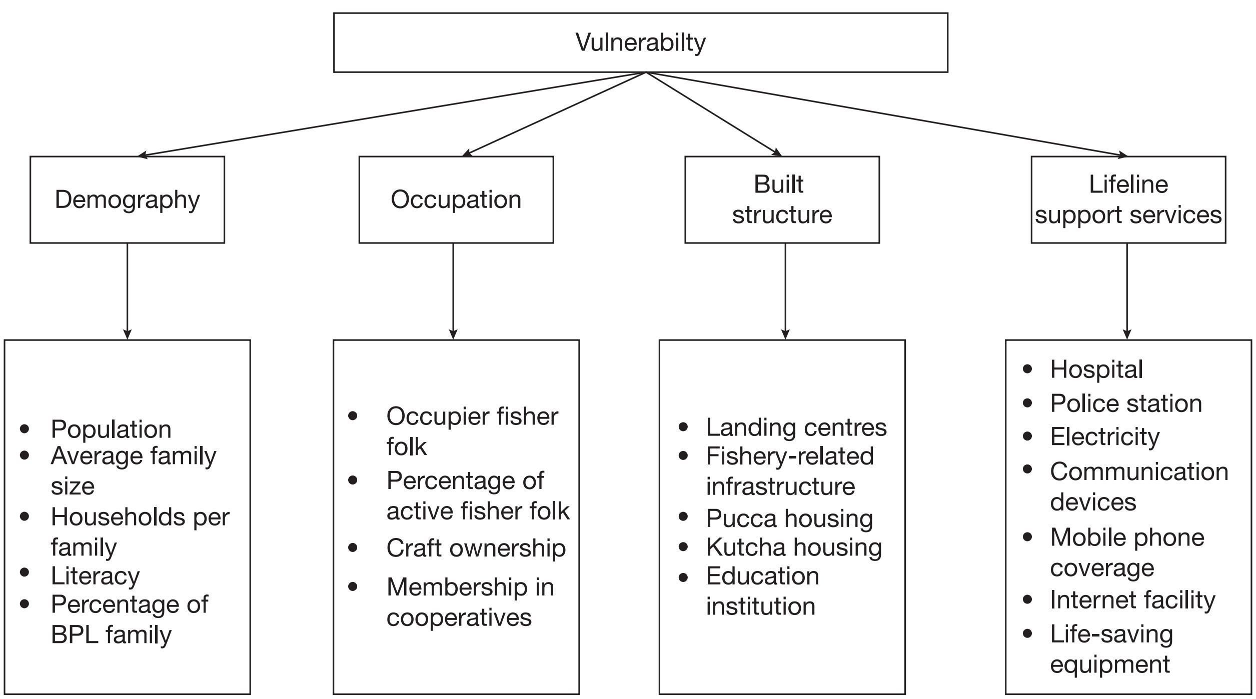

Figure 2: Sources of vulnerability and their indicators

- Step 2: Calculate average index (AI) for each of the four sources of vulnerability. This is done by taking a simple average of the indicators in each category.
  Average Index i = [Indicator 1 +……… + Indicator J]/J
  where, J = Number of indicators in each source of vulnerability
- Step 3: Aggregate across all the sources of vulnerability by the following formula.
  Vulnerability Index = $(AI_1 \times AI_2 \times AI_3 \times \ldots\ldots AI_n)1/n$, where n = Number of sources of vulnerability

After the values of the index are calculated for all the districts a ranking of the various districts can be carried out to identify the most vulnerable districts in terms of the overall vulnerability as well as the various sources of vulnerability used for measurement. In the present study, four different parameters – (1) demography, (2) occupation, (3) built infrastructure and (4) lifeline support services – were taken into consideration as the sources of vulnerability for the identification of the most vulnerable coastal district of Kerala. The mapping and assessment of vulnerability is carried out at the district level only.

Results and Discussion

The main aim of the study was to map and assess the vulnerability pattern of coastal districts in Kerala. The composite vulnerability index obtained by using the method described by IPCC is shown in Table 1. The highest value was obtained for the district Thiruvananthapuram, followed by the Alappuzha district, whereas the district Kannur is reported to be the least vulnerable coastal district in Kerala based on the four sources of vulnerability under consideration.

Thiruvananthapuram is identified to be the highly vulnerable coastal region as it has registered medium values in terms of all the indicators. Alappuzha has been highly vulnerable due to the network of environmentally sensitive wetlands, lagoons and sandy beaches. Based on the analysis of the index across the districts under study it is clear that the vulnerability varies across the districts. The variation in vulnerability is mainly attributed to the high amount of inequality in the distribution of resources in these regions. Moreover as the index takes into account a variety of sources of vulnerability into consideration, the variation in the index can be due to all these factors. The sources like demography and occupation have a direct impact on the people living in the area. The areas along the coastline of Kerala are thickly populated and are also prime agriculture producing lands. Therefore any changes on to these sources will have a direct impact on the vulnerability of the people living in this region. Social and political marginalisation leaves many fishers with little capacity to adapt to climate impacts thus making them more vulnerable. The socio-economic standard of a society determines its ability to cope with adverse events and is mainly contributed by education facility, sanitation facility, access to drinking water and healthcare facility which are also considered as the critical factor for the social development. The sensitivity of the fisherfolk increases due to their inadequate knowledge of climate change as a result of which they are not able to correlate influence of climatic changes on their livelihood. Changes in land use pattern could possibly magnify the effects of extreme climate events like fatalities from storms and other infectious diseases (Patz and Campbell, 2005). Similarly, the unregulated expansion of industries, the inadequacy at the policy, and planning and implementation levels such as inadequate disaster preparedness, rehabilitation measures, incentives and economic supports for the affected are declining the capacity of the community to cope with the changing climate. Smit and Wandel (2006) in their study have discussed in detail about various parameters on which the adaptive capacity of fishers depend and concluded that adaptation measures should be the prime focus while forming the various policies to counteract the impact of climate change. All these findings should be addressed and incorporated while forming a suitable disaster mitigation policy for them.

Table 1: Composite Vulnerability Index of Coastal Districts of Kerala

District	Demography	Occupation	Built Infrastructure	Life Line Support Services	Vulnerability Index
Thiruvananthapuram	0.648	0.750	0.660	0.929	0.74
Kollam	0.444	0.264	0.283	0.300	0.32
Alappuzha	0.503	0.520	0.401	0.623	0.51
Ernakulam	0.283	0.227	0.249	0.252	0.25
Thrissur	0.278	0.178	0.151	0.143	0.18
Malappuarm	0.360	0.382	0.276	0.300	0.33
Kozhikode	0.472	0.504	0.539	0.625	0.50
Kannur	0.341	0.060	0.120	0.068	0.11
Kasargode	0.396	0.113	0.053	0.087	0.12

Conclusion

The results of the present study provide necessary inputs to understand the vulnerability of fishing communities in Kerala due to climate change. From the study, it is apparent that vulnerability significantly varies across the nine coastal districts. As the vulnerability index developed tries to capture a comprehensive scale of vulnerability including many indicators that serve as proxies of development across various districts, this study helped to identify and examine potential factors that contributed to the vulnerability in each district. This would help to propose context-specific interventions and strategies to combat the negative impacts of climate change leading to sustainable adaptation to the changing climatic pattern. Additionally in the context of varying geography and variation in the nature and pattern of development along coastal districts of Kerala, this study sheds light on the need to consider location-specific vulnerability sources with higher priority while developing mitigation and adaptation strategies for minimising risk of coastal communities during frequent natural hazards. Moreover, the micro-level assessment of the pertinent factors of vulnerability would enable the formulation of specific measures to enhance coping capacity of the community locally. This would ensure containing and combating the risk due to climate change making the coastal community resilient to impending natural hazards. It further concludes that the developmental and welfare activities in the coastal areas need to be planned in a climate change perspective equipping the coastal population to adapt to changes in climate scenario. Finally, the study would also serve as a foundational research for a systematic assessment of causal factors of vulnerability to coastal hazards across different geographical scales along the Kerala coast.

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III Earthquake Risk Assessment

Seismic Microzonation Studies of Srinagar, Garhwal, India

P. K. S. Chauhan[a], Abha Mittal[a], Gayatri Devi[a] and Zamir Ahmad[a]

ABSTRACT: Seismic microzonation has been recognised as the most accepted tool in seismic hazard assessment and risk evaluation. It is defined as the zonation with respect to ground motion characteristics taking into account source and site conditions. The study is the improvements on the conventional macrozonation maps and regional hazard maps. Seismic microzonation of a region generates detailed natural frequency and ground amplification maps that predict the hazard at much larger scales. Damage patterns during earthquakes around the world have demonstrated that the local soil conditions at a site have a major effect on the level of ground shaking. In the Chamoli earthquake, epicentre located more than 300 km away from Delhi caused damage to some of the buildings (Tarang Apartments) built on filled up soil or on soft alluvium. Earthquake damage is commonly controlled by three interacting factors: source and path characteristics, local geological and geotechnical conditions, and type of the structures. Mapping the seismic hazard at local scales to incorporate the effects of local ground conditions is the essence of microzonation.

Site response studies using micro-tremor or ambient noise data are one of the well-known tools of seismic hazard assessment and microzonation. Different soil types behave differently for the same ground motion – some amplify it too much and some don't. It is well accepted that, besides the earthquake magnitude and epicentre distance, local geology exerts significant influence on earthquake ground motion at given location. In general the soft soil and thick overburden amplify the ground motion. Micro-tremor data provides an important input in seismic microzonation studies. Srinagar (Garhwal Himalaya), the largest growing city of Uttarakhand, India, lies in seismic zone-V and has a long seismic history. The micro-tremor data using Altus K2SMA has been collected at 47 locations from different parts of the city. The data has been analysed with the help of non-referenced site-dependent spectral ratio technique. This technique is known as horizontal-to-vertical spectral ratio technique and was developed by Nakamura. Observation of micro tremors can give useful information on dynamic properties of the site such as predominant period and amplitude; micro-tremor measurements can be used conveniently for seismic microzonation. The city has been divided into three zones on the basis of natural frequency(Nf). Most of the part of the city lies in zone–I which seems to be affected largely during the future earthquake. The central part of the city has a share of rest zones, i.e. II and III. Vulnerability index has been also computed and found quite high, more than 50 at many places. These locations could have higher degree of damages during the future earthquake.

KEYWORDS: seismic microzonation, micro-tremor, natural frequency, vulnerability index

Introduction

The regional seismic zonation does not incorporate local site effects induced during the earthquakes leading to its incapability for land-use development and planning and structural engineering applications at the city level. It is the need of present to overcome the limitations of regional zonation practices, especially in

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urban seismic provinces with growing population and unplanned urbanisation practices. The study of seismic microzonation will, therefore, provide an effective solution for urban planning. Seismic microzonation of urban centres helps in characterising potential seismic vulnerability and risk. The knowledge of which ensures safe designing of new structures or retrofitting the existing ones.

Seismic microzonation is a process that involves multidisciplinary approach. These include geological, seismological and geotechnical approaches for earthquake effects so that architects and engineers can site and design structures that will be less susceptible to damage during earthquakes. Seismic microzonation is the subdivision of a region into zones that have relatively similar exposure to various earthquake-related effects. This exercise is similar to the macro-level hazard evaluation but requires more rigorous inputs about the site-specific geological conditions, ground responses to earthquake motions and their effect on the safety of the buildings and ground conditions which would enhance the earthquake effects like the liquefaction of soils, the ground water conditions and the stability of slopes in the hilly terrain. Seismic microzonation must address the following aspects to obtain a reliable and meaningful Microzonation Hazard Map of any terrain/ urban centre (Seismic Microzonation Handbook, 2011).

Geological Consideration

- Regional and local geological studies
- Seismotectonic Map

Geotechnical Studies

- Geotechnical site characterisation based on Standard Penetration Test (SPT), Cone Penetration Test (CPT) and shear wave velocity.
- Recurrence interval/return period may be judiciously considered in the analysis.

Seismological Studies

- Earthquake catalogue at the local and regional levels for seismic source characterisation.
- Strong ground motion synthesis for Peak Ground Displacement/Velocity/Acceleration (PGD/PGV/PGA).
- Response spectra.
- Ground Motion Attenuation Relations both regional and site specific.

Site Effects Studies

- Predominant frequencies from Ambient Noise Survey (Nakamura Technique).
- Amplification factor from earthquakes using Standard Spectral Ratio, Horizontal-to-Vertical Spectral Ratio/Receiver Function and Generalised Inversion techniques.

Liquefaction Studies

- Liquefaction susceptibility map using Seed and Idriss (1971) Technique may be used as an initial model.

Other Studies

- Landslide Hazard Zonation Map to be prepared according to the Bureau of Indian Standards' Guidelines.
- In the regions of moderate to strong seismicity, seismic surveillance should be done through a strong motion network.

Microzonation Levels

A microzonation study is designed to map the different components of local seismic hazard at the scale of a study area, generally between 1:5000 and 1:25,000 (Bard et al., 1995). These include:

- Active tectonic structures
- Modification of the seismic signal due to local geomorphological conditions
- Induced phenomena such as liquefaction, settlements and landslides.

The methods used to achieve these vary in complexity according to the degree of precision sought. Three levels of precision are A, B and C and range from the most elementary to the most refined level of precision.

Level A

The most elementary level of study is generally based on a compilation and interpretation of available data. It is the least expensive study and the scale of microzonation ranges from 1:100,000 to 1:50,000.

Level B

This intermediate level of study provides much more reliable results than those for Level A. Specific surveys are generally carried out during this study level, including drilling, trenching, geological sampling and so on. The cost of this study remains reasonable, and the scale of microzonation generally ranges from 1:25,000 to 1:10,000.

Level C

This study is only carried out in areas where a very detailed level of mapping is required. Specific surveys and detailed calculations are involved. The cost of this study is high, but may be necessary in areas of high earthquake hazard risk. This scale of microzonation ranges from 1:10,000 to 1:5000.

Earthquakes in India

The Indian subcontinent has suffered much due to earthquakes being one of the most earthquake-prone regions of the world. The Indian landmass, covering an area of about 3.2 million sq km, has three broad morphotectonic provinces, namely,

- Himalaya and Tertiary mobile belt
- Indo-Gangetic foredeep
- Peninsular shield

All of these areas are characterised by distinctive stratigraphic, tectonic and deep crustal features (Pande, 2005). The Himalaya marks the largest active continent collision zone that has witnessed four great earthquakes in a short time span of 53 years between 1897 and 1950. Nearly 56 per cent of the subcontinent is prone to different levels of seismic hazard. This is amply demonstrated by the fact that more than 650 earthquakes in excess of M 5 have been recorded in India in the last century. The major seismic zones that have resulted as a consequence of the collision between the Indian and Eurasian plates are the Kirthar Sulaiman on the western part, the Himalayan on the northern part and the Arakan-Yoma mountain ranges on the eastern part of India.

The ongoing collision between the two plates has resulted in some of the great earthquakes with magnitude 8.0 and above along the margins of the plates. The collision of the Indian and Eurasian plates is at a rate of 5.5 cm/year (Khattri and Wyss, 1978). DeMets et al. (1994) predict a relative motion of India with respect to Eurasia being about 52 mm/year, through the global plate motion model Nuvel-1A. Michel et al. (2001) gave the relative expected motion between India and Sundaland block on the Myanmar boundary to be about 4.5 cm/year. With the help of Global Positioning System (GPS) measurements, Bilham et al. (1997) showed the convergence of Indian Plate with the southern Tibet to be at a rate of 20 ± 3 mm/year. Several devastating earthquakes have occurred during the last two centuries that imposed heavy casualties and economic setbacks on the country and its surrounding areas. The seismotectonic map of India is shown in Fig. 1.

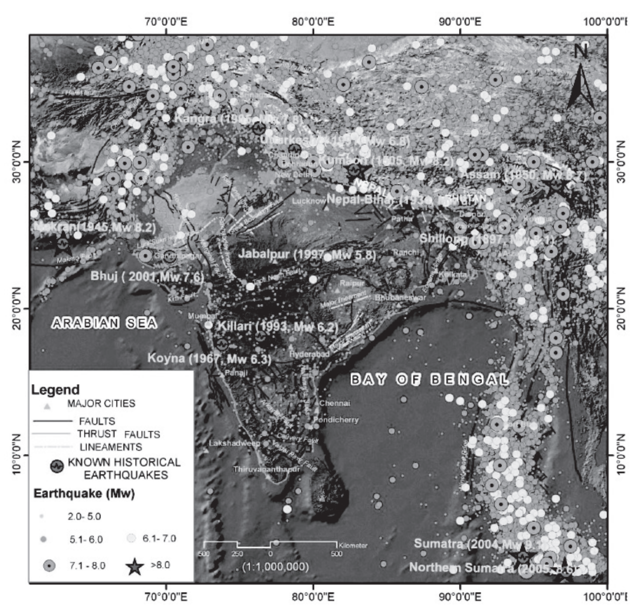

Figure 1: The seismotectonic map of India (after Nath et al., 2011c)

The important historic earthquakes of India are 1737 Calcutta, 1862 Eastern Bengal and the Arakan coast, 1819 Kutch, 1885 Kashmir, 1885 Bengal and 1897 Shillong and the recent ones are 1905 Kangra, 1934 (North) Bihar–Nepal, 1935 Baluchistan, 1945 Makran, 1950 Northeast Assam earthquakes and the 1960 Delhi earthquakes. The October 20, 1991, Uttarkashi earthquake of magnitude 6.5 claimed more than 1500 human lives. The significant earthquakes that adversely affected India are listed in Table 1. The earthquake casualties in India have been very high compared to other parts of the world. The death toll inflicted by major earthquakes in India goes beyond 10,000 and can be witnessed by the earthquakes of the 1905 Kangra (~25,000 deaths), 1934 Bihar–Nepal (~15,700 deaths), 2001 Bhuj (~20,000 death) and 2005 Kashmir (~80,000 deaths). Most of the deaths and casualties in India can be credited, to a major extent, to poor housing construction, in terms of design as well as the quality of materials, and improper planning. There are about 11 million houses vulnerable in seismic zone-V, whereas for seismic zone IV it is alarmingly 50 million. Nearly 80 million building units are at risk of being damaged in the event of an earthquake. The task is not only to restore the vulnerable houses in order to minimise the loss of human life and property but also to come up with a method of estimating quantitatively the seismic vulnerability of the existing built-up environment.

Table 1: List of Some Significant Earthquakes that Affected India

Date	Location	M	Source
September 1, 1803	Kumaon	Mw: 8.0	Ambraseys and Douglas (2004)
June 16, 1819	Kutch, Gujarat	Ms: 8.3	USGS
August 29, 1833	Kathmandu	Ms: 7.7	Bilham (1995)
January 10, 1869	Cachar, Assam	Mw: 7.4	Ambraseys and Douglas (2004)
May 30, 1885	Sopor, Jammu and Kashmir	Ms: 7.0	USGS
June 12, 1897	Shillong Plateau, Meghalaya	Ms: 8.7	USGS
April 4, 1905	Kangra, Himachal Pradesh	Ms: 8.0	ISC
August 31, 1906	Sibsagar, Assam	Ms: 7.0	ISC
July 8, 1918	Srimangal, Assam	Ms: 7.6	ISC
July 2, 1930	Dhubri, Assam	Ms: 7.1	ISC
January 27, 1931	Assam	Ms: 7.6	ISC
January 15, 1934	Bihar–Nepal Border	Ms: 8.3	ISC
June 26, 1941	Andaman Islands	Ms: 8.1	ISC
October 23, 1943	Assam	Ms: 7.2	ISC
July 29, 1947	Upper Assam	Ms: 7.7	USGS
August 15, 1950	Arunachal Pradesh	Ms: 8.6	ISC
December 10, 1967	Koyna, Maharashtra	Ms: 6.5	ISC
January 19, 1975	Kinnaur, Himachal Pradesh	Ms: 6.8	USGS
August 6, 1988	Manipur–Myanmar Border	Ms: 7.3	USGS
August 21, 1988	Bihar–Nepal Border	Ms: 6.8	USGS
October 19, 1991	Uttarkashi, Uttar Pradesh	Mw: 6.8	HCMT
September 29, 1993	Latur, Maharashtra	mb: 6.3	USGS
May 21, 1997	Jabalpur, Madhya Pradesh	mb: 6.0	USGS
March 28, 1999	Chamoli, Uttar Pradesh	Mw: 6.5	ISC
January 26, 2001	Kachchh, Gujarat	Ms: 8.0	Harvard Catalog
December 26, 2004	Sumatra	Mw: 9.1	USGS
October 8, 2005	Kashmir	Mw: 7.6	USGS

Figure 2: Google Earth image of study area

Study Area and Its Geology

Srinagar is a valley located in the lesser Himalayas of Uttarakhand, India. The latitude 30°13′20″ N and longitude 78°48′12″ E are the coordinates of the area of study with mean sea level 567 m above the mean sea level. In the perspective of the regional thrust in the Himalayas, to the north of the area of the study MCT (Main Central Thrust) is present and to the south MBT (Main Boundry Thrust) is exiting. The rocks types which are mainly exposed belong to the Srinagar phyllite, Kikaleshwar metavolcanics, Sumari quartzite, Marora limestone. A fault is also passing to the north of the city called North Almora Thrust (NAT) (Shekhar et al., 2011).

Lithological area is dominated by upper Proterozoic Phyllites which merge with flaggy quartzites towards north. The phyllites, which are tightly folded and fractured, are intercalated with sills and dykes of metabasics. Contact between the phyllites and flaggy quartzites is marked by southerly dipping North Almora Thrust, which is characterised by a wide shear zone around Srinagar (Sati et al., 2007).

Alaknanda river flowing through the valley bisects the city; the rivers show the features like gorges and steep turns. The sediments deposited were seen in a stratified manner on both banks of the river. The study area is shown in Fig. 2.

Site Response Studies

It has long been known that each soil type responds differently when subjected to ground motion from earthquakes. Usually the younger softer soils amplify ground motion relative to older more competent soils or bedrock. The potentially severe consequences of this phenomenon were demonstrated in the damage patterns of the 1985 Michoacan, Mexico earthquake (Singh et al., 1988), the 1988 Armenian earthquake (Borcherdt et al., 1989), the 1989 Loma Prieta earthquake (Hough et al., 1990; Borcherdt and Glassmoyer, 1992), and the Northridge earthquake in Los Angeles, California. Numerous other studies have also demonstrated the ability of surface geologic conditions to alter seismic motions (Borcherdt, 1970; King and Tucker, 1984; Aki, 1988; Field et al., 1992). Site effects play a very important role in characterising seismic ground motions because they may strongly amplify (or de-amplify) seismic motions at the last moment just before reaching the surface of the ground or the basement of man-made structures (Chauhan et al., 2014).

Figure 3: Micro-tremor data collection from different sites in Srinagar

Data Collection and Methodology

The data of about 47 locations (marked by red stars in Fig. 3) spread all over the Srinagar city have been collected using three component accelerograph ALTUS K2. The K2 is a full-featured strong motion accelerograph. Its critical damping was 66 per cent and sampling rate was kept at 100 sample/sec. To record micro-tremor data, SMA was kept at each site for a few hours (Fig. 3). The threshold level was lowered down to 0.005 per cent of full scale (2g).

The data has been analysed with the help of non-reference site-dependent spectral ratio technique. This technique is known as horizontal-to-vertical spectral ratio or Quasi Transfer Spectra technique. The H/V technique was developed by Nakamura (1989).

Results and Discussion

The H/V response curves obtained from the micro-tremor survey is exactly reflecting the geology and soil properties of the test location. It is observed that the natural frequency is high at locations close to ridge area and in gravelly sand deposits. It is less than 0.5 Hz in areas covered with high sedimentary thickness and close to river site. On the basis of natural frequency (Nf) the entire study area has been divided into three zones.

- Zone–I (Nf < 1.0 Hz)
- Zone–II (1.0 – 2.0 Hz)
- Zone–III (> 2.0 Hz)

The results of natural frequency show that most of the part of the city lies in zone–I.

Conclusion

The city has been divided into three zones on the basis of natural frequency. Most of the part of the city lies in zone–I which seems to be affected largely during the future earthquake. The central part of the city has a share of rest zones, i.e. II and III. Vulnerability index has been also computed and found quite high more than 50 at many places. These locations could have a higher degree of damages during the future earthquake.

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Integrated Geological and Geoinformatics-Based Seismic Hazard Zonation for South Andaman Region and Development of the Web-Based ANDMNSEISMOIS Tool

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ABSTRACT: Andaman region has been experiencing several earthquakes in the recent period due to the strike-slip motion and coseismal displacement along the linear edge of the arc. The national observation data shows the frequency of earthquakes has increased in the region which causes several damages in resources and losses of lives. Even, cities/towns are exponentially expanding, but the constructions are taking place without following much seismic guidelines. In general seismic hazard study is being focused with special reference to seismic waves, attenuation characteristics, site investigation and geophysical properties, whereas less priority has been given to integrated geoinformatics-based active tectonics studies. Also, seismic hazard information is being shared in limited manner to the society to minimise eventual damages. Hence, the present study aims to study and demarcate seismic hazard zone for the South Andaman region and develop web-based geospatial information tool for the region.

The South Andaman region is divided into various basins based on the drainage development and relief characteristics. Active tectonic index has been estimated by analysing various morphotectonic parameters for the watersheds. Also, various thematic databases such as geology, seismotectonic and isoseismic zone have been prepared and integrated with active tectonic databases for seismic hazard potential study. The spatial overlay analysis shows that the seismic hazard zone has been identified and classified into four zones, namely very strong, strong, moderate and slight. The maximum portion of the study area is occupied by very strong and strong hazard zone observed in the northern and central parts of the study region. The moderate seismic hazard zone is observed in south-eastern part surrounding the Port Blair region. It is also observed that higher frequency and magnitude corresponds with very strong, strong and moderate seismic hazard zone. Further, web-based information tool namely ANDMNSEISMOIS (Andaman Seismic Information System) Tool is developed using JavaScript integrated with QGIS. This will help seismologists, geologists, geotechnical engineers and planners for spatial understanding of various thematic databases related to earthquake and seismic potential of the region/city before they go for any kind of developmental activities.

KEYWORDS: seismology, geoinformatics, WebGIS, active tectonics

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Introduction

Earthquake is a natural phenomenon which is the result of coseismal displacement along the active tectonic zone (Kuk et al. 2000). In recent times, the frequency of earthquakes has increased in the Indian subcontinent which causes several damages to resources and losses of lives (Verma and Bansal 2014). Morphotectonic analysis and active tectonic study are the key elements for exploring the sub-surface geological phenomenon and are the useful parameters to demarcate the seismic hazard zone (Mahmood and Gloaguen 2012, Ghosh and Sivakumar 2017). Even, cities/towns are exponentially expanding, but the constructions are made without following much seismic guidelines, leading to seismic-induced damages. In general seismic hazard study, it is being focused with the special reference to seismic waves, attenuation characteristics, site investigation and geophysical properties (Nath 2004, Pal et al. 2008, Erol and Topal 2013, Moustafa 2015), but it also requires an integrated geoinformatics-based active tectonics studies. Hence, the present study aims to study and demarcate seismic hazard zone for the South Andaman region and develop web-based geospatial information tool for the region.

Study Area

The study area is South Andaman Island which is the highly seismic-prone zone in India. The latitudinal extension of the study area is from 11°00’ N to 12°10’ N and longitudinal extension is from 92°00’ E to 92°53’ E. The island is formed in complex tectonic sedimentary environments with a geographical area of 1250 sq km approximately. The region represents as undulated topographic landform where drainages are fragmented by tectonic disturbances (Fig. 1).

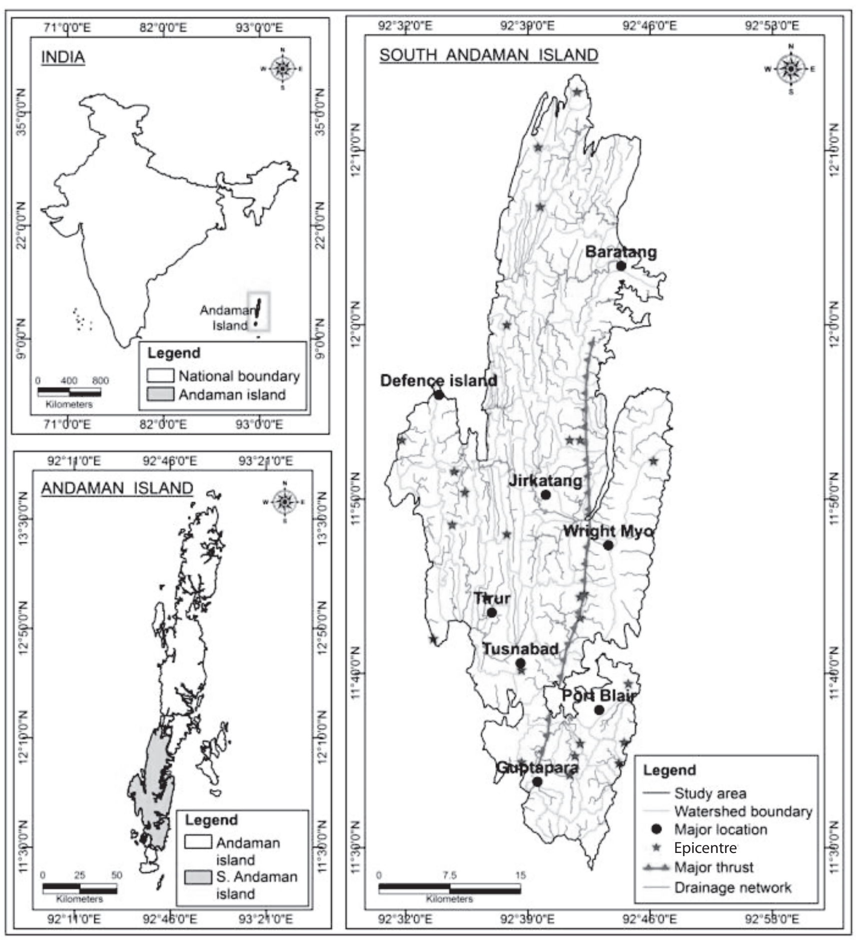

Figure 1: Location map of study area

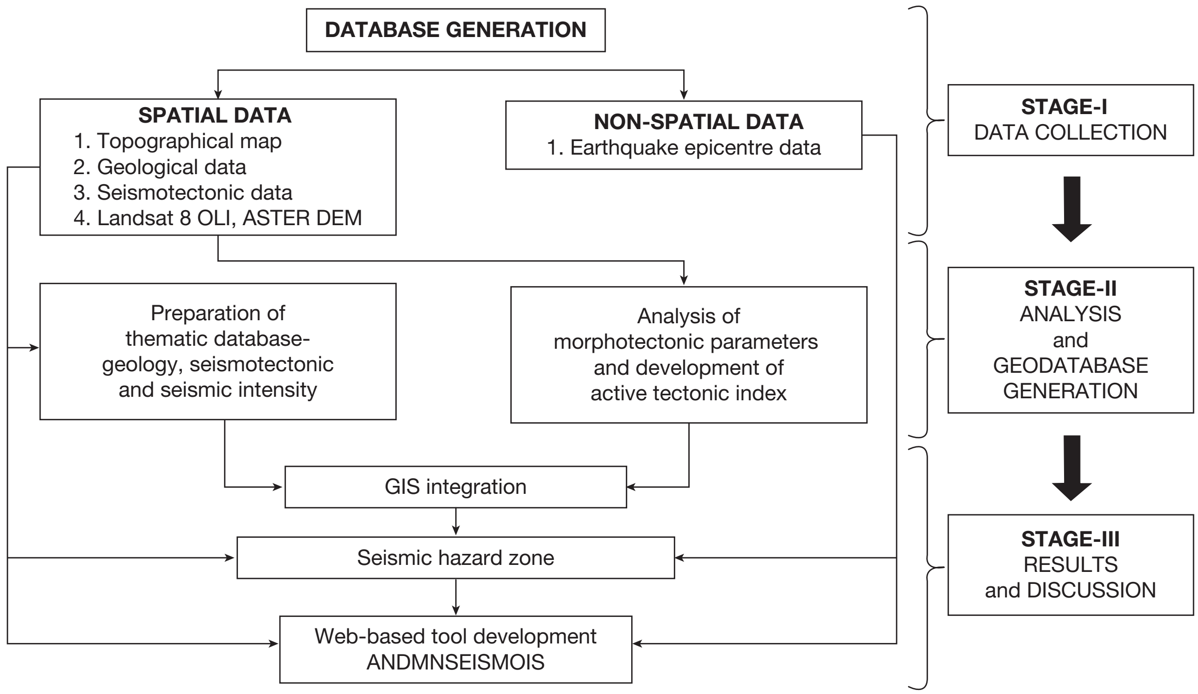

Figure 2: Flow chart of methodology

Materials and Methods

The study has been conducted in three stages, namely data collection, analysis and geodatabase generation, and result and discussion (Fig. 2). Topographical, geological and seismotectonic data along with satellite remote sensing data have been procured from different organisations which are used for further analysis and geodatabase creation. Various morphotectonic parameters have been analysed for the development of active tectonic index. Similarly, geology, seismotectonic and seismic intensity thematic databases have been prepared and integrated with active tectonic databases for the development of seismic hazard zone. Further, web-based information tool namely ANDMNSEISMOIS (Andaman Seismic Information System) Tool is developed using JavaScript integrated with QGIS software.

Result and Discussion

Thematic Geodatabase Generation

Drainage

Drainage map is generated using digital elevation data (DEM) and satellite images as shown in Fig. 3a. The drainages are originated in the central elevated part of the study region and flow in different directions as per the slope of the region and join in the Bay of Bengal. Also, the creeks are observed in the coastal region. The drainages in the region created various basins which are included for morphotectonic analysis.

Geology

The geology database is generated with the help of geological data as shown in Fig. 3b. Various geological formations are recognised such as Andaman flysch group, Namungarh and Hopetown acid igneous rock, ultra basic rocks, volcanic rock, upper white clay stone and mangrove clays formation (GSI 2012).

Seismotectonic Features

The seismotectonic geodatabase has been prepared using seismotectonic atlas and selected satellite images as shown in Fig 3c. The South Andaman region is classified into three seismotectonic zones which include Accretionary Prism, Accretionary Complex and Ophilotie/Melang. A numerous faults and significant earthquakes are observed in Accretionary Prism zone. Accretionary Prism is segregated from Accretionary Complex and Ophilotie/Melang unit by active thrust.

Seismic Intensity

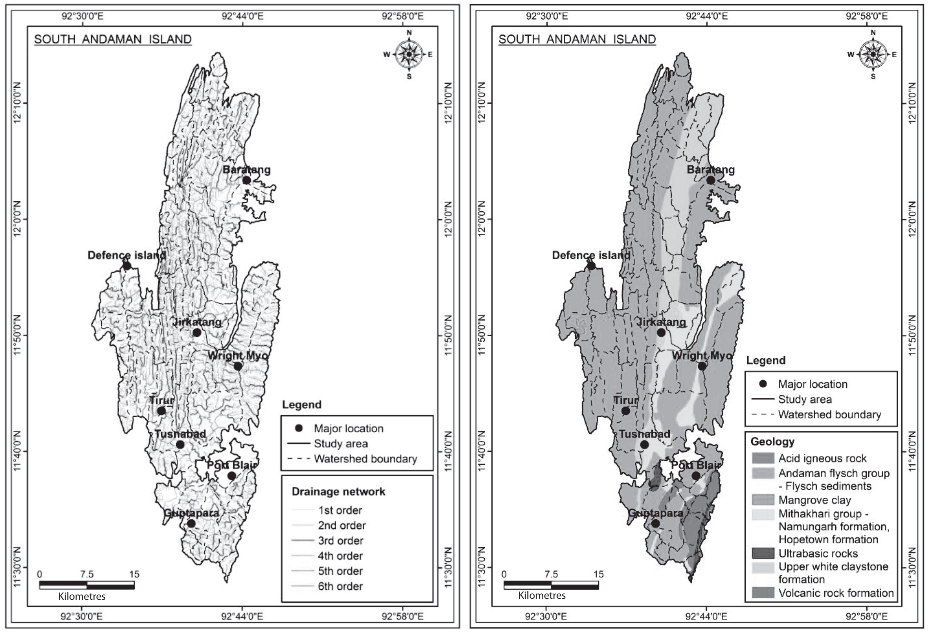

Figure 3: a. Drainage b. Geology

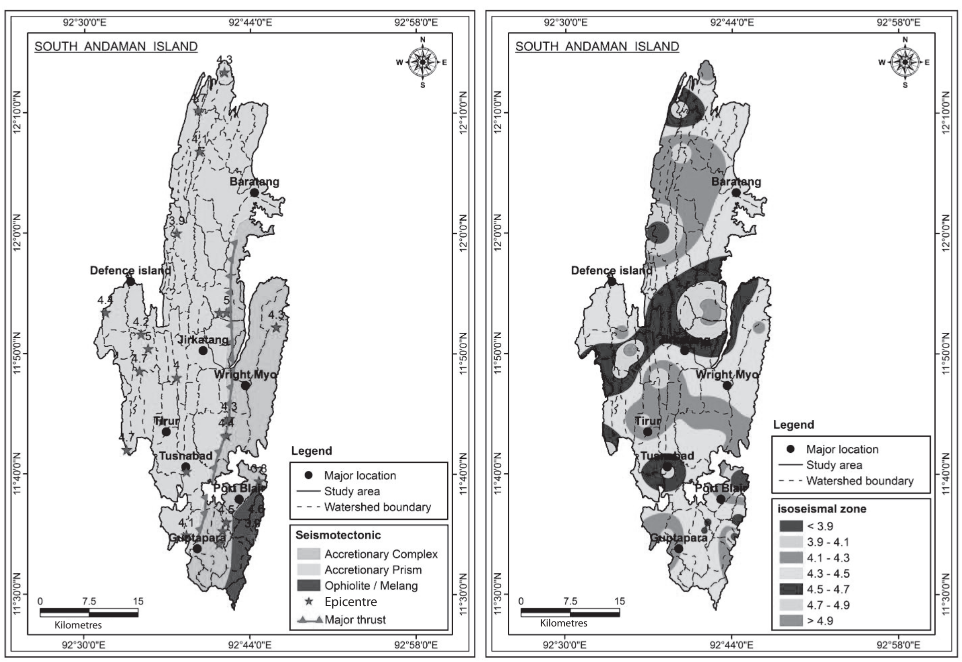

Figure 3: c. Seismotectonic d. Seismic intensity

Seismological data have been analysed during 1966–2015 where lowest and highest magnitudes are observed as 3.8 and 5.0 respectively. The seismic intensity geodatabase has been generated as shown in Fig. 3d. The earthquake magnitude varies from 3.9 to 4.9 which is higher in the central part around the Jirkatang region and Tusnabad in the southern part of the study region. The lower magnitude (below 3.9) is observed in south-eastern and north-western parts of the study region.

Analysis of Morphotectonic Parameters and Development of Active Tectonic Index

The different morphometric parameters have been analysed for the South Andaman region. Based on the formula given by Bull and McFadden (1977), the relative active tectonic index is estimated. The analysis shows that the very strong active tectonic zone is observed in w25, w85, w87, w44, w55, w51, w59 and w67 watershed in the central part, w80 in the western side and w42 in the eastern side. The strong active tectonic zone is found in w50, w54 and w21 watershed in the western side, w27, w26, w82 and w29 watershed in central part, w10, w05, w06 and w02 in the southern part and w76, w79, w82, w75, w77, w80, w81 and w78 watershed in the northern part (Fig. 4). The greater influence of drainage density, stream frequency, drainage texture and ruggedness index have been observed in this region which indicates weak subsurface, dissected topography, elongated shape of watershed are indicators for seismotectonic activity.

Seismic Hazard Zone

The seismic hazard zone is prepared using Weighted Linear Combination (WLC) method by integrating different thematic geo databases. According to their significance on earthquake, the suitable rank and weight have been assigned to select variables of geology (GE), seismotectonic (SET) and relative active tectonic index (IRAT) and Isoseismal zone (IS). As per the influence of the parameters towards seismic hazards, the weight has been assigned while the summation of weight is 1. In addition, the thematic layers are also reclassified into different sub-layers on the basis of parameters and have been assigned ranks from 1 to 4 based on their influence on earthquake (Table 1). The spatial intersection is carried out using spatial analysis tool in GIS platform to develop Geospatial Model for identifying the potential earthquake hazard zone for the study area.

The seismic hazard zone has been prepared which is divided into four zones, namely very strong, strong, moderate and slight (Fig. 5). The maximum portion of the study area is occupied by very strong and strong hazard zone, while the south-eastern part shows moderate and slight hazard zone. The output has also been compared with seismic frequency and magnitude data which shows higher frequency and magnitude in very strong and strong seismic hazard zone. The very high and high tectonic zone mainly covers in Andaman flysch group – flysch sediments geological surface which is the combined part of Accretionary complex and Accretionary prism seismotectonic zone.

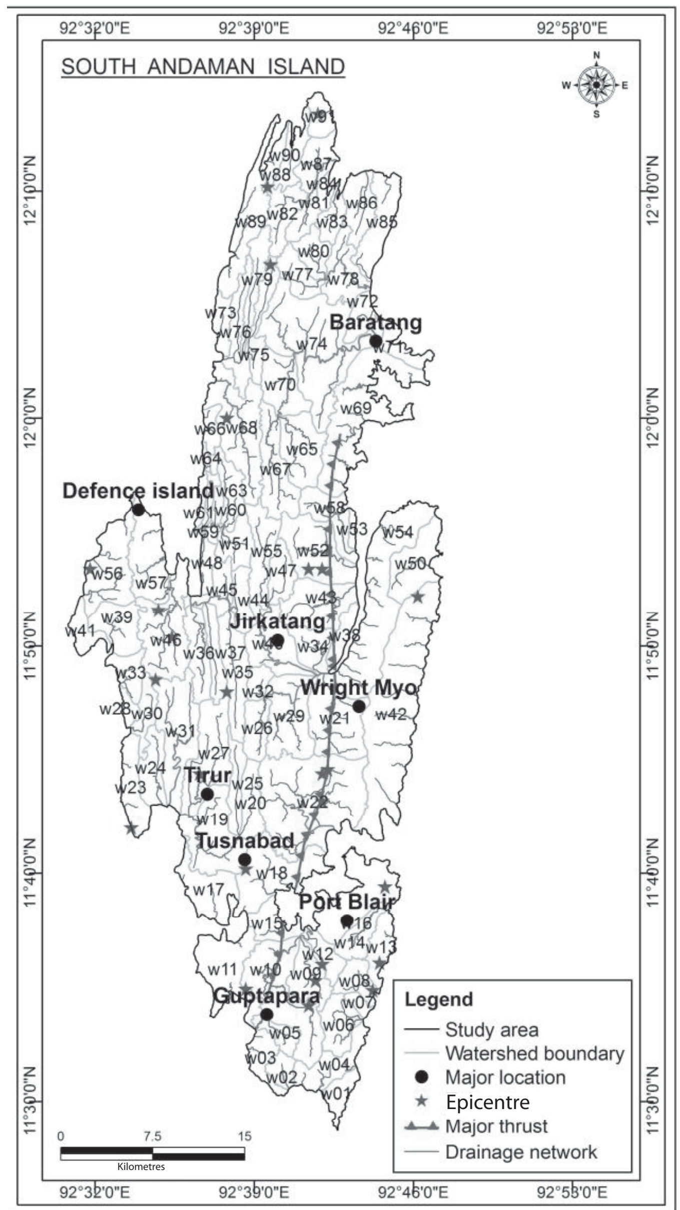

Figure 4: Watershed codes

Table 1: Assigning Rank and Weight to Seismological Parameters for Seismic Hazard Index

Parameters	Sub-layers	Rank	Weight	R*W
IRAT	V. High (<2.13)	4	0.4	1.6
	High (2.13–2.94)	4		1.6
	Moderate (2.94–3.75)	3		1.2
	Low (>3.75)	2		0.8
Geology	Acid igneous rock	1	0.3	0.3
	Andaman flysch group – Flysch sediments	4		1.2
	Mangrove clay	3		0.9
	Mithakhari group – Namungarh formation, Hopetown formation	2		0.6
	Ultrabasic rocks	1		0.3
	Upper white claystone formation	3		0.9
	Volcanic rock formation	2		0.6
Seismotectonic	Accretionary Prism	4	0.2	0.8
	Accretionary Complex	2		0.4
	Ophiolite/Melang	1		0.2
Isoseismal zone	< 3.9	1	0.1	0.1
	3.9–4.1	2		0.2
	4.1–4.3	2		0.2
	4.3–4.5	3		0.3
	4.5–4.7	3		0.3
	4.7–4.9	4		0.4
	>4.9	4		0.4

Figure 5: (a) Active tectonic zone; (b) seismic hazard zone of the Andaman region

Web-Based Information Tool

WebGIS-based information tool namely ANDMNSEISMOIS Tool is developed for visualisation of seismic hazard information where the shape file of various geospatial databases has been transformed to QGIS software. To visualise the information in web platform qgis2web plugins have been installed. The plugins has been connected with web tool and can help to prepare web map. The shape file of geospatial layers have been uploaded in qgis and reformatted its style for smooth visualisation. The web page has been developed based on JavaScript (.js) code.

The 'ANDMNSEISMOIS' tool visualises the different information such as general, seismotectonic, geology, relative active tectonic index and seismic hazard zone (Fig. 6). The tool displays general information such as location, drainage, watershed boundary and major thrust (Fig. 6a). Similarly, it compares geological formation, relative active tectonic index and seismic hazards zone (Fig. 6b) which shows that very strong seismic hazard zone corresponds with very high active tectonic zone in west-central part of the island where higher magnitude of earthquakes are noticed.

Similarly, the proposed tools visualise the seismic information surrounding Port Blair city (Fig. 7) which shows that the region is mainly located in moderate and slight hazard zone which corresponds with high and moderate active tectonic zone where the flysch group formation is dominant and also accompanying with morphotectonic evidences. The tool helps to identify the seismic vulnerable zone and various influencing parameters which are probable factors for seismic activity in a particular location.

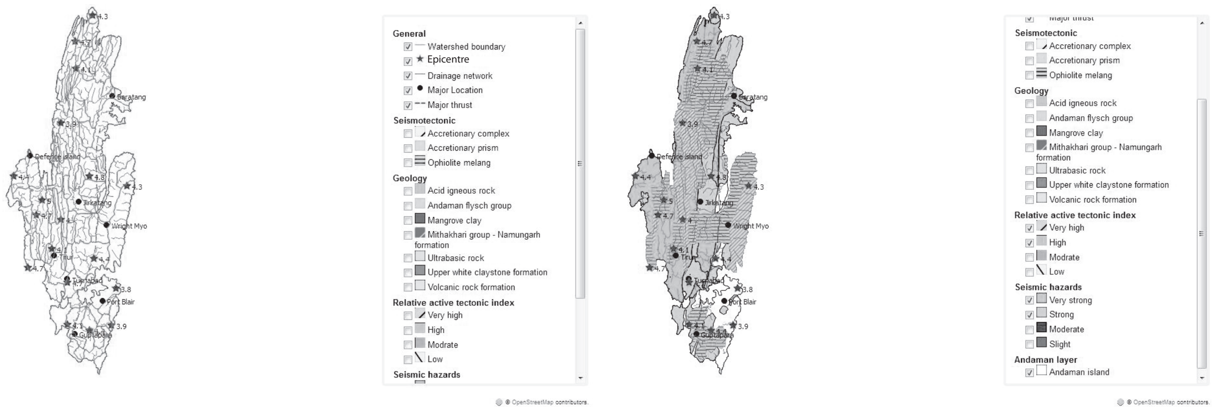

Figure 6: ANDMNSEISMOIS (Andaman Seismic Information System) Tool

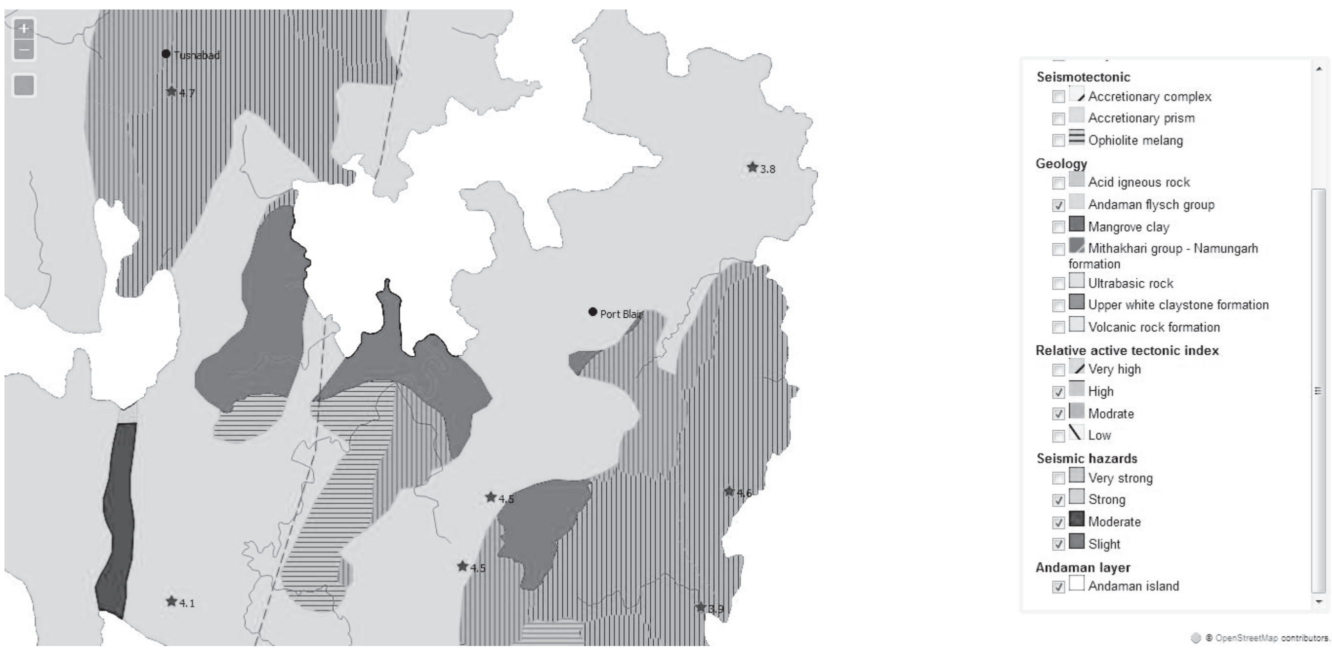

Figure 7: Seismic information surrounding Port Blair city

Conclusion

In the present study, seismic hazard zone is developed for the South Andaman region. The study shows that the high elevated region in the northern part mostly occupies very strong and strong hazard zone, while the southern part surrounding Port Blair city includes moderate tectonic zone occupying strong to moderate seismic hazard zone. The higher influence of drainage density, stream frequency, drainage texture and ruggedness index have been observed in strong and very strong active tectonic zone which indicates the existence of weak sub-surface, uneven dissected topography, elongated shape of watershed are the relevant signature for seismotectonic activity. Similarly, the influence of basin compactness, uplift and submergence and surface unevenness are the signatures for past earthquakes in the weak active tectonic region. It is also observed that the frequency of earthquake and magnitude are also high in very strong and strong seismic hazard zone. Further, the web-based tool will be helpful for geotechnical engineers, urban planners and so on to understand the seismological information at a glance before starting any construction and executing any development plan in the study area. The research work can be further used for infrastructure development and also can be compared with field observation data for a better understanding the seismotectonic activity.

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IV Landslide Hazard Zonation

Landslide Risk Assessment in Parts of Higher Himalaya, Uttarakhand: A Post-Kedarnath Disaster Approach Using Earth Observation Inputs

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ABSTRACT: The present study is focused on landslide incidences which are very frequent in the Himalayan region. The economy in most of the Himalayan region thrives more on tourism; hence, it's essential to take proper attention in these areas. The theme of this specific research was the preparation of a landslide inventory, damage assessment, hazard mapping and subsequently risk analysis. The study area extends from 30°19' to 30°49' North latitude and 78°49' to 79°21' East longitude, along NH-58 covering 642 km^2 of the area, and lies in the Mandakini River valley of Rudraprayag district of Uttarakhand, India. The aim is to identify the causes of landslides and then based on the causative factors, susceptibility and vulnerability were prepared. The entire analysis is carried out using the weighted overlay approach in ArcGIS 10.3 software. The susceptibility map of the region is prepared and categorised from low to very high susceptible zones. Accordingly, vulnerability and risk maps of the region are also prepared. The entities considered in risk assessment include agricultural land, roads and places of human settlements. The validation of the analyses results is carried out through field investigations and satellite imageries.

KEYWORDS: landslide inventory, susceptibility, vulnerability, hazard mapping and risk assessment

Introduction

The landslides are considered amongst major damaging disasters on the planet and these become more aggravated during the rainy season, though the main causative factors behind the slope instability are geomorphologic and geological in nature. The Himalaya, the youngest mountain chain, is a very tectonically active zone and landslides have become very frequent incidences here. Since the region is predominated with rugged mountain topography (relative relief > 300 m), high altitude (>1500 m), extreme environmental conditions, very limited industrial development and less agricultural land, the major source of livelihood is tourism, and therefore, frequent landslides have emerged as greatest threats to life and livelihood of the region (Champati ray et al. 2013a; Paul and Bisht 1993). Frequent seismic events also trigger such a large number of landslides as the study region consists of numerous faults, especially around the main central trust. The Garhwal Himalaya region has a history of landslides. Some very well-known landslides witnessed by Garhwal Himalaya are co-seismic in nature like the 1991 Uttarkashi earthquake that caused numerous massive landslides, especially on a 42 km road section between Bhatwari and Uttarkashi (Jain

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et al., 1992), and the earthquake during the year 1999 in Chamoli district of Uttarakhand caused widespread devastation (Kimothei et al. 2005). Besides this, in the year 1998 Malpa landslide in Uttarkashi killed 300 people including 60 pilgrims of Kailash-Manasarovar yatra (The Hindu 1998). However, the most horrible and devastating one was the Kedarnath tragedy of June 2013 caused due to cloud burst–induced heavy rainfall.

Landslide, in its firm sense, is a geological phenomenon that includes a wide range of movement of an earth mass down a slope, under the influence of gravity, and in general is triggered by a variety of external factors such as earthquake, intense rainfall, cloudbursts, water level change, storm waves and rapid stream erosion (Dai et al. 2002). Typically, specific sub-surface conditions get build-up due to pre-conditional factors that tend a slope at the verge of failure, whereas the actual landslide often requires a trigger force before soil mass gets in motion. The triggering factors increase the shear stress and decrease the shear strength of slope forming materials beyond critical values and cause failure.

In addition, due to rapidly increasing urbanisation, growing population, increasing exploitation of land resources, unscientific mining, unscientific construction practices, human developmental activities in form of unsafe locations, unsafe construction of roads and dams and river training works eventually create undesirable pressure over land especially on unstable slopes in hilly terrain and pose an increasing risk to environment and infrastructure. However, climate change in the form of glacial melting, unprecedented rain, extreme temperature conditions and so on is also extending these risks. Excessive deforestation also leads to increased vulnerability. So it's very important to effectively find ways for mitigation of landslides. For mitigation purposes, it is necessary to know what are the main causes and triggering factors for landslide in any particular area.

Landslide Risk Assessment

The risk assessment study involves analysis of hazards and consequences. Risk estimation is the process of establishing a measure of risk. Risk evaluation concludes the risk assessment study, where levels of risk will determine prevention measures. It is the process of making a decision recommendation on whether existing risks are tolerable and control measures are appropriate, and if not, whether alternative risk control measures are requisite. Landslide assessment through inventory generation forms the basis of any study, which is followed by mapping of vulnerable zones. Landslide risk mapping not only considers the exposure (or elements at risk) and vulnerability but also includes the susceptibility (Fell and Hartford 1997; Jelínek and Wagner 2007). Risk mapping is an important component of hazard analysis which is useful in planning mitigation strategies and includes both susceptibility and vulnerability assessment of elements at risk (e.g. settlement, road, and land use) taken under consideration for risk analysis. A number of landslide risk methods have been published recently which give a good idea of making landslide risk mapping and assessment (Cruden et al. 1997; Guzzetti 2000; Dai et al. 2002). Pardeshi et al. (2013) have outlined different trends and techniques for landslide hazard zonation. Marrapu and Jakka (2014) presented a critical review of various qualitative and quantitative methods adopted for landslide hazard assessment, outlining their limitations and suitability of application. A number of approaches have been adopted for the landslide risk assessment (Aleotti and Chowdhury 1999; Barredo 2000; Bonnard et al. 2004; Lee and Jones 2004; Glade et al. 2005; Eberhardt et al. 2007; Pareta et al. 2012). Here the main focus of the study is to make a landslide risk zonation map including the factors of susceptibility and the elements of vulnerability by applying the weighted overlay method. The major causative factors responsible for landslide hazard are first identified and their relationship with the occurrence of landslide is found out. Based on the association to the occurrence, some numerical weights are applied to the raster layers in order to generate the final output by using the Weighted Linear combination method in the GIS domain (Ayalew et al., 2005). This method is based on the weightage given by the different experts (Sarkar et al. 1995; Ishizaka and Labib 2009) who have worked on landslides and have an idea about the conditions which will cause landslides to occur and the situations post landslides.

Overview of Study Area

The study area extending from 30°19’ to 30°49’ North latitude and 78°49’ to 79°21’ East longitude, as shown in Fig. 1, falling in the survey of India topographic sheet numbers 53J and 53N, lies in the Mandakini River valley of Rudraprayag district. Rudraprayag covers an area of about 2439 sq km, covering Agastamuni, Guptkashi, Khat and Gaurikund. The climate varies from sub-tropical monsoon type (mild winter, hot summer) to tropical upland type. In the lesser Himalaya maximum rainfall occurs in the southern half which is about 70 to 80 per cent, August being the rainiest month, decreases rapidly after September and is least in November. Winter months receive a total annual rainfall of about 17 per cent. The winter precipitation is in association with snowfall, particularly at higher elevation. The precipitation during pre-monsoon which is about 7 per cent of total annual rainfall and the post-monsoon is frequently associated with thunderstorms. The annual average rainfall in the study area is 1485 mm and in the northern part of it at Ukhimath is 1995 mm.

Geomorphologically, the district is divided into two major units: the high denudational mountain and the river valleys. Separated from Siwaliks by the Krol thrust is the lesser Himalaya which is characteristically wide and mature in topography with deeply dissected valleys and gentle slopes suggestive of furiously active streams and rivers. Denuded and rugged terrain of lesser Himalaya is characterised by many transverse spurs emanating from the Great Himalaya. The general geomorphic features of the study region, as depicted in Fig. 2, include active flood plain, braided bar, channel bar, densely vegetated highly dissected hills, low vegetated highly dissected hills, moderately dissected hills, active river plain and piedmont alluvial plain. The highly dissected hills cover almost 90 per cent of the study area and most observed landslides are also concentrated in the same region. Very few landslides are there in flood plain and river.

Figure 1: Study area

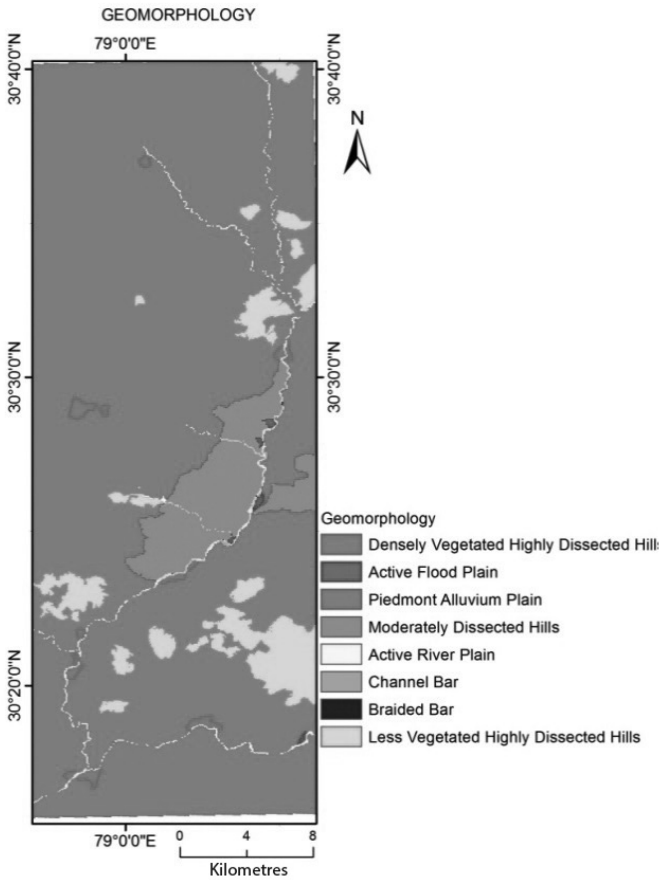

Figure 2: Geomorphology map of the study area

Geology of the Area

The rock formations of this area belong to lesser Himalaya, some from outer lesser Himalaya and most are from inner lesser Himalaya. Two rock sequences are observed to be exposed in Rudraprayag district; sandwiched between North Almora Thrust (NAT) and Main Central Thrust (MCT) constitutes the lesser Himalaya, while that exposed to the north of MCT constitutes the higher Himalaya. The higher Himalayan central crystalline rocks are observed to comprise low, medium and high grade rocks that have been intruded by both acidic and basic rocks. On the basis of lithology and tectonics, these rocks are divided into different litho-units. The main rock types observed in the area include granitic gneiss, quartzites, augen gneiss, garnet mica schist, calc-silicates, amphibolites and so on. Geological setting of the study area is shown in Fig. 3. The lower region of the study area consists of Rudraprayag Formation, having five different litho-units namely Lameri, Uttyasu quartzite, Thalasu Schist, Haryali quartzite and Karanprayag metavolcanics. Uttyasu quartzite is the oldest among these and is exposed mostly in the Kaliyasaur region. Its stratigraphy comprises of medium to coarse grained, white, pink, purple, rippled quartzite and grey slates with basic metavolcanics.

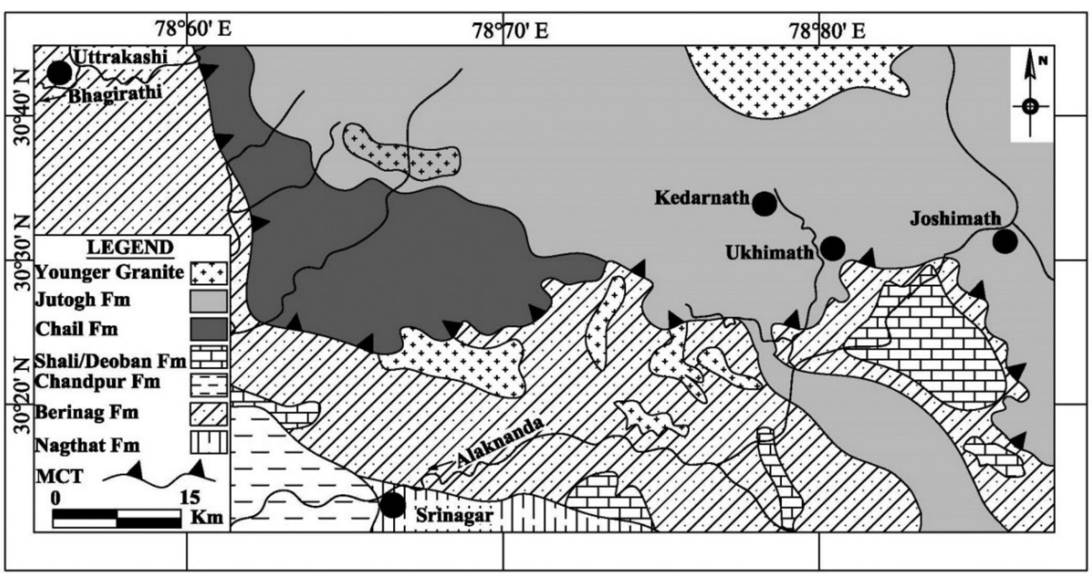

Figure 3: Geological map of the study area

Data Used and Data Preparation

The study region is covered under Survey of India (SOI) toposheets no. 53J and 53N (scale 1:50,000) and projected based on UTM system with WGS 84 datum with nearest neighbour resampling method. Consequently, spatial databases were generated on ArcGIS 10.3. Most of the data sets used in the current study was Indian Remote Sensing (IRS) satellite data products like LISS-IV data taken from Resourcesat-2 satellite. Geomorphology map was prepared by digitisation over multispectral LISS-IV image and further verified from the one available on Bhuvan portal. Geology map was prepared by digitising over the geological map of V. C. Thakur. Soil map was prepared through digitisation over Uttarakhand soil map from National Bureau of Soil Survey and Land Use Planning. Land use/land cover (LULC) map was prepared through digitisation and visual interpretation over LISS-IV multispectral image and further verified with LULC map provided from Forestry Department. Orthorectification was performed, Digital Elevation Model (DEM) was generated from Cartosat-1 stereo pairs using ground control points taken during field, and processed using ERDAS Imagine 2014. Cartosat-1 DEM was used to derive topographic parameters, namely slope and aspect. Lineament map was generated by spatial enhancement techniques mainly edge detection directional filters over LISS-IV imagery. Google Earth images along with ancillary terrain information from SRTM 30 m DEM Version 3 were also referred. Detail about the data used is given in Table 1.

Table 1: Details of Satellite Data

Data Type	Resolution	Acquisition Date
LISS-IV	5.8 m	June 21, 2012 (pre-disaster)
LISS-IV	5.8 m	December 1, 2013 (post-disaster)

Identification and classification of landslides is an essential requirement in pre- and post-disaster hazard studies (Brunsden 1985; Barlow et al. 2006; Martha et al. 2009). Landslide inventory was prepared using LISS-IV high-resolution satellite data (McCalpin 1984) and further validated through field survey and a few places by visual interpretation on Google Earth. For the preparation of landslide susceptibility map, various thematic layers (slope, aspect, geology, distance to linear features, land use/land cover, soil type, vegetation, geomorphology, mass wasting) were generated in Arc Map. Subsequently, all the vector layers, excluding the image-processed map (slope, aspect), were converted into raster layers. Risk analyses of hazards involve vulnerability assessment of elements at risk (settlements, roads and agricultural lands) and are taken into consideration for risk analysis. Details about the thematic layers prepared for both susceptibility and vulnerability maps are explained in Table 2.

Table 2: Thematic Layers and Their Source of Generation

S. No.	Thematic Layers	Source
Landslide Inventory		
1	Landslide location map	IRS-P6 (LISS-4) image
Susceptibility Mapping		
2	Slope	Generated from Cartosat-1 DEM (30 m)
3	Aspect	Generated from Cartosat-1 DEM (30 m)
4	Geology	Geological map (Thakur)
5	Structural features (Fault and lineaments)	Image enhancement (edge detection) IRS-P6 (LISS-IV) image
6	Stream	Hydrologic processing using Cartosat-1 DEM (30 m)

(*Continued*)

Table 2: (Continued)

S. No.	Thematic Layers	Source
7	Land use/land cover	Digitisation based on visual interpretation over LISS-IV MS image
8	Mass wasting	Digitised over LISS-IV imagery
9	Soil type	Soil Map
10	Vegetation	Supervised classification (maximum likelihood) (Validated with National Biodiversity map of India)
11	Geomorphology	Digitised based on literature survey
Risk Mapping		
12	Settlement	Digitisation based on visual interpretation over LISS-IV multispectral image and Cartosat-1 cross-checked with Google Earth
13	Road	
14	Agricultural field	Digitisation based on visual interpretation over LISS-IV MSS image

After thematic layer preparation, weighted overlay technique was used for generating the susceptibility and vulnerability maps, in which each layer is given some influence value and each class of all layers is also given some weightage. The distribution of weights amongst different thematic layers on which landslide occurrence is dependent is shown in Table 3. The weightage was given based on the relationship observed amongst the causative factors for landslide occurrence as observed on field and also previous literature by assigning a bivariate landslide susceptibility index (Wi) according to equation (1) for each causative factor on the basis of aerial densities (Yin and Yan 1988; Van Westen 1993; Conforti et al 2014):

$$W_i = \ln\left(\frac{DensClass}{DensMap}\right) = \ln\left(\frac{\left(N_{pix}S_i\right) \div \left(N_{pix}N_i\right)}{\left(\sum N_{pix}S_i\right) \div \left(\sum N_{pix}N_i\right)}\right) \quad (1)$$

where *Wi* is the weightage given to a certain class of a layer, DensClass is the density of landslide within the particular class, DensMap is the density of landslide within the entire map/layer, $N_{pix}S_i$ is the number of pixels falling within the landslide area occurring within the class i, $N_{pix}N_i$ is the total number of pixels within the class *i*, $\sum N_{pix}S_i$ is the total number of pixels representing landslides occurring in the whole study area, and $\sum N_{pix}N_i$ is the total number of pixels of the whole study area map.

Table 3: Distribution of Weights amongst the Different Thematic Layers for Weighted Overlay Technique

Raster	Percentage of Influence	Field	Scale Value
Geology	12	Lithology	
		Berinag Formation	6
		Chail, Bhatwari Formation	4
		Granite	3
		Central Crystalline	7

(*Continued*)

Table 3: (Continued)

Raster	Percentage of Influence	Field	Scale Value
Slope	29	Slope Amount	
		0–15	3
		15–25	5
		25–35	6
		35–45	7
		45–75	8
Geomorphology	17	Features	
		Densely Vegetated Hill	8
		Channel Bar	5
		Braided Bar	5
		Less Vegetated Hill	9
Lineament	15	Buffer Distance	
		>500 m	3
		500 m	5
		300 m	6
		100 m	7
Soil	6	Soil Type	
		TypicUstipsamme	3
		TypicHaplustolls	4
		FluventicEutrochr	6
		Lithic Ustorthents	7
LULC	5	Class Name	
		Crop Land	5
		Mixed Forest	2

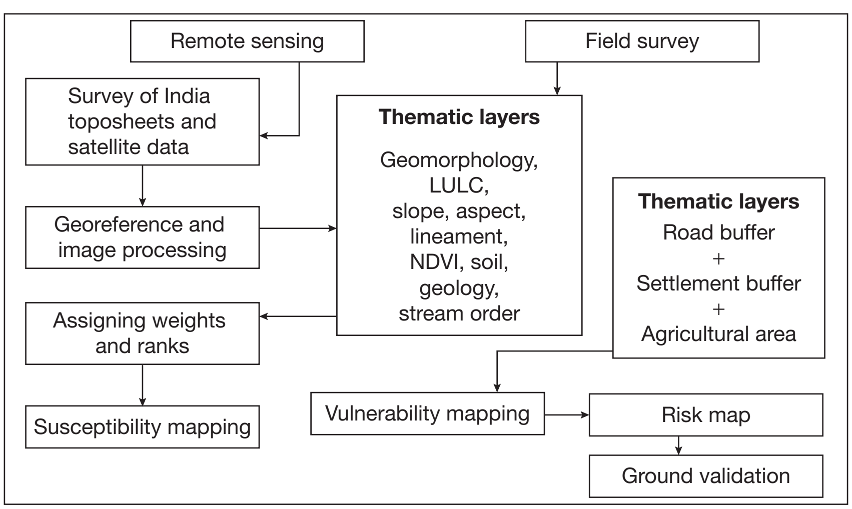

Figure 4: Flowchart depicting methodology of the study

The landslide sites identified during field trips and from visual interpretation of LISS-IV were also considered for assigning precisely the weight/scale value to each causative factor and their respective sub-classes. After the weight calculation, the thematic layers are reclassified to common scale factor 1–9 and added in ArcGIS 10.3 to give final susceptibility map using weighted overlay tool. All factor maps were integrated using weighted overlay model (WOM) according to equation (2) shown below.

$$S = \frac{\sum W_i S_{ij}}{\sum W_i} \tag{2}$$

where W_i is the weight of *i*th factor map, S_{ij} is the *i*th spatial class weight of *j*th factor map and S is the spatial unit value in output map.

In the study region of Rudraprayag major elements at risk considered are roads, built-up area and the agricultural field, which are first inferred from field investigation and then from available literature (Rautela and Lakhera 2000; Champati ray et al. 2007; Islam et al. 2014). The union of these three thematic layers in the ArcGIS 10.3 is used to prepare vulnerability map. Finally the product of susceptibility map and vulnerability map in GIS environment through raster calculator is obtained as the final risk map. The methodology implemented in the study area using weighted overlay method to derive landslide risk assessment map is described in detail in Fig. 4. The susceptibility map obtained is compared with the geographical data using Erdas Imagine 2014 for accuracy assessment. DGPS control points and corresponding reference pixels from thematic layer classified images were used for ground truth verification and validation of landslide susceptibility map. Various thematic layers used for susceptibility zonation using weighted overlay method are shown in Fig. 5.

Results and Discussions

Six causative factors (Geology, Slope, Geomorphology, Soil, LULC and Lineament) responsible for the occurrence of landslide in the area were identified from field survey and remote sensing methods for susceptibility mapping. Thematic layers corresponding to these were prepared following the methodology and integrated into ArcGIS 10.3 for analysis using weighted overlay method. A brief discussion about the results obtained is as follows:

Landslide Inventory

Inventory study forms the basis for any hazard zonation work. A total of 190 landslides have been detected and mapped using visual identification from high-resolution LISS-IV imagery as shown in Fig. 6. The landslides are found to be scattered throughout the area of interest. The common types of landslides observed are debris flows, rock slides and earth slides and very few are found to be rotational slides. Most of the landslides are observed to be situated on steeper slopes. From the inventory map it is evident that most of the landslides are located on the western side of the river Mandakini. The dispersion of the landslides indicates that landslides are frequent in the area. The recurring problems of landslide have caused major damages to the road infrastructure, public utilities, agricultural land, human settlements and so on in the study area.

Vegetation and LULC

The Normalised Difference Vegetation Index (NDVI) map indicates the vegetation type present in the study area; the higher the NDVI value, the higher is the vegetation. On draping of this layer with the landslide layer indicates that most of the landslides are in an area of comparably less vegetation. The LULC map consists of many classes, but broad classes are forest, crop land, barren land, fallow land, grassland and water body. On draping this layer with landslide it is seen that very less landslides are there in forest and water body class whereas high concentration is seen on fallow land and crop land. This is because of the fact that the less vegetated/scantly vegetated slopes, fallow land slopes receive more orographic rainfall resulting in increased landslide incidences.

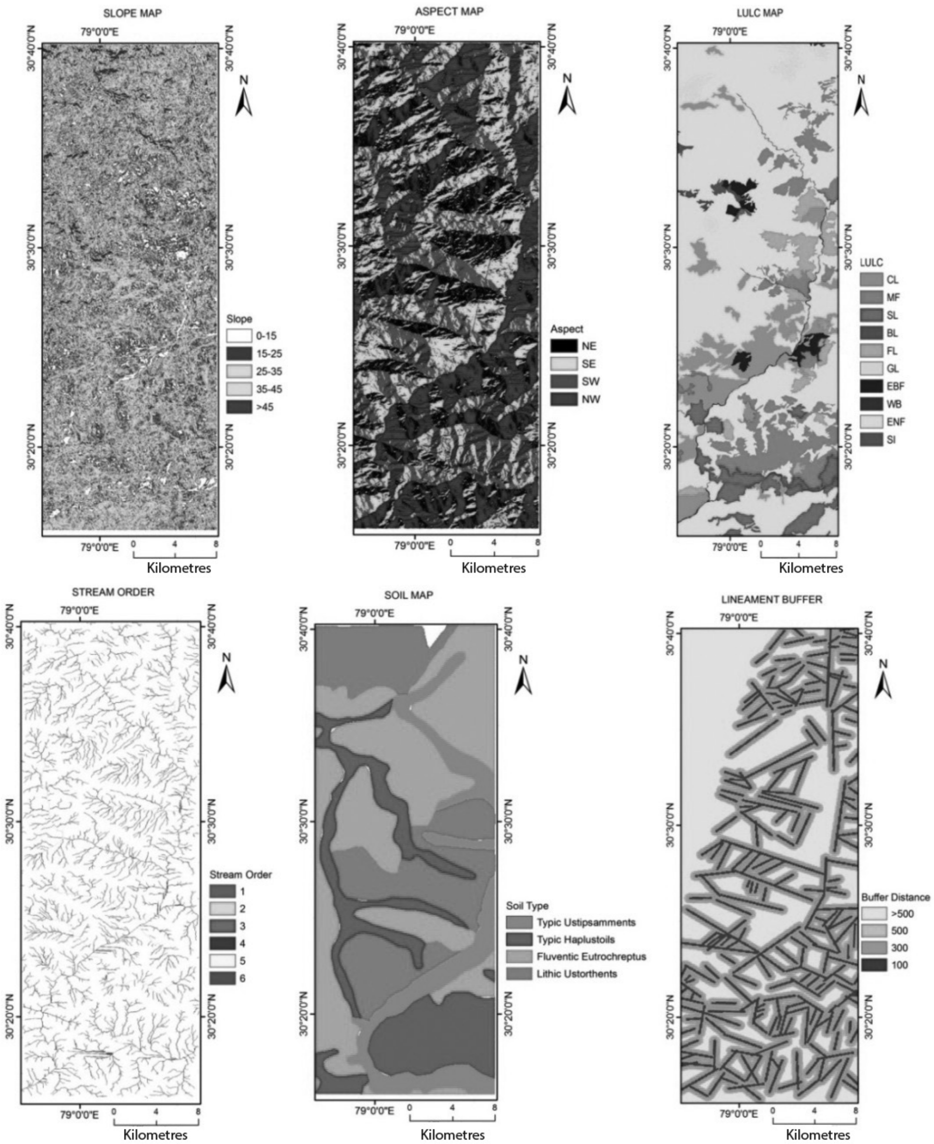

Figure 5: Various thematic layers used for landslide susceptibility assessment

Topographic Features

Topographic parameters basically include slope and aspect of the area generated from the Cartosat-1 DEM (30 m) using spatial analyst tool. Slope is an important parameter for the assessment of landslide. Slope map consists of five classes as defined by Anbalagan (1992) that are 0°–15°, 15°–25°, 25°–35°, 35°–45°, 45°–75°. The study area has slopes mostly greater than 15° and it is well known that in the Himalaya most of the landslide occur at slopes ranging between 25° and 55°. Most of the landslides in the study area are concentrated in the area having slopes ranging between 35° and 75°. A steep slope consisting of uniform isotropic material increases the possibility of land sliding. The aspect map of the area indicates the direction of the slope and this layer is classified into four classes NE, SE, NW and SW. The distribution of aspect is quite uniform in all directions and the distribution of landslide is more or less equal in all classes of aspect.

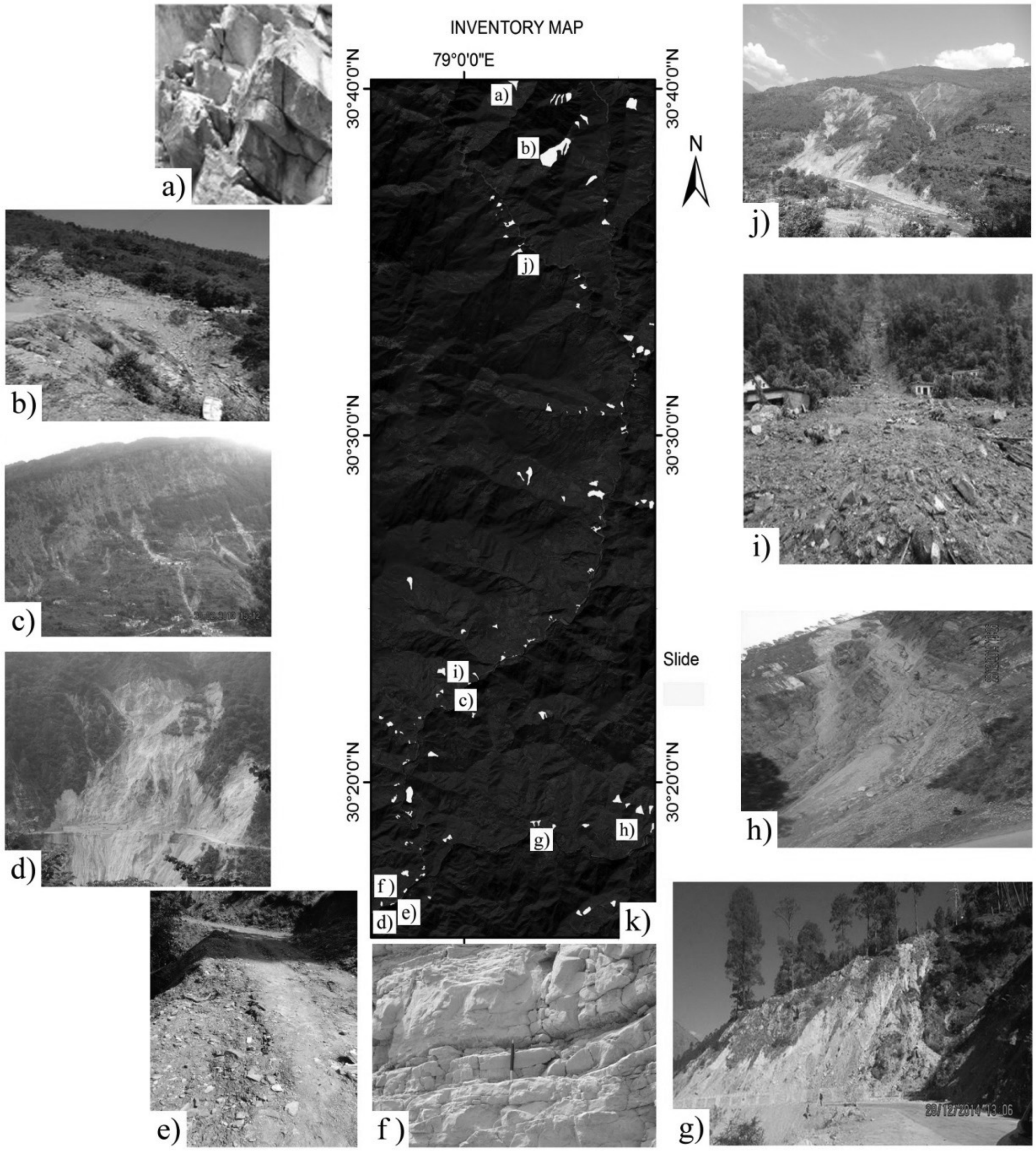

Figure 6: Landslide inventory map (k) depicting some of the major landslides in the study area as shown in (b), (c), (d), (e), (g), (h), (i) and (j). Exposed rocks and stratigraphy at Sonprayag and Rudraprayag regions are shown in (a) and (f). Damage incurred to settlements in Agastmuni region is shown in (i)

Linear Features

Tectonic structures like faults and thrusts are associated with extensive fractures and steep relief variations. It is seen from that the probability of landslide increases towards these lineaments. The area is full of lineaments including four major thrusts: Berinag Thrust, Bhatwari Thrust, Munsiari Thrust and Vaikrita (Main Central) Thrust. Other major lineaments are along the Mandakini River. Lineaments are classified into three classes based on the buffer distance (100 m, 300 m and 500 m) as shown in Fig. 5 and it is observed that landslides are mostly concentrated in the 100 m buffer zone. It is now concluded that as the buffer distance increases, the probability of occurrence of a landslide event decreases.

Landslide Susceptibility Analysis

The landslide susceptibility map was prepared through weighted overlay method. The weightage was given based on the relationship observed amongst the causative factors for landslide occurrence as observed on field and also previous literature by considering a bivariate landslide susceptibility index (Wi) for each causative factor on the basis of aerial densities. The methodology adopted to generate the susceptibility map is shown in Fig. 4. The landslide susceptibility map was classified into three classes, namely low susceptible, moderate susceptible and high susceptible zones. The total area is 642 km^2 and number of pixels are 75,738. Out of the total area, 11 per cent area shows low susceptibility, 74 per cent lies under moderate susceptible zone and 15 per cent lies under high susceptible zone as shown in Table 4 and Fig. 8. Also from the susceptibility map it can be observed that as we move upstream from Ukhimath, the area is mostly in high susceptibility zone.

Table 4: Statistics of Landslide Susceptibility Map

Susceptibility Class	Area (km^2)	Percentage Area (%)	Cumulative Area (%)
Low	68	11	11
Moderate	478	74	85
High	96	15	100

Landslide Vulnerability Analysis

Vulnerability here infers to the loss of life, infrastructure and property because of the landslide. This map was derived according to the methodology by adding the three thematic layers, i.e. road, built-up and land cover (especially agriculture) as shown in Fig. 7. The vulnerability map was divided into five classes, namely, very less, less, moderate, high and very high vulnerable zones. Out of the total area of 642 km^2, 49 per cent of it lies in very less vulnerable area, whereas, 16, 21 and 10 per cent of it are covered in less vulnerable, moderately vulnerable and highly vulnerable zones, respectively. Only 4 per cent of the area lies under very high vulnerable zone. The output vulnerability map is shown in Fig. 8 and Table 5 shows the statistics related to landslide vulnerability map.

Table 5: Statistics of Landslide Vulnerability Map

Vulnerable Class	Area (km)	Percentage Area (%)	Cumulative Area (%)
Very less	316	49	49
Less	104	16	65
Moderate	137	21	86
High	062	10	96
Very high	023	04	100

The vulnerability map infers that the areas under built-up, agriculture and near road are very high to high variable. As the distance increases from road built up and more, vulnerability is less. Out of the total area 4 per cent area, approximately 25 km^2 of it, is located in high vulnerable zone. Remaining of the area which is dominated by dissected hills are less susceptible because of the absence of settlements and roads.

Table 6: Statistics of Risk Analysis

Risk Class	Area (km^2)	Percentage Area (%)	Cumulative Area (%)
Low	405	63	63
Moderate	197	31	94
High	040	06	100

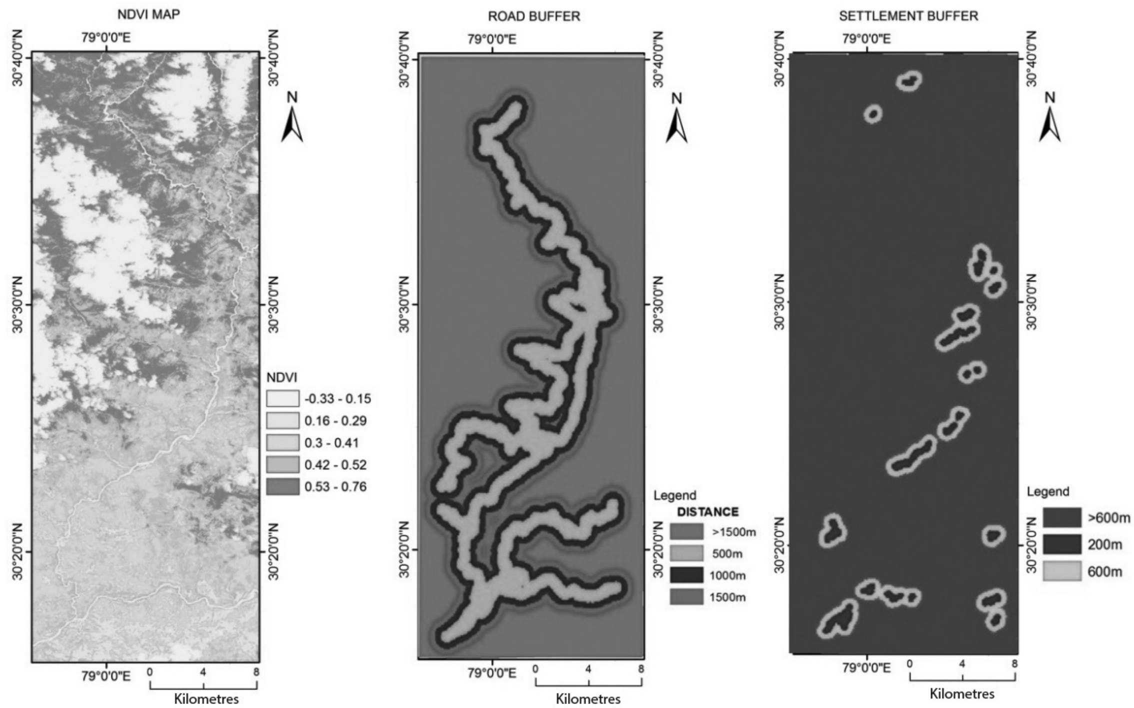

Figure 7: Various thematic layers used for landslide vulnerability assessment

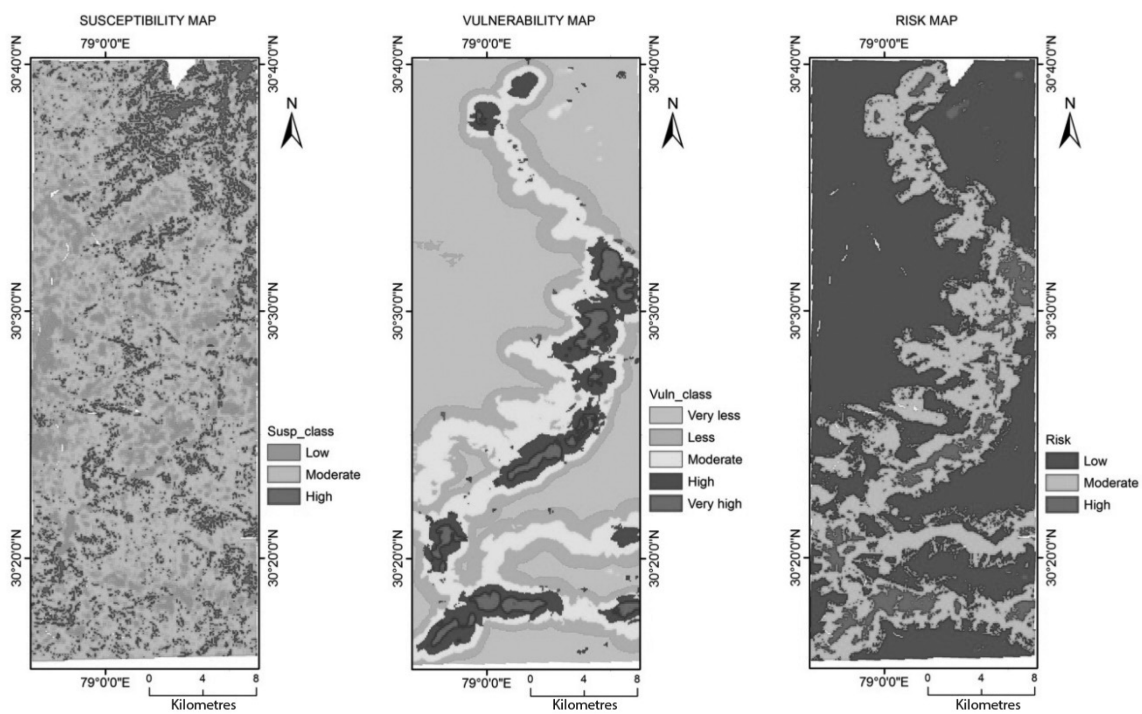

Figure 8: Maps showing susceptibility, vulnerability and risk zone for the study area

Landslide Risk Analysis

Risk is the product of susceptibility and vulnerability maps, i.e. risk map was derived by crossing the susceptibility and vulnerability map as described in the methodology. The risk map was divided into three classes, namely low, moderate and high risk zones. The total number of pixels in the risk raster layer is 75,738 covering 642 km^2 out of which most part of the study area (63 per cent) is under low risk zone. Only 6 per cent of the area is under high risk and the remaining 31 per cent lies in moderate zone. The risk statistics based on pixel densities are shown in Table 6 and landslide risk zonation map is depicted in Fig. 8. The elements considered for risk assessment included roads, agricultural land and houses. Also, pie chart distribution of landslide susceptible zone, vulnerable zone and risk zone is shown in Fig. 9. Upon overlay analysis of these three risk elements on risk map zonation attributes, it was inferred for agricultural land area in the region that 40 per cent of it is under low risk zone, 47 per cent lays in medium risk zone and 13 per cent lays in high risk zone. In the case of road features it was observed that 11 per cent of road cover area is under low risk, 61 per cent of road cover is under moderate risk and the remaining 28 per cent of the road-laden area is under high risk from landslide. Also considering the area cover of human habitats and settlement, it was observed that 41 per cent of settlements are in high risk zone, 56 per cent of them lay in moderate risk zone, and only 3 per cent of settlement locations are in low risk zone. The percentage distribution of agricultural land, roads and settlements at risk is well represented in the form of pie chart in Fig. 10.

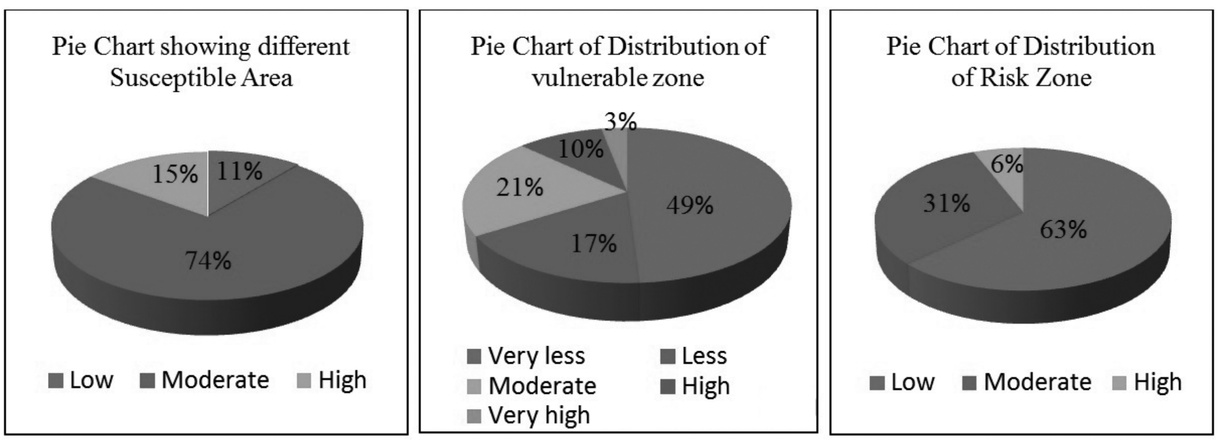

Figure 9: Pie chart distribution of susceptible, vulnerable and risk zones

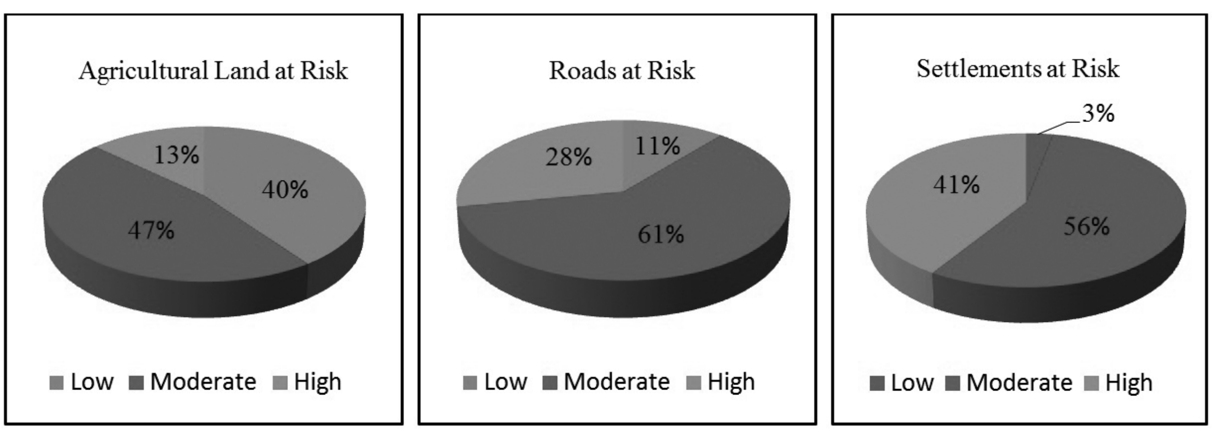

Figure 10: Pie chart distributions for agricultural land, roads and settlements at risk

Conclusion

High-resolution satellite images along with remote sensing and GIS technique is very helpful for hazard zonation as well as risk assessment. On the basis of this proper mitigation steps can be taken. A high-resolution LISS-IV image is very useful in preparation of inventory map and further in susceptibility and vulnerability maps. On the basis of the weightage and calculation, it can be inferred that geology was the predominant factor in causing a landslide. The next highest average was obtained for slope followed by lineament and geomorphology. Then other factors were given importance. The percentage of moderately susceptible zone is maximum nearly 74 per cent while in case of vulnerability most of the area is within very less to moderately vulnerable zone; hence after combination of two risk is determined and only 6 per cent area is under high risk zone. The area along the course of Mandakini River is highly susceptible because of the unconventional agricultural practices, unscientific road cutting and absence of proper drainage network, and in a few cases due to erosion of slope at toe by the river which makes the slope unstable especially during floods. Analysis result for risk elements shows that 13 per cent of agricultural land, 28 per cent of roads and 41 per cent of settlements are under high risk zone. The results obtained here can be used for land use planning and slope management.

Acknowledgements

This paper has been immensely benefited from contributions and consultations with all colleagues in Geosciences and Geohazards and other departments of the Indian Institute of Remote Sensing. Organisational support and overall guidance provided by Dr A. Senthil Kumar, Director, IIRS, and Dr Sarnam Singh, Dean (Academics), are also duly acknowledged. SLC and PKC are thankful to the Indian Space Research Organisation, Department of Space, Government of India, for the financial support provided in the TDP project.

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Landslide Hazard Zonation Using Object-Based Image Analysis for Chenab Valley in Jammu and Kashmir, India

Abhijit S. Patil[a], B. K. Bhadra[b] and S. S. Panhalkar[a]

ABSTRACT: A landslide is the movement of rock, debris or earth down along the slope under gravity. It may cause loss of people's lives and their private and public properties. Landslide is a common hazard in steep slope areas, especially during the rainy season. A study of landslides helps urban planners, engineers and local communities to reduce losses caused by existing and future landslides by means of prevention, mitigation and avoidance. Therefore, the prime aim of this paper is to produce an acceptable landslide hazard map for Chenab valley, Jammu and Kashmir. Semi-automatic extraction of landslides is a suitable method which has been used in this paper to extract location and extent of the landslides. IRS LISS-IV and CartoDEM have been used for object-based image analysis to extract and prepare landslide inventory map. About 84 landslides potential sites have been identified by semi-automatic extraction approach. Landslide Numerical Risk Factor (LNRF) model is derived by using 13 thematic layers with landslide inventory to prepare landslide hazard map. Results showed that 21 per cent of the area of the Chenab valley is falling under the very high hazard zone category of landslide. The final result of investigation will definitely be useful in decision-making procedures at the time of emergency and to prepare preparedness plan for high risk areas of Chenab valley.

KEYWORDS: object-based image analysis (OBIA), landslide numerical risk factor (LNRF), GIS, semi-automatic extraction

Introduction

Natural hazards are physical phenomena caused by geophysical, hydrological, meteorological or biological factors that injure people and damage the properties. Landslides are one category of natural disasters, which can be caused by natural processes or anthropogenic activities. Landslides are defined as the outward and downward movements of the earth materials under gravity without the aid of running water as a transporting agent (Crozier, 1986).

Remote sensing and Geographical Information System (GIS) are very efficient tools, which are used for scientific investigation of landslides. Landslides inventory mapping or historical landslides mapping can be used for landslide hazard zonation and landslide risk assessment. Traditionally, pixel-based methods have been used for mapping changes based on high resolution (HR) or very high resolution (VHR) satellite imagery (Chen et al. 2012; Hussain et al. 2013). More recently, object-based image analysis (OBIA) has emerged as a new standard in the field of remote sensing (Blaschke et al. 2014a). OBIA has a high potential for accurate landslide delineation and change detection from satellite imagery (Blaschke et al. 2014b). The extraction of landslides carried out by using OBIA has recently been employed for satellite-based change analysis. eCognition is the software package developed

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by Trimble, which is based on object-based image analysis. It has ability to detect the size and shape of landslides using temporal satellite images.

The coupled analysis of pre- and post-event images has the capability to detect spectral and/or morphologic changes, which can be attributed to new and/or reactivated landslides (Borghuis et al. 2007; Mondini et al. 2011). The reflectance of landslide in an image is brighter than initial (pre-)image that is the main function of automatic extraction. Due to landslides, the fresh soil and rocks expose on the upper surface of the earth which causes enhancement in the brightness of that landslide area.

Several studies have shown the applicability of OBIA for landslide mapping using knowledge-based and statistical approaches (e.g. Martha et al. 2010; Lahousse et al. 2011; Stumpf and Kerle 2011; Hölbling et al. 2012; Blaschke et al. 2014b; Kurtz et al. 2014).

A semi-automated approach was presented here based on object-oriented image analysis (using LISS-IV Mx 5.8 m and CARTODEM-1 10 m) with Landslide Numerical Risk Factor (LNRF) model for scientific delineation of landslide hazard zones.

Study Area

Chenab Valley lies between the middle and outer Himalayan ranges in the Jammu region of Jammu and Kashmir (J&K). The valley enclosed the Anantnag district of Kashmir from the north, Kishtwar district from the north-east, Chamba district of Himachal Pradesh (HP) and Kathua district from the South, the Udhampur district from the south-west and Salal Reasi from the west, with Doda in its middle. For landslide studies, the area is selected in the part of Chenab valley which is extended in five districts, namely Chamba (HP) and Doda, Kargil, Kishtwar and Udhampur (J&K). The areal extent of the study area is 7213 sq km, which is bounded by 32°51'48" to 33°45'57"N latitude and 75°29'34" to 76°46'47"E longitude (Fig. 1). Kishtwar is the major urban settlement near Chenab valley and also a district headquarter.

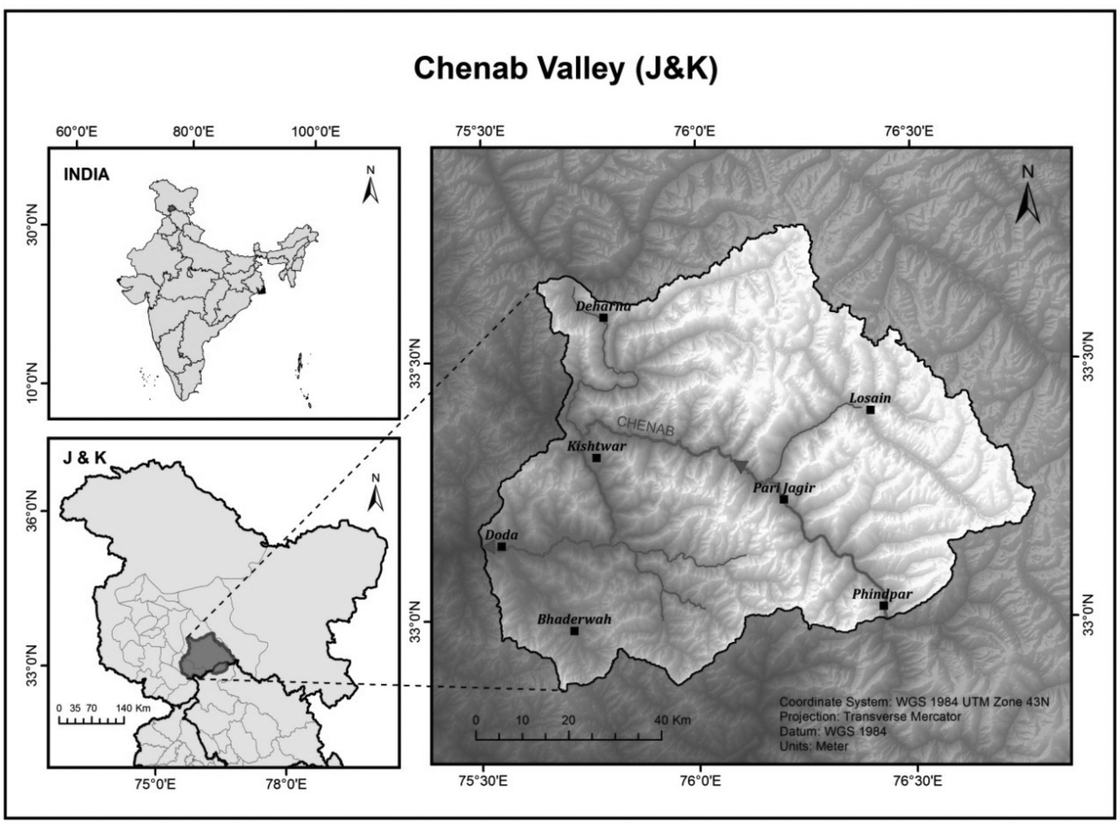

Figure 1: Location of the study area

Database and Methods

The prime objective of this paper is to demarcate zones of the landslide hazard using Landslide Numerical Risk Factor model. The detailed methodology is given in Fig. 3. The present study is primarily based on LISS-IV Mx and CartoDEM. Various kinds of thematic layers have been generated using the given datasets (Table 1). The object-based image analysis has been carried out by using these data sets. To geometric and radiometric corrections of an image, the Orthorectification and Top of Atmosphere (TOA) have been used respectively.

Rule Set for Landslide Detection

The landslide inventory of the Chenab valley region during 2013–14 has been mapped by using Standard Operation Procedure (SOP) of National Remote Sensing Centre (NRSC) to automatic landslide extraction in eCognition. NRSC has developed a rule set for landslide extraction to eCognition environment by using LISS-IV satellite images as mentioned in Fig. 2.

Description of Rules

1) Determination of Landslide Candidate Area

The first rule reveals that the difference of top of atmosphere between two images should be greater than equal to -0.004 for determination of landslide candidate area.

2) Removal of Snow Cover

Once landslide candidate area is determined, then snow cover area has to be removed from candidates by determining height should be greater than equal to 3200 m (season-wise value can be changeable).

3) Removal of Barren Land

Barren land can be detected as a landslide event because it shows near about the same reflectance of landslide. Principal component can be used to remove barren land (mean PC5 >= -17). The difference (>= 0.08) of vegetation cover (GNDVI) can also be used for the removal of barren land from landslide candidates. The difference (<= 100) of post brightness of satellite images is used to be remove barren land.

4) Removal of River Sand

River sand also characterises the same reflection of landslide for that it has to be removed. The slope of the terrain is used to remove the river sand (>= 14) from the landslide candidates.

5) Landslide Inventory

Final rule has to be prepared for merging and exporting of landslides into shape file format which has location and aerial extent.

Table 1: Database

S. No.	Input Data	Data Type	Source	Time Period
1	Pre-landslide images	Satellite data	RS2-LISS-IV Mx (5.8 m)	(September/ October) 2013
2	Post-landslide images	Satellite data	RS2-LISS-IV Mx (5.8 m)	(September/ October) 2014
3	DEM	Satellite data	CARTOSAT_1	2014
4	Geology	Collateral	GSI/*Journal of Asian Earth Sciences*	2010
5	Precipitation	Collateral	Website-accuweather.tamu.edu	2000–13
6	Geomorphology and lineament	Collateral	NGLM Project	2011/14
7	Earthquake	Collateral	QUICK BULLETIN/other	July 2013 to October 2014
8	LULC/NDVI	Satellite data	RS2-LISS-IV Mx	2014
9	Road and settlement		Toposheet/RS2-LISS-IV	2014
10	Drainage	Collateral/ Satellite data	Toposheet/RS2-LISS-IV/other	2014

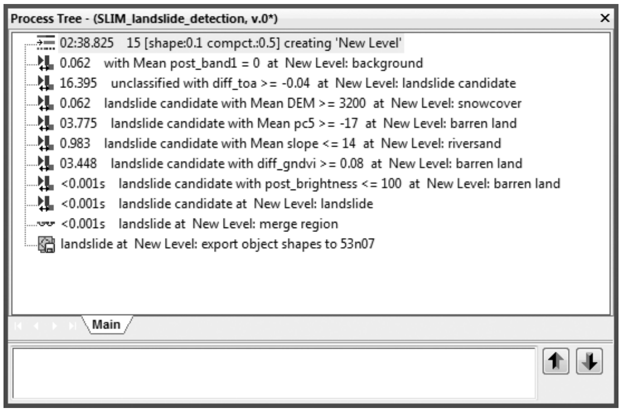

Figure 2: Rule set for landslide detection in eCognition

[pc = Principal Component, diff = Difference, gndvi = Green Normalised Difference Vegetation Index, toa = Top of Atmosphere]

Image Segmentation

Image segmentation is a method for dividing the image into small regions or segments and is a major step in OBIA. A typical optimisation procedure aims at minimalising under and over-segmentation to increase the efficiency and accuracy of classification technique (Martha et al., 2011). The major advantage of OBIA is the accurate result that can be easily verified on real word (Barlow et al., 2006).

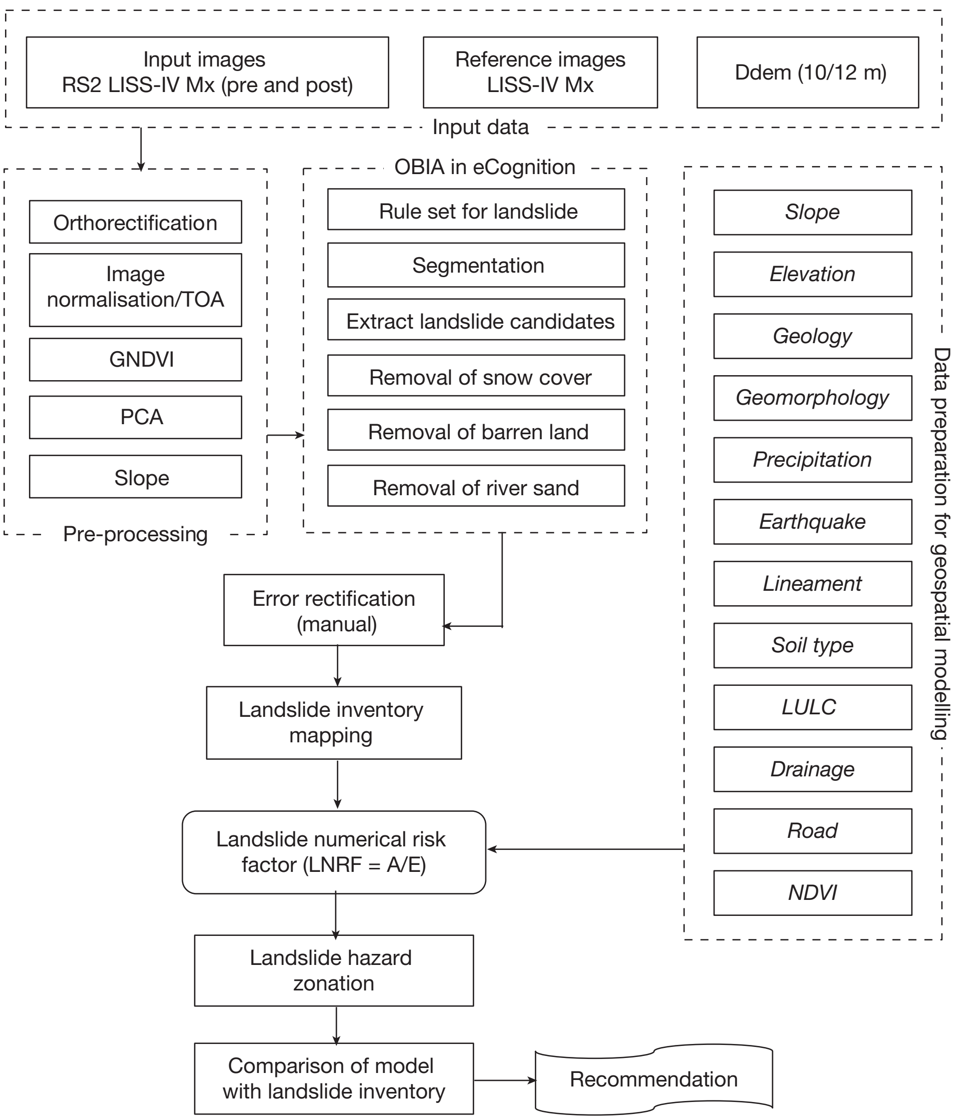

Figure 3: Flow chart showing the detailed methodology for landslide mapping and geospatial modelling

In eCognition, segmentation is controlled by scale, colour and shape, with the shape being composed of compactness and smoothness. The scale parameter is a function of the image resolution and is used to control the maximum allowed heterogeneity of the object, with a lower scale parameter yielding a higher number of segments. There are a number of segmentation techniques introduced by eCognition out of those techniques multi-resolution segmentation technique (Fig. 4) is used to image segmentation process for the present research work. It merges the pixels or existing image objects, based on homogeneity criteria (shape and compactness).

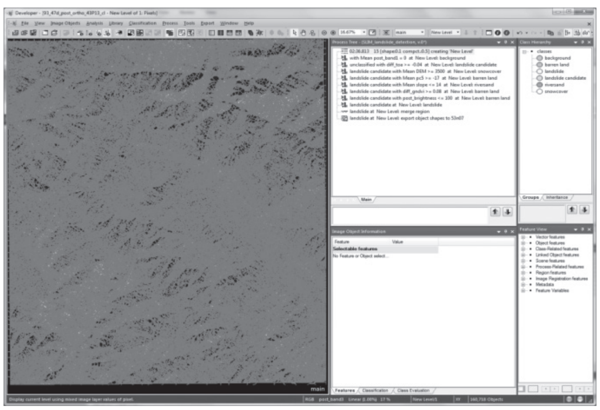

Figure 4: Multi-resolution image segmentation

The images of pre (2013) and post (2014) have been segmented at a scale of 15. The segmentation has been done using multi-resolution segmentation algorithm in rule-based model. The compactness/shape was set 0.2/0.5 for both images.

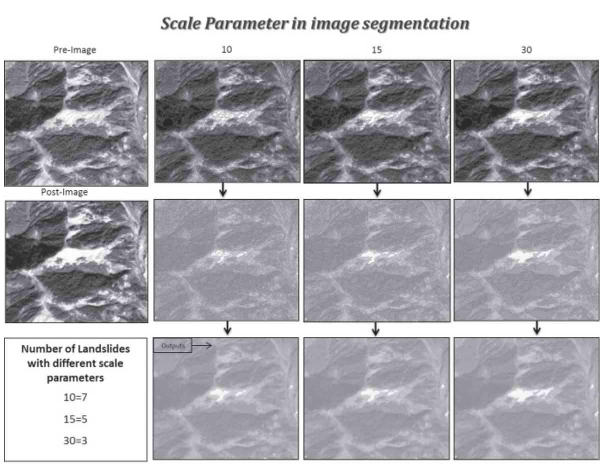

Figure 5: Scale parameter in an image segmentation

Different scale parameter shows different size of segmentation and the number of landslides also may get change which is expressed in the form of Fig. 5.

Elimination of False Landslides

By applying rule set in eCognition, snow, barren land, river sand and landslide have been classified separately. With the classification of all land features, false landslide signatures have been eliminated from the data. DEM, PC5, GNDVI and slope data were used for the classification of snow, barren land and river sand and for identifying real landslides. Rules have been mentioned in 3.3.2.1 section. The classification of different features is graphically explained in Fig. 6.

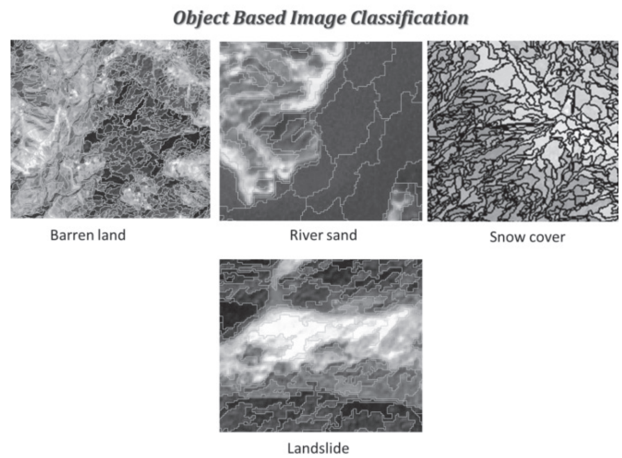

Figure 6: Object-based image classification

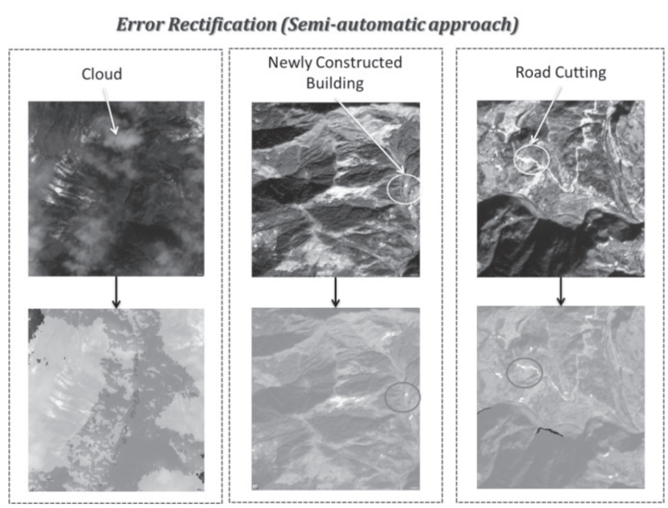

Figure 7: Error rectification

Object-oriented classification introduced some signature errors, which have been corrected manually by expert's knowledge. Cloud, shadow, newly constructed buildings and road cuttings are the major error generation factors in landslide inventory (Fig. 7). To remove these errors the visual interpretation keys have been used for error rectification. Manually these errors can be removed by using experts' experience known as the *semi-automatic approach* for landslide detection.

Landslide Inventory

After the process of error rectification the result is obtained as 'Landslide Inventory' which is showing the location and extent of landslides in the form of vector polygon data.

Geospatial Modelling – *Landslide Numerical Risk Factor (LNRF)*

For the present investigation, factors such as slope, elevation, geology, geomorphology, major thrust, lineament, earthquake, precipitation, drainage, NDVI, LULC, road and settlement were selected for the LNRF model. Landslide Numerical Risk Factor (LNRF) model (Gupta and Joshi, 1990) is a suitable model, especially in mountainous regions. Weighted values of various factors have been determined for every phenomenon. This model is expressed as per equation 1.

$$\text{LNRF} = \text{A/E} \quad \text{(Eq. 1)}$$

A: landslide area in every unit
E: mean area of landslide in the whole unit
As per equation 1, the weight of each homogeneous unit is estimated and weighted maps and related tables were prepared and LNRF is calculated (Table 2). Finally, zonation map of the landslide was prepared.

Table 2: The Unit Weight Base on the LNRF Model (Ali Mohomadi Torkashvand et al., 2014)

LNRF	Weight
0.67>	0
0.67–1.33	1
1.33<	2

Result and Discussion

Landslide Inventory

Figure 8 represents landslide inventory map (2013–14) of the study area along Chenab valley in southern Jammu and Kashmir. Total areal extent of landslides in the study area is estimated as 268043 m^2 (26.8 hectares) with 84 landslides. Most of the landslides in Inventory Map are located nearer to river valleys, which indicates steep slope of valley sides causing instability of land surface. The western part of the study area held approximately 70 per cent of landslides, whereas the eastern and northern parts of the study area has a lower concentration of landslides. Kishtwar and Doda are the major cities, which are surrounded by many landslides. Most of the landslides are located along Chenab valley, where river has one major meander.

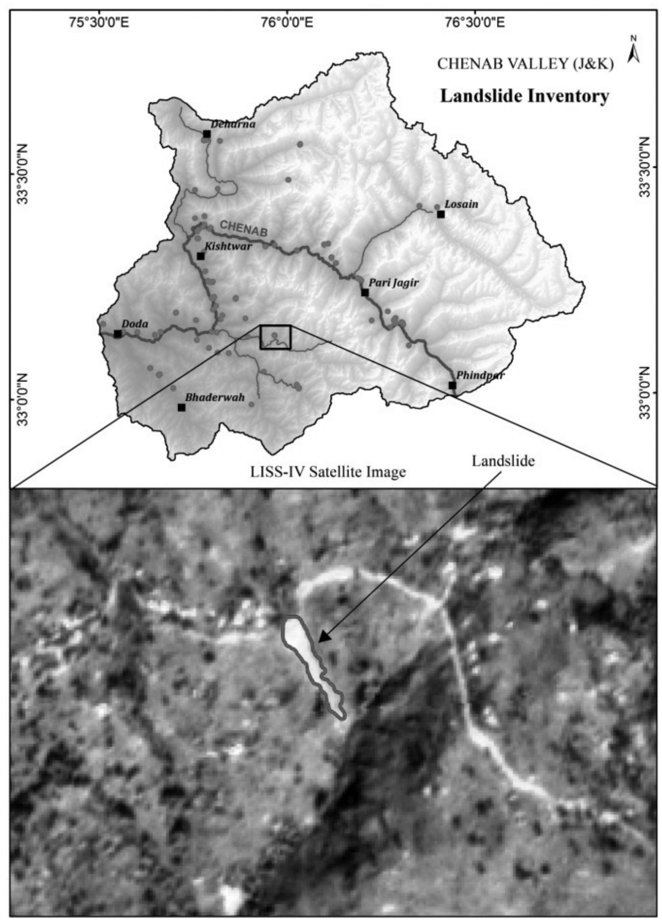

Figure 8: Landslide Inventory with a full view of single landslide (2013–14)

Thematic layers for LNRF

Geology

Geology or rock type is an important factor in controlling slope stability. The geology of the study area has been prepared by using GSI map. The spatial distribution of different rock types with geological formations has been shown in Fig. 9. Landslide layer is overlaid on the geology layer which shows different rock types in the study area. The maximum area is covered by Dolomite-Limestone rocks (41 per cent) followed by Phyllite-Schist (21 per cent), Phyllite-Quartzite (16 per cent), Phyllite-Slate (12 per cent), Granite (6 per cent), Limestone (3 per cent), Slate-Phyllite-Quartzite (0.20 per cent) and Siltstone-Limestone (0.005 per cent). It has been observed that 27 landslides have occurred in areas of Phyllite-Quartzite rocks and there was no landslide in Slate-Phyllite-Quartzite rocks area.

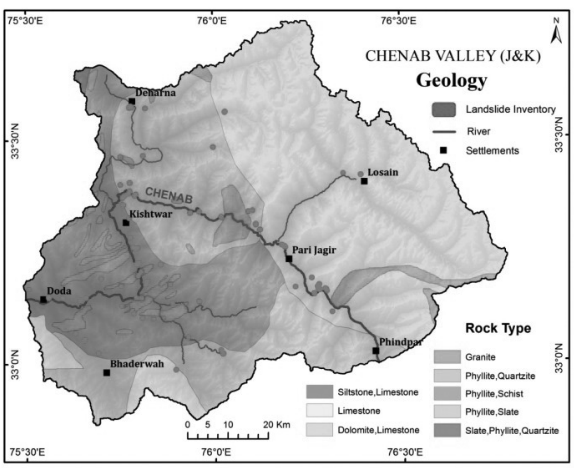

Figure 9: Geology with landslides

Elevation

The Elevation map of the study area has been prepared by using Cartosat-1 DEM (10 m resolution). By using DEM data set, the primary data product and secondary data product have been generated. Elevation levels of the basin vary from 818 m to 6489 m (Fig. 10). Basin elevation classes are divided into 10 categories and the mean height of the basin is calculated as 3653 m.

The highest part of the study area is covered by 4000–4500 m (15 per cent) elevation and the least area is covered by >5500 m (1 per cent) elevation. Comparatively, in the western part of the study area, lower elevation is observed, whereas in the case of the eastern part of the study area higher elevation is observed due to the presence of elevated hills. As per the Elevation parameter, the highest concentration of landslides is in 1500–2000 m (30 per cent landslides) elevation class followed by <1500 m (25 per cent landslides), 2000–2500 m (23 per cent landslides), 2500–3000 m (16 per cent landslides) and 3000–3500 m (6 per cent landslides).

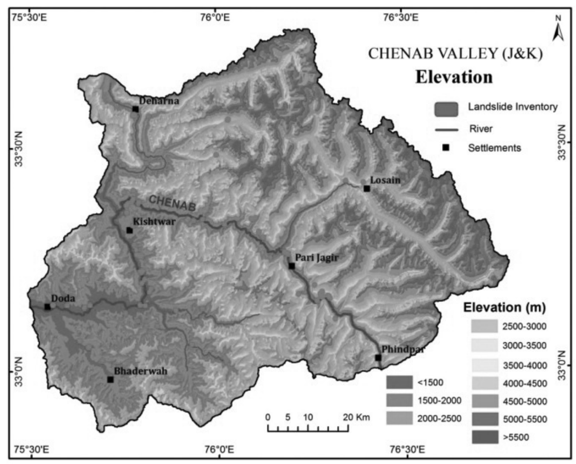

Figure 10: Elevation with landslides

Geomorphology

The geomorphology layer of the study area has been extracted from the existing GIS database of the National Geomorphology and Lineament Mapping (NGLM) project (Ref. Bhuvan website of NRSC). Spatial distribution of different landforms (Geomorphic Units) at Level-2 is shown in Fig. 11. It has been observed that there are 11 geomorphic landforms that existed in the study area. The highest geomorphic area is covered by Structural Origin – Highly Dissected Hills and Valleys (71 per cent) – and the least area is covered by Water Bodies – Pond (0.0008 per cent). Nearly 84 per cent existed (Inventory) landslides are located in Structural Origin, Highly Dissected Hills and Valleys, which is the area of highest concentration of landslides in geomorphic units followed by Water Bodies, River (9 per cent landslides); Fluvial Origin, Piedmont Alluvial Plain (5 per cent landslides) and Denudational Origin, Piedmont Slope (2 per cent landslides).

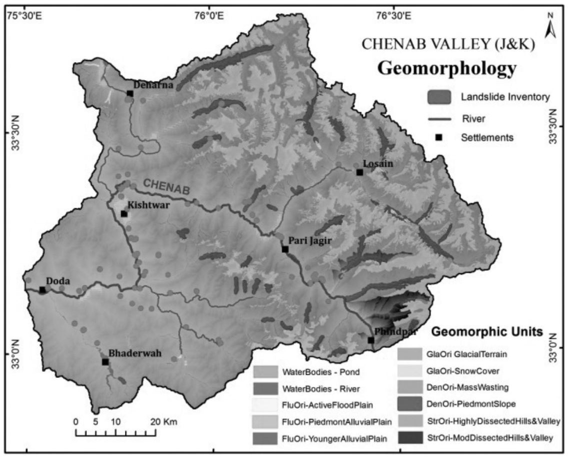

Figure 11: Geomorphology with landslides

Slope

Slope is important thematic layer in landslide study, which can determine the extent and intensity of the landslide. Slope map is prepared by using Cartosate-1 DEM with 10 m spatial resolution. Slope of the entire study area has been divided into eight categories from 0 to 80 degree range (Fig. 12). The area statistics of different slope categories shows that maximum area is under 30^0–40^0 (31 per cent) followed by 20^0–30^0 (30 per cent), 10^0–20^0 (15 per cent), 40^0–50^0 (14 per cent), <10^0 (7 per cent), 50^0–60^0 (3 per cent), 60^0–70^0 (0.2 per cent) and >70^0 (0.001 per cent). Most of the landslides are located in higher gradient areas.

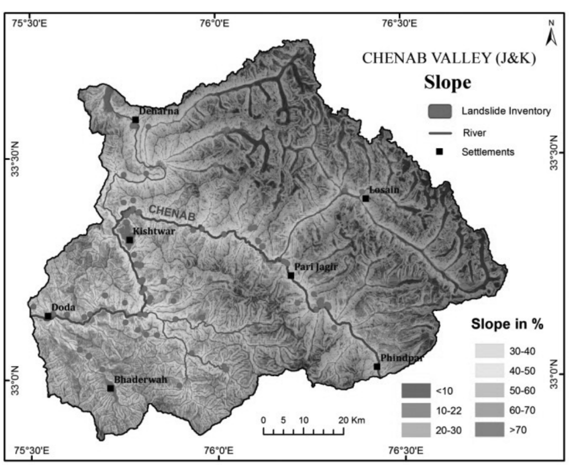

Figure 12: Slope with landslides

Major Thrust

The structural map of the study area has been prepared using geotectonic maps of GSI and *Journal of Asian Earth Sciences* (2010). The major structures are represented by thrust/fault buffer or distance from the thrust planes (Fig. 13). Main Central Thrust (MCT) is present at the base of High Himalayan Crystalline Zone (HHCZ), i.e. Jutogh and Vaikrita Group of rocks. The highest concentration of landslides is found near the buffer zone of major thrusts, namely, 5000 m (45 per cent landslides), followed by 10,000 m (25 per cent landslides), 15,000 m (15 per cent landslides), 20,000 m (7 per cent landslides), 25,000 m (5 per cent landslides), 30,000 m (7 per cent landslides) and 35,000 m (1 per cent landslides).

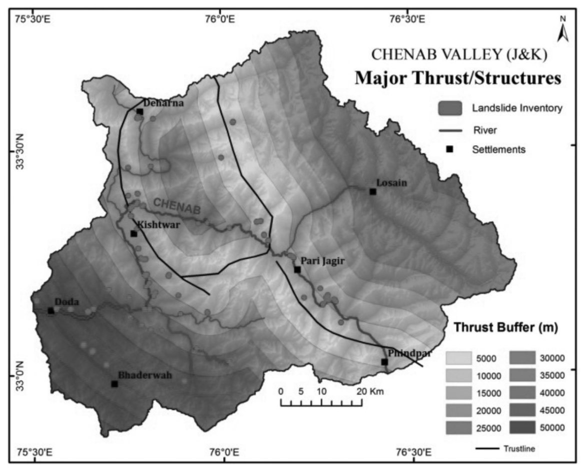

Figure 13: Major thrust planes with landslides

Earthquake

In this research work, earthquake data has been analysed through interpolation of reported magnitudes at different locations. Epicentral location of earthquakes and their magnitudes in the study area are varying from 3.3 to 5.2, which is a medium magnitude range in the 10 point Richter scale (Fig. 14). Interpolated contour map has been generated by showing earthquake magnitudes in five different zones. Nine earthquakes are denoted in the earthquake map, which are located mostly in the western part of the study area. Most of the landslides are located in 4.1–4.3 and 4.3–4.6 earthquake magnitude classes.

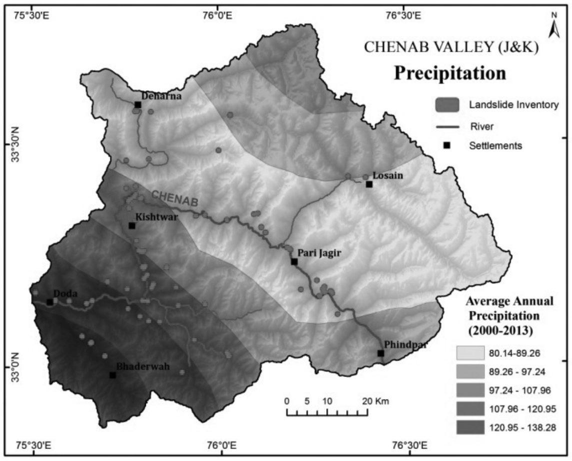

Figure 14: Earthquake epicentral locations with landslides

Lineament

A lineament is a linear feature in a landscape which is an expression of an underlying geological structure such as a fault. Here, lineament buffer/distance has been used as secondary data product of lineament layer. Lineament Distance of the entire study area has been divided into 14 categories from 1000 m to 14,000 m range with 1000 m interval (Fig. 15). In 1000 m buffer zone, 39 per cent existed landslides are located, which denote highest concentration of landslide followed by 2000 m (34 per cent landslides), 3000 m (9 per cent landslides), 5000 m (9 per cent landslides), 4000 m (8 per cent landslides) and 7000 m (1 per cent landslides).

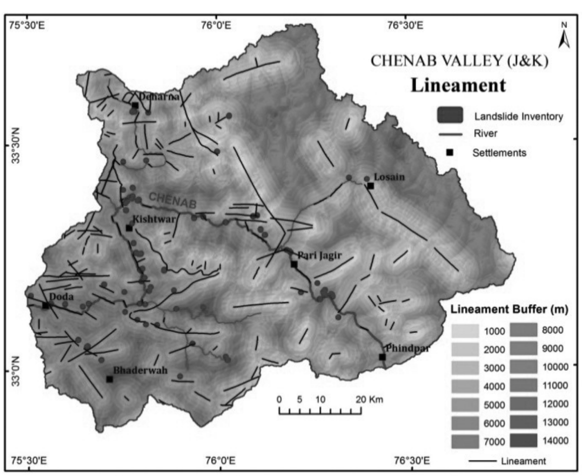

Figure 15: Lineament with landslides

Precipitation

The daily observed precipitation data (2000–13) was collected from the website accuweather.tamu.edu, which is freely available in the form of 0.33 degree grid data.

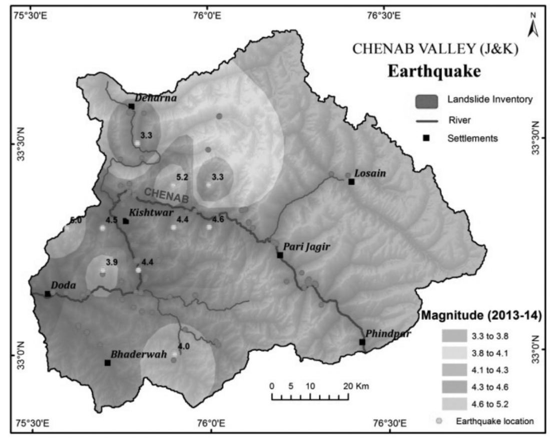

Figure 16: Precipitation with landslides

The point data of precipitation has been interpolated by using the Kriging-Exponential interpolation method. It has been observed that annual average precipitation range lies between 80.1 mm to 138.2 mm (Fig. 16). The average annual precipitation of the entire study area has been divided into five categories. In 80.14–89.26 mm precipitation zone, 43 per cent existed landslides are located, which records highest concentration of landslide in average precipitation zones followed by 97.24–107.96 (22 per cent landslides), 89.26–97.24 mm (19 per cent landslides), 107.96–120.95 mm (9 per cent landslides) and 120.95–138.28 mm (3 per cent landslides).

Land Use/Land Cover

Figure 17 shows the overlay of the Landslide Inventory layer on LULC. The existing LULC map of 2011–12 (India WRIS) has been used to prepare LULC map.

Although, the LULC units have been mapped on 1:50,000 (1:50K) at Level-2 classification schema (Fig. 17). The simplified map has been prepared with depiction of LULC unit at Level-2 via settlement (0.04 per cent area), snow and glacier (20 per cent), river/stream/canal (0.4 per cent), fallow (0.2 per cent), crop land (5 per cent), plantation (1 per cent), scrub forest (24 per cent), evergreen forest (33 per cent) and barren rocky land (16 per cent). Most of the landslides are located under category of scrub forest (38 per cent landslides) followed by barren rocky (19 per cent landslides), evergreen forest (19 per cent landslides), crop Land (18 per cent landslides), plantation (4 per cent) and river/stream/canal (2 per cent landslides).

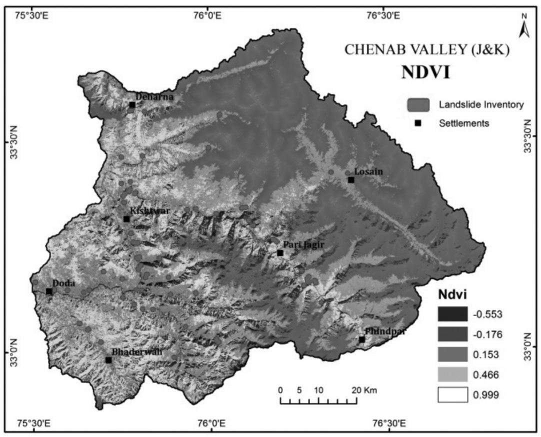

Figure 17: LULC with landslides

NDVI

For the present investigation, NDVI has also been calculated by using LISS-IV satellite images of the study area. NDVI has been categorised in five zones (range from -0.55 to 0.99).

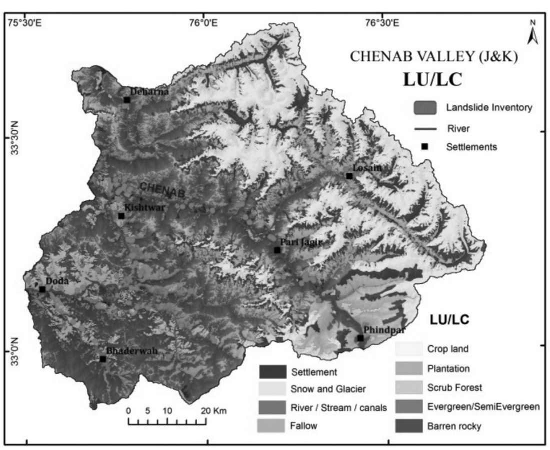

Figure 18: NDVI with landslides

About 50 per cent existed landslides are located in 0.15 to 0.466 category which denotes highest concentration of landslide in NDVI followed by 0.153 (26 per cent landslides), 0.999 (19 per cent landslides), -0.176 (2 per cent landslides) and -0.553 (2 per cent landslides) (Fig. 18).

Drainage

For the analysis purpose, major rivers have been used to prepare map of Drainage Buffer (Distance). Drainage distance has been divided into five categories which are 2000 m, 4000 m, 6000 m, 8000 m and 10,000 m (Fig. 19). All overlapped landslides are concentrated in only two categories: 2000 m (94 per cent landslides) and 4000 m (6 per cent landslides).

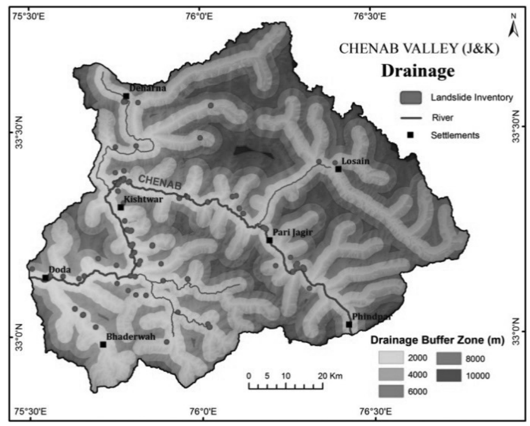

Figure 19: Drainage with landslides

Road

In the monsoon season, most of the landslides occur near roadsides in mountainous regions. In the study area, except in some parts of the northern area, all over road has spread. Road Distance (buffer) is the second product of the road layer is categorised in five classes: 5000 m, 10,000 m, 15,000 m, 20,000 m and 25,000 m (Fig. 20). All overlapped landslides are concentrated in only two categories: 5000 m (98 per cent landslides) and 10,000 m (2 per cent landslides).

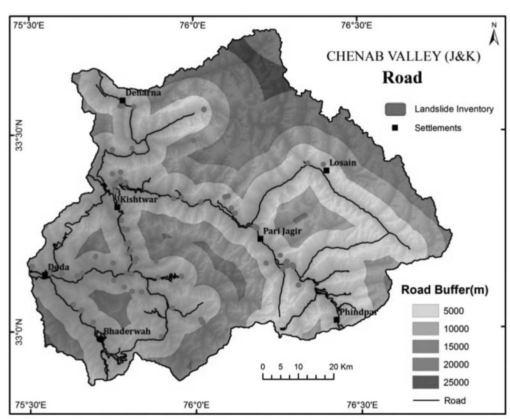

Figure 20: Road with landslides

Settlement

Landslides are also triggered by anthropogenic activities. Settlement is also most vulnerable to landslides. The distance from the settlement has been represented in settlement distance map (second product of settlement layer) of the study area (Fig. 21). Kishtwar, Doda, Dehran, Baderwah, Phindpar, Pari jagir and Losain are the major settlements with minor 634 settlements. Settlement Distance (Buffer) has been categorised in five classes , namely, <1500 m, 3000 m, 4500 m, 6000 m and >6000 m. Seventy-six per cent of existed landslides are located under <1500 m category which has highest concentration of landslide in settlement distance followed by 3000 m (13 per cent landslides), 4500 m (6 per cent landslides) and >6000 m (5 per cent landslides).

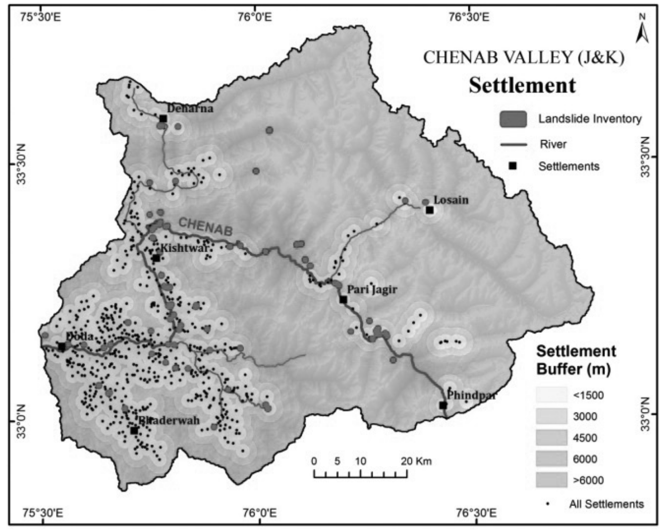

Figure 21: Settlement with landslides

Tabular Result of LNRF

Table 3: Integration of Landslide and Elevation Layer

S. No	Area of Elevation Units			Landslide (LSD)			Geospatial Analysis		
	Elevation Units	Area (Ha.)	Geog. Area (%)	No. of LSD	Area (Ha.)	Geog (%)	LNRF (A/E)	Weight	Instability
1	<1500	29,365.6	4.071	23	8.386	31.285	3.129	2	High
2	1500–2000	61,419.1	8.514	28	8.216	32.144	3.214	2	High
3	2000–2500	90,544.3	12.552	21	5.638	21.034	2.103	2	High
4	2500–3000	91,961.4	12.748	15	2.392	8.923	0.892	1	Medium
5	3000–5000	84,047	11.651	6	1.773	6.614	0.661	0	Low
6	3500–4000	92,616	12.839	0	0	0	0	0	Low
7	4000–4500	1,07,795	14.943	0	0	0	0	0	Low
8	4500–5000	10,1722	14.101	0	0	0	0	0	Low
9	5000–5500	53,001.8	7.347	0	0	0	0	0	Low
10	>5500	8907.67	1.235	0	0	0	0	0	Low
Total		72,1379.87	100.000	93	26.804	100			
Mean					2.680				

Table 4: Integration of Landslide and Earthquake Layer

S. No	Area of Earthquake Units			Landslide (LSD)			Geospatial Analysis		
	Earthquake (Mag.)	Area (Ha.)	Geog. Area (%)	No. of LSD	Area (Ha.)	Geog (%)	LNRF (A/E)	Weight	Instability
1	3.30–3.85	34,341.000	4.760	7	2.249	8.391	0.420	0	Low
2	3.85–4.09	2,83,781.000	39.339	7	4.253	15.865	0.793	1	Medium
3	4.09–4.24	2,96,115.000	41.049	44	13.398	49.983	2.499	2	High
4	4.24–4.55	92,255.800	12.789	26	6.905	25.761	1.288	1	Medium
5	4.55–5.19	14,883.600	2.063	0	0.000	0.000	0.000	0	Low
Total		7,21,376.400	100.000	84	26.804	100.000			
Mean					5.361				

Table 5: Integration of Landslide and Geology Layer

S. No	Area of Geology Units			Landslide (LSD)			Geospatial Analysis		
	Geology Units	Area (Ha.)	Geog. Area (%)	No. of LSD	Area (Ha.)	Geog (%)	LNRF (A/E)	Weight	Instability
1	Phyllite, Slate	85,600.52	11.866	4	0.562	2.096	0.168	0	Low
2	Granite	45,694.62	6.334	5	0.775	2.892	0.231	0	Low
3	Phyllite, Quartzite	113.859.6	6.334	5	0.775	2.892	0.231	0	Low
4	Slate, Phyllite, Quartzite	1457.091	0.202	0	0.000	0.000	0	0	Low
5	Phyllite, Schist	1,53,681.9	21.304	31	15.137	56.471	4.518	2	High
6	Dolomite, Limestone	2,97,733.1	41.272	19	4.389	16.374	1.310	1	Medium
7	Undifferentiated Bhimdasa and Sincha Formation	23,328.39	3.234	1	0.070542	0.263	0.021	0	Low
8	Undifferentiated Lolab and Karihul Formation	34.26,741	0.005	0	0	0	0	0	Low
Total		7,21,389.49	100	83	26.804	100.000			
Mean					3.351				

Table 6: Integration of Landslide and Geomorphology Layer

S. No.	Area of Geomorphology Units			Landslide (LSD)			Geospatial Analysis		
	Geomorphic Units	Area (Ha.)	Geog. Area (%)	No. of LSD	Area (Ha.)	Geog (%)	LNRF (A/E)	Weight	Instability
1	DenOri-Mass Wasting Products	71.199	0.010	0	0.000	0.000	0.000	0	Low
2	DenOri-Piedmont Slope	11,776.000	1.632	2	1.318	4.917	2.018	2	High
3	FluOri-Active Flood Plain	340.534	0.047	0	0.000	0.000	0.000	0	Low
4	FluOri-Piedmont Alluvial Plain	7382.900	1.023	5	1.018	3.799	1.559	2	High
5	FluOri-Younger Alluvial Plain	1087.760	0.151	0	0.000	0.000	0.000	0	Low
6	GlaOri-Glacial Terrain	36,554.900	5.067	0	0	0	0	0	Low
7	GlaOri-Snow Cover	1,30,036.000	18.026	0	0	0	0	0	Low
8	StrOri-Highly Dissected Hills and Valleys	5,12,839.000	71.092	78	23.770	88.679	36.393	2	High
9	StrOri-Moderately Dissected Hills and Valleys	15,748.300	2.183	0	0	0	0	0	Low
10	WaterBodies-Pond	5.914	0.001	0	0	0	0	0	Low
11	WaterBodies-River	5533.590	0.767	8	0.698	2.605	1.069	1	Medium
Total		7,21,376.097	100	93	26.804	100.000			
Mean					2.437				

Table 7: Integration of Landslide and Lineament Layer

S. No.	Area of Lineament Units			Landslide (LSD)			Geospatial Analysis		
	Lineament Units	Area (Ha.)	Geog. Area (%)	No. of LSD	Area (Ha.)	Geog (%)	LNRF (A/E)	Weight	Instability
1	0–1000	1,71,448.00	23.767	34	13.302	49.625	6.948	2	High
2	1000–2000	1,55,643.000	21.576	30	8.976	33.488	4.688	2	High
3	2000–3000	1,22,639.000	17.001	8	1.738	6.486	0.908	1	Medium
4	3000–4000	90,047.700	12.483	7	1.324	4.938	0.691	1	Medium
5	4000–5000	61,506.800	8.526	8	0.870	3.244	0.454	0	Low
6	5000–6000	33,839.800	4.691	0	0	0	0	0	Low
7	6000–7000	22,171.200	3.073	1	0.595	2.219	0.311	0	Low
8	7000–8000	18,709.700	2.594	0	0	0	0	0	Low
9	8000–9000	16,433.600	2.278	0	0	0	0	0	Low
10	9000–10,000	14,691.600	2.037	0	0	0	0	0	Low
11	10,000–11,000	10,053.300	1.394	0	0	0	0	0	Low
12	11,000–12,000	3222.540	0.447	0	0	0	0	0	Low
13	12,000–13,000	963.504	0.134	0	0	0	0	0	Low
14	13,000–14,000	6.632	0.001	0	0	0	0	0	Low
Total		7,21,376.376	100.000	88	26.804	100.000			
Mean					1.915				

Table 8: Integration of Landslide and LULC Layer

S. No.	Area of LULC Units			Landslide (LSD)			Geospatial Analysis		
	LULC Units	Area (Ha.)	Geog. Area (%)	No. of LSD	Area (Ha.)	Geog (%)	LNRF (A/E)	Weight	Instability
1	Barren rocky	1,11,986.000	15.524	22	6.284	23.445	2.110	2	High
2	Crop land	35,636.300	4.940	20	6.779	25.290	2.276	2	High
3	Evergreen/semi-evergreen	2,38,635.000	33.081	22	3.213	11.987	1.079	1	Medium
4	Fallow	1192.440	0.165	0	0.000	0.000	0.000	0	Low
5	Plantation	8356.120	1.158	5	1.344	5.014	0.451	0	Low
6	River/stream/canals	2999.770	0.416	2	0.271	1.010	0.090911	0	Low
7	Rural	293.548	0.041	0	0.000	0.000	0.000	0	Low
8	Scrub forest	1,76,509.000	24.468	43	8.913	33.254	2.993	2	High
9	Snow and glacier	1,45,768.000	20.207	0	0	0	0	0	Low
Total		7,21,376.178	100.000	114	26.804	100.000			
Mean					2.978				

Table 9: Integration of Landslide and Major Structure Layer

S. No.	Area of Major Structure Units			Landslide (LSD)			Geospatial Analysis		
	Major Structure Units	Area (Ha.)	Geog. Area (%)	No. of LSD	Area (Ha.)	Geog(%)	LNRF (A/E)	Weight	Instability
1	0–5000	1,72,565.000	23.922	38	14.202	52.983	5.298	2	High
2	5000–10,000	1,39,645.000	19.358	21	3.152	11.759	1.176	1	Medium
3	10,000–15,000	1,04,135.000	14.436	9	2.108	7.864	0.786	1	Medium
4	15,000–20,000	75,644.000	10.486	6	0.628	2.344	0.234	0	Low
5	20,000–25,000	75,541.300	10.472	4	1.366	5.096	0.510	0	Low
6	25,000–30,000	66,493.400	9.218	6	5.113	19.077	1.908	2	High
7	30,000–35,000	49,822.100	6.907	1	0.235	0.878	0.088	0	Low
8	35,000–40,000	31,128.200	4.315	0	0	0	0	0	Low
9	40,000–45,000	6321.310	0.876	0	0	0	0	0	Low
10	45,000–50,000	80.734	0.011	0	0	0	0	0	Low
Total		7,21,376.044	100.000	85	26.804	100.000			
Mean					2.680				

Table 10: Integration of Landslide and Precipitation Layer

S. No.	Area of Precipitation Units			Landslide (LSD)			Geospatial Analysis		
	Preci. Units (mm)	Area(Ha.)	Geog. Area (%)	No. of LSD	Area(Ha.)	Geog (%)	LNRF (A/E)	Weight	Instability
1	80.14–89.26	3,12,796.000	43.361	33	7.775	29.005	1.450	2	High
2	89.26–97.24	2,02,230.000	28.034	18	8.120	30.292	1.515	2	High
3	97.24–107.96	1,00,891.300	13.986	21	4.230	15.781	0.789	1	Medium
4	107.96–120.95	62,645.900	8.684	9	4.069	15.181	0.759	1	Medium
5	120.95–138.28	42,812.900	5.935	3	2.611	9.741	0.487	0	Low
Total		7,21,376.100	100.000	84	26.804	100.000			
Mean					5.361				

Table 11: Integration of Landslide and Road Layer

S. No.	Area of road Units			Landslide (LSD)			Geospatial Analysis		
	Road_dist (m)	Area (Ha.)	Geog. Area (%)	No.of LSD	Area (Ha.)	Geog (%)	LNRF (A/E)	Weight	Instability
1	< 5000	4,23,150.000	58.659	82	24.660	92.002	4.600	2	High
2	5000–10,000	1,87,955.000	26.055	2	2.144	7.998	0.400	0	Low
3	10,000–15,000	66,818.100	9.263	0	0.000	0.000	0.000	0	Low
4	15,000–20,000	31,198.400	4.325	0	0.000	0.000	0.000	0	Low
5	20,000–25,000	12,254.700	1.699	0	0.000	0.000	0.000	0	Low
Total		7,21,376.200	100.000	84	26.804	100.000			
Mean					5.361				

Table 12: Integration of Landslide and NDVI Layer

S. No.	Area of NDVI Units			Landslide (LSD)			Geospatial Analysis		
	NDVI Units	Area (Ha.)	Geog. Area (%)	No.of LSD	Area (Ha.)	Geog (%)	LNRF (A/E)	Weight	Instability
1	< (-0.553)	15,870	2.200	3	0.250	0.932	0.047	0	Low
2	(-0.553)–(-0.176)	52,703	7.307	3	0.123	0.457	0.023	0	Low
3	(-0.176)–(0.153)	3,05,780	42.394	38	7.566	28.226	1.411	2	High
4	(0.153)–(0.466)	2,08,338	28.885	72	13.898	51.851	2.593	2	High
5	(0.466)–(0.999)	1,38,585	19.214	28	4.968	18.534	0.927	1	Medium
Total		7,21,276	100.000	144	26.804	100.000			
Mean					5.361				

Table 13: Integration of Landslide and Slope Layer

S. No.	Area of Slope Units			Landslide (LSD)			Geospatial Analysis		
	Slope Units	Area (Ha.)	Geog. Area (%)	No. of LSD	Area (Ha.)	Geog (%)	LNRF (A/E)	Weight	Instability
1	< 10	49,620.600	6.879	4	0.282	1.051	0.084	0	Low
2	10–20	1,09,631.000	15.197	17	4.905	18.299	1.464	2	High
3	20–30	2,17,258.000	30.117	42	8.679	32.379	2.590	2	High
4	30–40	2,25,253.000	31.225	45	7.710	28.764	2.301	2	High
5	40–50	99,889.200	13.847	16	3.571	13.322	1.066	1	Medium
6	50–60	1,85,74,300	2.575	10	1616	6028	0.482	0	Low
7	60–70	1140.480	0.158	1	0.042	0.158	0.013	0	Low
8	>70	9.720	0.001	0	0	0	0	0	Low
Total		7,21,376.300	100.000	135	26.804	100.000			
Mean					3.351				

Table 14: Integration of Landslide and Settlement Layer

S. No.	Area of Settlement Units			Landslide (LSD)			Geospatial Analysis		
	Settlement dist. (m)	Area (Ha.)	Geog. Area (%)	No.of LSD	Area (Ha.)	Geog (%)	LNRF (A/E)	Weight	Instability
1	< 1500	1,62,020.000	22.4598545	64	21.685	80.902	4.045	2	High
2	1500–3000	1,04,693.000	14.51295857	11	2.229	8.315	0.416	0	Low
3	3000–4500	81,812.500	11.34117298	5	1.130	4.216	0.211	0	Low
4	4500–6000	63,962.500	8.866735239	0	0.000	0.000	0.000	0	Low
5	> 6000	3,08,888.000	42.81927871	4	1.760	6.567	0.328	0	Low
Total		7,21,376.000	100.000	84	26.804	100.000			
Mean					5.361				

Table 15: Integration of Landslide and Drainage Layer

S. No.	Area of Drainage Units			Landslide (LSD)			Geospatial Analysis		
	Drainage_dist (m)	Area (Ha.)	Geog. Area (%)	No.of LSD	Area (Ha.)	Geog (%)	LNRF (A/E)	Weight	Instability
1	< 2000	3,93,306	55	79	25.528	95.238	4.762	2	High
2	2000–4000	2,39,640	33	5	1.276	4.762	0.238	0	Low
3	4000–6000	71,643	10	0	0.000	0.000	0.000	0	Low
4	6000–8000	14,893	2	0	0.000	0.000	0.000	0	Low
5	8000–10,000	1894	0	0	0.000	0.000	0.000	0	Low
Total		7,21,976	100	84	26.804	100.000			
Mean					5.367				

**LNRF = Landslide Numerical Risk Factor *A = Area of landslide *E = Mean area of landslide*

Landslide Hazard Zonation Using LNRF Model

The LNRF has been calculated by integrating 13 thematic layers (Geology, Geomorphology, Slope, Elevation, Lineament, Major thrust, Earthquake, Precipitation Drainage, NDVI, LULC, Road and Settlement) with *Landslide Inventory layer*. The assigned weightage of respective LNRF values of each thematic layer has been added in the attribute table. All thematic layers with their respective attribute tables have been integrated. For further analysis, the sum of LNRF values are found within a range from 3 to 26. The highest value (26) indicates summation of highest weightage of all the 13 layers and represents the high hazardous zone. So, this range (3–26) has been grouped into four categories based on the vulnerability of the landslide-prone area, namely Very High (20–26), High (15–20), Medium (12–15) and Low (3–11). Spatial distribution of these zones with landslide occurrence in 2013–14 is depicted in Fig. 22 and the area statistics is given in respective map. It has been observed that 34 per cent of the total study area falls under High LHZ, which is found mostly in the western part of the study area. Around 25 per cent area falls under Middle LHZ, which is confined to the area along Chenab valley. Hence, 21 per cent area of the valley is occupied by the Very High and 20 per cent area is occupied by Low LHZ.

For the assessment of the LNRF result, model is compared with Landslide Inventory which is rectified by the expert's knowledge-based classification. About 94.91 per cent (77 landslides out of 84) landslides are falling under Very High Hazard Zone (Table 16).

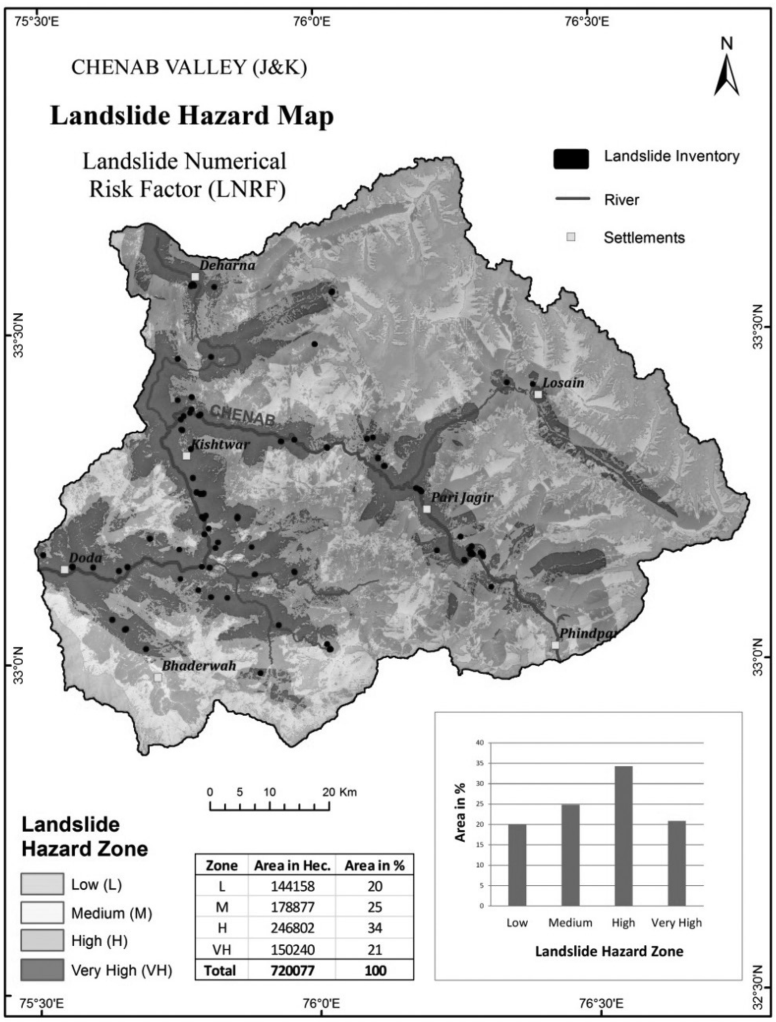

Figure 22: Landslide Numerical Risk Factor (LNRF)

Table 16: Assessment of LNRF model Using Landslide Inventory

Method	Landslide Hazard Zones	Area Under Category (Ha)	Area Under Category (%)	Number of Landslides (2013–14)	Area under LSD (Ha) in 2013–14	Area under LSD (%)
LNRF	Very high	1,50,240.16	20.86	77	25.41	94.81
	High	2,46,802.35	34.27	7	1.39	5.19
	Medium	1,78,876.62	24.84	0	0	0
	Low	1,44,157.74	20.03	0	0	0
	Total	7,20,076.87	100	84	26.8	100

Conclusion

The landslide inventory in the study area using OBIA technique with semi-automatic extraction approach has recognised 84 landslides during the 2013–14 period. Hence, with the help of Landslide Inventory layer the LNRF is calculated by integrating 13 thematic layers (Geology, Geomorphology, Slope, Elevation, Lineament, Major thrust, Earthquake, Precipitation Drainage, NDVI, LULC, Road and Settlement). Thus LNRF model results show that about 21 per cent area is susceptible to very high landslide hazard and 34 per cent area vulnerable to high hazard zone. The OBIA technique with semi-automatic extraction approach denotes that 94.4 per cent landslide area comes under the very high landslide hazard zone category of LNRF model, while only 5.19 per cent landslides are observed in high landslide hazard zone category. Therefore, overall investigation reveals that the steep slope of Chenab valley is representing very high landslide hazard zone. In conclusion, it is very clear that the Chenab valley represents a relatively high potential for landslide, which is dangerous for unplanned anthropogenic activities.

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Linking Hazards of Landslide and Urban Flood in the North-East Himalayan Region

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ABSTRACT: Climate change has not only intensified rainfall and urban flood in recent years but has also triggered the hazard of landslide posing a major threat to the population, buildings and the environment. About 10.098 sq. km. of north-east Himalayan region is prone to landslide and experiences a high amount of rainfall. The city of Guwahati in the north-east Himalayan region is already suffering from increasing intensity of urban flood and 43 per cent of its area is susceptible to landslide. There are 20 dissected residual hillocks and 366 landslide-prone sites located all over the city. The present study is an attempt for assessing landslide risk in Guwahati by developing a landslide hazard zonation map and to establish its linkage to urban flood-related risks, using geographic information system (GIS). In an expert opinion survey on the urban flooding issue in the city, 12 out of 16 respondents mentioned that the earth materials brought by the water flowing from the hillocks in the form of landslides block the already inadequate side-drains of the city. Out of seven urban flood causative factors, four (contour and slope, soil type, land use and rainfall distribution) are also related to landslides. These four factors were graded using the analytical hierarchy process (AHP) and their relative weights were derived. All the layers were integrated, as per the obtained weights, in order to generate the final landslide hazard zonation map showing five different categories of vulnerability. The proposed map was found to match with the actual sites prone to landslides as per published literatures. Next it was compared with the urban flood hazard map derived from a parallel study along with the ground reality which showed strong logical linkage between the two hazards. The knowledge elicited from this study will help in scientific and holistic planning for mitigation of the combined risk of urban flood and landslide.

KEYWORDS: geographic information system, hazard mapping, North-east Himalaya, landslide, urban flood

Introduction

In recent years, rainfall and urban flood have been intensified by climate change phenomenon and it has also triggered the hazard of landslide, thus posing a major threat to the population, buildings and the environment (Gariano & Guzzetti, 2016; RECARE, 2018). Centre for Research on the Epidemiology of Disasters or CRED (2018) has reported a loss of 130,000 lives and 50 billion USD since 1900, including the recent catastrophic landslides in Afghanistan (2014, 2015, 2018), the USA (2014, 2018), the Philippines (2018) and India on annual basis. According to an Economic Times report of 2017, climate change has cost India 10 billion USD every year (Mohan, 2017). India is one of the most disaster-prone countries of the world; where 68 per cent of its land is susceptible to drought, 60 per cent to earthquakes, 12 per cent to floods and 8 per cent to cyclones (World Focus, 2014). According to the Geological Survey of India (GSI), 0.49 million sq. km. of the landmass in India is prone to landslides and the Himalayan mountain region is one of the areas to be affected the most, due to anthropogenic activities and climate change. The mountain range

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was formed due to the collision of Indian and Eurasian plates. The northward movement of the Indian plate causes continuous stress on the rocks, rendering them inherently friable (easily crumbled), weak and prone to landslides. A chunk of about 10.098 sq. km. of north-east Himalayan region is not only prone to landslide, but it is located in seismic zone-V, the flood-prone valley of Brahmaputra river, and experiences a high amount of rainfall (2125 to 4142 mm annually) (Lal, 2014; Sarmah & Das, 2018a).

Against this multi-hazard-prone backdrop, Guwahati, the capital of the largest north-east state of Assam, demands special mention. The government of India's recent 'Act East' policy for making the north-east states as a gateway to Indo-ASEAN economic growth may attract intense urbanisation in Guwahati which is already suffering from increasing intensity of urban flood, unplanned growth, landslides and a major earthquake is highly expected (Singh, 2017). This paper aims to develop a landslide hazard zonation map of Guwahati and establish its linkage to urban flood-related risks.

Literature Review

The literature review for the current study has been categorised into three major sections, namely (1) causes of landslides; (2) landslide-prone Guwahati city; and (3) need for landslide hazard assessment for Guwahati.

Causes of Landslide

Landslide is defined as the down-slope movement of earth materials such as rocks, soil, vegetation or a combination of all these under the influence of gravitational force (United States Geological Survey, 2018). Dortch et al. (2009) mentioned steep slopes as a factor in triggering large landslides, especially in the mountainous belts of the Himalayan region. To add to this, high-intensity rainfall, which induces slope failure due to the soil properties, is also a primary factor which controls the instability of slopes and contributes in causing landslides (Rahardjo, Ong, Rezaur, & Leong, 2007). Outdated land use policies and lack of knowledge among the masses are also a reason for a land becoming vulnerable to landslides. A report by Highland & Bobrowsky (2008) mentions that the growing population of a region may be limited to a certain geographic expansion so that no one occupies the unstable, steep or remote areas that may increase the risk to their lives. Simple low-tech precautions may be adopted in the day-to-day schedule of a region to ensure immediate safety in a landslide occurring scenario.

Landslide-Prone Guwahati City

The soil type, contour-slope, urbanisation activities and high-intensity rainfall make Guwahati landslide prone. Its strategic location adds to its criticality for maintaining the basic lifeline of surrounding eight north-east Indian states. This region is narrowly connected to the rest of the country via national highways (NH31, NH37, NH40), state highways, a broad-gauge railway line and the busiest airport of the region – all located at or passing through Guwahati. If during a disaster this road and rail connectivity is hampered, it will cut-off the lifeline of the entire north-east region, thus causing disruption to the vital facilities and damage to the population and the buildings (Sarmah & Das, 2018b). This is evident from a recent news report stating that *Multiple landslides have blocked vital transport routes, hindering the relief work in the affected state. Security forces comprising of paramilitary troops, state forces as well as the Army, have been deployed in carrying out the relief operations and required medical support in the affected state* (The Indian Express, 2018).

In 1971, when the capital of Assam was shifted from Shillong to Guwahati (also called as Dispur), haphazard growth of the city began; the population started rising at 16.93 per cent per decade and people started to settle and take over the wetlands and hillocks (Desai, Mahadevia, & Mishra, 2014). Thus cutting down of the hillocks for human use and rampant deforestation have rendered the slopes unstable, compounding the city's vulnerability to damaging landslides which in turn also started deteriorating the surrounding natural environment. After a quick downpour, rock falls, failure of slopes and debris flows create landslides in the surrounding hills, which cause casualties and losses to the properties. Three thousand hectares of the city land out of the total 7023 hectares is landslide prone. The first major landslide in Guwahati took place in 1972 in areas of the Kharguli hillock (Das, Ray, & Nain, 2014). There are 20 dissected residual hillocks located all over the city, some names being Nilachal, Khanapara, Nabagraha, etc. (AEC & ASDMA, 2012). All of them pose the threat of landslide by a varying extent and the brunt of climate change and growing urbanisation has added to its woes. The devastation caused by these events demands strategies for both mitigation and preparedness to reduce the effects of such events, and for gearing up the relief, rescue and rehabilitation protocols well before their occurrence.

Need for Landslide Hazard Assessment for Guwahati

Two major studies have been conducted on landslides of Guwahati. The first one was a landslide hazard zonation map developed by the Assam Electronics Development Corporation Limited (AMTRON) in 2002 in Geographic Information System (GIS) platform where the Guwahati Municipal Corporation (GMC) area was considered, including airport and north Guwahati areas, and divided into high, medium and low landslide hazard zones (AMTRON, 2002). The second study in 2012 was jointly done by the Assam Engineering College (AEC) and the Assam State Disaster Management Authority (ASDMA) and was a much detailed 'Summary of potential landslide areas of Guwahati'. Here survey was done to identify 366 landslide-prone areas of the city based on 13 parameters namely, slope material, slope inclination, slope height, vegetation cover, land movement, recent land use change, presence of overload structures, leakage of water within slope, availability of drainage path, rock fall possibility, maximum size of rock boulder, possible loss of life and possible damage to structures, and scoring was done to show the degree of vulnerability (high, medium and low). The selection of parameters and scoring system were not mentioned in detail. And finally a 'landslide index' was prepared to mention which site requires 'immediate attention' and which sites 'do not require immediate attention'. But this report strongly recommended the preparation of a landslide hazard zonation map for assessing the vulnerability of various zones and thereby impose bylaws regarding cutting, construction and other slope-related activities according to the risks (AEC & ASDMA, 2012). In this connection when both these reports were compared, it was found that each one had a different list of sites prone to landslides. Moreover, in 2013, the city got zone-wise restructuring where 60 wards were re-arranged into 31 wards, thus bringing in significant changes in planning policies where these two earlier reports lost their relevance to a great extent.

Methodology

For developing a landslide hazard zonation map for Guwahati and to establish its linkage to urban flood-related risks. Geo-informatics using common software, namely GRASS GIS 7.2.2, ERDAS Imagine 2014, QGIS 2.18.16 and ArcGIS 10.5, was used. Overview of the research methodology is shown in Figure 1.

Guwahati Municipal Corporation (GMC) with an area of 216 sq. km. and having a population of about 10 lakhs constitutes 31 wards and faces recurring urban floods annually three to four times. In a recent expert opinion survey on the urban flooding issue in the city, 12 out of 16 respondents have repetitively mentioned that the earth materials brought by the water flowing from the hillocks in the form of devastating landslides block the side-drains of the city, which are already inadequate in Guwahati (Sarmah & Das, 2018b). For this survey, seven urban flood causative factors were chosen critically. They were broadly classified under environmental factors (contour and slope, rainfall distribution, soil type and choked natural drains) and urbanisation factors (land use, population density and road network). These factors were graded using the analytical hierarchy process (AHP) and their relative weights were generated. In developing the relative weights, an expert in this field compared every possible pairing and entered the ratings into a 9-point (1 = equal importance to 9 = extreme importance) pairwise comparison matrix.

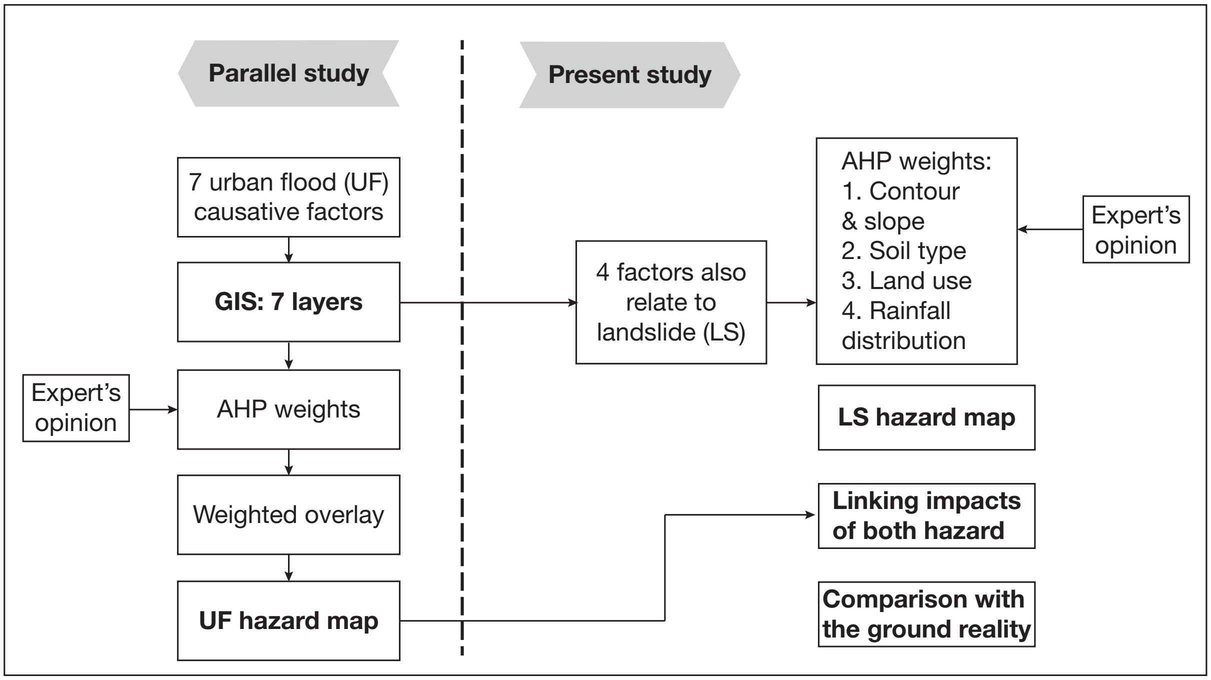


Figure 1: Research methodology

As per literature, out of these seven parameters, four, namely, contour and slope, rainfall distribution, soil type and land use, are also related to landslides. A parallel study by the authors and their peers on urban flood in Guwahati placed contour and slope, soil type, land use and rainfall distribution in first, second, third and fourth positions respectively totalling up to 86.37 per cent of the impacts. As per literature review (section 2.1), these factors are also responsible for landslides. 12 out of 16 experts mentioned about them as primary causes triggering landslide and which eventually worsen the urban flood in Guwahati. The landslide-related factors were then further analysed to produce a set of normalised weights summing to 1 in GIS-based IDRISI software. The contour and slope maps were prepared from the digital elevation model (DEM) obtained from the United States Geological Survey (USGS), the soil type map was acquired from the local agriculture department and digitised and land use analysis for the year 2018 was performed using temporal remote sensing data from Landsat-8 series operational land imager (OLI) sensors (30 m).

All these four layers were integrated, as per the obtained normalised global weights, in order to generate the final landslide hazard zonation map showing the very high, high, medium, low and very low hazard zones. The final map was then compared with actual sites prone to landslides as per published literatures. The urban flood hazard map obtained from a parallel study and the landslide hazard map developed during this current study were compared with the ground reality situation of the city to derive the linking impacts of the two hazards. Based on the findings, qualitative recommendations were made for mitigation of landslides in the city, which also trigger the occurrence of urban floods.

Result and Discussion

Top four causative factors for urban flood found through a parallel study are noted by literature as controlling factors for landslides. They were used for developing the landslide hazard zonation map. The global weights for these factors, generated in IDRISI software, were normalised for the current study and used for developing the landslide hazard zonation map. These four layers common to both urban flood and landslide showed higher relative weight, that is, contour and slope = 0.37, soil type = 0.3, land use = 0.21 and rainfall distribution = 0.12. Thus showing a clear linkage between the two hazards.

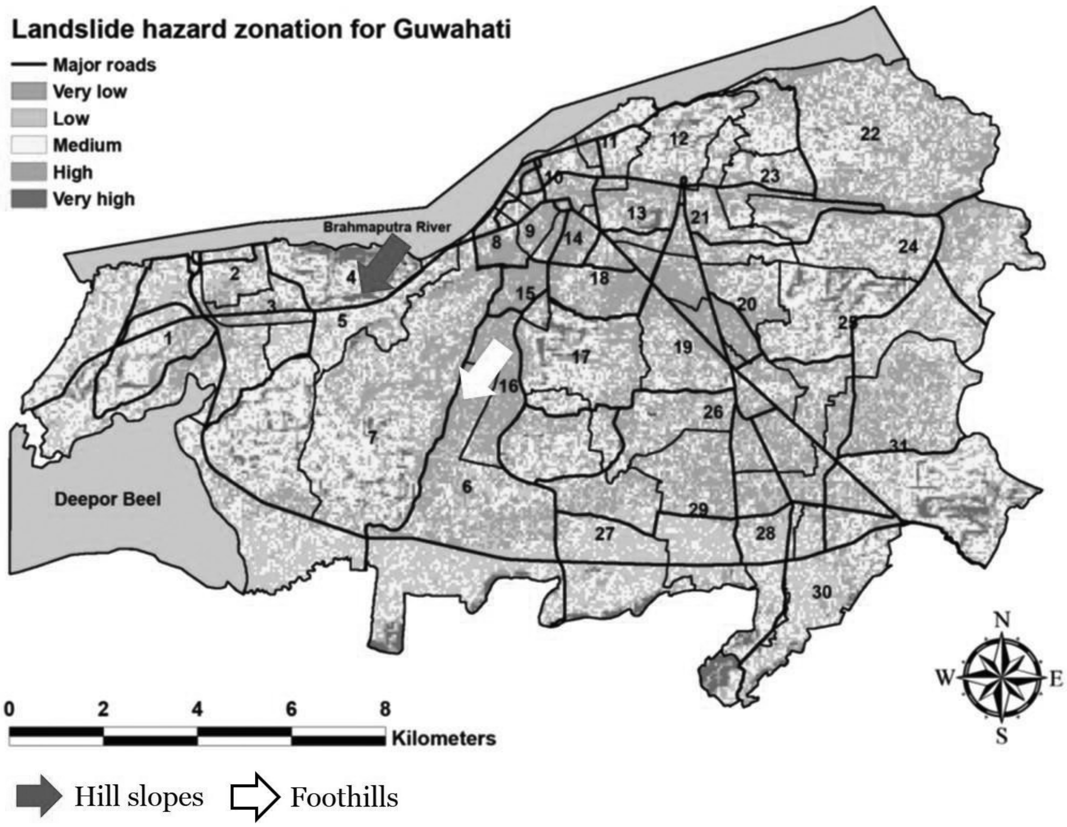


Figure 2: Landslide hazard map for 31 wards of GMC area

These four layers were then overlapped, as per the obtained weights, in order to generate the final landslide hazard zonation map (Figure 2) showing the very high to very low hazard zones. The 366 landslide-prone sites, as mentioned by AMTRON (2002) were plotted from Google Earth in GIS platform in Figure 6. It was observed that the actual landslide affected sites fall on the very high and high hazard zones of the city; that is, the ground reality situation matched with the proposed landslide hazard zonation map (Figure 2).

Thus out of 366 landslide-prone sites noted by AMTRON (2002), 36 sites were surveyed by the authors for the present study. These sites were falling under very high and high hazard zone as per proposed map. Three cases are described here briefly to illustrate the major issues.

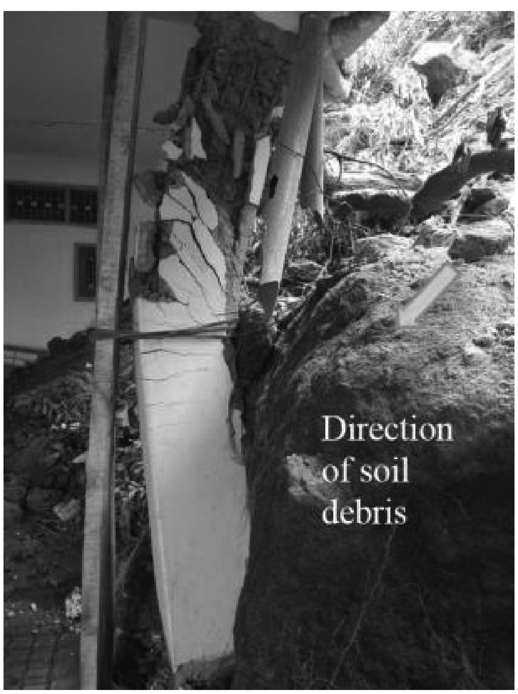
- *Case 1:* Nabagraha hillock in ward no. 12

This area of the city has faced many slope failures. Further failure may be a threat to the residences, causing damage to the electric posts, block pipelines and the main road. Figure 3 shows the impending threat of loose debris next to a residence.

Figure 3: Landslide at Nabagraha hillock

Figure 4: Landslide at Hengerabari hillock

(a)



(b)

Figure 5: Landslide at Narengi hillock

- *Case 2:* Hengerabari hillock in ward nos. 21 and 25

This section of the city is vulnerable to the residents if failure occurs. Unscientific cutting for construction purpose has rendered the slopes unstable and the rocky boulders may slide down anytime and cause damage in the foothill areas. Moreover, the loose soil present may slide down after a quick downpour blocking the side drains and main road down-slope. Figure 4 shows an example of the unstable slope which poses threat for the dwellers nearby.

- *Case 3:* Narengi hillock in ward no. 24

This area has been reported for many fatalities due to landslides in the past years. A G+2 residential building (Figure 5b) was also documented after rocks and boulders damaged the columns of the open-ground story; thus misbalancing the entire building and convincing the residents to vacate immediately so that the same can be repaired. This showed that although people are aware of the issues of the urban flood, such unexpected damages brought by a landslide, mainly to the lower story of buildings and affecting their load transfer capacity, can prove to be of more risk if both the hazards are not dealt with conjointly. In another case, a temple was also seen to have been dangerously located at a landslide-prone point with the absence of a retaining wall (Figure 5a).

Some of the common landslide causing factors in all the surveyed sites were found to be: lack of vegetation on steep slopes; absence of retaining wall; debris accumulating at the foot hills and blockage to natural drainage.

The initially obtained urban flood hazard map and the proposed landslide hazard map by this current study were compared and it was found that the five different hazard levels (very high to very low) in the foothills and hill slopes interchange (Figures 2 and 6). This means the foothills which are of very high hazard areas during urban floods interchange to very low hazard category when landslides are considered. Similarly, the hill slopes are of very high hazard during landslides, whereas interchange to very low category when urban floods are considered. Though urban flood and landslide are not mathematically modelled in the present study, it is obvious from the present study that both hazards are highly linked.

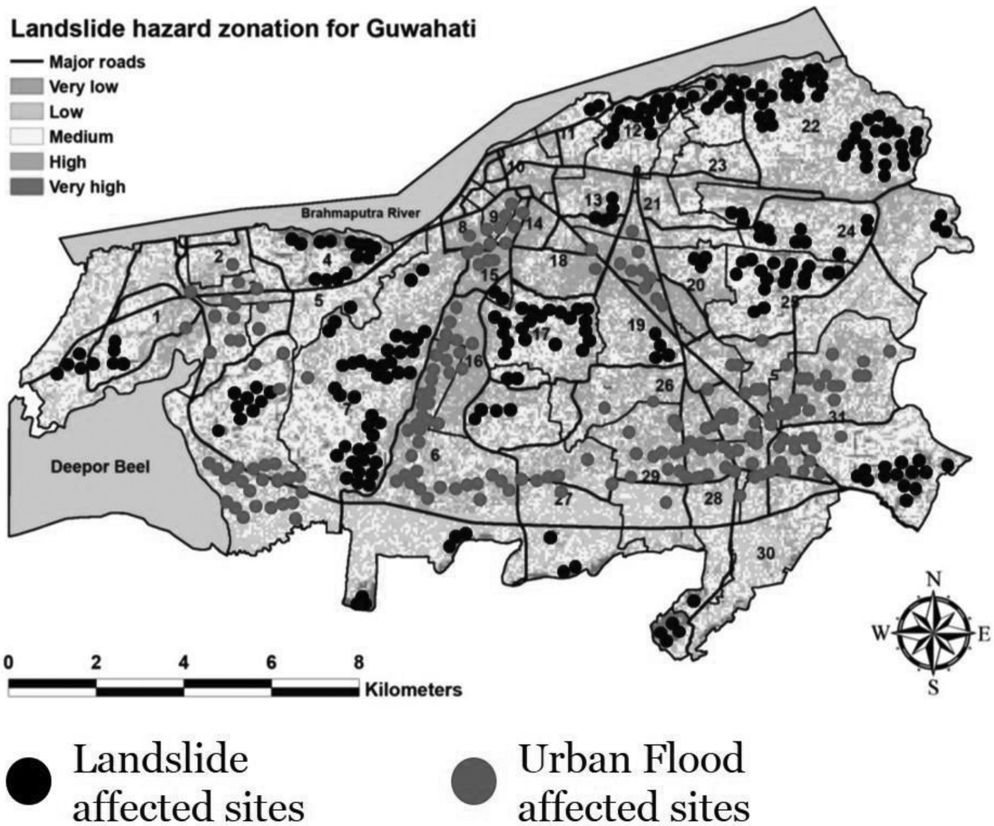


Figure 6: Ground reality: Urban flood-affected sites versus landslide affected sites

To mitigate the losses from landslides, and consequently to manage the recurring urban floods in the city, few strict measures, such as any construction work or human settlement on the hills should be immediately stopped, plantation of trees, improvement of both surface and sub-surface drainage, construction of retaining walls, mass awareness, use of geo-nets to contain the rocks which are likely to fall, government schemes such as Jawaharlal Nehru National Urban Renewal Mission (JNNURM), etc., should be adopted for the holistic improvement of the environment, buildings and the people located at the high-risk zones.

This study thus illustrates the short-term (policies) as well as long-term initiatives (hazard zonation) that can be undertaken in Himalayan urban settlements to potentially manage and reduce landslide losses. Based on the zonation of this study, the government will be able to assess, prioritise and scientifically plan and execute a future course of action to mitigate landslide disaster in Guwahati. Management of landslides requires a coordinated and multi-faceted approach among many stakeholders strengthened by the requisite operational, legal, institutional and financial support.

Conclusion

Unplanned urbanisation and climate change are the key factors causing disasters in the 21st century. This study discussed the issues related to landslide hazard which triggers the occurrence of urban floods in Guwahati. The fact that the actual landslide-prone sites lie on the very high and high zones of the proposed hazard map, showing that the four factors of contour and slope, soil type, land use and rainfall distribution, chosen for this study are empirically correct. Comparison between the two hazard maps shows that in case of urban floods the foothills are vulnerable, while for landslides the hill slopes are vulnerable.

The major contribution that this study makes is the development of a landslide hazard zonation map for the city of Guwahati, and the relation between landslides and urban floods by showing that the debris carried down-slope by landslides is the major factor causing urban floods in the low-lying areas of the city and by decreasing the adequacy of the existing drains, as also pointed out by the esteemed experts. Other north-east Indian cities situated in the Himalayan range with similar natural set up and expecting an upsurge in urbanisation and economic growth may develop their planning policies based on the generic methodology developed in this study. As a scope of future research, urban flood and landslide can be mathematically modelled for the city so as to establish the precise link between the two.

Acknowledgements

Authors would like to acknowledge their deep sense of gratitude to all the field experts, the concerned organisations and the residents of the study area for their contribution to the study. The authors would also like to thank the ICAR National Bureau of Soil Survey and Land Use Planning, Regional Centre, Jorhat, Assam, for providing a soil typology map of Kamrup (Metro) district of Assam. We also acknowledge the help of Dr. Bharath H. Aithal, Aishwarya Narendr, Chandan MC, Nimish Gupta and Dipanjan Nag during the work.

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Landslide Investigation Using Electrical Resistivity Tomography: A Non-invasive Technique

Philips OmowumiFalae[a, b], Debi Prasanna Kanungo[a], P. K. S. Chauhan[a] and Rajesh Kumar Dash[a, b]

ABSTRACT: Landslides of various sizes and types are widespread and represent a serious hazard in hilly terrains of the Himalayas. The investigation of landslide involves various approaches based on multiple ranges of observations. Geological, geomorphological and geodetic survey as well as geotechnical and geophysical investigations are prominent among these approaches. Geophysical methods such as seismic, geoelectrics, magnetometry, gravimetry, thermometry, ground penetration radar (GPR), etc. have been used for landslide characterisation. Among these methods, geoelectrical and seismic methods have widely been used in landslide investigation. Electrical Resistivity Tomography (ERT) is the most common method usually adopted for landslide characterisation. This technique has helped in delineation of slip surface, lithological variations and hydrological conditions of landslides. In the present study, ERT technique has been used at Pakhi Landslide in Garhwal Himalayas for detailed investigation. The pre- and post-monsoon data of resistivity from several profiles were collected and inverted to get subsurface variation of resistivity. The results obtained after the inversion of resistivity data were in agreement with geotechnical and geological investigations. This technique is a non-invasive, cost-effective and time-saving method and can be considered as a good tool for characterising the landslide.

KEYWORDS: landslide, geophysical, ERT, slip-surface, lithology, hydrology

Introduction

Landslides of various sizes and types are widespread and represent a serious hazard in hilly terrains of the Himalayas. The investigation of landslide involves various approaches based on multiple ranges of observations. Geological, geomorphological and geodetic survey as well as geotechnical and geophysical investigations are prominent among these approaches. Geophysical methods such as seismic, geoelectrics, magnetometry, gravimetry, thermometry, ground penetration radar (GPR), etc. have been used for landslide characterisation. Among these methods, geoelectrical and seismic methods have widely been used in landslide investigation. Electrical resistivity tomography (ERT) is the most common geophysical method usually used for landslide characterisation. Electrical resistivity tomography (ERT) is a geophysical technique in which electrical current is injected into the ground between one pair of electrodes and the voltage is measured between another pair. It is the product of electrical resistance and a cross-sectional area that measures the potential differences below the surface point, produced by direct electrical currents, to assess the ability of electricity conductivity of rock or soil (Burger et al., 2006; Sirles et al., 2012). Electrical resistivity surveys have progressed from the convention-

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al 1D vertical electrical soundings (VES Schlumberger method), which provided single point layer depths and resistivity, to advance techniques that provide 2D, 3D and 4D high-resolution electrical images of the subsurface (Lapenna 2003; Falae et al., 2019). The introduction of geoelectrical tomography system and improvement in processing and inversion algorithms, to model the measured apparent resistivity pseudo-section in a true resistivity cross-section model (Loke and Barker 1996), helped in the advancement of the survey.

Many factors determine the stability of slope, such as bedrock type, soil type, soil thickness and hydrologic conditions, which influence the electrical resistance of rock and soils (Gance et al., 2016; Crawford and Bryson, 2018). The application of ERT has been proven effective as non-invasive, time and cost effective in landslide investigations to identify the shear zone, lithological contrast, soil and rock types, moisture contents and slope morphology (Sastry and Mondal, 2013; Souisa et al., 2015; Crawford et al., 2018). The method has not been restricted to a particular type of landslide; as various type of landside can be investigated using the technique (Falae et al., 2019).

Although there are other means of deriving subsurface information of landslide such as exploratory drilling but they are often costly and lengthy geotechnical undertakings. Often,few of these are required complementing the result obtained from ERT as the result cannot be interpreted independently. In this study, ERT was used to investigate Pakhi Landslide for both the pre- and post-monsoon period. The objective was to (i) identify the landslide lithology, (ii) delineate the shearing zone (iii) identify area with water saturation.

Case Study of Pakhi Landslide

Pakhi landslide is a retrogressive translational debris slide, located along Rishikesh-Badrinath National Highway (NH-58) in Uttarakhand state of India (Figure 1). The slide is about 1.8 km away from Pakhi village and at about a distance of 9 km from Pipalkoti on NH 54 corridor of Garhwal Himalayas. Various works have earlier been carried out on the landslide (Kanungo et al., 2013; Kanungo et al., 2017). Several profiles of ERT have been carried out on the landslide during May and November (pre- and post-monsoon) period of 2018. Wenner array which is robust, high signal-to-noise ratio and high characterisation of horizontal discontinuities (Bellanova et al., 2016; Khalil et al., 2018) were adopted for the acquisition of data, using a multi-cable electrode imaging system, ABEM terametre. The results were processes using RES 2DINV software developed by Loke and Barker (1996).

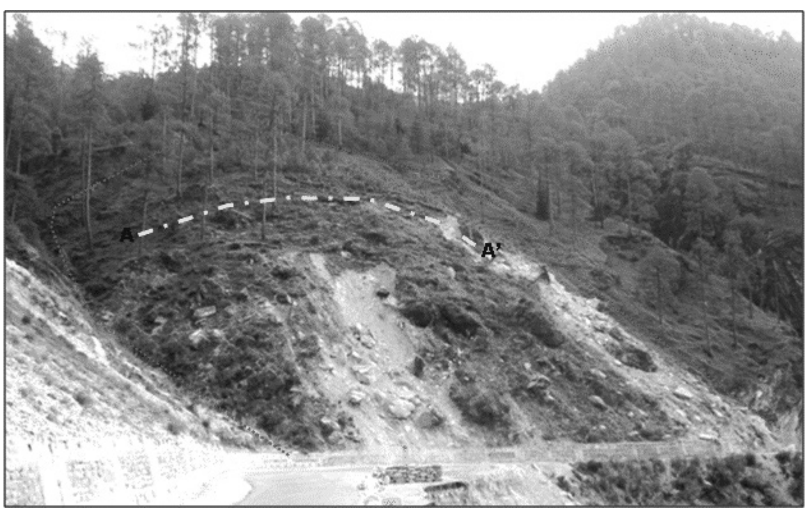


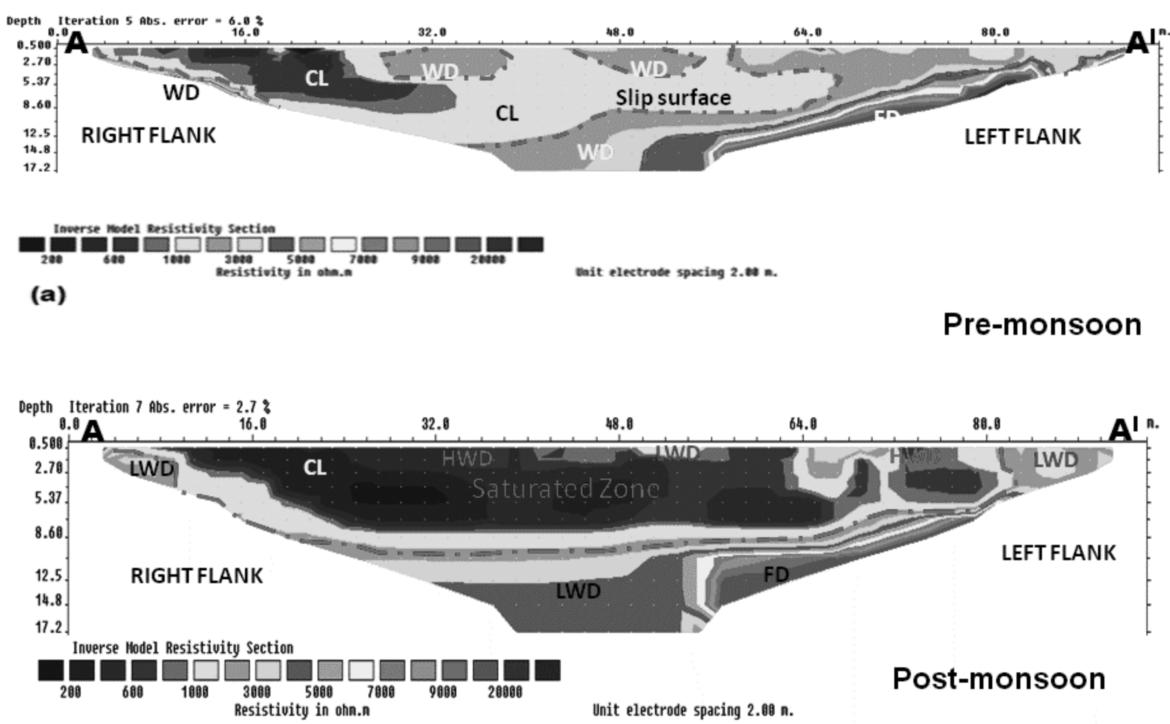
Figure 1: Panoramic view of Pakhi landslide along Rishikesh-Badrinath National Highway (NH-58) in Uttarakhand state of India

Results and Discussion

The result of the field observations indicated that the landslide is a retrogressive debris slide, which has several reactivation phases occurring majorly during the monsoon period. The ERT inversion result presented here are for both the pre- and post-monsoon periods. The results enable us to track the distributions of electrical resistivity, determine the thickness, changes in the hydrological conditions as well as the vulnerability of each layer. The first layer (I) has an assumed lower resistivity range of <1000 Ωm, which is interpreted as colluviums. The second layer (II) is observed to have a somehow middle range of resistivity values of the order of 1000–4500 Ωm and can be inferred as weathered dolomite, while the third layer is interpreted as fresh dolomitic limestone having higher range of resistivity values >4500 Ωm.

During the pre-monsoon period, no evidence of water-saturated zone was observed on the inversion results. The slip surface of the landslide was assigned to the boundary between the colluviums and the weathered dolomite (Sass et al., 2008; Crawford et al., 2018).

The results of the post-monsoon period were characterised by homogeneous low resistivity (between 101 and 800 Ωm), corresponding to the saturated or nearly saturated colluviums layer (Figure 2b). Higher values (up to 4500 Ωm) are observed in the shallow unsaturated weathered dolomites layer, while the value of the fresh dolomites remains unchanged (>4500 Ωm) during post-monsoon period. Except for the conductive lens in the upper left flank part of the image, the resistivity decreases with depth, from 180 Ωm at the surface to 700 Ωm at about 8.7m m depth in the saturated soil. This zone indicates the level of water seepage on the slope. The degree of weathering of the dolomitic layer as observed from the inversion result also reflects the rate of weathering as either high weathered dolomite (1500–4500 Ωm) or low weathered dolomite (800–1500 Ωm) material depending on partly water seepage into weathered dolomites reducing the resistivity values (Figure 2b); this clearly reveals the reason why the movement of the slope is higher during the monsoon and post-monsoon.



(b)

Figure 2: Inverse model of resistivity sections along profile line (a) Pre-monsoon (b) Post-monsoon (CL – colluvium; WD – weathered dolomites (HWD – highly weathered dolomites, LWD – low weathered dolomites); FD – fresh dolomites)

Conclusion

The application of ERT technique as a non-invasive, cost-effective and time-saving method can be considered as a good tool for characterising landslide.

The result obtained from the application has shown that the method has the ability to:

- Delineate the shear zone (slip surface)
- Determine the material/layering thickness
- Material properties/characterisation by indicating the degree of weathering through rate of water seepage
- Identify the water saturated zone

These have been achieved by information obtained from the distribution of resistivity contrasts which correspond to the boundaries between two layers of the sliding materials and the bedrock. ERT profiling could delineate landslide features in a continuous manner; thereby overcoming the limitations of localised information through borehole investigation and physical mapping of surface exposures on cut-slope faces.

With the recent success recorded by the application of ERT in landslide investigation, it can be concluded that the technique as a non-invasive, cost-effective and time-saving method is considered as a good tool in predicting landslide hazard. ERT can help in localising and limiting the number of boreholes which can further disturb the already distressed slope. The major drawback of this method is the non-uniqueness of its result and reliability on other data to make decision.

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Soil Erosion Modelling and Its Impact on Landslide Vulnerability: A Correlation Study on Rampur Tehsil, Himachal Pradesh

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ABSTRACT: The present research is carried out to assess the soil erosion vulnerability of the study area and its impact on landslide by correlating the landslide occurrences in the study area. Survey of India Toposheets, Geological Survey of India Maps, ASTER GDEM and LANDSAT 8 OLI/TIRS sensors and rainfall data from Indian Meteorological Department are used as data sources. Rainfall erosivity, soil erodibility, crop cover, land use landcover, slope length have been used as causative factors for monitoring soil erosion. Revised Universal Soil Loss Equation (RUSLE) method is applied to solve the modelling problem of the soil erosion. Landslide inventory mapping is carried with the help of Google Earth, LANSAT and LISS III imageries. The data was processed in GIS environment to derive the soil erosion map and landslide impact due to soil erosion of the study area. The rate of soil erosion was differentiated into seven classes ranging from 0.92 to 35, where 0.92 represents the least amount of soil erosion and 35 represents the highest amount of soil erosion. The values less than 5 were observed all through the places covering glaciers and forest which are least prone to soil erosion. The values between 6 and 25 indicate low to medium stage soil erosion. These areas cover agricultural field, degraded forests and forest blanks. The areas with the highest amount of erosion were observed along the barren lands and built-up lands where the rate of erosion exceeds more than 30. A total of 96 landslides were mapped from the Google Earth imageries for the year 2017. Among these landslides nearly 79.1 per cent occur along the very low rate of soil erosion and 20.8 per cent occurred along the low rate of soil erosion. The landslides are clustered in the study area mainly located along populated areas such as Rampur, Jhakri, etc. Some of the landslides are located along the national highway extending between Rampur and Shimla.

KEYWORDS: RUSLE model, rainfall erosivity, soil erodibility, crop factor, LULC, GIS, landslide inventory

Introduction

Soil erosion is a naturally occurring process on various land surfaces, but nowadays it is accelerating due to anthropogenic activities such as mining, deforestation, construction, nuclear power plants, agricultural pesticides and malpractices, overstocking and overgrazing, etc (Abdul Rahaman, S et al., 2015). So, it has become a critical issue to manage and restore the degrading land along with conserving the environment. Soil erosion is one of the most serious problems in recent times which affects both cultivable and forest lands (Bhat, S et al., 2017). It creates serious problems in agriculture and water resources

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management by removing the top fertile soil and its subsequent deposition in reservoirs and lakes. The Himalayan region is more prone to slope instability due to its rugged terrain (Pannikkar, S. V, et al., 1996). Each year the state is affected by one or more major landslide causing social and economic losses. Loss of life, damages to houses, roads, communication lines and agricultural lands are some of the examples. The fragile nature of rocks forming mountain along with climatic and various anthropogenic causes has made state vulnerable to landslides. Integrated use of remote sensing and GIS can be used in soil erosion assessment studies. The input parameters required for soil erosion modelling can be generated by remote sensing (Biswas, S, et al., 2015). Geographical Information System helps in creation of a database for the catchment which is very much useful for carrying out spatial analysis thereby helping the decision makers in framing appropriate measures for critically affected areas (S, Lamyaa, K, et al., 2018). There are several methods to determine the annual soil erosion and sediment yield rate, each with their pros and cons (Morgan 2005). These models include the Universal Soil Loss Equation (USLE), Revised Universal Soil Loss Equation, Morgan, Morgan and Finney method (MMF), Water Erosion Prediction Project and Griffith University Erosion Sedimentation System. Several other authors also studied the impact of soil erosion on land surfaces (Woldemariam, et al. 2018., G., Sahu et al. 2017., Biswas, S, et al. 2012., Bengal, W, et al. 2018).

In the present study, an attempt has been made to analyse the soil erosional loss of Rampur Tehsil, Shimla district, HP, and its relation with landslide occurrences. The research is carried out using empirical method of RUSLE equation processed in GIS environment.

Objectives

- To prepare various thematic layers such as soil, slope length and steepness, NDVI, LULC and rainfall erosive factor.
- To categorise the vulnerability of the study area based on the extension of soil erosion.
- To study the relationship between landslide and soil erosion.

Study Area

Rampur Tehsil is located between 31^{0}15’3” to 31^{0}44’10” North latitude and 77^{0}30’19” to 77^{0}59’21” East longitude. The total geographical extent of Rampur Tehsil is 987 Km^{2}. According to 2011 census Rampur Tehsil consists of 218 villages and a total population of 77,542. The literacy rate stands at 93.63 per cent which is greater than the literacy rate of Himachal Pradesh 91.4 per cent. Sutlej is the main river that drains through the Rampur Tehsil. The soil features of Rampur has been classified into three main types namely coarse loam, fine loam and glaciers. The geology of the study area can be differentiated into schist, slate, alluvium and glacier. Timber and charcoal are the important forest produce. Besides them resins, grass, medicinal herbs and bamboos are also produced at minor quantity. Agriculture and horticulture are the important economic activities of the Rampur Tehsil. Along with that tourism and other small-scale industrial jobs bring boon to Rampur Tehsil. Most of the Tehsil’s agriculture is dependent on rainfall. The climate is suitable for growing cereals, off season vegetables, temperate and stone fruits. The study area has subtropical highland climate under Koppen climate classification The climate is subtropical in the valleys and temperate in the hilltops. The average annual rainfall of the study area is 999.4mm out of which 75 per cent occurs during the monsoon period from June to September. The temperature can go as low as 0^{0}C during winter times and as much as 40^{0}C during summer times. The study area is given in Figure 1.

Data Used

The base map of the study area was digitised from Survey of India toposheets. One cloud free satellite data LANDSAT 8OLI (26/01/2018) was downloaded from United States Geological Survey website. Soil data covering the study area was received from Soil and Land use Survey of India. In addition a 30 m ASTERGDEM data was downloaded from USGS website for topographical analysis. Rainfall data has been acquired from Indian Meteorological Department, Shimla. The types of data used is given in Table 1.

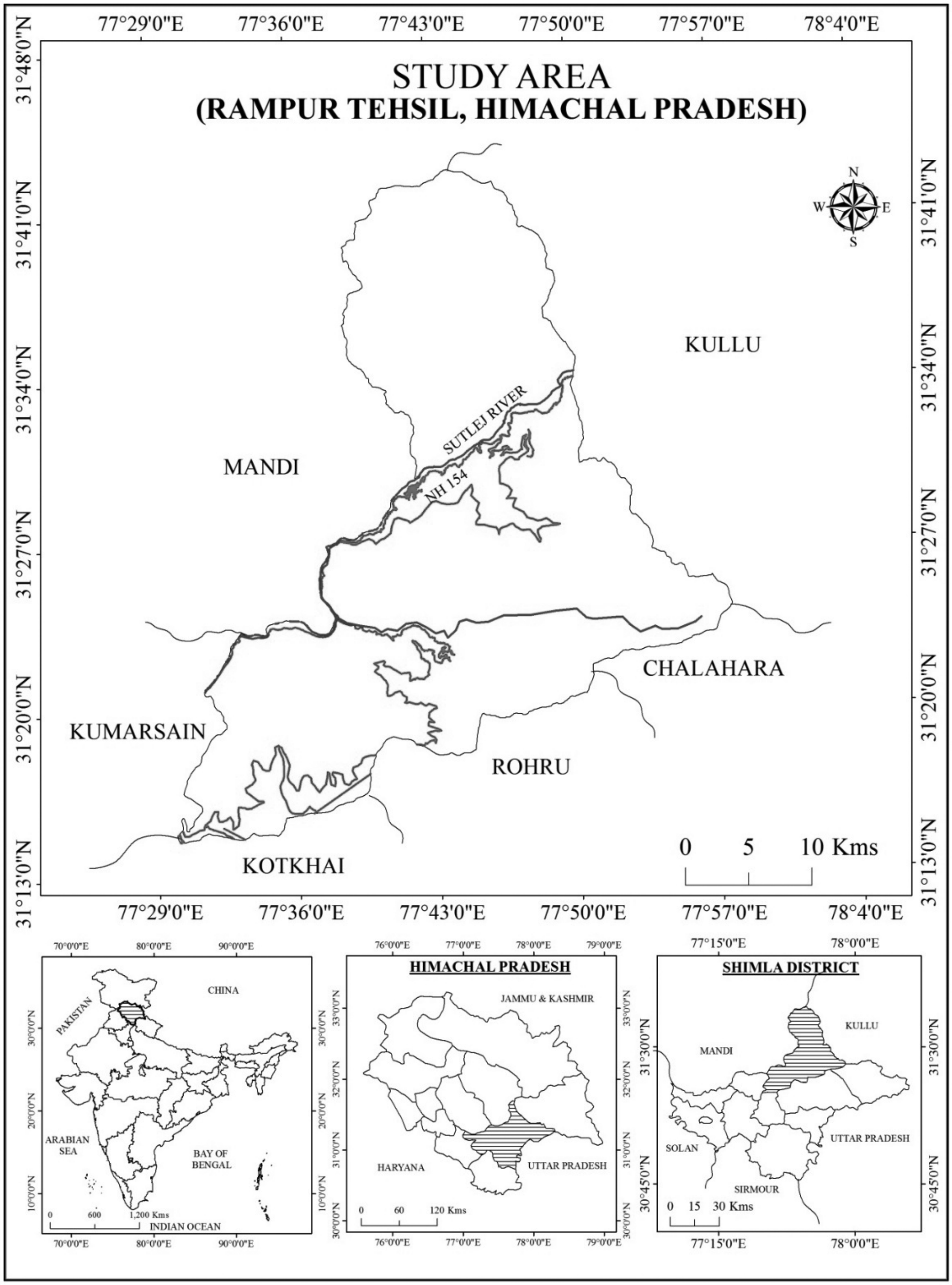

Figure 1: Study area

Table 1: Data Used

Sl. No	Data	Source	Date	Resolution
1	Toposheets	SOI	1987	1:50,000
2	Rainfall	IMD	2000–2017	-
3	Soil	SLUSI	-	1:50,000
4	Geology	SLUSI		1:50,000
5	Geomorphology	SLUSI		1:50,000
6	Landsat 8 OLI	USGS	26/01/2018	30 m
7	ASTERGDEM	USGS	2009	30 m
8	Landslide Inventory	Google Earth	2017	0.4 m

Methodology

The Revised Universal Soil Loss Equation (RUSLE) model is used to study the long-term annual soil losses due to raindrop splash and runoff. According to Jiang et al., (2014) “To build the quantification model as many as possible of the criteria that influences soil erosion should taken into consideration”. Soil erosion modelling was carried out using empirical method of RUSLE equation that uses five different factors such as rainfall erosivity (R) factor, soil erosivity (K) factor, slope length (L) and slope steepness (S), cover management (C) and conservation practices (C). These datasets were acquired from multiple sources, processed in GIS environment to get the soil erosion rates.

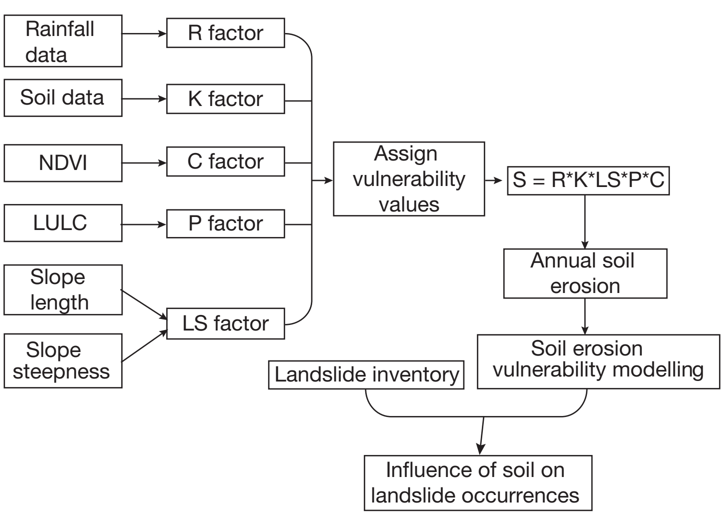

Figure 2: Flowchart of methodology

Data Analysis

Rainfall Erosivity Factor

The R factor estimates the rainfall-induced soil erosion rates due to the joint effect of rainfall kinetic energy and duration. The mean annual rainfall was calculated for three stations namely Rampur, Rohru and Kumarsain between the year 2000 and 2017. The mean annual rainfall was calculated using Inverse Distance Weighted method (IDW). Finally, the rainfall erosivity was calculated using the formula

$$R = (38.46 + (3.48 X P)) \qquad \text{Eq 1}$$

where P = Average annual rainfall calculated by IDW method.

The final result revealed that the annual average rainfall of the Rampur Tehsil varies between 404–435 mm/year for the year 2000 to 2017.

Soil Erodibility Factor

The K factor represents the rate of soil erosion per year based on the rainfall rate of a particular year. The vulnerability of soil to erosion will greatly increase or decrease depending upon the type of soil content. For instance fine sand and silt soil are prone to rainfall erosion compared to others. The K classes with higher value depict the soil that is more prone to rainfall induced to erosion and lesser the values the least prone to erosions. Rampur Tehsil has four different types of soil namely coarse loamy, fine loamy, glacier and habitation. The values of these classes are given as 0.07, 0.18, 0.1 and 0.1, respectively.

Table 2: Soil Erodibility Factor

Sl. No	Soil	Area in km^2	K Factor
1	Coarse loamy	49.68	0.07
2	Fine loamy	835.33	0.18
3	Glacier	102.85	0.5
4	Habitation	0.13	0.5
Total		987	

LS Erodibility Factor

The slope Length (L) and slope steepness (S) represent the effect of terrain and topography on the dislodging of soil. The more the length and steepness of the terrain, the higher the soil erosion occurs. The LS factor was calculated from ASTERGDEM of 30 m grid size. The LS factor represents the amount of soil erosion under 23.13 m of slope length and steepness of 9 per cent and free of vegetation. The LS factor for Rampur Tehsil was found to be in the range of 0–64. The below mentioned formula was applied to calculate the Slope Length

$$L = (\lambda/22.13)m \qquad \text{Eq 2}$$

Lambda = Field Slope Length
M = Variable Slope Length

The LS factor was classified into five types ranging from values more than 4.5 per cent to values less than 1 per cent.

Cover Management Factor

The C factor depicts the effects of forest and agriculture practices on land that directly affects the soil erosion. It represents the rate of soil erosion with respect to specific kind of vegetational practices in that area. First the NDVI is calculated from LANDSAT 8 OLI data using NIR and Red band using the equation. The NDVI value of the study ranges from -0.13 to 0.4 which indicates the presence of forest and agricultural practices. The spatial variation of the C factor was calculated using the equation

$$NDVI = [\,NIR - RED]/[\,NIR + RED] \qquad \text{Eq 3}$$

$$C = ((1 - NDVI)/2) \qquad \text{Eq 4}$$

P Factor

P factor represents the soil conservation practices both natural and anthropogenic that reduce the soil erosion due to rainfall runoffs. P factor normally depicts the LULC classes of both natural and anthropogenic features. The P factor usually ranges from 0 to 1 where 0 depicts the good conservation practices and 1 represents the less cultivation practices. The LULC features observed in the study area are forest, agriculture land, glacier, barren land and build-up lands. The P factors for these features are 0.1, 0.4, 1.0, 1.0 and 0.3 respectively.

Table 3: Conservation Practices Factor

Sl. No	LULC	Area in km^2	P Factor
1	Agricultural land	114.14	0.4
2	Barren land	138.88	1
3	Build-up land	12.58	0.3
4	Forest	661.76	0.1
5	Glacier	60.51	1
	Total	987	

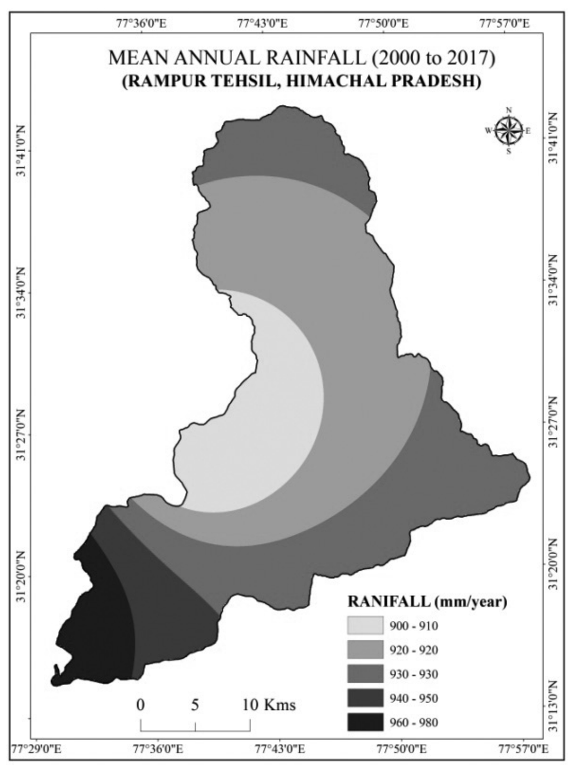

Figure 3: Mean annual rainfall (2000 to 2017)

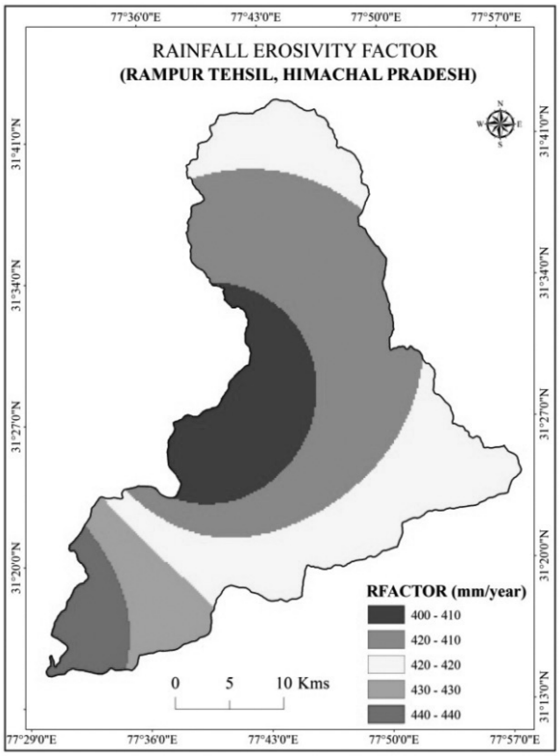

Figure 4: Rainfall erosivity factor

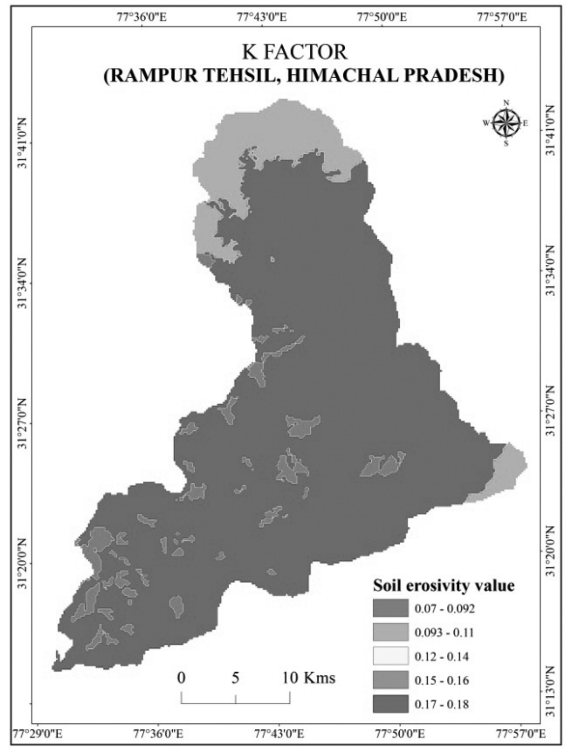

Figure 6: Soil (K) erosivity factor

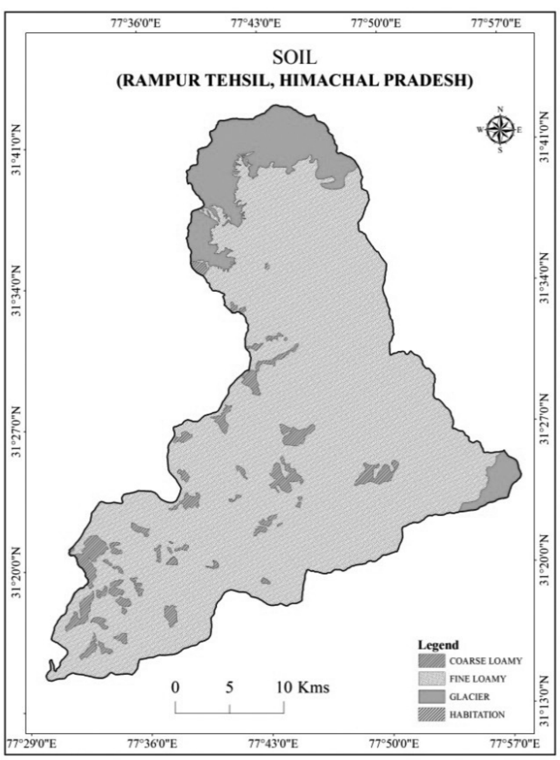

Figure 5: Soil

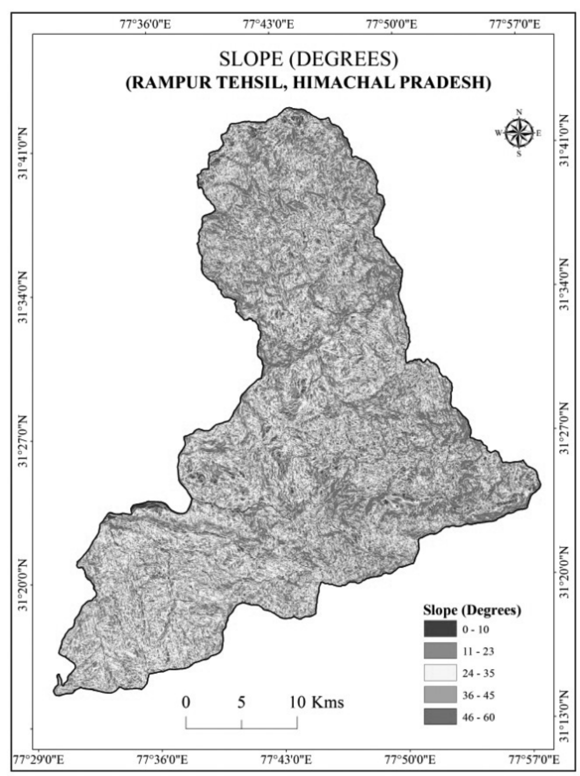

Figure 7: Slope

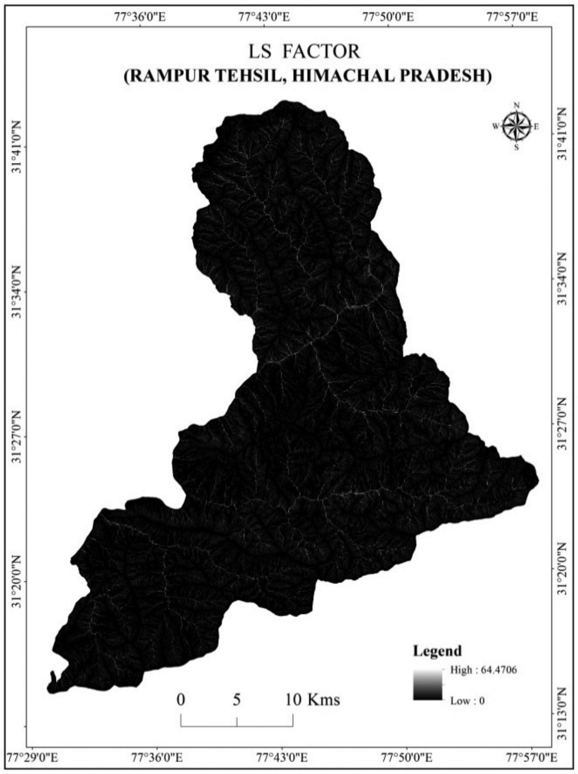

Figure 8: LS factor

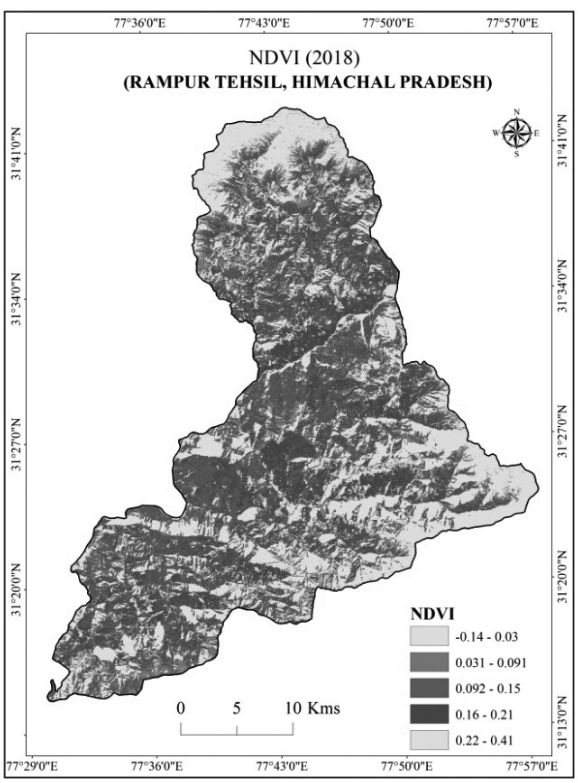

Figure 9: NDVI

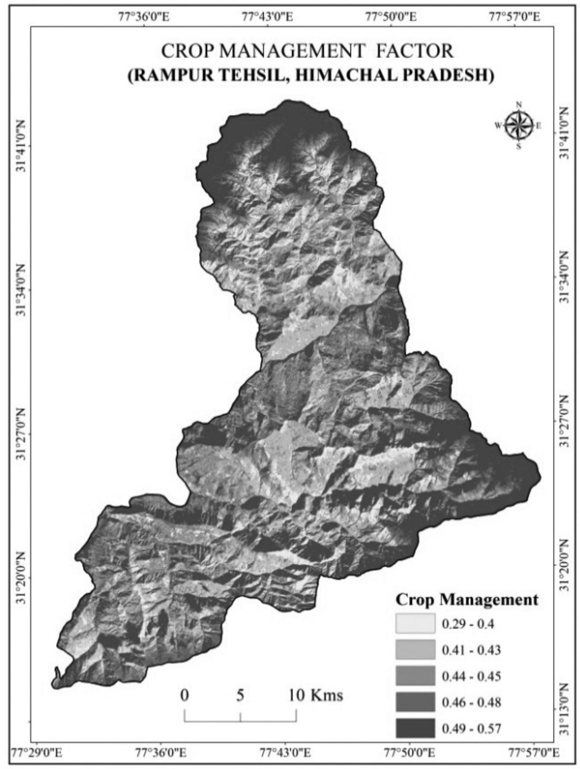

Figure 10: Crop management factor

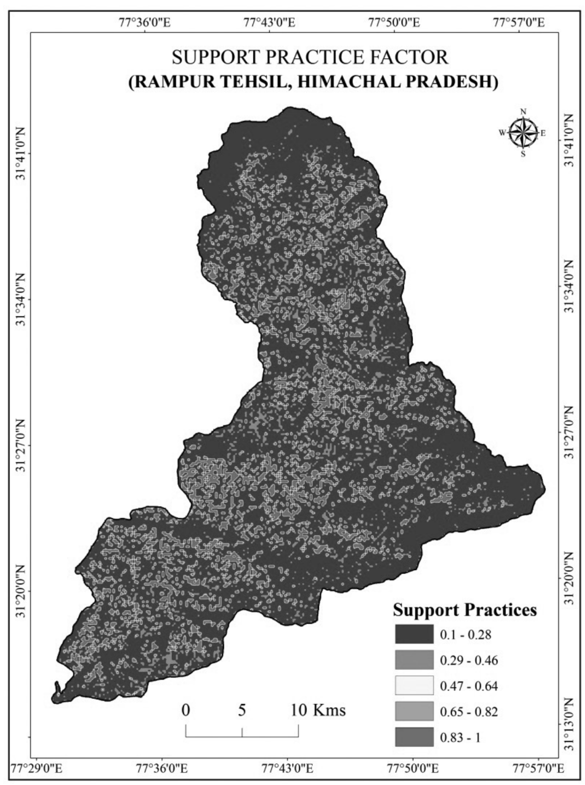

Figure 11: Support practice factor

Findings

Once the primary factors causing soil erosion have been identified and delineated these are then multiplied to produce the final annual soil erosion rates for the study area based on the empirical model of the RUSLE equation.

$$A = R*K*LS*C*P \qquad \text{Eq 5}$$

- A = Mean annual soil loss
- R = Rainfall-based erosion
- K = Soil factor
- LS = Slope length and steepness
- C = Cover management factor
- P = Support practice factor

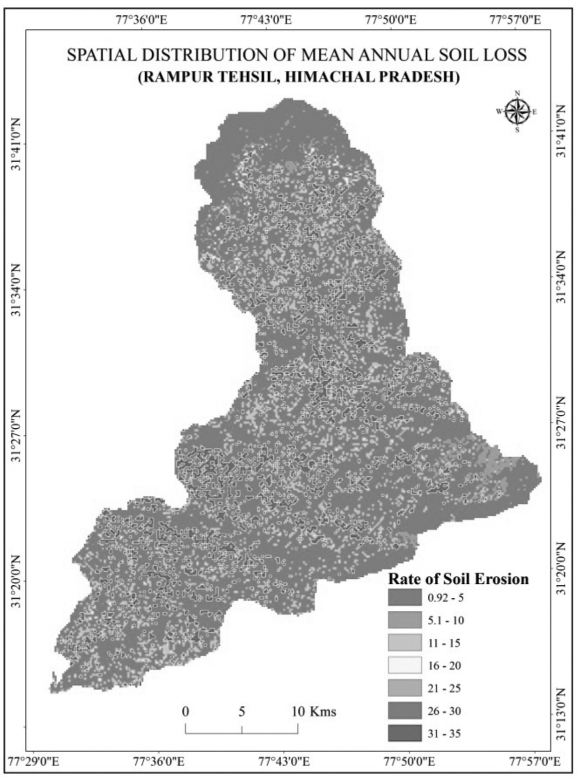

Figure 12: Spatial distribution of mean annual soil loss

The rate of soil erosion was differentiated into seven classes ranging from 0.92 to 35, where 0.92 represents the least amount of soil erosion and 35 represents the highest amount of soil erosion The values less than five were observed all through the places covering glaciers and forest which is least prone to soil erosion. The values between 6 and 25 indicate low to medium stage soil erosion. These areas cover agricultural field, degraded forests and forest blanks. The areas with the highest amount of erosion were observed along the barren lands and built-up lands where the rate of erosion exceeds more than 30.

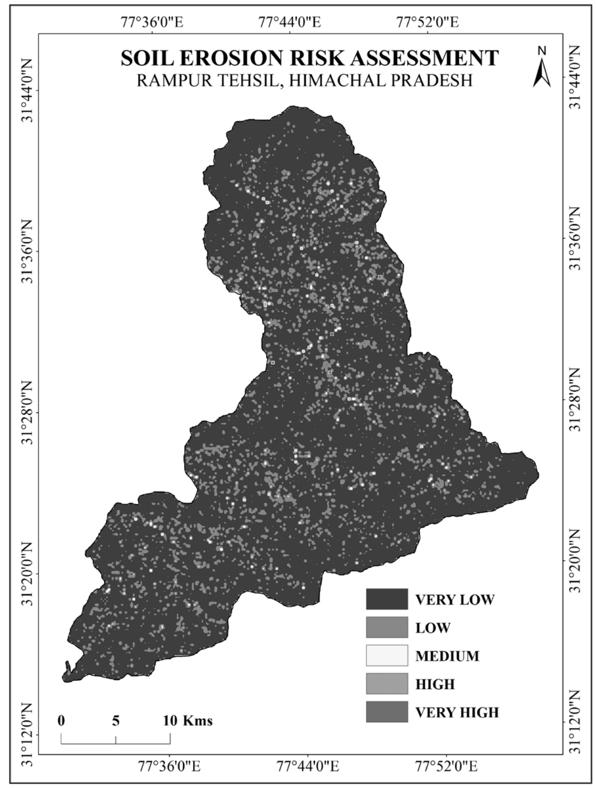

Figure 13: Soil erosion risk assessment

A total of 96 landslides were mapped from the Google Earth imageries for the year 2017. Among these landslides nearly 79.1 per cent occur along the very low rate of soil erosion and 20.8 per cent occurred along the low rate of soil erosion. The landslides are clustered in the study area mainly located along populated areas such as Rampur, Jhakri, etc. Some of the landslides are located along the national highway extending between Rampur and Shimla. Location of landslides is given in Table 3.

Sl. No	Soil Risk Area	Landslide Inventory	%
1	Very low	76	79.17
2	Low	20	20.83
	Total	96	100.00

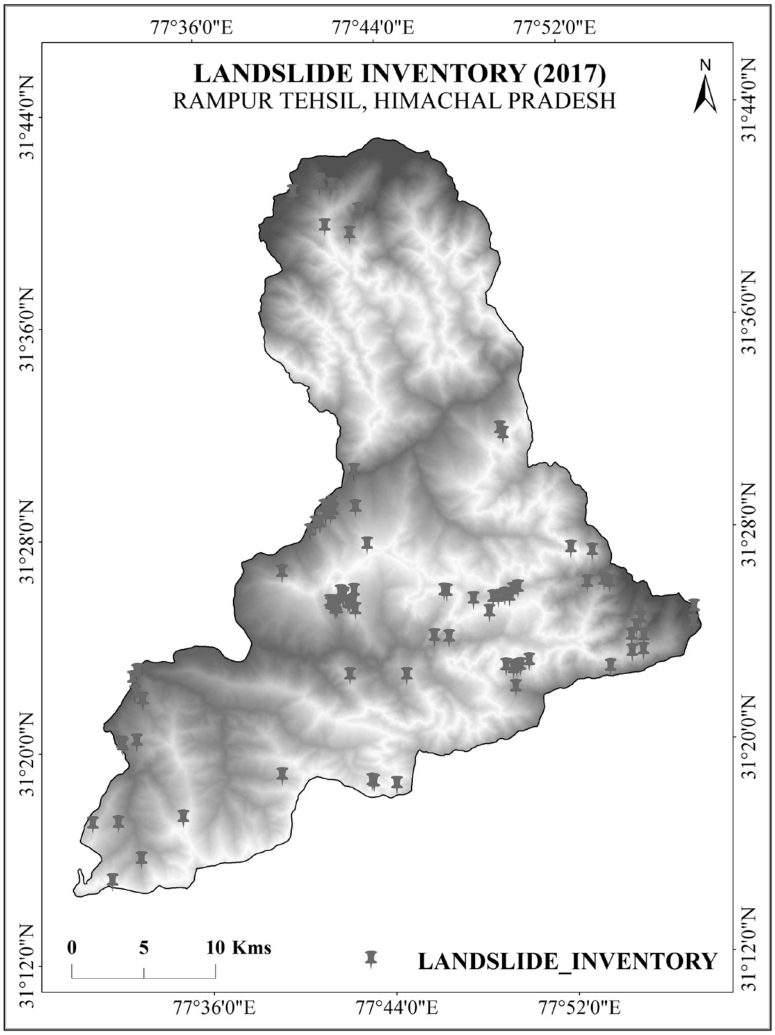

Figure 13: Landslide location (2017) source: Google Earth imageries

Conclusion

This study estimated annual soil loss rate and its relation to landslide location, assessed through spatial evolution of erosion risk and mapped priority areas for Rampur Tehsil using various parameters. We used the RUSLE model developed in GIS environment. The model results offered a reliable quantitative estimate of rainfall-induced soil loss rates and spatial distribution of erosion risk in the study area. The relation between landslide occurrences and soil erosion reveals that most of the landslide occurred along the low soil erosion-prone areas. These locations are mainly accumulated in nearby town areas and along the national highway, etc.

Acknowledgements

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V Drought Risk Management

Assessment of Agricultural Drought in Alwar (Rajasthan) Using Vegetation Condition Index (VCI) and Standardised Precipitation Index (SPI)

Harish Samaria[a]

ABSTRACT: Drought is one of the most frequently occurring national disasters in India. With its increased frequency and expanded coverage in the recent years, about one third of the country is either drought-prone or under desert areas. These areas are lagging behind in agriculture and also in overall economic growth. Owing to its severe effect on productivity of rain-fed crops and indirect effect on employment as well as per capita income, agricultural drought has become a prime concern worldwide. The occurrence of drought is mainly a climatic phenomenon which cannot be eliminated. However, its effects can be reduced if actual spatio-temporal information related to crop status is available to the decision makers. Alwar district of Rajasthan is located in close proximity to the Aravalli mountain range. It has 12 subdivisions and 14 blocks. As per the Census of 2011, the district has a total population of 36,74,179, spread across 2021 inhabited villages. Alwar is prone to multiple hazards, including droughts, heat waves, cold waves, industrial disasters, road and rail accidents, bore-well accidents, earthquakes and fire accidents, among others. In the present study, data were used for monitoring agricultural drought through Vegetation Condition Index. VCI was calculated for whole Alwar.

KEYWORDS: drought early warning, Vegetation Condition Index (VCI), Standardised Precipitation Index (SPI), Rainfall Anomaly Index (RAI), Yield Anomaly Index (YAI), Normalised Difference Vegetation Index (NDVI)

Introduction

Agricultural drought plays a major role in the economy of agrarian countries like India where more than 65 per cent people are dependent upon agriculture. About 16 per cent of India's total area is drought-prone and about 50 million people are annually affected by drought. The drought-prone areas of the country are mainly confined to western and peninsular India mainly arid, semi-arid and sub-humid regions.

In India, 80 per cent of annual rainfall comes from southwest monsoon, and very important for the whole country, especially for the low rainfall belts like Rajasthan state. Any kind of deficiency in monsoon,mostly because of climate change, causes higher frequencies of droughts in these areas as high as once in every four years (Gupta *et al*., 2011). Out of 13 states repeatedly declared as drought-prone, Rajasthan is the most critical state in the country with highest probabilities of drought occurrence and rainfall deficiencies. Several records show that about 48 drought years have been reported of varied intensity since 1901 in last 102 years and only 9 years out of them were totally free from drought (Rathore, 2005).

In the year 2002–2003, India has faced one of the worst and exceptional drought episodes in terms of magnitude, spacing, dispersion and duration. The occurrence of drought makes the land incapable of cultivation throughout the year and this situation renders harsh and inhospitable environmental

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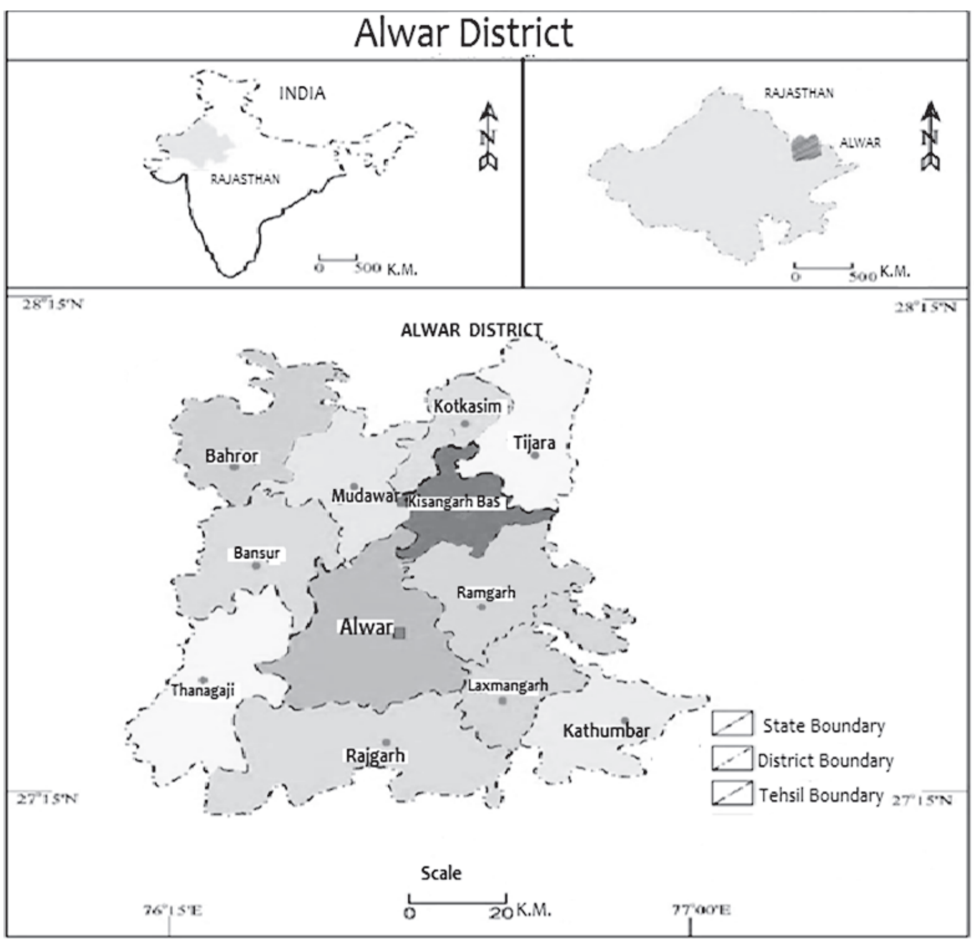
condition for human beings, livestock population and biomass potential and plant species. So, there is an urgent need to make an effort to monitor and mitigate drought disaster with reference to span of time. A well-designed mitigation and preparedness plan can help the decision makers to reduce the effect of drought. In this context, monitoring of onset, duration, intensity and extent of drought has become important for managing the adverse impact of drought.

Study Area

Alwar district of Rajasthan is famous for lakes, old forts and mix culture of adjoining state Haryana and national capital of India. Apart from this Sariska Tiger Reserve is also located, and it is main attraction for tourists in Alwar, having vast biodiversity. India is agricultural state in beginning of the days, its nature and diversity in religion, ethnicity and a huge mass of people living in villages adding the essence of flavour in biodiversity. According to official data of census 2011, released by Directorate of Census operations in Rajasthan, the total population of Alwar has increased from 2,992,592 (in the year 2001) to 3,674,179 (in 2011). Thus, there has been an increase of 22.78 per cent since 2001, that is over ten years period, in comparison to 27.22 per cent increase during the period 1991–2001. The density of population has increased to 438 per square km in 2011 from 357 per square km in 2001. The total proportion of Alwar population relative to Rajasthan has increased to 5.36 per cent from 5.30 per cent during the period 2001 to 2011 and the average literacy rate has increased from 61.74 in 2001 to 70.72 in 2011.

The study area is Alwar district of Rajasthan, India. It comes under Agro-Ecological Region 4 and Eco-Sub region N8D2 (Dry Semi-Arid). The latitudinal extent is from 270 to 280 N and longitudinal extent is from 760 E to 770 E. The soils of the area are broadly of coarse texture and the prevalent soil order is Inceptisol. The natural vegetation comprises scrubs in the elevated part and semi-arid vegetation in plains. The predominant crops are wheat and mustard in Rabi season (winter) and bajra in Kharif (monsoon) season.



Methodology

Daily rainfall data from Indian Meteorological Department for a period of July, August 2014 and 2016 were collected and processed on Excel sheets according to the requirements to obtain critical area maps. Several rainfall indices were generated in the study, to estimate the change occurring in rainfall patterns between the two periods:

- Change in average annual rainfall
- Change in average number of wet days
- Month wise change in monsoonal rainfall

SPI Calculation and Mapping

Standardised Precipitation Index (SPI) is the simplest drought index based on precipitation data, developed in 1993 by Thomson b. Macke to measure precipitation deficit for multiple time scales. According to normal distribution, it can be calculated by taking the difference of the precipitation from the mean for particular time scale then dividing by the standard deviation,

$$\text{SPI} = (X - \bar{X})/\sigma$$

$$\sigma = \sqrt{\frac{\sum dx^2}{N} - \left(\frac{\sum dx}{N}\right)2}$$

where X is precipitation for the station, $\bar{X}$ is mean precipitation and σ is standardised deviation. The long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero. Drought event occurs when SPI is continuously negative and reaches an intensity of -1 or less and ends when the SPI becomes positive.

In the present study SPI value was calculated. Vegetation Condition Index (VCI) depends upon Vegetation Agricultural Index (VAI) and Vegetation Forest Index (VFI). The government data has also been taken for this study.

Assessment of Agricultural Drought

Table 1: Tehsil Wise SPI during Drought 2014 and 2016

S.N.	SPI14 (July)	SPI14 (September)	SPI16 (July)	SPI16 (September)
1. Alwar	0.81	1.42	1.69	0.39
2. Bansur	1.00	-0.47	-0.61	-0.74
3. Bahror	-0.38	-1.26	-1.23	-2.83
4.Govindgarh	0.80	1.65	1.33	1.26
5. Kathumbar	-0.22	-0.73	-0.49	0.13
6 Kishangarh bas	1.04	-0.23	-0.61	0.86
7. Kotkasim	1.50	1.55	1.54	-1.61
8. Laxmangarh	-1.09	-0.70	-0.98	-0.10
9. Malakheda	-0.36	0.38	0.27	-0.96
10. Mandawar	0.63	-0.55	-0.5	1.14
11. Neemrana	-2.26	-1.51	-1.69	-1.77
12. Reani	-0.36	0.38	0.47	-0.96
13. Rajgarh	1.13	0.25	0.43	-0.45
14. Ramgarh	-0.81	0.11	0.33	1.07
15. Thanagaji	-0.41	1.00	0.64	0.63
16. Tijara	-0.99	-1.49	-1.39	1.47
	= 11.79	= 8.13	= 7.74	= 8.51

Categorisation of SPI14

Very low = -1.0 and Above

Laxamgarh and Neemrana tehsil are situated in this category.This is due to the low amount of rain.That is, these tehsils have got the minimum rank of SPI.

Low = -0.01 to -1.0

SPI has been in the range of -0.01 to -1.0 in this category.This category includes Bahror, Kathumbar, Malaheda, Reani, Ramgarh Thanagaji, Tijara tehsil. SPI has been reformative in comparison to previous years.

Middle = +1.0 to more than

This category includes Alwar, Bansur, Kotkasim, Laxmangarh and Rajgarh tehsil. The value of SPI in this category has been corrected,due to good rain fall.

Categorisation of SPI16

According to the 2016 data, SPI has been identified, in which according to the study of actual calculation in the estimation of drought under class wise study,it has been kept in the following categories

Very low = -1.0 and Above

There are a total of three tehsils (Bahror, Neemrana and Tijara tehsil) in this category. Here SPI16 has the highest negative status.

Low = -0.01 to -1.0

This category includes five tehsils of the district including Bansur tehsil,Kathumbar tehsil, Kishangarh bass tehsil,Laxmangarh tehsil and Mandawar tehsil. Drought prospects seem to be less.

Middle = +0.01 to more than

There are more tehsils of study area in this category. The number of tehsil is 8. Alwar, Govindgarh, Kotkasim, Malakheda, Reani, Ramgarh, Thanagaji tehsil are included. Here are the general situation of SPI has been found, due to agriculture has been favourable condition.

Drought Monitoring Through SPI

The SPI is a very popular meteorological drought index which has been frequently used by decision makers for measuring and monitoring the intensity of meteorological drought events.Except these, SPI is useful for identifying spatio-temporal extent of long-term historical droughts. In this study, this index was used to identify the incidence of meteorological drought, its intensity and spatio-temporal extent and thus comparing the results with agricultural drought index VCI. The spatiotemporal pattern of SPI shows that there was a prolonged dry condition prevailing during the monsoonal season of 2016.

VCI and SPI of July and September

In order to study the temporal variation of VCI, a drought year VCI sequence was compared with that of a wet year. The average VCI value was found below 40 for all of the tehsils of Alwar during the drought year, among them maximum districts were having VCI value below 5 which indicates drought condition of the region, whereas, the vegetation condition of maximum tehsils of Alwar was above normal during September, 2016. The difference between VCI of drought year and normal year was highest in the September indicating the effect of varying monsoon.

While talking about agricultural drought, the whole scenario remains incomplete if we do not focus on meteorological conditions of the region. In order to study the highly variable nature of monsoonal rainfall, the SPI values of both the years are compared with each other.

Vegetation Condition Index (VCI)-2016

Tehsil	VCI = VFI (Vegetation Forest Index)	VCI = = VAI (Vegetation Agricultural Index)
1. Alwar	2.46	1.41
2. Bansur	0.00	1.41

Tehsil	VCI = VFI (Vegetation Forest Index)	VCI = = VAI (Vegetation Agricultural Index)
3. Bahror	-0.70	0.03
4. Govindgarh	-0.84	-2.09
5. Kathumbar	-0.781	1.01
6. Kishangarh bas	0.08	-0.71
7. Kotkasim	-0.81	-0.32
8. Laxamgarh	-0.25	0.69
9. Malakheda	0.29	-00.41
10. Mandawar	-0.44	0.97
11. Neemrana	-0.79	0.30
12. Reani	-030	-0.04
13. Rajgarh	2.06	-0.22
14. Ramgarh	-0.84	0.41
15. Thanagaji	1.12	-0.26
16. Tijara	-1.85	0.89

The following table is obtained when we study Vegetation Condition Index.

Category	VCI = VFI	VCI = = VAI
Very low (-1.00 to less than)	Tijara tehsil	Govindgarh, Rajgarh tehsil
Low (0.00 to -1.00)	Bansur, Bahror, Govindgarh, Kathumbar, Kotkasim, Laxmangarh, Mandawar, Neemrana, Reani, Ramgarh	Alwar, Kishangarh bas, Kotkasim, Malakera, Neemrana, Reani, Thanagaji
Medium (0.01 to above)	Alwar, Kishangarh bas, Malakera, Rajgarh, Thanagaji	Bansur, Bahror, Kathumber, Laxmangarh, Mandawar, Ramgarh, Tijara

Fig. 1

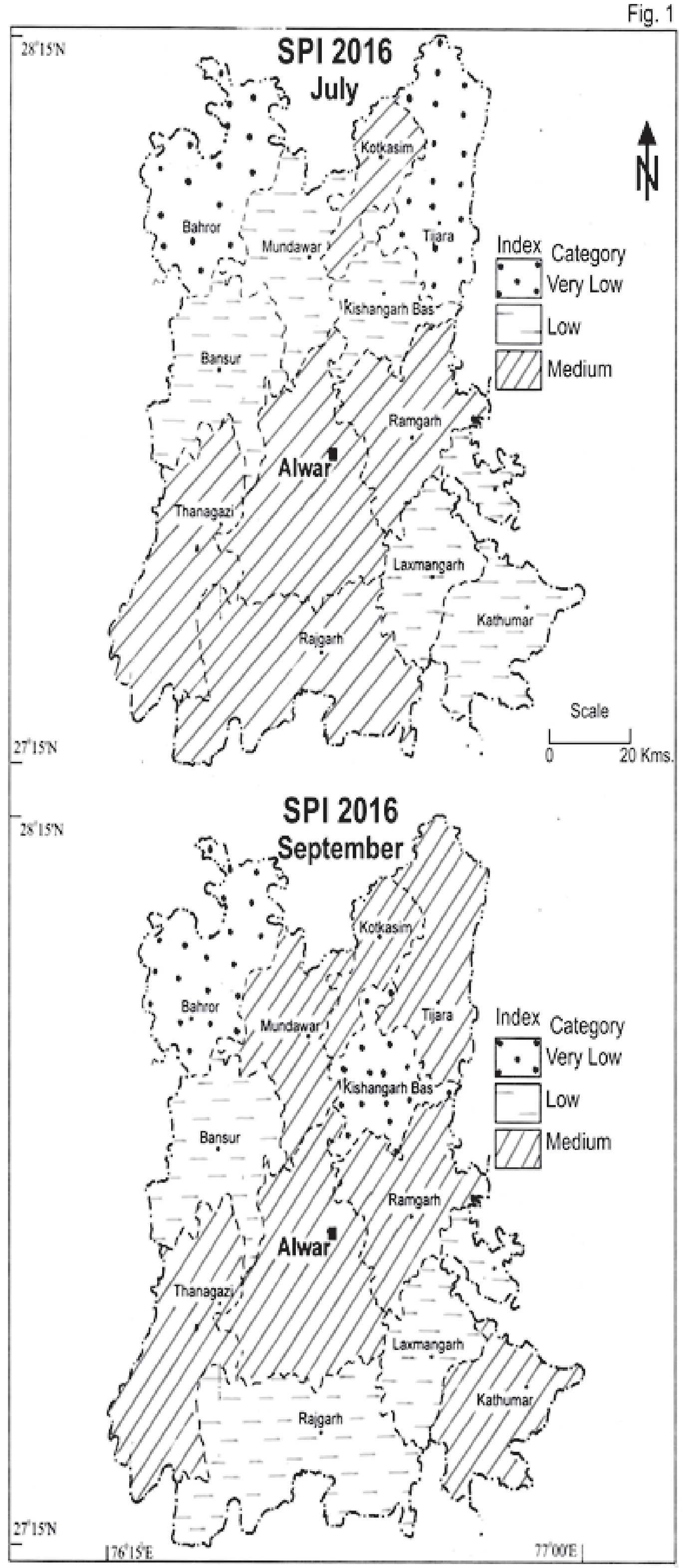
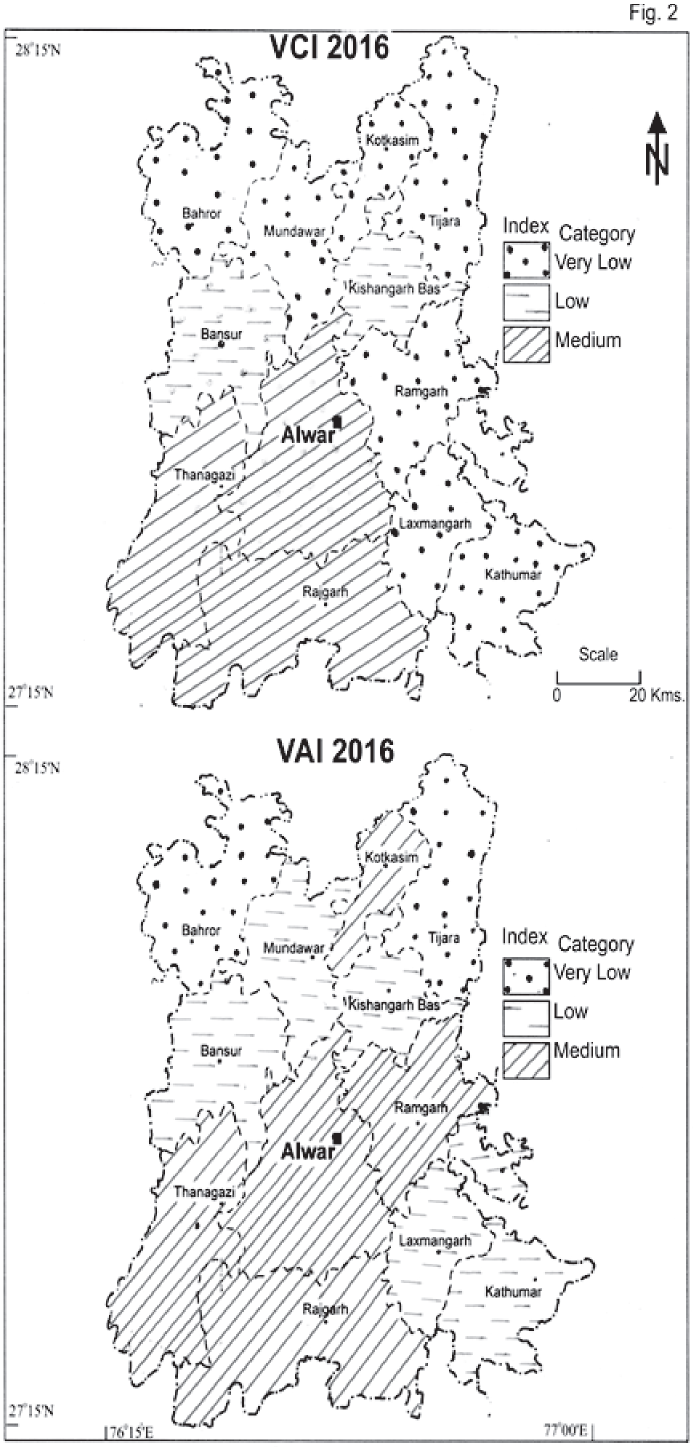


Fig. 2



Conclusion

The present study attempts to identify the spatio-temporal extent of agricultural drought over Alwar using remote sensing-based Vegetation Condition Index (VCI) and assesses the performance of VCI by comparing the estimates with meteorological drought indicator SPI. It was found that VCI estimates can be useful for monitoring onset, duration and spatio-temporal extent of agricultural drought. The VCI was found less than 25 per cent over most of the areas of Rajasthan in 2016 indicating drought-related stress during that year. While comparing the estimates of the meteorological-based Standardised Precipitation Index (SPI), the results were found identical with the outcome of VCI. SPI14 has been in negative in the month of July 2014, which is the reason for rain distribution. September 2014 SPI value has been found to improve positive situation in mostly tehsils. This is due to the excess of rainfall and the number of rainy days is going to increase. Vegetation Condition Index is a deficiency in some tehsils and some have more than usual conditions. VCI has been overwhelming in Alwar tehsil, Rajgarh and Thanagaji. This is due to the geographical situation (Aravalli hills) and the Sariska forest area. VCI value in Banasur tehsil is positive, which reflects the density of VCI = VAI. Here the regional expansion of kharif crops is high.The quantity of VCI is low in Alwar Rajgarh thanagazi which is due to lack of kharif crops.

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Analysing the Water Balance for Drought-Prone Regions of Marathwada, India

Richa Dhawale[a], **Saikat K. Paul**[a] **and Jeeno Soa George**[a]

ABSTRACT: Water resource is rapidly depleting and its management, especially in drought-prone region, is becoming difficult leading to increasing water demand and supply gap. Hence, sustainable management of water resource is the immediate priority. Water balance studies require knowledge of water availability for present and future conditions for various sectors intended to balance the water resource. The study is conducted for the region of Marathwada consisting of eight districts. The present study calculates the soil moisture deficit and moisture surplus with spatial and temporal changes for the study area using these components. The Palmer Drought Severity Index (PDSI) for water balancing is calculated to evaluate the soil moisture deficit of Marathwada region for the period 1957–2017. It gives the water balance model depicting the water surplus and water deficit months. The analysis shows water surplus from July to September and water deficit from November to May. The study evaluates Kharif season as drought free and water deficit in Rabi season. This study analyses the need for crop-shift to avoid crop damage during drought. Based on the analysis, all the sectors of urban system need to augment short-term and long-term policies to overcome the water crisis for balanced water resource.

KEYWORDS: water balance, soil moisture deficit, water surplus, drought region, PDSI

Introduction

Drought is a long-term phenomenon lasting from months to years causing significant ecological as well as economic damage. It is manifested with reference to depletion in surface and groundwater resources and crop failure (NAAS, 2011). There is an expected increase in drought severity and frequency with climate change (Vasiliades et al., 2011; Wilhite et al., 2014). Also, the future projection of available water denotes the annually increasing gap between the water demand and supply gap for all the sectors. Hence, drought risk assessment is important to develop early warning system to reduce potential damage to water resource (WMO, 2000). Sustainable management of water resource is one of the key aspects in effective water management. One of the approaches associated with sustainable water management is balancing the water resource.

Water balance studies are becoming vital due to increasing demand for fresh water in domestic, industrial and especially in the agricultural sector (Arjun, 2017). It requires knowledge of water availability for current and impending conditions for various sectors intended to balance the water resource. It is calculated on the basis of three components which are potential evapotranspiration (PET), monthly rainfall, water surplus and deficit (moisture departure) (Arjun, 2017). Moisture departure is defined as the net change in the supply and demand of water in which supply is precipitation and stored soil moisture (Vasiliades et al., 2002). Besides, demand is potential evapotranspiration which is the amount needed to recharge the soil, and runoff needed to keep the rivers, lakes and reservoirs at a normal level.

There are various studies associated with water balance indicating the soil moisture deficit, runoff and drought severity. However, the need is to develop a

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systematic study of water balance indicating major temporal changes over the year. Hence, the present study conducts the evaluation of a drought-prone region for balanced water resource. It uses the approach based on Palmers Drought Severity Index (PDSI) analysing the soil moisture deficit of surface water balance. The PDSI was developed by Palmer (1965) intending to quantify the water departure from surface water balance. There are various drought indicators given by World Meteorological Organisation listed in the *Handbook of Drought Indicators and Indices* for analysing drought severity. The PDSI is categorised as the meteorological drought index (Svoboda et al., 2017) for water balance. The standardised measure of PDSI ranges from −4 (dry) to +4 (wet) with values below −3 representing severe to extreme drought (Palmer, 1965). It incorporates past and present moisture supply and demand which is precipitation and PET into a hydrological system respectively (Palmer, 1965; Wells et al., 2004). Also, PDSI is widely used to study temporal aridity changes in climates (Sivakumar et al., 2011). The PET is calculated using Thornthwaite equation for calculating the soil moisture deficit (Thornthwaite et al., 1957) for input parameter in PDSI but the present study uses Penman-Monteith equation. The present approach calculates the PDSI and self-calibrated PDSI (scPDSI) for understanding the soil moisture deficit and water balance of the region. Also, calculating the drought frequency gives the overall estimate of drought severity of the region.

Table 1: PDSI Categorisation of Drought Severity

PDSI Value	Drought Category
4.00 or more	Extremely wet
3.00 to 3.99	Very wet
2.00 to 2.99	Moderately wet
1.00 to 1.99	Slightly wet
0.50 to 0.99	Incipient wet spell
0.49 to −0.49	Near normal
−0.50 to −0.99	Incipient dry spell
−1.00 to −1.99	Mild drought
−2.00 to −2.99	Moderate drought
−3.00 to −3.99	Severe drought
−4.00 or less	Extreme drought

Study Region

The present study is concerned with the analytical study of drought and water balance at Marathwada, a semiarid region of Maharashtra. The area occupied by the region is 64,590 square kilometres. It is known for its routine and severe drought and has overall endured an increasing trend of rainfall deficit over the years. It consists of eight districts named Aurangabad, Jalna, Hingoli, Beed, Latur, Nanded, Parbhani and Osmanabad. The region develops its significant share of economy from agricultural sector. The average gap between water demand and supply for this sector amounts to 1656 hectare metre per year. In 2015, the precipitation levels decreased by about 50 per cent to normal rainfall affecting the districts majorly (Katalakute et al., 2016). Drought in 2016 resulted in significant number of farmer suicides due to severe losses in crop and livestock production. Also, water supplies to public and industrial *location of Marathwada region* sectors were affected because of reduced surface and groundwater supplies. The cracking of soil is common in the region due to its chemical composition.

Figure 1: Map showing geographical

Methodology

The water balance approach is adopted to reduce the imbalance occurred due to agricultural sector. The study was conducted using Palmers Drought Severity Index (PDSI) for water balance. It calculates the drought coefficient giving the statistics of the wet and drought months of the region. The data used for the study is Available Water Content (AWC) of the soil, monthly PET and rainfall for past 60 years. PET calculated using Thornthwaite equation gives an overestimated drought condition, hence PET is calculated using Penman-Monteith equation (Schrier et al., 2011) for the present study. Using this data, monthly average moisture departure is calculated for the period 1957–1990 and 1991–2017. The temporal changes are observed over the years and compared for these two time periods.

Further, timeseries data is plotted against self-calibrated PDSI (scPDSI). The PDSI does not satisfactorily represent the drought condition for other areas of the world as it was first calibrated using empirical values of the USA (Wells et al., 2004). Whereas, scPDSI calculates the PDSI with revised constant as per local climate characteristics giving the severity of drought for a region. The scPDSI allows for a more region- and climate-specific approach to include global variations in surface vegetation since it incorporates the parameters of vegetation characteristics (Wells et al., 2004).

Results and Discussion

The global water balance has changed intensely due to natural and anthropogenic influences. The present study states the water imbalance condition of Marathwada region in Table 2. The PDSI is a two-stage bucket model of the soil where top layer is assumed to hold 25 mm of water and the second layer holds the moisture depending on local climatic condition. The AWC value for the present study is taken as 100 mm. The potential values based on PET, recharge, runoff, loss, potential recharge, potential runoff and potential loss are weighted as per the climate of the region which gives climatically appropriate potential values represented as α, β, γ and ᶖ (Wells et al., 2004). These potential values are called the water balance coefficient. Further, moisture departure is calculated from the difference of actual precipitation of a specific month and the computed potential values. The product of soil moisture departure and climate characteristics gives moisture anomaly index (Z-index).

Table 2: The Average Values of the Water Balance Elements for the Analysed Period

	Actual ET	Potential ET	Recharge	Soil Storage (Previous Month)	Potential Recharge	Runoff	Deficit	Loss	Potential Loss	Potential Runoff	Pre-cipita-tion	Moisture Department
January	10.88	91.77	0.00	8.22	91.73	0.00	80.88	7.04	7.32	8.27	3.84	9.44
February	4.34	104.98	0.00	1.23	98.77	0.00	100.64	1.19	1.29	1.23	3.15	4.77
March	7.10	128.23	0.03	0.04	99.96	0.00	121.13	0.08	0.06	0.04	7.02	7.34
April	6.42	142.99	0.02	-0.01	100.01	0.00	136.57	0.01	-0.01	-0.01	6.41	5.43
May	15.39	149.12	0.00	0.00	100.00	0.00	133.72	0.00	0.00	0.00	15.39	12.81
June	103.73	117.11	31.30	0.00	100.00	1.70	13.38	0.00	0.00	0.00	136.73	47.49
July	51.02	51.78	60.04	31.30	68.70	73.48	0.76	0.09	17.48	31.30	184.45	73.94
August	45.43	45.43	7.46	91.25	8.75	126.64	0.00	0.00	37.81	91.25	179.53	73.42
September	51.94	51.94	0.57	98.71	1.29	118.32	0.00	0.34	44.82	98.71	170.50	68.53
October	57.87	60.01	0.11	98.95	1.05	23.98	2.14	16.95	50.88	98.95	65.01	43.22
November	71.65	91.11	0.63	82.10	17.90	1.38	19.46	53.27	65.85	82.10	20.39	23.28
December	29.21	87.46	0.37	29.46	70.54	0.00	58.25	22.89	24.84	29.46	6.69	17.21

The PET values in graph from January to May are more than monthly average precipitation as shown in Figure 2. It shows the water store is being used up by vegetation or lost by evaporation making it drought-prone and water deficit period. The precipitation levels during June, July, August and September are more than PET. It denotes the soil water store is full leading to surplus water and better crop production. Also, these are the kharif crop season therefore, crop grown during this season will have sufficient quantity of soil moisture. But, the major kharif crops grown in the region are sugarcane, soyabean and cotton. They are water-intensive crops thereby, reducing the soil moisture leading to poor groundwater conditions or soil moisture deficit. The region undergoes radical imbalance of water resource. The monthly average soil moisture deficit is depicted in Figure 4. It shows the change in soil moisture deficit between the reference period (1957–1990) and period after 1990 is 3.02 per cent. The observed number of extreme to severe drought months before 1990 were more compared to number of drought years before 1990. Due to reduced precipitation levels and long dry spell in the year 2015, especially from September to December, 40 to 50 per cent yield of soybean crop in soil with low water-holding capacity of the region was lost, as reported by agricultural department. Also, sugarcane plantation in Latur district suffered 65 to 70 per cent yield decline. Also, there was a clear decline in rabi (winter) crop sown due to deficient rainfall and low soil water moisture. The Z-index based on PDSI values is calculated for the period 1990–2017. Also, using Mann-Kendall's trend test applied over the same period gives a negative slope of -0.007 and p-value as 0.198 showing the increasing trend of drought over the years as per Figure 4. The necessary actions and policy formation to be accounted considering the severity of drought. The trend result can be validated through the early warning declaration given by government of Maharashtra for 32 districts to be drought-prone. The PDSI is calculated for the period 1946–2017 to quantify the long-term drought severity for the region.

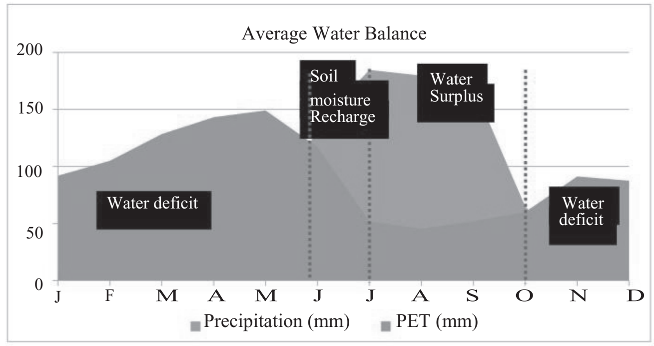

Figure 2: Average water balance of Marathwada calculated for the period of 1957–2017

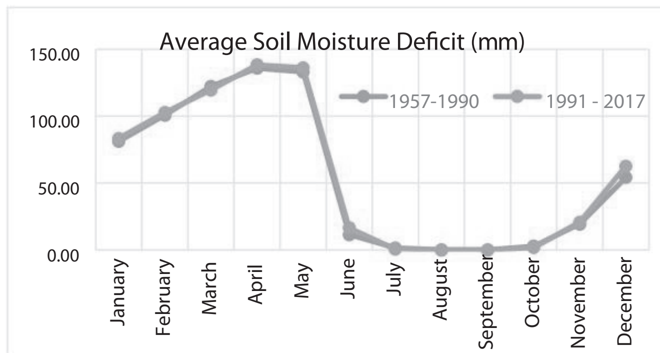

Figure 3: PDSI-based Z index for the period of 1990–2017

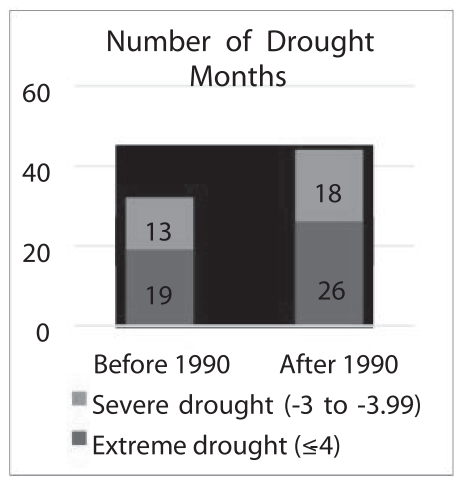

Figure 4: Number of severe and extreme drought months observed before and after 1990

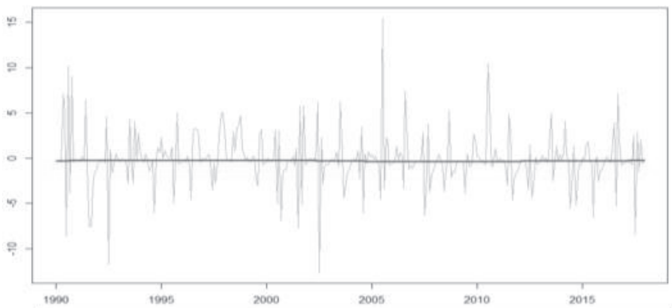

Figure 5: Average soil moisture deficit (mm) for Marathwada averaged over the period from 1957 to 2017

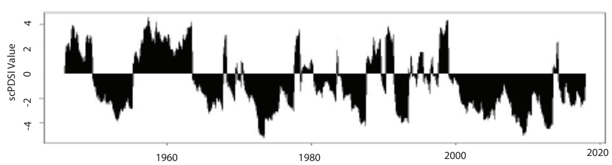

Figure 6: scPDSI plotted for 1957–2017

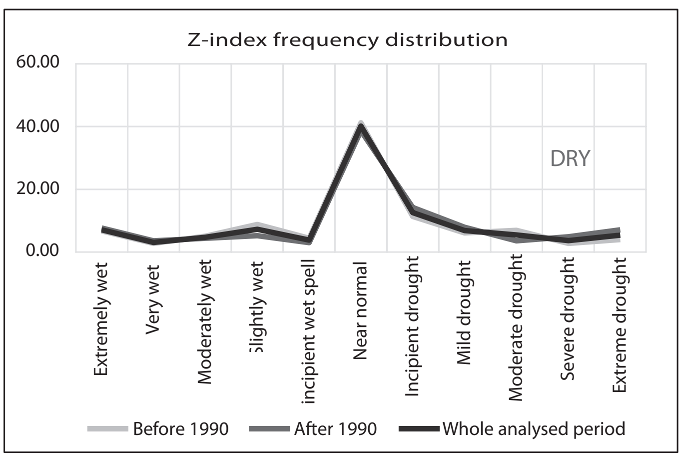

Figure 7: Z-index frequency distribution graph for the period 1957–2017

Further, time series of self-calibrated PDSI (scPDSI) is plotted which automatically adjusts the values as per local climate characteristics (Figure 5). The graph shows severe drought period from 2004 to 2015 which can be confirmed from the previous drought events for the region. Lastly, drought severity frequency distribution is plotted for Z- index for the period 1957–1990. It shows considerable number of months under moderate to severe drought frequency while some under extreme drought conditions. The future drought events can be estimated from the previous years PDSI values hence, early warning of drought events can be prepared.

Conclusion

Marathwada region is undergoing drought from past years resulting in failure of crops and water scarcity for other sectors. The approach used to analyse the water balance of the region defines the water surplus and water deficit of a region. The analysis shows the increasing trend of drought years in near future. Based on this analysis, preparedness and policy formation for the coming year can be taken into consideration. The drought months for the period 1990–2017 has increased in number than the reference period, that is 1957–1990. The soil moisture deficit is affected also due to type of cropping pattern. Hence, this study analyses the need for crop-shift to avoid crop damage during drought. Also, strategically changing the cropping pattern as per available soil moisture will reduce the scarcity of water resource in domestic and industrial sector. The study thus helps in forming the strategies required to strengthen the policies to reduce the potential damages caused due to drought. Awareness programmes and strict policies for better agricultural practices may be implemented. All the sectors of urban system need to augment short-term and long-term policies based on the analysis to overcome the water crisis for balanced water resource.

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Framework for Drought Vulnerability Analysis: Micro-level Study of Selected Villages in Datia and Lalitpur Districts, Bundelkhand Region, Central India

Sreeja S. Nair, Anil K. Gupta and M. S. Nathawat[a]

ABSTRACT: Bundelkhand region of India is prone to recurring drought due to geo-hydrological features coupled with socio-economic settings. Study of the pattern of meteorological, hydrological and agricultural drought and their relationship clearly indicates that it is not the hazard, that is meteorological phenomenon, but vulnerability is the major factor which is determining drought impacts. Rainfall deviations coupled with socio-economic factors, infrastructure, environmental and institutional factors make the region susceptible to changing climatic conditions and drought. A contextualised framework for drought vulnerability analysis has been developed and field tested at village-level in Lalitpur and Datia districts, representing the constituent states of Uttar Pradesh and Madhya Pradesh. Multiple social research methods were applied including focus group discussions and interviews in six villages of Datia and three villages of Lalitpur. The analysis is qualitative in nature with use of Geographical Information Systems for spatial analysis and presentation of the vulnerability indicators. The study depicts that vulnerability profile of villages within the same developmental blocks varied significantly. Comparative analysis of Datia and Lalitpur districts shows high-level vulnerability in the villages of Datia as compared to Lalitpur district.

KEYWORDS: vulnerability, indicators, drought, Bundelkhand

Introduction

Drought is a slow onset ecological hazard, which a rises with the scarcity of water due to one or more reasons including failure of rainfall, deficiency of reservoirs and water resources, and resultant failure of crops, and consequently a level of serious socio-economic distress. Drought is a weather-related natural disaster often aggravated by environmental degradation and socio-economic deprivation (Gupta et al., 2014). It can affect large geographical areas for shorter or longer periods and, thus, has serious impact on life, ecosystems, livelihoods, economy, environment and the overall human well-being. Bundelkhand region of central India has been experiencing drought due to complex geo-environmental, socio-economic and institutional factors. Occurrence of a meteorological drought did not necessarily result in a hydrological or an agricultural drought and also vice versa (Singh et al., 2013; Nair et al., 2014). Scientific analysis alone shows that though Lalitpur district experienced higher frequency and intensity of meteorological drought, it was relatively less affected in terms of hydrological and agricultural droughts (Nair et al., 2014). Contrarily, meteorological drought was not severe in Datia district which experienced severe agricultural drought (Singh et al., 2012; Nair et al., 2013).

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Vulnerability is the susceptibility of the ecosystems and community at large to the adverse impact of meteorological phenomena. The term vulnerability is highly contextual and the meanings and scope of the vulnerability analysis also vary (Smit et al., 1999; Brooks et al., 2005; Adger, 2006; Füssel,2007, Sen, 1982). Drought vulnerability depends on the availablity and accessibility of infrastructure, management practices, limitations of technology and of the economy, or on environmental constraints and many cases social factors dominate (Turner et al., 2003). For example, deficiency in precipitation may not impact agriculture if irrigation systems are well developed and farmers have access to the same. Similarly, vulnerability of the community to diarrhoea and other waterborne diseases will be low in the periods of drought if safe drinking water sources are available. Another example could be farm foreclosure related to drought; the underlying cause of this vulnerability could be multiple, such as small farm size because of historical land appropriation policies, lack of credit for diversification options, farming on marginal lands, limited knowledge of possible farming options, a lack of local industry for off-farm supplemental income or government policies (G. Naumann et al., 2014).

Hazard-centric mitigation measures are inadequate for interventions particularly in the case of drought. Understanding vulnerability to drought can help delineate interventions to increase capacity and thereby to reduce hazard effects. The present study aimed to develop a framework for drought vulnerability analysis at micro level. The framework and methodology capture vulnerability indicators such as inadequate physical, socio-economic, environmental and institutional factors. Objectives include identifying the key components and indicators of vulnerability, assigning influence and weightage for the indicators, developing framework for vulnerability analysis and field test of the method to understand its relevance in the study villages.

Methodology

Methodology adopted was a combination of scientific as well as social science research methods. Vulnerability indicators identified through a combination of approach involving Delphi, extensive literature survey and expert opinion were tested in few villages of Datia and Lalitpur districts. Selection of villages for household-level vulnerability analysis was based on multiple criteria. Ranking of parameters and components through influence assignment through a set of experts including Government officials, NGOs, experts engaged with Integrated Water Management Programmes (IWMP) and Watershed Committee Members (Community Representative) for finalising the framework of Drought Vulnerability Analysis (DVA) was carried out during the period of July 2014. Data collection for testing the framework of vulnerability analysis has been carried out in nine villages through focus group discussions (FGD) and interview with community members. This comprised six villages in Datia district as well as three villages of Lalitpur district. Separate discussions with men and women groups considering prevailing gender concerns in the region were carried out. Micro-level vulnerability analysis at village-level and effectiveness of mitigation measures have been carried out through multiple social science methods following the scientific data analysis. Primary data was collected through formative observations, transect walk, focus group discussion, interview and sample survey at household level. Spatial vulnerability analysis has been carried out using Arc GIS applying weighted overlay analysis and results are presented in the form of thematic maps and tables.

Result and Discussion

Vulnerability Analysis

Vulnerability analysis has been carried out at village-level in Lalitpur and Datia districts. The important second criterion was IWMP programme and villages were selected for a comparison of those covered under IWMP and which didn't. Besides this, accessibility, size of villages and community settings to cover broad range of issues and vulnerability were considered. Process of vulnerability study included the following:

- Identification of key components of vulnerability and assigning *Influence Values* for physical, environmental, socio-economic and institutional components based on expert opinion and field visits.

- Identification of key Indicators under each of the components of vulnerability and assigning *Weightage* based on expert opinion and field visits.
- Vulnerability scoring for selected villages in Datia to test the vulnerability analysis framework.
- Vulnerability analysis of six villages of Datia and three villages of Lalitpur districts based on formative observations and interaction with community and transect walk.

Vulnerability Analysis Framework

When a hazard meets vulnerable conditions it becomes disasters by creating damages and losses. Impact of drought is felt more severely by poor people living in rural areas who depend on agriculture for their livelihood. Since vulnerability is location specific and varies from place to place, it is often difficult to replicate one method developed for a particular geographical setting to other countries or other regions without necessary appropriation. Further, Bundelkhand is characterised by multiple facets of vulnerability which are associated with socio-economic issues, poor infrastructure, environmental degradation and inadequacy of governance. Hence, a methodological framework for carrying out vulnerability assessment has been devised after extensive review of literature on vulnerability assessment, pilot visits and interaction with experts. This framework is intended to capture four components vulnerability and 22 indicators under the four components. The indicators are specific to drought vulnerability in a predominantly agrarian society.

DELPHI has been used for identifying all possible indicators of vulnerability. DELPHI is a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem (Linstone & Turoff, 1975). 42 indicators were identified through the officials from central ministries and respective line departments who participated in national-level training programme on Drought Risk Mitigation and Management at the National Institute of Disaster Management. The framework for vulnerability assessment has been developed in the current research considering five components and 22 indicators. Indicators listed in the DEPHI exercise as well as from the literature survey were shared with five experts across NGOs, academia, technical experts and government officials working in the field. Components and indicators were identified and influence value was assigned to different components through the experts and are given in Table 1 and Figure 1.

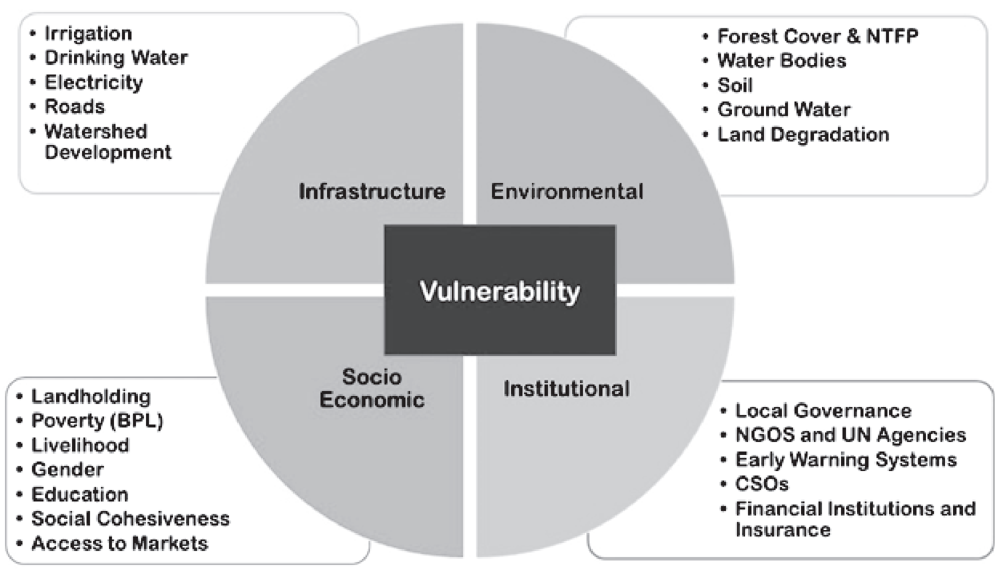

Figure 1: Framework for vulnerability assessment

Interaction with experts and field officials combined with observations in the field indicated that most villages are vulnerable to drought impacts due to multiple factors. According to NGOs, infrastructure development is taking place but, however, the socio economic and institutional factors are even more influential on people's vulnerability in these settings. However, government officials and field experts felt that substantial reduction in vulnerability is possible by infrastructure improvements. According to the experts from academia who are engaged in research studies relating to Bundelkhand region, community is highly dependent on environmental services and, hence, ecological degradation is key factor determining their vulnerability. Average of the values assigned by five experts for various components was almost same. And hence, equal influence has been assigned to all the components in vulnerability analysis at the village-level.

Table 1: Components and Their Indicators, for Contribution to Vulnerability and Relative Influence Value Assigned by the Experts

Component	Influence (Average)	Influence (%)	Expert	Indicators
Physical/ Infrastructure	**27**	10	Expert 1 (NGO)	• Irrigated area (cropped area under irrigation) • Electrification (status particularly in farms) • Safe drinking water (source and access) • Roads (condition and access) • Water harvesting and distribution systems
		40	Expert 2 (Govt official)	
		10	Expert 3 (Academia)	
		25	Expert 4 (Technical Expert)	
		50	Expert 5 (Field Official)	
Socio-economic	**23**	30	Expert 1 (NGO)	• Landholding (agricultural land) • B.P.L. family • Livelihood diversification • Education and awareness • Gender (women participation and empowerment) • Social cohesiveness • Markets
		20	Expert 2 (Govt official)	
		20	Expert 3 (Academia)	
		25	Expert 4 (Technical Expert)	
		20	Expert 5 (Field Official)	

(*Continued*)

Table 1: (Continued)

Component	Influence (Average)	Influence (%)	Expert	Indicators
Environmental and Natural Resources	**24**	20	Expert 1 (NGO)	• Forest cover & NTFP • Natural water bodies • Soil (water-holding capacity and organic content) • Land degradation/waste land/ desertification • Ground water
		20	Expert 2 (Govt official)	
		40	Expert 3 (Academia)	
		25	Expert 4 (Technical Expert)	
		15	Expert 5 (Field Official)	
Institutional	**26**	40	Expert 1 (NGO)	• Local governance systems (Panchayats) • NGOs • Early warning systems • Community level, organisations • Insurance
		20	Expert 2 (Govt official)	
		30	Expert 3 (Academia)	
		25	Expert 4 (Technical Expert)	
		15	Expert 5 (Field Official)	

Village-level Micro-analysis for Testing the Vulnerability Analysis Framework

Field visits with formative observations transect walk, interviews of villagers and focus group discussions were held in four villages of the Datia Block. Objective of these visits was to test the for vulnerability analysis framework (the formats) as well as to check the influence values as assigned by the experts. From the visit it became evident that most villages are vulnerable due to the contributing factors, for example, poor infrastructure, socio-economic attributes, environmental degradation as well as inadequate institutional support. Villages selected for analysis were (i) Govind Nagar, (ii) Bilauni, (iii) Kamhar, (iv) Sallaiya Pamar, (v) Dhan Karera and (vi) Khatrawani. Secondary data has been collected for the villages from census data and primary data based on field surveys. Vulnerability is expression of characteristics and circumstances of a community – their individuals, assets, systems and resources, which make them susceptible to damaging effects of a hazard. There are many aspects of vulnerability, arising from various physical, social, economic, environmental and institutional factors.

a. Datia District

Physical Vulnerability

Physical vulnerability is the condition attributed due to poor infrastructure facilities. There are many indicators as facets of physical vulnerability. For the analysis of drought vulnerability, five key indicators, viz., irrigated area (cropped area under irrigation), safe drinking water (source and access), electrification (status particularly in farms), roads (condition and access), and watershed development (check dams, stop dams, etc.).

Analysis carried out in six villages based on formative observations and focus group discussion with the villager's group in Kamhar Village revealed low physical vulnerability. All the indicators of physical vulnerability attained equal weightage assigned. Score of 1 to 5 has been designated for the increasing order of vulnerability. Physical vulnerability based on five indicators at village-level has been computed applying "Weighted Overlay" method in Arc GIS Spatial Analyst. Analysis shows Govind Nagar, Salaiya Pamar and Biloni under medium vulnerability category whereas Khatrawani and Dang Karera villages as highly vulnerable and Kamhar under the low vulnerability category.

Socio-economic Vulnerability

Socio-economic vulnerability refers to social, economic and demographic factors that affect the resilience of communities. Studies have shown that in case of a disaster socially vulnerable groups are likely to be more adversely affected, that is, they are less likely to recover and more likely to perish (Flanagan et al., 2011). Seven key indicators, viz., Land-holding (enough agricultural land available for multiple cropping), B.P.L Family (poor family with low buying capacity during the period of drought), Livelihood Diversification (dependency on agriculture or more than agriculture alone), Education and Awareness (literacy and awareness about the problems), Gender (women participation and empowerment, education), Social Cohesiveness (incidences of theft, dacoits, etc., during drought, other social support systems that may prevail during drought periods) and Access to Markets (distance and access to markets).

Table 2(a): Physical Vulnerability Analysis of Six Villages in Datia District

Village	PHV1	PHV2	PHV3	PHV4	PHV4	PHV	Category
Biloni	3	4	4	3	2	3	Medium
Dang Karera	4	5	4	4	5	4	High
Govind Nagar	3	2	4	4	3	3	Medium
Kamhar	2	2	4	2	2	2	Low
Khatrawani	3	5	4	4	2	4	High
Salaiya Pamar	3	3	3	4	2	3	Medium

PHV1 = Irrigated Area (cropped area under irrigation), Safe Drinking Water (source and access), PHV3 = Electrification (status particularly in farms), PHV4 = Roads (condition and access), PHV5 = Watershed Development

Table 2(b): Socio-economic Vulnerability Analysis of Six Villages in Datia District

Village	SEV1	SEV2	SEV3	SEV4	SEV5	SEV6	SEV7	SEV8	Category
Biloni	3	3	3	3	4	2	4	3	Medium
Dang Karera	4	4	4	4	5	4	4	4	High
Govind Nagar	3	4	2	4	3	4	4	3	Medium
Kamhar	3	4	1	4	4	2	4	3	Medium
Khatrawani	4	4	4	4	4	4	5	4	High
Salaiya Pamar	4	3	3	3	4	5	4	4	High

SEV1 = Landholding (agricultural land), SEV2 = B.P.L Family, SEV3 = Livelihood Diversification, SEV4 = Education and Awareness, SEV5 = Gender (women participation and empowerment), SEV6 = Social Cohesiveness, SEV7 = Access to Markets

Analysis has shown most villages with high-level socio-economic vulnerability. Gender inequality and lack of social cohesiveness emerged as key issues in most villages. Weighted average of seven socio-economic indicators shows that three villages (Khatrawani, Salaiya Pamar and Dang Karera) were under high vulnerability category and other three (Govind Nagar, Kamhar, Biloni) in medium vulnerability category. Weightage of 14 each was assigned to five indicators, and 15 each to social cohesiveness and gender concerns since these are predominant problems in all the villages.

Environmental Vulnerability

Natural resource depletion and resource degradation are key aspects of environmental vulnerability. Examples include loss of wetlands, depletion of surface and ground water resources, deforestation, soil erosion, land degradation, etc. Five indicators, viz., forest cover and availability of non-timber forest produces (NTFP), natural water bodies, soil (water holding capacity and organic content), ground water condition (water-level and quality), land degradation/waste land/desertification, were used for environmental vulnerability analysis.

Equal weightage has been assigned to all the indicators. Scores of 1 to 5 have been designated on increasing order of vulnerability. Weighted average of five Indicators reflects that two villages (Salaiya Pamar and Dang Karera) are under high vulnerability category and other four (Khatrawani, Govind Nagar, Kamhar, Biloni villages) are in medium vulnerability category.

Institutional Vulnerability

Institutional vulnerability refers to institutional and systemic weaknesses within the community that make them more susceptible to adverse impact of hazards (Turner et al., 2003). On the opposite, effective institutional arrangements can enhance the resilience against adverse impact of disasters. Institutions include local governance systems, NGOs, other community-level organisations and self-help groups and financial institutions like credit societies, etc.

Table 2(c): Environmental Vulnerability Analysis for Six Villages in Datia District

Village	ENV1	ENV2	ENV3	ENV4	ENV5	ENV	Category
Bilauni	4	2	2	2	4	3	Medium
Dang Karera	4	4	4	4	4	4	High
Govind Nagar	2	4	3	2	3	3	Medium
Kamhar	1	4	3	3	4	3	Medium
Khatrawani	4	3	3	4	3	3	Medium
Salaiya Pamar	4	3	4	4	4	4	High

ENV1 = Forest Cover and NTFP, ENV2 = Natural Water Bodies, ENV3 = Soil (water-holding capacity and organic content), ENV4 = Ground Water, ENV5 = Land degradation/waste land/desertification

Table 2(d): Institutional Vulnerability Analysis of Six Villages in Datia District

Village	INST1	INST2	INST3	INST4	INST5	INST	Category
Biloni	3	4	4	4	4	3	Medium
Dang Karera	4	3	4	4	4	4	High
Govind Nagar	3	2	3	3	5	3	Medium
Kamhar	2	4	4	4	1	3	Medium
Khatrawani	4	3	4	4	5	4	Medium
Salaiya Pamar	5	2	3	3	2	3	High

INST1 = Local Governance Systems (Panchayats), INST 2 = NGOs, INST3 = Early Warning Systems, INST4 = Community-Level Organisations, INST5 = Financial Institutions and Insurance

Five indicators, viz., Local Governance Systems (Panchayats), NGOs, Early Warning Systems, Community Level Organisations and SHGs and Financial Institutions and Insurance, were used for Institutional Vulnerability Analysis. Weighted average of five indicators reflected that the two villages (Khatrawani and Dang Karera) were under high vulnerability category and other four (Salaiya Pamar, Govind Nagar, Kamhar, Biloni villages) in the category of medium vulnerability.

Composite Vulnerability Analysis

Composite Vulnerability Analysis of six villages in Datia district based on four components and 22 indicators has been computed and reported in Table 2(e). Composite vulnerability reflected Dang Karera, Khatrawani and Salaiya Pamar villages as highly vulnerable and other three villages under medium vulnerable category.

b. Lalitpur District

Physical Vulnerability

Analysis has been carried out in three villages based on formative observations and focus group discussion with villagers. Results show Pawa village with high physical vulnerability and Masora Kalan and Narahat villages having moderate physical vulnerability. It is interesting to mention here that there are many dams and canals in Lalitpur district area. But, farmers in two out of three villages felt water risks. As per their information, water is not released timely by the irrigation department, and hence, they are not benefiting from the irrigation systems.

Table 2(e): Composite Vulnerability of Six Villages of Datia District

Village	PHV	SEV	ENV	INT	CVUL	Category
Biloni	3	3	3	3	3	Medium
Dang Karera	4	4	4	4	4	High
Govind Nagar	3	3	3	3	3	Medium
Kamhar	2	3	3	3	3	Medium
Khatrawani	4	3	3	4	4	High
Salaiya Pamar	3	4	4	3	3	High

Table 3(a): Physical Vulnerability Analysis of Three Villages in Lalitpur District

Village	PHV1	PHV2	PHV3	PHV4	PHV5	PHV	Category
Pawa	5	2	4	4	3	4	High
Masora Kalan	3	2	1	4	4	3	Medium
Narahat	5	1	4	4	2	3	Medium

PHV1 = Irrigated Area (cropped area under irrigation), Safe Drinking Water (source and access), PHV3 = Electrification (status particularly in farms), PHV4 = Roads (condition and access), PHV5 = Watershed Development

Figure 2: Map depicting vulnerability profile of study villages in Lalitpur district

Socio-economic Vulnerability

Table 3(b): Socio-economic Vulnerability Analysis of Three Villages in Lalitpur District

Village	SEV1	SEV2	SEV3	SEV4	SEV5	SEV6	SEV7	SEV	Category
Pawa	5	4	3	5	4	4	3	4	High
Masora Kalan	1	2	2	2	2	4	3	2	Low
Narahat	4	3	3	2	3	4	1	3	Medium

SEV1 = Landholding (agricultural land), SEV2 = B.P.L Family, SEV3 = Livelihood Diversification, SEV4 = Education and Awareness, SEV5 = Gender (women participation and empowerment), SEV6 = Social Cohesiveness, SEV7 = Access to Markets

Analysis of the socio-economic factors revealed Pawa Village in the high vulnerability category whereas Masora Kalan in the low vulnerability and Narahat village in the medium vulnerability category. Number of incidences of dacoits and theft were reported in these villages and such incidences increased during drought periods.

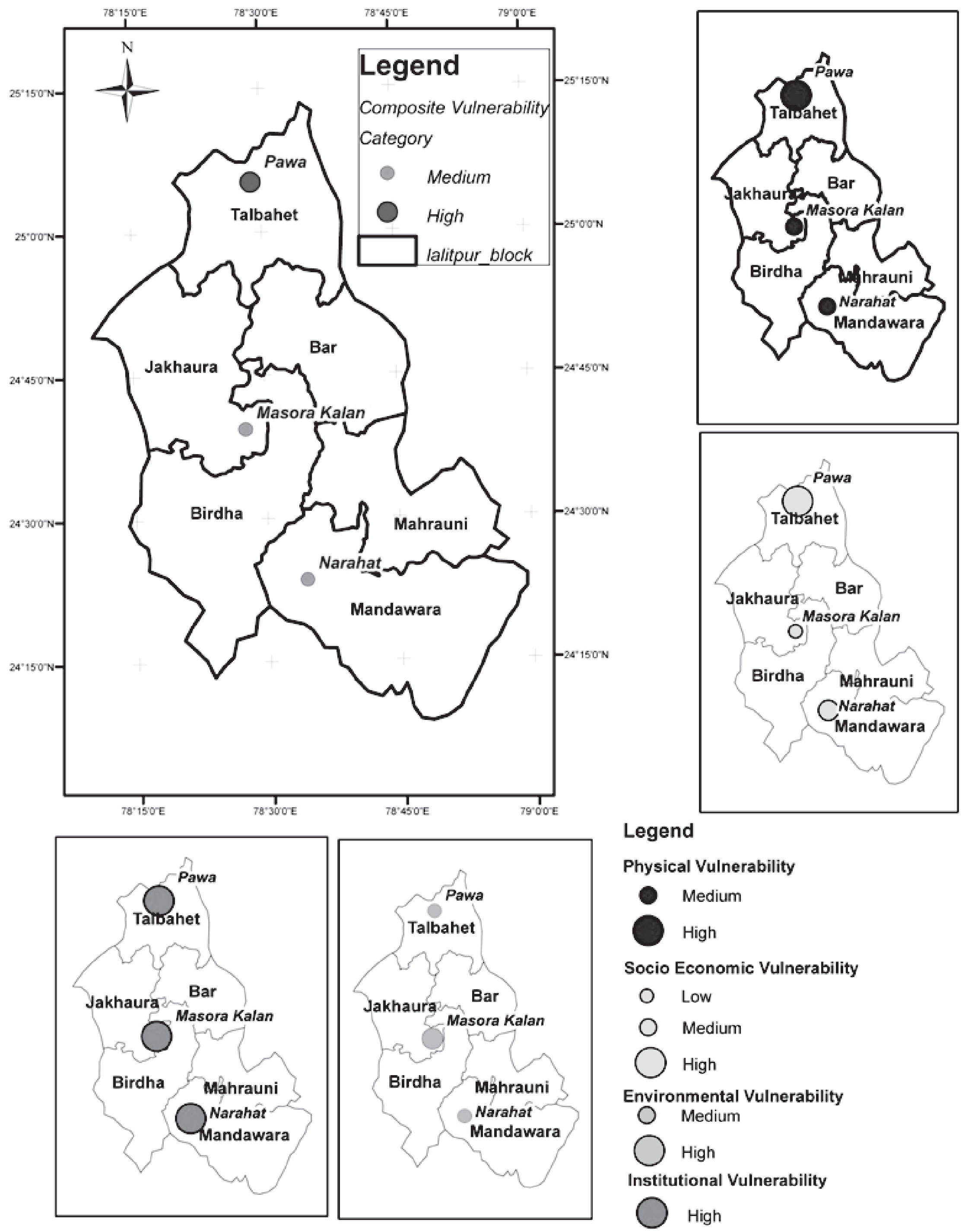

Figure 3: Map depicting vulnerability profile of study villages in Lalitpur district

Environmental Vulnerability

Table 3(c): Environmental Vulnerability Analysis of Three Villages in Lalitpur District

Village	ENV1	ENV2	ENV3	ENV4	ENV5	ENV	Category
Pawa	2	4	2	4	3	3	Medium
Masora Kalan	2	4	4	4	4	4	High
Narahat	2	4	4	2	4	3	Medium

ENV1 = Forest Cover & NTFP, ENV2 = Natural Water Bodies, ENV3 = Soil (water-holding capacity and organic content), ENV4 = Ground Water, ENV5 = Land degradation/waste land/desertification.

Table 3(d): Institutional Vulnerability Analysis of Three Villages in Lalitpur District

Village	INS1	INS2	INS3	INS4	INS5	INS	Category
Pawa	3	4	4	4	4	4	High
Masora Kalan	4	4	4	4	4	4	High
Narahat	4	5	4	4	4	4	High

INST1 = Local Governance Systems (Panchayats), INST 2 = NGOs, INST3 = Early Warning Systems, INST4 = Community-Level Organisations, INST5 = Financial Institutions and Insurance

Analysis reflected environmental vulnerability as highest in Masora Kalan village. According to the farmers, soil erosion and depletion of ground water have become a serious problem in the village, particularly during recent times. Water-holding capacity and organic content of soil are also not good. Narahat and Pawa villages having moderate environmental vulnerability were reported. Since there are no significant natural water bodies, irrigation is totally dependent on canals. Very less emphasis has been given on watershed development. IWMP is yet to cover many villages in its project area.

Institutional Vulnerability

Institutional vulnerability appears to be high in all the villages. Local governance systems are weak. Only one or two NGOs work in this area. Due to socio-political reasons NGOs withdraw from the area after short period of their intervention. Farmers were not benefitted from *Fasal Bima* (crop insurance) since it don't cover losses of individual farmers. Community-level organisations and self-help groups exist in villages in papers, as per the community informants. There are hardly any credit societies and/or microfinance institutions exist in these villages.

Composite Vulnerability Analysis

Table 3(e): Composite Vulnerability Analysis of Three Villages in Lalitpur District

Village	PHV	SEV	ENV	INS	CVUL	Category
Pawa	4	4	3	4	4	High
Masora Kalan	3	2	4	4	3	Medium
Narahat	3	3	3	4	3	Medium

Table 3(e) has shown results of Composite Vulnerability Analysis of three villages of Lalitpur district based on four components and 22 indicators. The analysis reflected that Pawa Village is highly vulnerable, whereas other two villages are in medium vulnerability category.

Discussion and Conclusion

Indicators of vulnerability vary depending upon the typology of hazards as well as temporal and spatial scale. The present study was found helpful in developing a framework for vulnerability and mitigation analysis, contextual to the Bundelkhand region since the factors influencing vulnerability were analysed in depth for drought.

Study has been carried out in selected villages of Datia and Lalitpur to test the methodology for vulnerability analysis. Vulnerability analysis at the village-level has been carried out based on qualitative indicators. Weightage to each indicator has been assigned in a scale of 1–4 based on the FDGs and formative observations since quantitate analysis was not feasible with limited data of socio-economic, environmental and institutional factors. Comparative analysis of villages in Lalitpur and Datia district reveals that villages in Datia are relatively more vulnerable than those in Lalitpur district. Composite vulnerability analysis of six villages in Datia district based on four components and 22 indicators has been carried out. Composite analysis results reflected that Dang Karera, Khatrawani and Salaiya Pamar Villages are highly vulnerable and other three villages are medium vulnerable. In Dang Karera vulnerability is contributed due to all components, viz. infrastructure, socio-economic, environmental and institutional factors. However, in Khatrawani village vulnerability is attributed by poor infrastructure and weak institutional mechanisms. In Salaiya Pamar socio-economic problems and environmental factors are leading to high vulnerability. In Lalitpur district, infrastructure for combating with drought and water scarcity is relatively better. Only one out of the three villages, that is, Masora Kalan in Lalitpur, was highly vulnerable and its vulnerability was found high due to socio-economic, environmental and institutional factors. There was no extreme hydrological drought recorded in Lalitpur during the major drought period (2004–07) (Nair et al., 2013, Singh et al., 2013). Despite excess rainfall in 2013 (as per record of IMD) and many structural interventions including Rajghat dam, hydrological drought has been intensified and recorded more frequent in Lalitpur (CGWB data). However, situation was found improving in Datia after the year 2009. Vulnerability profile of villages within the same block also varied significantly. Socio-economic, environmental and institutional factors were contributing substantially to the vulnerability in Lalitpur however in Datia all the factors including physical vulnerability are high.

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Drought Response and Relief by 'Jaldoot Express': A Case Study of the Latur Drought 2016

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ABSTRACT: This paper analyses the administrative capacities for drought response and relief management from the perspective of regional water users and decision-makers. It is the study of water supply of Latur city for the drought 2016. It involves study of water requirement of Latur city, feasibility analysis of water supply options and effective distribution of water during drought period.

After consecutive drought years and poor rainfall in the year 2014 and 2015, the situation in Latur region became worst resulting in acute water shortage in summer 2016. The water supply for Latur city was totally collapsed as almost all nearby water sources were dried, thus forcing the administration to take an unusual step of water supply by railway wagons. After doing analysis of all possible options, water supply by railway wagon was found to be the only feasible solution for that situation. This case study is an attempt of explaining the emergency water supply system of Latur city for the drought year. The water distribution was done effectively even though it was first experienced with short notice. The daily water supply by railway wagon was less than 25 per cent of city requirements; still the developed temporary distribution model fulfilled the city water demand effectively. This model involves receiving and unloading of water from wagon in temporary well, pumping it to the filtration plant and distribution to households at door step. In order to avoid wastage, unfair distribution and malpractices of all water tankers were GPS enabled and continuously monitored in the war room established at the Collector Office. Single contact policy was adopted for avoiding overlapping of relief work for same region. All the necessary arrangements related to temporary distribution was done in four days only by the team of the Collector of Latur. This case study will help disaster managers in formulating drought response strategies in future.

KEYWORDS: drought response, Latur drought, Jaldoot Express, railway wagon water supply

Introduction

Marathwada region is extremely prone to drought conditions and this region is experiencing it regularly after every three years. Drought impacts are long lasting, at times lingering for many years; and human or social factors often aggravate the effects of drought (Wilhite, Donald A. et al., 1985). The drought risk management involves two main approaches: the crisis management approach and preventive approach. The crisis management approach starts when drought begins and has mainly drought response strategies. This approach often results in inefficient technical and economic solutions as these actions are taken with little time for evaluating optimal actions and stakeholder participation is very limited. The preventive approach is long term and has maximum involvement of stakeholders (Garrote L.,Cubillo F., 2008). The drought situation always severely paralyses urban water supply system. Reliability is an important dimension of urban

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water supply system (Howe, C. W., Smith M. G et al., 1994), which is always questionable during drought situations as every time each city administration spends huge amount of money in short-term relief activities of drinking water supply. Three interrelated factors are leading to water supply problem in urbanised regions of developing countries (1) high rate of population growth, (2) lack of investment in water supply water infrastructure, (3) the upper limit imposed by availability of water sources (Bruggen, Borghgraef & Vinckier, 2010). The issues with Indian urban water supply system are (1) increasing water demand due to increase in population and industrialisation, (2) depletion of ground water due to over extraction of ground water, (3) deteriorating water quality due to inefficient sewage network (Das A., Jethoo A.S., Poonia M., 2012) and (4) huge water leakage (Srivivasan V., Gorelick S., Goulder L., 2010).

Indian cities are undergoing rapid urbanisation at the cost of limited available resources. Today, water is the most important scarce natural resource in India. The water scarcity is resulting in conflict between societies. In future it is predicted that water scarcity will lead to wars between countries. Already this is experienced in India where states are fighting with each other for their water share. As per UN report on water conservation published in March 2017, due to India's unique geographical position in South Asia and increasing water demand, the Indian sub-continent will face severe water crisis and India would be at the epicentre of this conflict. According to the report the situation in India will be worst by 2050 and almost all parts of the country will face water scarcity. As per National Commission on Water Resources Development (NCIWRD) report, the total water availability in India per annum is 4000 billion cubic meter (BCM), of which the utilisable water is only 1123 BCM per annum. The conditions are treated as water stressed and water scarce if annual per-capita availability is less than 1700 cubic metres and 1000 cubic metres respectively. The annual per-capita availability in the years 2001 and 2011 was assessed as 1820 cubic metres and 1545 cubic metres respectively which may reduce further to 1341 and 1140 in the years 2025 and 2050 respectively (GOI 2017).

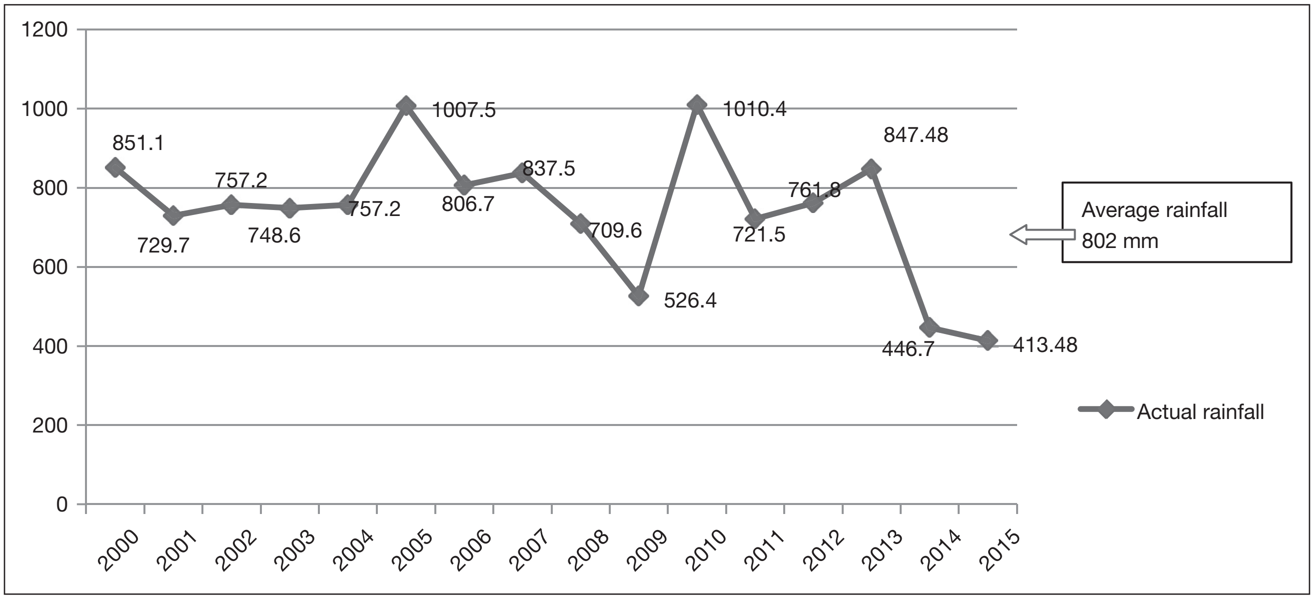
Approximately, only 10 per cent of Latur district area is irrigated by surface water sources. As a result, district population depends on open wells and bore wells which resulted in over pumping of ground water in this region. As per the notice issued by Maharashtra Water Resources Regulatory Authority ground water resources are overexploited in Latur district. In the year 2016 the ground water level of Latur region has decreased by 3.9 metres due to over pumping. Almost everywhere in India, fresh water aquifers are being pulled down by 1–3 metres every year (Seckler D, Barker R, Amarasinghe, U. 1999).

Information of Latur City

Latur is one of the most droughts affected town from Marathwada region of Maharashtra state. It is situated on Deccan plateau and having coordinates 18.4088° N, 76.5604° E. Latur city has the 'D' class Municipal Corporation and it was established on 25th October 2011. From the year 2010 to January 2015, water distribution systems of Latur city was with the Maharashtra Jeevan Pradhikaran. Afterwards, it was transferred to Latur City Municipal Corporation. The town is important educational, industrial and trade centre of Marathwada region. The estimated current population of Latur town is 425,000 and floating population which comes for educational, employment and business purpose is near about 75,000. After the 1993 devastating earthquake, the city has rapidly increased due to migration of large number of earthquake affected villagers from Latur and Osmanabad regions.

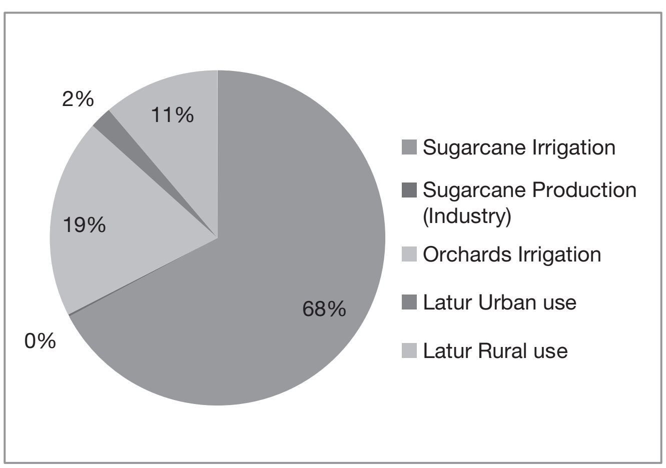
Rainfall of Latur City

The average rainfall for Latur region is 802 millimetre. Latur district generally experiences rainfall (monsoon) season from June to September. The rainfall in months July, August and September is comparatively more than remaining months. The district has an average of 42 rainy days per year. All major, minor and seasonal water resources were dried due to poor rainfall of three consecutive years. Following graph shows the rainfall of Latur district for last 15 years.



Graph 1: Rainfall in Latur region
(Source: www.latur.gov.in)

The 2014 and 2015 monsoons were in deficit in significant parts of the Central India, especially in Marathwada. For the same period Latur district received even lesser rainfall than other parts of Marathwada region. It was less than 50 per cent of normal rainfall. This has impacted agricultural, industrial and domestic sectors at regional scale and water supply at city level.



Graph 2: Water requirement of Latur district (2012)
(Source: TARU)

Sources of Water Supply to Latur City

Latur city is dependent on primary water source-Manjara Major Project and the secondary sources – Sai and Nagzari barrages. The secondary sources have very less storage capacity and hence provide seasonal water supply. Apart from this there are 1019 public bore wells in the town, out of which power pumps are installed on 668 and hand pumps on 321. Approximately, 1 MLD of water is available from these sources.

Table 1: Sources of Water Supply for Latur

Sr. No.	Particulars	Manjara Dam	Nagzari Barrage	Sai Barrage
1	Storage capacity of dam (In Million Cubic Meters – MCM)	224.09	3.48	0.22
2	Existing water supply scheme capacity from dam (million litres per day – MLD)	80.00	19.20	8.60
3	Distance from city (km)	40	7.3	10.5

(*Source: Latur Irrigation division no.1*)

Entire catchment area of Manjara dam is located in the rain shadow zones and the dam was overflowed only four times in last 30 years. Hence, Latur city always suffers from water crisis. Also, there are many small reservoirs/tanks dams on this river upstream, which divert/store water and as a result Manjara dam never gets sufficient water (TARU, 2015).

Water Availability and Requirement for the Drought Year 2016

Almost all major water sources were dried in January 2016. As per general norms of water requirement 100 litres per capita per day, the total demand of water for the city is 50 MLD and considering leakages of 10 per cent and other demand as 10 per cent, the demand is around 70 MLD. Whereas, the water demand as per scarcity norms for the same region is about 35 MLD (including demand of hotels, lodges, schools, colleges, hospitals and offices, etc.)

Table 2: Water Storage Level in Different Sources in Monsoon 2015 and 2016

Sr. No.	Name of Dam	Water storage in Monsoon Year 2015 (MCM)	Water Storage in January, 2016 (MCM)
1	Manjara Dam	4.232	0.766
2	Sai Barrage	0.17	00
3	Nagzari Barrage	1.21	00

(Source: Maharashtra Jeevan Pradhikaran)

Objectives

- To study Latur region's water requirement and its distribution
- To explain Latur city's water distribution management during drought 2016
- To study contingency plan of water supply by railway wagon

Methodology

Case study method was adopted for conducting this study. Exploratory research design was used for this research. It is based on both primary as well as secondary data. Secondary data was collected from newspapers, government reports, Collector office, Latur Municipal Corporation, irrigation department, Maharashtra Jeevan Pradhikaran (MJP) and research documents. Primary data was collected from officers of district administration Latur, municipal administration Latur and local representatives by discussion method.

Findings and Discussion

The data collected from discussions with officers and other respondents was analysed both qualitatively and quantitatively. The outcomes of discussions are as follows.

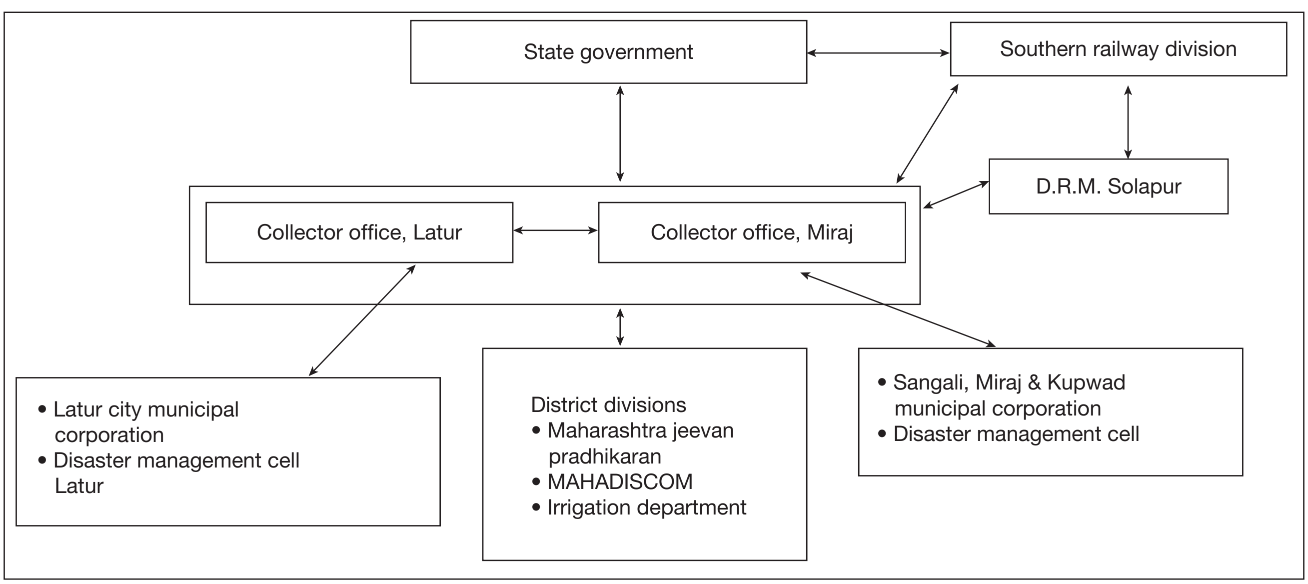


Figure 1: Organisations involved in Latur city water management for 2016

Planning

As the city's water requirement was immediate and public and media pressure was increasing, all necessary planning was done in 15 days only.

Evaluation of Alternatives

The main source of water supply for Latur city is from Manjara dam which was dried in the month of February 2015. So, administration started searching for various options through Presumption Survey. Looking at the immediate, enormous and economical water requirement with available resources following feasible options were available:

- To supply water by Railway from Pandharpur:

Pandharpur-Latur rail distance is just 206 km (3.5 hr journey). It was comparatively cost effective to bring water from this place, but since Pandharpur was facing water scarcity problem and being a religious place it has huge floating population; therefore this option was not considered. Also, water at this source was reserved for drinking purpose only due to scarcity situation.

- To supply water from Lower Terna Dam by tankers:

Government approved the proposal of daily supply of 4 MLD of water by tankers from Terana dam which is 57 km away from Latur. But still the quantity of water available was far less than city's daily demand. Also, this water was reserved for the surrounding villages only.

- To supply water by railway from Miraj:

Latur-Miraj rail distance is 343 km (7 hr journey) which was more than any other available options. But still this option was selected because the water availability was more and also railway department and local people showed willingness for water sharing. After doing feasibility analysis the decision was taken to supply water from Miraj by railway wagon.

Water Assessment

The district administration prepared estimation of water requirement for district, available water in different sources, after filtration availability, water leakages and water required for direct beneficiaries. Water prospecting was done first time where chart was prepared date wise for availability of water and its projection for demand fulfilment in terms of number of days. Previous year data was referred for doing water prospecting.

Water Rationing

Anticipating future water scarcity problems, the district administration started water rationing from December 2015 by making water supply at the interval of 18–20 days. As a preparedness measure, district administration reserved all water reservoirs for drinking purpose only. Water quotas were fixed as per population for all towns and villages and monitoring was done while water lifting.

Administrative Approvals

State government approved proposals on priority basis as a special case for this project.

Financial Provision

The total budget sanctioned for Latur and Miraj was Rs. 524 lakhs. Of which, the budget of Rs. 326 lakh and Rs. 198 lakh was sanctioned to Latur and Miraj respectively for loading, unloading and transporting water to tanker filling points (GOM, 2016 April 12). Apart from this, Latur Municipal Corporation was sanctioned Rs. 2120 lakh for water distribution. The cost incurred for transporting water by railway wagons from Miraj to Latur for one trip was approximately one crore ('Railways to use 50-wagon train to transport water to Latur', 2016). Total 111 trips of train delivered water of 2595 lakh litres to Latur city in just 120 days ('Jaldoot water train completes last run to Latur', 2016). Approximate expenses incurred for water supply to Latur city from April to June 2016 were Rs. 137.44 crores.

Legal Provisions

To avoid disturbances and unfair practices in water distribution, the district magistrate imposed section 144 of IPC (unlawful assembly) at six tanker filling points. Anticipating water scarcity all new constructions were stopped and major water consuming commercial units like swimming pool, vehicle washing centre were closed down up to further notification. To reduce water demand, educational institutes were asked to prepone their annual examinations.

Execution

Railway Department

Railway department provided two trains of 50 wagons (equivalent to 450 tankers) each ('Second: "water train" reaches Latur', 2016). The capacity of each wagon was 54,000 litters. The wagons were procured from Kota, Rajasthan; which were later on cleaned and then filled up. The first trip took 17 hours for reaching Latur station due to busy single line track. Later on duration of journey was reduced to 7 hours by doing proper scheduling.

Supply Centre: Miraj

The detailed plan was prepared by Miraj administration in just 48 hours. Historical Haider khan well was cleaned and water was temporarily stored in it. Then water was supplied to filtration tank through 4.5 km underground pipeline. From filtration plant water was transported to Miraj pumping station via 2.7 km underground pipeline (Gaikwad S., 2016). Underground pipeline work at platform was carried out in late night hours considering busy rail traffic at the station. All wagons were steam-cleaned, then cleaned with chemicals, scrubbed and finally washed with high-pressure water jets. Filling of the wagons was divided into three shifts – 9 p.m. to 4 a.m., 6 a.m. to 9 a.m. and 2 p.m. to 8 p.m. At the end of every shift, the train was moved from platform no. 2 (where the filling usually happens) back to the yard, to make space for other trains to halt at the station (Rashid A., Dattatrye M., 2016). Each refill was taking around 12–14 hours before being dispatched to Latur and nearby villages ('Indian Railways' train carrying water completes 100 trips to Latur, 2016).

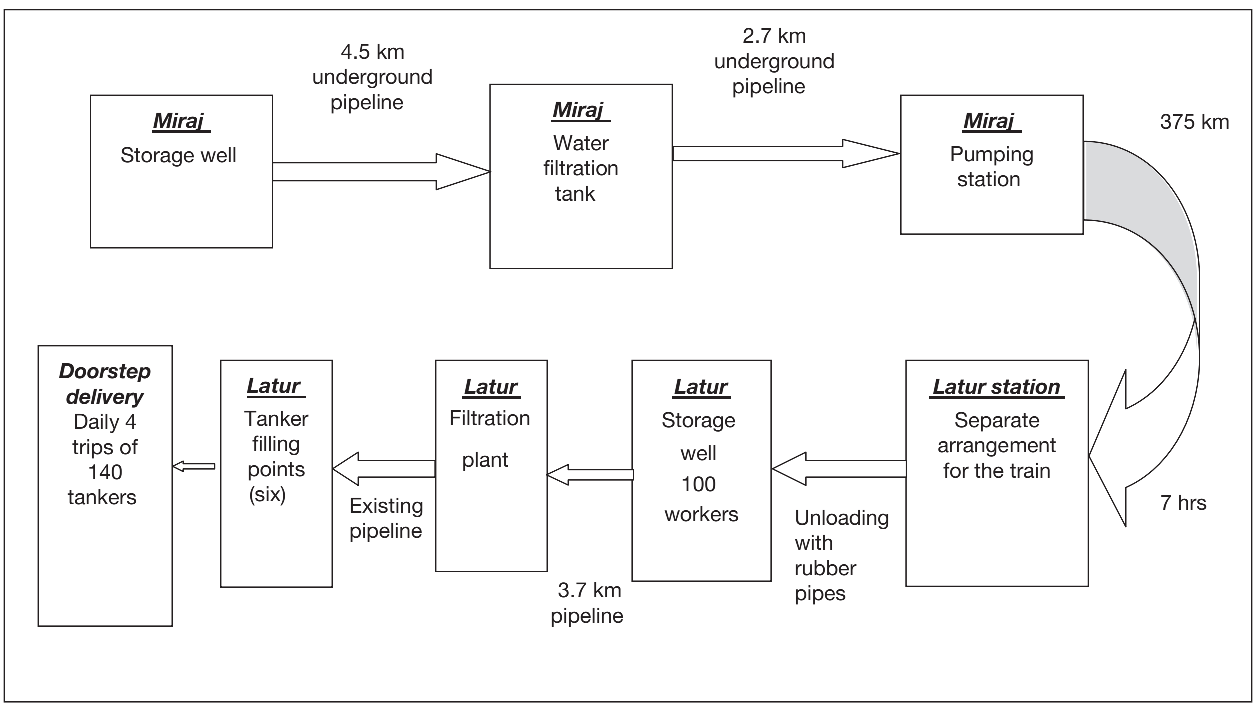


Figure 2: Stages of Jaldoot water supply
(Source: www.latur.gov.in)

Table 3: Tanker Filling Points with Coverage

Sr. No.	Tanker Filling Points	Distance from Filtration Plant	Water Distributed to Ward Numbers
1	Arvi water tank	0.5 km	1, 11, 12, 13, 14, 15
2	Sarasvati Colony	3.5 km	16, 17, 18, 19, 20, 21, 22, 23, 35
3	Gandhi Chowk water tank	3 km	2, 6, 7, 8, 9, 10, 24, 25, 26, 27, 34
4	Nanded road water tank	4 km	3, 4, 5, 28, 29, 30, 31, 32, 33

(Source: Latur city Municipal Corporation)

Receiving Centre: Latur

- Special arrangements were made at the backside of Latur railway station for water train.
- Gravitational pipeline of diameter 450 mm and 500 mm head was laid-down parallel to railway track for receiving water from railway wagons and delivering it to storage well.

Nearest well of Mr. S.R. Deshmukh was used for temporary storage of water. The well was desilted. Plastering is done after fixing the rooster net to the inner side of well. Then Torpolin of 20 micron was spread inside the well. The necessary fabrication work was done inside the well for making pumping arrangement. A new pump house was erected near well. It took three hours for unloading every trip of train and filling water from wagon to well. Initially 108 helpers were used to unload water from wagons, later on it was minimised to 20 after installation of rubber pipes.

- For uplifting the stored water from Deshmukh well to Arvi water treatment plant 12 pumps of capacity 15 BHP were installed. For uplifting of water 350 mm DIK-9 uplift pipe line having length of 3.3 km was laid down.
- After filtration, water was distributed through existing pipeline to four different tanker filling points covering all zones of Latur city.

- Water distribution: The existing water distribution pipeline has around 50–60 per cent leakage; therefore, the decision was taken to distribute water through tankers. For doorstep water distribution Global Positioning System (GPS) enabled water tankers were used. Total 140 tankers were deployed for distribution of water to 35 wards; each tanker did four trips per day. Ten stand posts were erected at every tanker filling centres for speedy filling of tankers. Water cards were distributed to each household for equal water distribution. Other than the single outlet, all inlets of tankers were locked before leaving filling points to avoid chaos situation at the distribution point. Water distribution schedule was displayed on the district website and communicated through local newspapers to all households in advance. Households were intimated by the tanker attendant in advance before the arrival of tankers and told to keep their water cards and containers ready.

Coordination and Controlling

War Room

As per instructions of Honourable Chief Minister of Maharashtra state, War room was established at district head quarter for quick decision-making, coordination, monitoring and for public assistance. The war room was functioning for 24 hours a day and seven days a week from March to September 2016. In every shift, team of eight persons consisting of telephone operator, programmer and other officials were working. The decision-making at war room was simplified and made fast by keeping minimum administrative formalities. The war room was given access to a toll-free number, landline and whats app number for communication. A complaint log book was maintained and token number was given to every registered complaint for future reference purpose. Feedback of every token was recorded in prescribed space of complaint log book. All tanker filling points were monitored from war room by CCTV cameras for 24 hours. IT specialists of war room tracked all tankers by using GPS. Information related to water intake and distribution was regularly updated on Collector office website and communicated to press and electronic media.

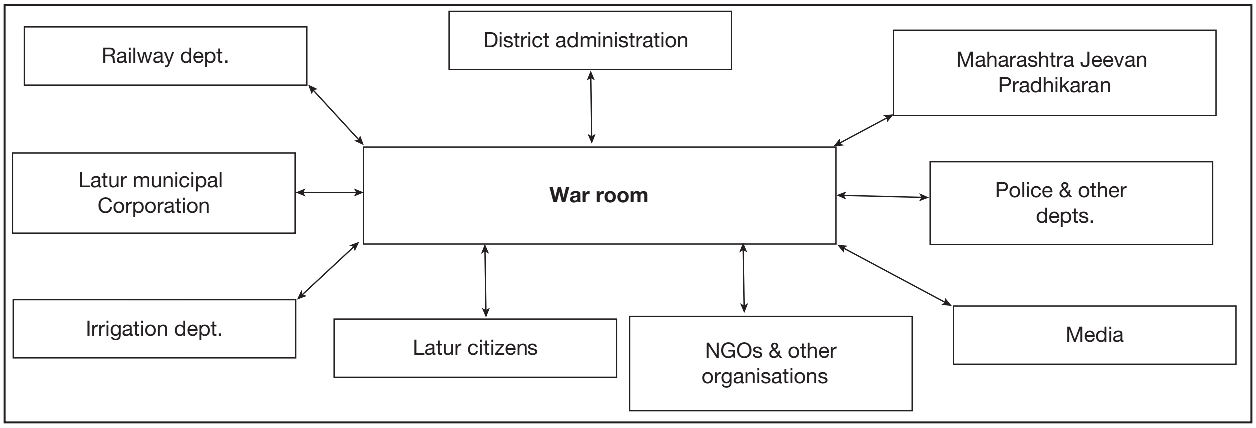


Figure 3: War room communication, coordination and control mechanism

Monitoring System

Latur municipal corporation jurisdictional area was divided into four zones covering all 35 wards for effective monitoring. Each zone was assigned to the officer of Deputy Collector cadre and zonal officers of municipal corporation. CCTV cameras were fixed at every tanker filling points, filtration plant and at railway unloading centre. All tankers were continuously monitored by GPS. A team of Deputy Municipal Commissioner, Tahsildar and Deputy Engineer of MJP was assigned the job of monitoring and assistance at unloading centre. Review of daily work and next day planning were done regularly by officer in charge of the war room. For fair and equal distribution of water, ward officers (appointed by district collector) and guardian officers of Latur Municipal Corporation were assigned to do monitoring at micro level. Feedback was taken from local representative of every ward and households. Priority was given to citizens complaints registered at the war room.

Challenges

- This was first experience for Maharashtra state and second for the nation, therefore set standard operating procedure was not available.
- Availability of resources like trained manpower, equipments and materials was another hurdle for this project. Also, administration had to work simultaneously on other drought-related relief work with same available resources.
- Planning and necessary arrangements were made in very short duration of one week.
- Because of increasing severity of water shortage, citizens were becoming panicked resulting in enormous pressure of public, representatives and media.
- Since the nature of work was very vast and technical, administration had to work on war footing with limited resources in short notice.
- Mobilisation of relief work from government, NGOs and other social organisations without repetition was also a major challenge.

Innovative Practices

- Since this activity was done first time in Maharashtra, all operating procedures were unique and innovative.
- All coordination of the project was done through the war room with minimum errors.
- Monitoring the movement of tankers by using GPS was one of the best practices.
- To avoid overlapping of relief work of NGOs, CBOs and corporate agencies single contact system was implemented. In single contact system the outsourcing of relief work was categorised and then assigned to each approached social organisations on the basis of their expertise, financial capability and area of interest.
- The record of amount of water received and distributed was maintained and updated on

Collector office website on daily basis, which helped in making water distribution system transparent and effective.

- Almost all families of Latur city were issued water cards through ward officers personally for doorstep delivery.

Conclusion

Three years of consecutive droughts dried all nearby surface and underground water sources of Latur region. The water supply by railway wagon was the only feasible solution for providing immediate short-term relief to citizens of Latur. The first Jaldoot Express arrived Latur on April 12, 2016 and its last trip was on June 30, 2016. It did total 111 trips and supplied 2595 lakh litres of water to Latur city for almost three months. Approximately it used to take 35–40 hr to transport water from Miraj water source to doorstep of Latur households (which includes time for transportation from source to storage well, filtration at Miraj, loading, train journey, unloading, filtration at Latur plant and doorstep delivery). The total project cost of delivery of water was approximately Rs. 137.44 crores. The cost of delivering one litre of water from Miraj to the doorstep of Latur household was Rs. 5.29. The cost of unloading and doorstep distribution (work of Latur administration) for one litre of water was Rs. 0.94 only. The doorstep delivery decision was necessary for minimising water wastage and conflicts in the society. Almost all families of Latur received water at their doorstep for three months. Apart from this relief work, the district disaster management team was busy in implementing other drought relief activities such as fodder for live stock, water for rural people, etc. As long-term drought mitigation strategy rainwater harvesting work was done on massive way during the same period. All government officers and public representatives were involved for creating awareness, motivation and guidance. The Collector of Latur randomly visited households of all wards for motivating people for rainwater harvesting. These households were given appreciation certificates and relaxation in property tax for doing rainwater harvesting. Total 4200 households did rainwater harvesting in three months of duration.

Acknowledgements

Though the water supply by railway wagon was first experience for everyone in Maharashtra, that is administration, people, supporting organisation etc.; there were no conflicts or any major social issues. This was possible only because of support of the state government and collective work of administration, railway department, municipal corporations, social organisations, other government departments, media and most important citizens of Latur. The project was completed successfully only because of exceptional leadership of the former Collector of Latur Mr. Pandurang Pole**.** We are thankful to all these people and departments for supporting us and providing necessary information.

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How Long Will We Like a Good Drought? Perspectives and Alternatives to Address Drought in Odisha

Debabrata Patra[a]

ABSTRACT: In 2018, the Odisha Government Special Aid Commissioner (SRC) (SRC Notice No. 8537 and 913631/10/18 and 11/28/2018) announced a drought on 2.57 hectares of cultivated land in 11 western districts of Odisha that they only have scant rain.

A Famine Commission was then formed, the recommendations of which represent an important milestone in Odisha's economic history. The Odisha Famine Commission, which presented its report on April 6, 1867, cited the delays and deficiencies in the adoption of effective measures to contain the disaster and identified the main causes of the drought.

One of the officers charged by the Famine Commission was T. E. Ravenshaw, the provincial commissioner who made a serious mistake in misjudging the state's grain supplies. Harsh Mander says in his article in *The Hindu*, "District authorities in India are still largely guided by updated versions of the famine codes originally developed by colonial administrations.

It is quite ironic that the updated versions of these colonial famine codes remain the primary guide for public authorities in times of natural disasters in free India. However, it is now quite clear that the drought needs a long-term solution and can no longer be considered as inevitable as it was in colonial times, nor can we rely on minimalist measures to combat the drought.

It is now very clear, however, that the drought needs a long-term solution and can no longer be considered as inevitable as it was in colonial times, nor can we rely on minimalist measures to combat the drought. Tribal villages can be self-sufficient in terms of improving their access to land, forests, water and unmanaged forest products through the use of traditional water extraction techniques without compromising ecology.

KEYWORDS: droughts, perspectives, self-sustainability, models, social welfare programme

Introduction

20 years after the publication of P Sainath's book, *Everybody Loves a Good Drought*, the basic and long-term issues pertaining to drought still exist in India. Ironically the first story in the book, among many others, was from Nuapada, Odisha. The question is how long will we continue to like a good drought? And how the menace of drought will continue to loom large on the farmers in rural India?

The frequency of drought has been increasing six droughts in last 20 years (Status of Agriculture in Odisha, Directorate of Agriculture & Food Production, Govt of Odisha, 2009). More and more people are coming into its ambit. In 2018, Special Relief Commissioner (SRC) Government of Odisha (SRC Notification no 8537 &

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9136–31/10/18 and 28/11/2018) announced drought in 2.57 lakh hectares of crop area across eleven western Odisha districts, which received scanty rainfall. As many as 6528 villages under 1373 panchayats of 77 blocks and 18 urban local bodies (ULBs) of nine districts – Baragarh, Bolangir, Deogarh, Jharsuguda, Kalahandi, Nabarangpur, Nuapada, Sambalpur, Deogarh, Nabarangpur and Sundargarh have sustained crop loss of 33 per cent and above due to moisture stress. The monsoon was supposed to be a 'normal' one this year.

Ironically, 2016 marked 150th year of one of the most devastating famines in the history of Odisha – known as the *Na Anka* famine which happened in 1866, killing a third of its population. Subsequently, a Famine Commission was formed and its recommendations constitute an important milestone in the economic history of Odisha. The Odisha Famine Commission which submitted their report on April 6, 1867 attributed the delays and deficiencies in the adoption of effectual measures to check the calamity and listed three main causes for the drought – a. inevitable circumstances, b. peculiarities of the system of administration and c. certain errors and shortcomings on the part of different individual officers. One of the officers who was indicted by the Famine Commission was T.E. Ravenshaw, the commissioner of the province who made a gross mistake in misjudging the stocks of food grain in the state. It will be interesting to note how many of the causes identified in colonial times are still applicable!

Harsh Mander says in his article in The Hindu, 'District authorities in India are still substantially guided by updated versions of Famine Codes that were initially developed by colonial administrators. Their main objective was to save lives at minimal cost to the colonial exchequer. There is considerable irony that updated versions of these colonial Famine Codes continue to be the principal guide to public authorities in times of natural disaster in free India'. However now it is quite clear that drought needs a long-term solution and it can no longer be considered as inevitable as it was deemed in the colonial times neither we can depend on the minimalistic measures to address drought.

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Monsoon and Drought

With the advent of monsoon each year, the issue of drought is pushed into oblivion. But we need to be very clear that it is not entirely the monsoon deficit which causes drought. We hardly use 20 per cent of the water got by monsoon rains says Richard Mohapatra, Managing Editor, Down to Earth in a State consultation on Drought in Odisha in May 2016. What causes drought is our failure to make use of the water given by the monsoon by creating many micro-level water harvesting structures. These structures are much more effective at the local level to provide water and recharge the aquifers. Odisha has been witnessing the paradox of drought. With average rainfall also people start suffering because our entire agricultural systems are not geared to face the drought in a systematic manner. So even with little deficit in rainfall, people are not able to cope with it.

Though Odisha receives an average annual rainfall of the order of 1451.2 mm, there are wide variations from year to year. Less than 1100 mm of rainfall occurred seven times since 1951—in 1965, 1974, 1976, 1979, 1987, 1996 and 2002. All these are marked as severe droughts years, wherein the drought caused considerable reduction in kharif rice production. This suggests that there is at least one severe drought year in every decade, thus underlining a high degree of vulnerability of the state to drought. Odisha has faced drought in most of the years in the latter half of the 1990s. During 1996–97, all districts (except Koraput and Malkangiri) were affected by drought. The drought was so severe that more than 50 per cent villages in the state had crop loss of 50 per cent or more. The drought situation in 1997–98 was less severe, but the severity increased thereafter. The severely drought-affected districts in the state during the period were: Boudh, Jharsuguda, Balangir, Sambalpur, Bargarh, Nuapada, Sonepur and Sundargarh in the western part of Odisha; Balasore, Jajpur, Nayagarh and Khurda in the eastern part; Koraput and Malkangiri in the southern part; Mayurbhanj in the northern; and Dhenkanal and Angul in the central part. More than half of villages in these districts had crop loss of 50 per cent or more.

The nominal forest cover remained constant at around 30 per cent, but the effective forest cover dwindled to less than 17 per cent. This is due to the unchecked degradation of forest cover. This has resulted in a decrease in the closed forest area (as per cent of total forest area) from 77 per cent during 1972–75 to 30 per cent by 1996. At the level of districts, it is only in the districts of Mayurbhanj and Kandhamal that the effective forest cover has remained at around 30 per cent. Increased degradation of forests has resulted in increased vulnerability to droughts and floods. The land is more prone to droughts due to the increased moisture stress as a result of more rapid run-off of rainwater (Odisha State Human Development Report 2004).

In addition the irrigation potential of the state has not yet fully realised even though the state government is spending a lot on water resources department which consumes the lion's share (Rs 16,765 crores in 2018–19) of the budget given for agriculture. The water sources available (11 per cent of country's water resources with 3.81 per cent of the share of cultivable land) in the state could have been used to irrigate much more lands as NABARD opines that agricultural production and productivity in Odisha are low as assured irrigation, a critical input to achieve such ends, is not adequately available in the state. The state has 61.8 lakh hectares of cultivable land, of which 57.74 lakh hectares could be brought under irrigation with available water resources.

Status of Social Security and Employment Guarantee Programmes and Drought

A primary drought assessment done by ActionAid in 38 villages (covering districts of Bargarh, Kandhamal, Sundergarh, Ganjam, Bolangir, Koraput and Nuapada) in Odisha in May 2016 showed that about 57 per cent of the ponds and *bandhas* created by MGNREGA have failed to work because the structures were badly planned with the inlets and outlets damaged. An estimate by Down to Earth (1–15, May 2016) says 12.3 million water conservation structures have been created under MGNREGA. And it comes 21 structures per villages. India's drought-related expenditure since independence is Rs. 3.5 lakh crores and 64 per cent of the total expenditure under MGNREGA was on agriculture and agriculture-related works. From its inception in 2006 to March 2016, the government has spent over Rs. 3 lakh crore on MGNREGA.

The ActionAid study further says that, 70 per cent of the required food is not there for the drought-affected families since many of them have not received the ration since February 2016. Thus the government programmes which were meant to provide employment, protection against shortfall of food grains needs to be very effective to provide a safety net during the drought. MGNREGA has failed to check migration due to lack of work opportunity and delayed payment. Roughly 20 per cent people have migrated in the villages surveyed. These social security programmes provide much relieved succour at the times of drought. Although government has announced 150 days of employment under MGNREGA, hardly 1 per cent of the people surveyed in the village have got 150 days of employment. The drought package announced by state government and the Supreme Court (SC) orders on drought (May 2016) could provide good support to the communities in times of drought. Unfortunately not many in the villages are aware about these packages and SC announcements.

With regard to the effectiveness of the social security schemes, the drought assessment report of ActionAid revealed the following:

- 12 per cent households didn't receive food grains through PDS since February 2016 in Ganjam and April 2016 in Kandhmal respectively because of the confusion created by the distribution/non-distribution of new ration cards. All these created severe food crisis.
- Though Anganwadi centres were functional during the drought period, children were not provided with additional eggs and milk as per Supreme Court order. In 34 per cent villages the Anganwadi centre is located within the distance of about 1–3 km and it was difficult for the children to travel such a long distance and collect food.
- 70 per cent families obtained loan from money lender at the interest rate that ranges from 36 to 40 per cent to meet the food need and other essentials.

Impact of Drought on Children: Case for an AWC

Village Andhari in Pandripada GP of Polasra block in Ganjam district is a small village of 45 families, all belonging to poor tribal community. Situated in forest land and hills, the village has no good communication facility. All the households of the village depend on agriculture for their livelihood. The villagers live their lives, barely producing enough food grains to support them for the whole of the year. Without an effective irrigation facility, the villagers have to live on the mercy of the monsoon rains for farming and good harvest. However, scanty rainfall in the last kharif season has been causing them untold misery with a host of problems like food insecurity, water crisis, borrowing, migration and pressure and distress on women and children. There is an Anganwadi centre at Pantiama, about 3 km away from the village to which 25 children go to attend. In the post-drought situation, severe heat condition has been prevailing in village with very little drinking water. It is obviously not advisable that such small children should go to the distant AWC walking under the sun when there is small amount of water available for them to drink as the community is facing the shortage of drinking water. Unfortunately, the AWC there does not provide more food meant to be provided during drought. Again, there are so many irregularities to which the community could not monitor properly. In this context, the community demands a new AWC at the village. In such case the children could be provided services at their own village and get the parental care. The villagers would also monitor the AWC in their own village more carefully.

Status of Agriculture, Landholding and Forest Produce and Its Relation to Drought

Another key thing in view of the impending drought is the selection of the type of crops which needs to be used in a drought scenario. With exception of millets, farmers have lost 40–70 per cent of the paddy cultivation. As a result, farmers do not have adequate seeds for the next crop even if there is adequate monsoon this year. Apart from this forest produces also sustain the drought-affected families although decline in forest produce is never taken into account while calculating drought loss. Drought also hits the landless the most because work in the village dries up and he is forced to migrate. A patch of land would enable one to cultivate something at least vegetables where there are water sources. There are examples of landless women forming collectives (not registered cooperatives but informal groups) in Sundergarh have taken land on lease and cultivated vegetables which provided not only some extra money but also gave extra nutrition to the family. This availability of adequate nutrition is extremely important as during the drought there is drastic reduction of nutrition levels of women and children.

The landholding pattern of the state is extremely skewed. In southern Odisha, 87 per cent tribals are living under poverty line. State holds 3/4th of land and 20 per cent households are landless. Invariably access to commons lands and water sources is enjoyed by upper caste landed households. This means during a drought the landless families will be in debt and migrate to other states. Money lenders always take as this an opportunity to invest money for loan at higher rate of interest (it reaches 36 per cent per annum) and there are no preventive measures by the local administration.

Supreme Court (SC) Order on Drought in May 2016

In response to a PIL filed by Swaraj Abhiyaan, the honourable Supreme Court reprimanded the states of Haryana, Gujarat and Bihar of not reporting drought in time, let alone taking remedial measures to help the affected. The SC order said – 'An ostrich-like attitude is a pity, particularly since the persons affected by a possible drought-like situation usually belong to the most vulnerable sections of society. The sound of silence coming from these States subjects the vulnerable to further distress... The failure of these States to declare a drought (if indeed that is necessary) effectively deprives the weak in the State the assistance that they need to live a life of dignity as guaranteed under Article 21 of the Constitution'. The court observed that there was no national plan to face the disaster as mandated under the Disaster Management Act, 2005. Although, the DM Act has been in force for more than 10 years, the National Disaster Mitigation Fund has not yet been constituted. The court therefore observed, 'Evidently, anticipating a disaster such as a drought is not yet in the "things to do" list of the Union of India and ad hoc measures and knee jerk reactions are the order of the day and will continue to be so until the provisions of the Disaster Management Act are faithfully implemented'.

SC directed the government to draw up a National Plan on Disaster, National Disaster Mitigation Fund (within three months of judgement) constitute National Disaster Response Force (within six months of judgement) and revise drought management plan by December 31, 2016. SC also directed the government to ensure timely declaration of drought by considering all the parameter especially rainfall, areas sown, normalised difference vegetation index and moisture adequacy index. SC also insisted on the use of modern technology to make an early determination of a drought or a drought-like situation. There is no need to continue with colonial methods and manuals that follow a colonial legacy. In the end SC directed government to focus on prevention and preparedness and mitigation of a disaster like drought. SC said 'Innovative methods of water conservation, saving and utilisation (including ground water) should be seriously considered and the experts in the field should be associated in the exercise'.

Is Farm Loan Waiver Way Out?

Loan waivers are increasingly becoming more popular to deal with agrarian crisis. However without infrastructure investment and without understanding the social structure of Indian agriculture, farm loan waivers do not work except in short-term and few privileged sections. The tenant farmers who form the majority (at least 80 per cent) in sector of agriculture can't get access to these waivers since land is not in their names. Kerala is the only state that has a tenancy law in place with an implementation mechanism. Data on farmer suicides also confirm that they occur more among tenant farm holders and small and marginal land owners growing cash crops like cotton, than food or horticulture crops.

Union government data on the indebtedness of agricultural households according to land size (extracted from bank statistics) shows that the average outstanding loan of the smallest farmers owning less than one hectare is one-tenth that of farmers owning 10 hectares or more. It is also one-sixth and one-fourth the size of loans of farmers having 4 to 10 hectares and 2 to 4 hectares respectively.

Contrary to popular belief, small and marginal farmers and agricultural labourers rarely access institutional credit. Moneylenders account for 36 per cent of agricultural credit at usurious rates of 24–48 per cent (All India Debt and Investment Survey, ICRIER Working Paper No. 302).

Owing to fragmentation of land, the area operated by small and marginal farmers has increased from 19 per cent to 45 per cent of total cropped area in the last 50 years (1961–2011). This would mean that persons of small means and very low capacity to invest in technology and modern practices are engaged in agriculture.

A universal loan waiver will be through the banking channel where most loans are not taken by small and marginal farmers but by bigger farmers and if at all, the loans taken by the bigger farmers but shown against the names of small and marginal farmers. So instead of settling the loan with the bank, it is better to give the support amount per household to the bottom 70 per cent of rural households by Direct Benefit Transfer (DBT). Currently, agricultural households owe an average of Rs 47,000 borrowed from moneylenders. Along with the DBT transfer, the government should recognise the importance of moneylenders in the agricultural economy where timely credit, even though small, is important and weak collateral recognition is critical to extending succour to small and marginal farmers.

The Case of Hiralal: Faulty Crop Selection, Lack of Irrigation, Bad Loans and Failure of Welfare Measures

Hiralal Sahu, age-55, lived in Nuapara (Dhenkimunda) village under Kansada Gram Panchayat of Paikmal block of Bargarh district. He killed himself by consuming poison on October 9, 2015. The district administration reported that he has lost his life due to family disturbance not for crop failure and loan burden. When the fact finding team reached the village, people were cutting the paddy crop at their respective fields. Crops harvest seemed all right. We thought that there is no drought in this village. We asked the people about this, later we realised that our perception was wrong. A few acres of land are getting water from the nearby Minor Irrigation Project. However, majority agriculture fields of the village are depending upon torrential rain for its crop growing. We asked about the cotton cultivation. Cotton crop cultivation was initiated only 4/5 years back in Dhenkimunda village. More than 20 farmers of the village are doing cotton cultivation. It needs 5000 to 6000 of rupees per acre for its cultivation cost. It also requires two to three types of chemical fertilisers and vitamin dosages. An agro business man of village Bhutamunda had encouraged the farmers and provided all sorts of support for cotton cultivation. Now the farmers are depending upon him for cotton farming. A few of them are investing their own money. Previously people were cultivating black gram, green gram, yellow gram like pulses in these fields, now it is covered with cotton crops.

Bedamati, wife of late Hiralal, has two daughters and one son. Last year, her elder daughter has got married and another daughter is a person with disability – deaf and dumb. Only son is working in a cloth factory in Gujarat since last 5 years. There are 20 acres of land (upland requiring irrigation) in the name of Hiralal. Hiralal harvested 150 packets of paddy from it in 2014. In 2015, he had cultivated paddy in 6/7 acres, black gram in two acres, cotton in one acre of land, only. Due to lack of rain, all the crops were ruined. He had borrowed money from a person of Patharel village for cotton cultivation. The farmers of the village gheraoed and locked the irrigation office for one month because of interruption in water supply.

After Hiralal's suicide, Tahasildar, Block Development Officer and Inspector-Charge of Paikmal came to his house and asked about the matter to her wife Bedamati. Two thousand rupees was given to her from the Gram Panchayat office for cremation purpose. Hiralal had borrowed money from different sources – From Utkal Gramya Bank – Rs 63,000/-, from NFBI-SKS (microfinance group) Rs 15,000/-, from SHG Rs 18,200/-. Last year, during his daughter's marriage he had mortgaged his land and got a loan of Rs 1.5 lakhs. Two years back, Hiralal had obtained one second hand Power Tiller with his cousin brother's partnership, now it is nonfunctional but Rs 30,000/- have paid back to the moneylender.

According to Hiralal's wife, Bedamati, 'they were in right track, before 3/4 years and they did not have loan'. But Hiralal suffered Jaundice and admitted at hospital for 15 days and had to spend thousands of rupees. From then Hiralal's health was not in normal condition. Bank and cooperative society loan for the farmers are not available in this region so the farmers have been have accessing it from the private moneylenders with 10 per cent interest per month. It is the root cause of exploitation to the farmers. The land is in joint Patta in families so the farmers cannot obtain loan from the banks and the cooperative societies or sell it.

Hiralal's is a classic case where all that ails Indian agriculture sector is highlighted – faulty crop selection – cotton, lack of irrigation – 20 acres of land but no irrigation, bad loans – with high rates of interest from the moneylender and failure of welfare measures including health which is tormenting the Indian farmers so much that they are forced to take the extreme step or leave the sector and migrate.

Alternatives and Way Out: Long-term Measures

As rightly pointed out by Odisha State Human Development Report 2004, crop insurance is only a short-term solution after the event has occurred and it is important to think of long-term measures against drought. These could include, inter alia, soil and water conservation measures, in a participatory mode, in all the watersheds. Massive afforestation and community forest management, changes in the cropping patterns in terms of adopting drought resilient traditional millet-based agricultural practices would also be necessary for providing financial sustainability to the agricultural sector. In the areas in which I visited in Kandhamal, millets and mixed cropping saved the day for the tribal communities there. An agricultural field in Kandhamal full of fruit trees laden with mangoes, lemon and vegetables was a sight to behold even in this drought. Women collectives practicing climate resilient millet and vegetable cultivation have escaped the drought menace. Even in this drought some farmers in Kandhamal have reported good produce of Sorghum and other millets. Pagarpadi village in Tumudibandh Block of Kandhamal had cultivated oil seeds two to seven species; legumes/pulses 12 to 39 species; paddy two to five varieties and millets 6 to 10 varieties. 25 kutiakandh households of this village has got good yield from Sorghum cultivation. Low input climate resilient agriculture is thus the need of the hour.

Sorghum (a variety of little millet) was found as the most drought resilient crop which gave good yield even in the extreme drought condition. The tribal farmers of Kandhamal have been practicing mostly millet-based mixed farming system with low input cost. During the extreme weather conditions, these crops found to be climate resilient and relatively gave good yield than paddy. The tribal farmers are still doing cultivation for food. The cultivation has not been influenced by the present market economy of large-scale production. 789 farmers in Tumudibandh of Kandhamal have been cultivating 26 types of millets and 39 types of pulses, 7 types of oil seeds, 5 types of paddy in 582 acres of land. 325 farmers of 20 villages have been working on maintaining purity in 16 types of millets to ensure 90–95 per cent germination. This has helped the farmers in getting good yield in the traditional farming process. The chances of cross pollination in millets are relatively less than paddy. The farmers are conserving the seeds by maintaining purity and application of organic manures, pesticides and insecticides like Jibamruta, bijamruta, panchagabya, general compost, vermin compost, nimashtra, brahmashtra. The farmers can be supported further to shift from physical purity to genetic purity. Since pure varieties of millet seeds were used hence the germination was good and the extent of loss in the present drought situation was very less.

Supporting community to have increased access to uncultivated forest produces in terms of facilitating recognition community rights over forest resources under FRA would help community in mitigating drought situation. 13 kutia kandh villages in Kandhamal have received title for their rights over 3250 acres of community forest under Forest Rights Act and also they are in the process to develop community forest management plan. Recognition of rights has strengthened the community in accessing the uncultivated forest produces and that has supported the community in meeting food scarcity during the drought situation.

There is a bright example of the community action by a primitive tribal community towards conservation of rain water in terms of using their indigenous knowledge, skill and local resources. 18 Paudi Bhuyan households of Kiri Village in Sundergarh district have constructed small check dam using the local resources and made available of water for irrigation to 36 acres of land.

The drought code needs to be changed to suit the present conditions. As rightly pointed out the Supreme Court in its recent orders on drought in May 2016 the Government of India must insist on the use of modern technology to make an early determination of a drought or a drought-like situation. There is no need to continue with colonial methods and manuals that follow a colonial legacy. It is high time that state governments realise the vast potential of technology and the Government of India should insist on the use of such technology in preparing uniform State Management Plans for a disaster.

As women and children, landless families, marginal farmers are the ones who are most affected by the drought, these groups should be given the special facilities under social welfare programmes.

Very briefly, if we could give agricultural land to women and landless with small water harvesting structures around their fields and encourage them to practice climate resilient agriculture then perhaps we will not see this severity of drought. It may be wishful thinking but unless we do that, we will inevitably face drought with increasing intensity.

Apart from the above, the following alternative measures are suggested to mitigate the impact of drought.

Prioritise the Need of Disadvantaged Community: The drought mitigation measures should take into consideration the caste and social dynamics prevalent in the villages. The people in dire need and the poorest need to be identified and reached out first as an effective way to reduce the vulnerabilities of the disadvantaged community.

Support the Small and Marginal Farmers: The small and marginal farmers and share croppers are found to be the most disadvantaged groups. Hence there should be timely support of agricultural inputs, long-term credit facility and assured irrigation to meet the drought situation.

Strengthen Collective Farming and Ensure Land to Landless: Provide incentive to the women collective and farmers engaged in millet-based mixed cropping and drought resilient crops, and maintaining of seed varieties and seed purities. Single women should be provided with land, input supports and credit facility for collective farming. Provide land to the landless and ensure physical possession of land. And support them further with agriculture input, long-term credit support.

Drought Response and Accountabilities of the State: The state government needs to strengthen the existing mechanism and undertaken immediate assessment of the drought by enhancing its forecasting procedure and using the technology. Along with this the drought declaration and action need to be taken immediately and proactively by releasing the fund for quick action in the ground.

Conclusion

As women and children, landless families, marginal farmers are the ones who are most affected by the drought, these groups should be given the special facilities under social welfare programmes. The tribal villages can be made self-sustainable in terms of increasing their access to land, forest, water and uncultivated forest produces by using the traditional water harvesting techniques without harming the ecology. Along with this revival of ecological farming, millet-based mixed faming system and community efforts for conservation and promotion of traditional varieties of seeds are vital in ensuing food sovereignty of the community.

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PART II HUMAN-INDUCED DISASTERS

VI Climate Change

Hydrological and Ecological Impacts of Land Use/Land Cover and Climate Change to Mitigate Extreme/Disaster Events in the Western Ghats River Basin, India

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ABSTRACT: In this study, the hydrological response of land use/land cover (LULC) and climate change under the historical and future time period is investigated. Here we assessed and compared the streamflow for historical (1981–2000) and future (2060–2080) using Soil and Water Assessment Tool (SWAT) model for the historical (1988) and future (2075) LULC at the sub-basin scale of Kadalundi river basin which was highly affected during 2018 flood in Kerala. The LULC maps for 1988 are derived from Landsat images and 2075 LULC was projected using land change modeller to identify transitions from the first LULC to second. The future climatic parameters were derived from five general circulation models for the representative concentration pathway (RCP) 8.5 emission scenarios. The hydrologic model was calibrated for the period from 1981 to 1990 and validated from 1991 to 2000 using monthly streamflow data. The results showed mainly increases in urbanisation and agriculture, and a decrease in the forest, grassland, from 1988 to 2075 LULC. The results indicated that under the same condition of soil texture and terrain slope for streamflow and the sensitivity of rainfall-runoff relationship to rainfall increased by urbanisation, agriculture and decreased by forests and grassland and it would continue impacting negatively in future. The combined impacts of LULC and climate show streamflow decreases because of mainly decrease in rainfall and climate change. Planners and policy makers can use these results to mitigate the negative effects in the river basin.

KEYWORDS: LULC, climate change, streamflow, SWAT, hydrology

Introduction

Flooding is the most common ecological and natural disaster in India from the last two decades such as 2005 Mumbai, 2015 Chennai, 2016 Assam, 2017 Gujarat and now 2018 in Kerala. It is important to understand the impacts of future climate change in addition to the current management by taking into account future LULC change on hydrological responses. The rapid LULC change, such as extensive agriculture expansion, deforestation, unplanned urbanisation and population growth, particularly in a developed country like India, has been a major challenge, for water resource management. LULC change alters basin hydrology by affecting surface runoff, evapotranspiration, soil erosion, soil infiltration capacity and water quality of the basin. In addition, climate change is another major issue in recent decades which is considered as

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a critical factor and additional challenge in present water resource management. The climate change and human activities affect precipitation, extreme events (flood and drought), annual, seasonal and monthly streamflow and ET which can significantly impact the regional hydrology at the river basin scale. The IPCC AR5 report stated that extreme rainfall events during the Indian summer monsoon are expected to increase and floods are likely to increase in the future. In this regard, many researchers have published their works related to impacts of LULC and climate change such as Kim et al. (2013), Wilson and Weng (2011) on streamflow. Many studies also reported the effects of only future climate change on hydrology such as Zhang et al. (2007), Zuo et al. (2016). Furthermore, some studies reported on future LULC impacts but consider only one area like urbanisation (Wagner et al. 2016; Wilson and Weng 2011). However, the combined impacts of LULC and climate change and its comparison to future LULC and climate change results simulation on surface runoff need to be investigated. Modelling the effects of past and future LULC and climate change on hydrology in the river basin may be useful for management of water resource and extreme events (floods and droughts) in the area which may help to the management of same at a sub-basin level.

Within the above framework, the main objectives of this study are to assess and compare the historical (1988) and projected future LULC (2075) and climate change (2060–2080) under RCP 8.5 emission scenario on streamflow for Kadalundi river basin, Western Ghats, India. Five different GCMs are used after ensemble for assessment of climate change for the future time period (2060–2080). The Kadalundi river basin situated in the Western Ghats of India is one of the highly affected river basins during the 2018 flood of Kerala. In addition, Western Ghats is global hotspot region due to the biodiversity and presence of a variety of species (Myers, 2000). In this study, the open source, semi-distributed hydrological model SWAT is used for computing the impacts of LULC and climate change on streamflow and SWAT-CUP with Sequential Uncertainty Fitting algorithm (SUFI-2) is used for calibration, validation and sensitivity analysis on a river sub-basin scale.

Study Area and Data

The Kadalundi river basin (KRB) is situated in the Western Ghats region of India as shown in Fig. 1. The basin has approximately 1106 km^2 area and lies between latitude 10.54°–11.12° N and longitude 75.50° –76.24° E. The highly undulated topography and rainfall variation lead to a different climatic zone within the river basin. The different climatic zone of river basin partly dictates suitable area for the presence of certain vegetation and crops. The elevation varies from 0 m to 1289 m. The basin is characterised by mountain ranges, valleys and steep slopes. The climate of the basin is dominated by north-west monsoon and tropical climate with the majority of the rain (more than 80 per cent) falling during monsoon season (June to September). The movements of the Inter-Tropical Convergent Zone (ICTZ) also affect the climate in this river basin. The average annual precipitation of the basin is 2525 mm during past 40 years. As per the Food and Agricultural Organisation (FAO) soil classification system, the soil types include sandy clay loam and clay loam. The main land use categories are forest and grassland; hilly region and plantation, agriculture; villages and small towns dominated across the river channel. The major crops in the basin include paddy, pulses and coconuts. For simulation of the SWAT model, digital elevation model (DEM) from Cartosat, LULC from Landsat, soil data from Food and Agricultural Organisation (FAO) and climatic data from Indian Meteorological Department (IMD) are used. The streamflow data is collected from the Central Water Commission of India.

For estimation of future runoff, climatic data for future time period namely precipitation, minimum and maximum temperature were collected from Coordinated Regional Downscaled Experiment South Asia group (http://cccr.tropmet.res.in/cordex/files/downloads.jsp) for five Coupled Model Inter comparison Project 5 (CMIP5) using general circulation model (GCM) simulation in daily time steps.

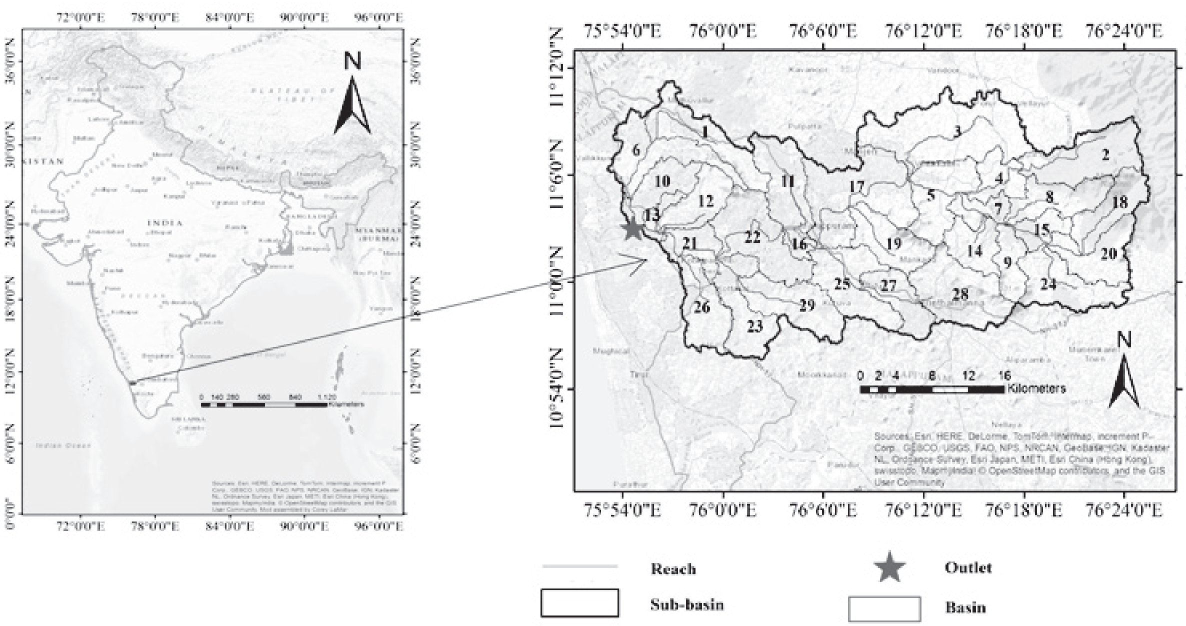

Figure 1: Location of study area and division of sub-basin of KRB

Methodology

SWAT Model

A physically based and open source SWAT hydrological model which is coupled with ArcGIS was used for simulating the streamflow at sub-basin scale in this study. The SWAT model is developed for simulating ungauged and particularly has limited data in the river basin scale (Arnold et al. 1998). It is also used for assessing the impact of LULC and climate change on streamflow and sediment yields, pesticides, nitrate and phosphate load in the channel by different researchers (Zuo et al. 2016). The SWAT model includes large uncertainty in calibration from inputs and observed data. SWAT-Calibration and Uncertainty Program with Sequential and Uncertainty Fitting (SUFI-2) algorithm was used for calibration because of its simplicity and effectiveness (Arnold et al. 2012). The SWAT model divides the river into first sub-basins and further Hydrological Response Units (HRUs) on the basis of uniqueness of terrain, LULC and soil types. The soil conservation service (SCS) curve number (CN) method is used for computing surface runoff (Arnold et al. 1998) on the basis of the soil hydrological groups, antecedent soil moisture and LULC characteristics. The details of theoretical documentation of SWAT model are given in website (https://swat.tamu.edu/documentation/).

Classification and Future Projection of LULC

The historical LULC for 1988 was collected from Landsat image and corrected atmospheric interference by using the dark-object subtraction method before classification. The Landsat images were collected post-monsoon season (October to January) and cloud free for 1988 LULC. The supervised image classification with maximum likelihood technique was used because of its strength. There are mainly six land use classes of the forest, agriculture, plantation, grassland, urban and water body in the river basin. The overall accuracy and kappa coefficient (κ) in the ranges of 88 per cent and 0.82, respectively, are normally acceptable. For the assessment of future streamflow due to future LULC change, 2075 LULC were projected. A Land Change Modeler (LCM) was used for projection of LULC which is incorporated within Idrisi's software.

GCM Climate Data and Preprocessing

The direct use of GCM data which is available on coarser resolution (generally 2.5° × 2.5°) for climate variables which is significantly affecting hydrological impact assessments is not acceptable at the regional scale and needs to downscale. In this study, the GCM data (simulated) were bias corrected using the IMD gridded data (observed) at a daily timescale for rainfall and temperature by a quantile-based method (Li et al. 2010). The quantile-based remapping approach provided fairly accurate results with satisfactory statistical properties of observed and simulated (GCM) time series.

Calibration and Validation of the SWAT Model

The sensitive parameters were evaluated for streamflow before calibration of SWAT model for the period of 1991 to 2000 (10 years) at river gauge station which is located in sub-basin number 22 (Fig. 1a). The same simulation setup was used in the validation of streamflow for another 10 years (2001 to 2010) after calibration. All simulated data were collected and converted in daily to monthly time step for the assessment of LULC and climate change in the river basin. Latin Hypercube (LH) One Factor at a Time approach which is incorporated within SUFI-2 was used to identify the sensitive parameters. The performance of the model for simulating streamflow was evaluated by the Nash-Sutcliffe coefficient (NS), the coefficient of determination (R^2) and per cent bias (PBIAS).

Results and Discussion

LULC Change for 1988 and 2075

The spatial distribution of different LULC for 1988 and 2075 maps is presented in Fig. 2, and LULC area and percentage growth are listed in Table 1. Forest, plantation and grassland areas were decreased and agriculture and urban area were increased from 1988 to 2075. Urban and agriculture areas increased from 4.84 per cent to 12.70 per cent and 10.19 per cent to 43.08 per cent respectively whereas forest, grassland and water bodies will be decreased from 38.01 per cent to 17.24 per cent, 28.91 per cent to 7.26 per cent, and 2.01 per cent to 1.42 per cent respectively from 1988 to 2075, probably because of the conversion of grassland areas into agriculture and urban and forest areas into agriculture and plantation. Thus, the sequence of conversion of land use was identified as forest to plantation and grassland to agriculture to urban. The maximum positive percentage growth was found in the agriculture (322.77 per cent), followed by urban and plantation by 162.40 per cent and 13.93 per cent respectively.

In contrast, the maximum negative growth occurred in the grassland (74.89 per cent), forest (54.64 per cent), and water bodies (29.35 per cent). The results indicate that the expansion of mostly agriculture and urbanisation in the KRB will lead to land degradation, potentially affecting streamflow in the future. In addition, it indicates that previous land degradation will lead the local people to reforestation to manage with the dearth of fuel wood and wood for other uses.

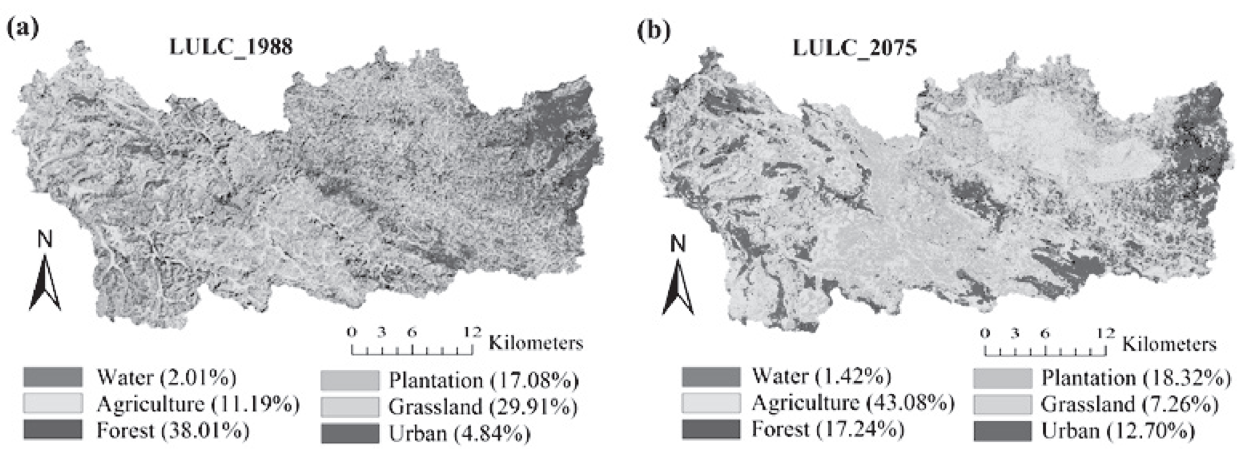

Figure 2: Classified maps for 1988 (a) and projected map of 2075 (b) of the Kadalundi river basin

Table 1: Area (Km²) and Overall Amount of Change (per cent) in LULC of Study Area over the Period of 1988–2075

LULC Type	1988 (Km²)	% of Study Area	2075 (Km²)	% of Study Area	Amount of Change (Km²)	Percentage Growth
Water	22.23	2.01	15.71	1.42	-6.53	-29.35
Agriculture	112.70	10.19	476.46	43.08	363.76	322.77
Forest	420.39	38.01	190.67	17.24	-229.72	-54.64
Plantation	177.84	16.08	202.62	18.32	24.77	13.93
Grassland	319.74	28.91	80.30	7.26	-239.45	-74.89
Urban	53.53	4.84	140.46	12.70	86.93	162.40
Total	1106	100	1106	100		

Calibration and Validation of the SWAT Model

The most sensitive parameters adjusted during calibration of the SWAT model for streamflow were SCS-CN, followed by the deep aquifer percolation factor (RCHRG_DP), available water capacity of soil layer (SOL_AWC) and other parameters. For streamflow, the parameters related to base flow and surface runoff have almost equal sensitivity. The SWAT model was calibrated spatially at gauging station in sub-basin 22 for streamflow. The comparisons between observed and simulated scattered plot for monthly streamflow during the period of calibration (01/01/1991–12/31/2000) and validation 01/01/2001–12/31/2010) are presented in Fig.3. The R^2 and E_{NS} values for streamflow were greater than 0.65, and the PBIAS values were ±20 per cent for both calibration and validation periods, suggesting a favourable model performance (Moriasi et al. 2007). In the VRB, rainfall events often persist in short duration with high intensity.

Overall the reliability between the results simulated by the model and the observed values as well as their R^2, E_{NS} and PBIAS values indicated that the model performed well for a monthly time scale.

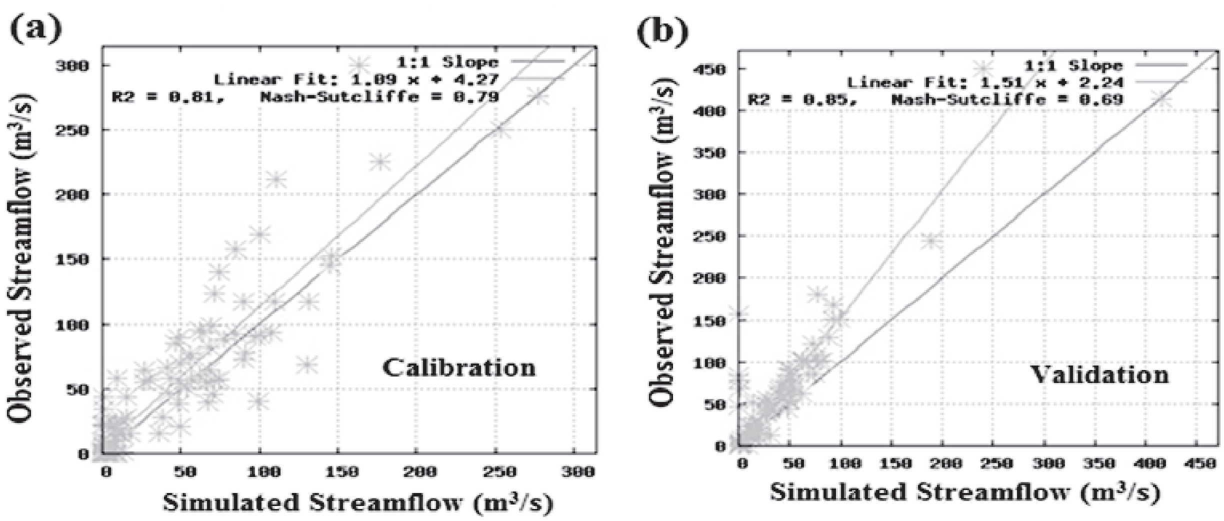

Figure 3: Scattered plots between the observed and simulated monthly streamflow values for the calibration (a) and validation period (b)

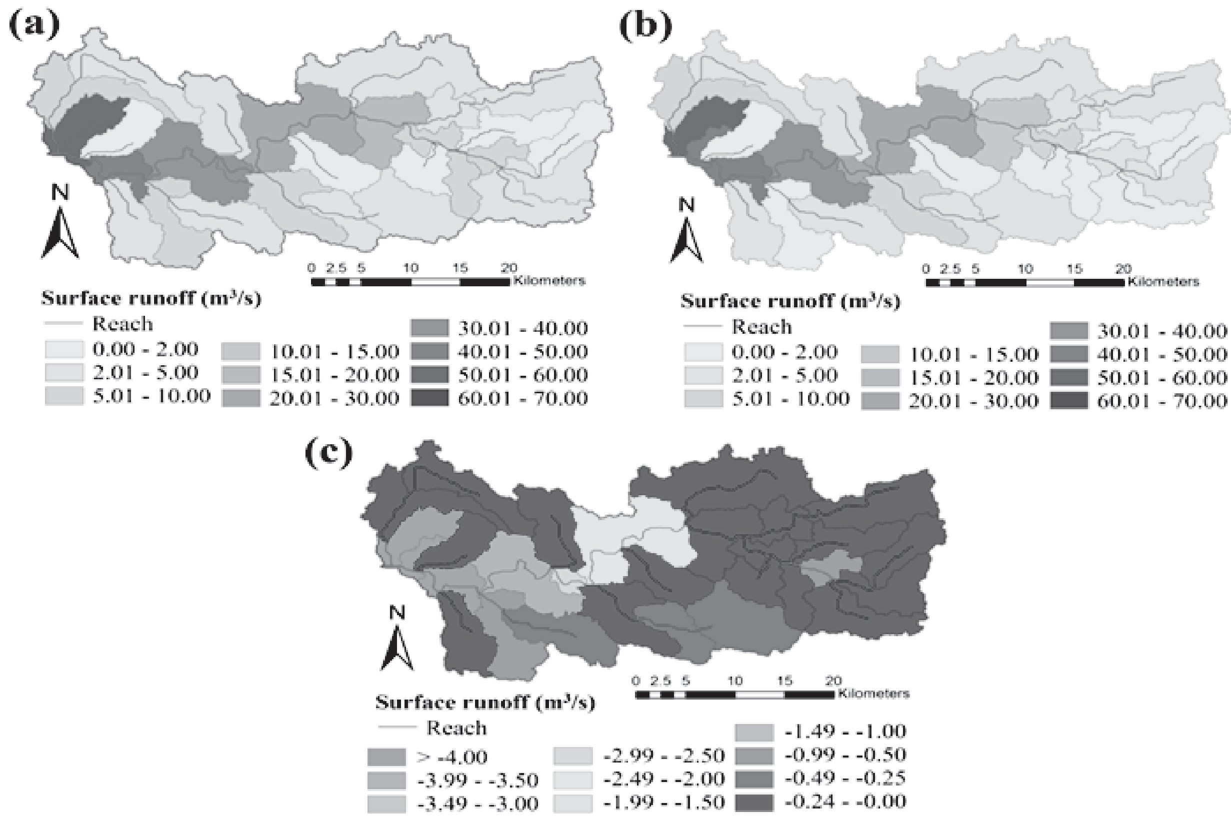

Figure 4: Spatial distribution of actual streamflow in m^3/s (a) for LULC 1988 and climate 1981–2010, (b) for LULC 2075 and climate 2060–2080 and (c) change in streamflow

Impacts of Historical and Projected Climate and LULC Change on Streamflow

Figure 4 illustrates the spatial distribution of the mean monthly change in the surface runoff under the LULC and climate change under RCP 8.5 emission scenario. The results showed that the surface runoff would decrease by 9.11 per cent in RCP 8.5. The spatial distribution of the change in surface runoff (Fig. 4a and b) under 8.5 emission scenarios indicated that the streamflow would mainly decrease in the downstream region of the basin. This may be because more LULC changes were expected to occur in the downstream region and lower annual precipitation was expected under RCP 8.5. Figure 4c indicated the change in streamflow due to climate and LULC change which indicated most of the basin showing decreasing surface runoff and mainly along the river channel of the basin. At a sub-basin scale, the proportions of changes for agricultural and urban land use were positively correlated, whereas those for forests, grasslands and bare land were negatively correlated. Sinha and Eldho (2018) reported that an increase in the agriculture area and a decrease in the forest area may increase the surface runoff in the Netravati river basin, India. The projection of the streamflow changes in the basin strongly depends on the trend of projected climatic changes (e.g. precipitation and temperature). These results suggest that planners should consider both LULC and climate change on the streamflow when planning water resource management.

Conclusion

In this study, the impacts of LULC and climate change are investigated on streamflow of Kadalundi river basin using SWAT hydrological model. The results indicated that the major changes in LULC that affected surface runoff were an expansion of agriculture and urban area and decline of forest and grassland area from 1988 to 2075. From the analysis, it can be concluded that agricultural area is directly linked to the surface runoff. However, the decline in forest and grassland has the same effect on the surface runoff. The streamflow change caused by changes in LULC and future climate is essential for water resource management and planning. The variation of streamflow is estimated to become more severe in the future and leads drought condition in the Kadalundi river basin. The frequency of occurrence and the average size of extreme weather events are increasing in India, and agriculture and urban expansion are supposed to increase the intensity of extreme events (drought and flooding). Because of this aspect, it is important that long-term water resource plans should be adjustable to the insight of these impacts. Planner and policy maker should develop a land use plan to mitigate the negative effect of the expansion of agriculture and urban areas. The results of the methodology of this study can be used for planning of drought risk management and mitigation in the increase in climate change scenarios.

Acknowledgements

The authors acknowledge the Department of Science and Technology (DST) for financial support to this study. We wish to express our deep gratitude to Central Water Commission and Indian Meteorological Department, India, for providing hydrological and meteorological data. Authors also acknowledge the sponsorship of the project entitled 'Impacts of Climate Change on Water Resources in River Basin from Tadri to Kanyakumari' by INCCC, Ministry of Water Resources, Govt. of India.

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Impact of Anthropogenic Climate Change in Desertification: In the Context of Impoverishment and Migration

Mehul Padharia[a]

ABSTRACT: Desertification affects approximately one-sixth of the world's population, 70 per cent of all drylands and one-quarter of the world's total land area (UNSDG, n.d.). Arid region is the most affected area for land degradation and desertification. The aim of the Sustainable Development Goal 15 of 2030 is to "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation and halt biodiversity loss". Human indulgence and climate variations may cause the desertification.

This paper expostulates the desertification factors from the human indulgence perspective and causes of migration, by means of the extensive literature review. Desertification is a serious problem which is emerging rapidly and the world is facing its consequences. Many alternatives and research process are combating with this issue but these are not reducing the growth of desertification. Through a review of global literature, the role of human activity involved and the effects of climate change in soil degradation and desertification are identified. On the basis of these identified factors, gaps in policies and drought disaster management risk reduction in the Indian context are investigated.

KEYWORDS: drought, desertification, climate change, migration, disaster management

Introduction

Desertification, also known as desertisation, is a process by which the bio-productivity of the drylands has been reduced by natural or human causes. The definition of desertification given by UN in 1977 conference held in Nairobi is "The destruction or diminution of the biological potential of the land and can lead to the ultimately desert-like condition". UN Conference on Environment and Development held in 1992 in Rio de Janeiro dictates the word desertification as "land degradation in dry sub-humid, arid and semi-arid areas". This type of land degradation can be a result of various factors, including human activities and climatic variations. Desertification is basically believed to be a reduction of biological productivity of land mass. There are several definitions of desertification that have been encountered and resulted in an almost the same view. Another UN report of 1992 explains the term desertification as "resulting mainly from adverse human impact" (Stafford Smith, 2002). This definition given by UN especially focuses on the connections between humans and their lifestyle that affect the human comfort in arid and semi-arid areas. There are several other opinions proposed for the desertification which depict peerless issues and particularly temporal and spatial scales of interest (Assessment, 2005). Desertification word was previously focused on the destruction or degradation of the biological productivity of land, leading to desert-like condition (Stafford Smith, 2002).

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Impoverishment and Poverty

In India, there are many policies and frameworks for soil degradation that are in place, there appears to be very little or no consideration for drought disaster risk reduction. Loss of biodiversity and climate change were accepted as the biggest challenges to sustainable development in the 1992 Rio Earth Summit which later assisted in the formulation of the United Nations Convention to Combat Desertification. The factors for the desertification can be climatic as well as changing rainfall patterns, low soil moisture and high evaporation. However, the majority of them are the human-induced, which include poverty, technology, global and local market trends and it is fateful to say that poverty is the cause and also a consequence of land degradation (GnY, 2017). To overcome these issues, a set of management and mitigation options are deciphered in this paper. In spite of the many problems and issues, dry area gives a great opportunity for development, only if it is organised wisely at global, national and local levels. It is very important to identify the linkage between desertification and the migration of livelihood and livestock. Food insecurity and impoverishment are the main causes for migration. There is an intense need to look after these issues in urban development so that it can ameliorate the development challenges through sustainable land management practices. 25 per cent of India's total land is suffering desertification while 32 per cent of the land mass faces degradation. Water-logging, soil acidity and salinity-alkalinity are the major forms of land degradation including soil erosion and wind erosion. In fifth National Report of Indian government on Desertification and Land Degradation, the government admitted that desertification is a major concern for the environment of the country resulting in implications for sustainable development. Rajasthan, Maharashtra, Odisha, Jammu & Kashmir, Gujarat and Andhra Pradesh are most desertified lands in India which require the attention of policymakers. According to a study, 68 per cent of the total land of India is drought-prone area and its vulnerability is increasing rapidly due to climate change, particularly in dry areas. Environment Ministry and Indian Council of Forestry Research and Education have jointly prepared a report which depicts the causes of degradation. Loss of vegetation, rapidly cutting trees in forest protected areas or beyond permissible limits, unsustainable fodder extraction and wood cutting, encroachment on forest lands and bushfires resulting in degradation. Other factors including human intervention leading to an extensive degradation comprise "Overgrazing, overexploitation of vegetation for domestic purpose, cultivation and extension of the hazard-prone land area, improper use of soil conservation measures, non-adoption of the measures for use of agro-chemical products, improper management and planning of irrigation systems and intensively extraction of groundwater".

India is the second most populous and seventh largest country by area in the world. With a peninsular shape and increasing population density of this country, the vulnerability to various kinds of disasters has been increasing rapidly and desertification is one of them. The 7516 Km coastline of India makes it vulnerable to coastal desertification. Rising sea level re-sorts the thinking of the people who want to live in the coastal area. Prosperous and affluent people residing in coastal areas of India are also afraid that even inch of rise in water level in the sea can snatch their land. Many countries around the world share the same concern. Various coastal areas such as Rio de Janeiro, Shanghai, New Zealand, London and Australia may be under water within the century (DTEStaff, 2016). India loses more and more land to desertification. Desertification affects the biodiversity as well as food production of the country which leads to hunger, poverty, economic and political instability and migration. A report by Government of India (2018) on desertification and land degradation atlas of selected districts of India depicts that more than 50 per cent of the land areas of 14 Indian states have been desertified.

The United Nations Convention to Combat Desertification (UNCCD) is considering these factors to declare the year of 2006 as "International Year of Desertification". Various agencies, institutions or organisations are working on the various research projects on climate change and its impact and the sustainable development of the drylands and their communities. Gujarat Institute of Desert Ecology (GUIDE), CAZRI and AFRI in Rajasthan are working on sustainable enhancements of productivity in drylands.

The rate of exploitation of land resources and leading to land degradation is much more adverse and rapid in the fragile drylands systems, which require to be addressed quickly (GUIDE).

Build-Back-Better

In a disaster management context, the response mechanism and procedures have been given more importance and have been well established but comparatively little is done for disaster mitigation and prevention. Policymakers need to focus on the various ecological issues arising in drylands and to combat with these issues a sustainable ecological approach can be done to minimise the land degradation which eventually leads to desertification. To combat with desertification hazard, it is important that countries should prepare their disaster management plan in the context of desertification and implement their strategies. The land which is left impoverished would impoverish its inhabitants later. If desertification strikes in an area, the productive land becomes less productive and, if not controlled, it becomes a desert-like landscape which will not be able to nourish its inhabitants who depended on it previously (Kosmas & Geeson, 1999). Billions of people of the developing country live in dry land and depend on that ecosystem. With the urban agglomeration and increase in population land resources of drylands are affected. Human population is the most crucial indicator of desertification in a developing country like India (Bhaskar & Parwal, 2016). In recent past, it has been a cause of fear due to fast dissipation of the biodiversity, demanding for immediate mitigation measures to control further land degradation leading to desertification.

Global warming and other environmental changes caused by human arise the current problem which eventually tends to desertification. Drylands are spreading extensively as desert barriers continue to expand. We have to learn how to live in the desert like places in the most compatible ways. Assessing the environmental problem in the context of human activity based on an important knowledge of the previous events helps to make sustainable policies (Cooper, 2012).

The production of cattle, sheep and goat is the main and sometimes only agriculture activity available for the population living in desert-like areas (Saidi & Gintzburger, 2013). Desertification affects a large portion of Indian rangelands but it remains very hard to delineate, quantify and precisely locate for the mitigation purpose. The pressure of human activity affects the ecosystems and sometimes makes it dry, semi-arid and semi-humid. This activity reduces the growth of foliage, changes in vulnerability, accelerates the delineation and increases biomass for habitation. In other words, improper use of land resulting in a desert-like condition is called desertification (Singh, Nicolas, & Eslamian, 2018). Sometimes mismanagement of water resources can be the main cause of the problem which can be solved by water conservation, salt control, proper use of good water-proofing techniques, the use of advanced irrigation system, management of water runoff and flood control. These techniques can mitigate the effects of desertification and also help in increasing the productivity of the land.

Conclusion

The selection and utilisation of indigenous techniques to fight with desertification in countries depend on culture and pursuance of the community. The proper organisation and management of government policy and proper use of resources can also affect the mitigation mechanism in the context of desertification. Build-Back-Better is the main key to cope with the desertification which includes short-term emergency response measures and long-term planning with particular focus on the production which is affected by the desertification and degradation of the land. The developed and developing countries both are the example of the successful implementation of the strategy and programme to combat with desertification. Strategical measures such as proper water management, drainage construction for water runoff, salinity control, soil conservation, construction and maintenance of forest protected area and parks to resuscitate the affected area for restoring purpose were taken.

To cope with desertification, proper and coordinated technologies and measures are required. Agriculture sensitisation programme should include economic and social aspects that should promote the community to use appropriate technologies. Research centre should be developed and have capability to disseminate the information in specific economic, ecological and sociological conditions.

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Climate Change, Disasters and Security Issues: Concerns and Implications for India

Sunil Kumar Chaudhary[a]

ABSTRACT: Climate change and disasters are fast emerging as the most defining challenges of the 21st century as global risks with impacts far beyond just the environment and implications on national security and development. This paper examines the climate change-disaster-security nexus in context of India, the future projections of the IPCC and other regional assessments, along with the disaster profile of the country and the trend of rising disasters. For India, tackling the challenge of climate change and increase in disaster risks posits particular significance, presently poised as India is in an upward development trajectory. Valuable time and resources would be consumed in handling the increasing risks, which would impinge on its development, unless appropriate mitigation measures and mechanisms are not put in place now, and policies redefined to address the challenge. An analysis of the impact of climate change on the risk of natural hazards and its implications for national security is put forth with proposed preparedness strategies and emergent policy imperatives. A range of options and strategies to deal with disaster risk reduction and climate risk reduction are viewed from a 'risk management' approach. Ensuring that development planning processes integrate climate risks as well as disaster risks will require 'risk identification', that is bringing together and effectively disseminating information on vulnerability and hazards. Translating the macro-level options into courses of action at the micro local level poses a complex challenge and will require a range of risk reduction and risk spreading options micro-scoped to the regional/local context.

KEYWORDS: climate, disaster, security, India

Introduction

Climate change and disasters are fast emerging as the most defining challenges of the 21st century. The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) has provided compelling evidence that climate change is advancing rapidly as a global risk with impacts far beyond just the environment. Recent projections and analytical studies indicate that the increasing global temperatures, arctic and glacial melt down, sea level rise and other climate change-induced environmental degradation will give rise to extreme weather events and overstretch many societies' adaptive capacities within the coming decades thus increasing societal vulnerabilities. Concomitantly a global review of the statistics of disasters by the Centre for Research on the Epidemiology of Diseases (CRED) indicates that natural disasters are increasing in terms of frequency, complexity, scope and destructive capacity. Hitherto disasters were linked to climate change through short-term natural variability manifesting in extreme weather events such as cyclones, storms, floods, droughts, heat waves, windstorms and other natural

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hazards with potential for catastrophic loss of human lives, damages to infrastructure and environment. However, with the climate change manifesting at an unprecedented rate with increased variability and frequency of extreme events, long-term implications and possibility of abrupt change, fuelled largely through anthropogenic cause, these two processes have the potential to coalesce generating destructive forces which could cause mega disasters unless urgent, radical and resolute mitigation actions are not implemented.

For India, tackling the challenge of climate change and increase in disaster risks posits particular significance, presently poised as India is becoming a major global power. Valuable time and resources would be consumed in handling the increasing risks, which would impinge on geo-strategic imperatives, unless appropriate mitigation measures and mechanisms are not put in place now, and policies redefined to address the challenge.

The subsequent arguments analyse the impact of climate change on the risk of natural hazards in India and implications for security and propose preparedness strategies and emergent policy imperatives.

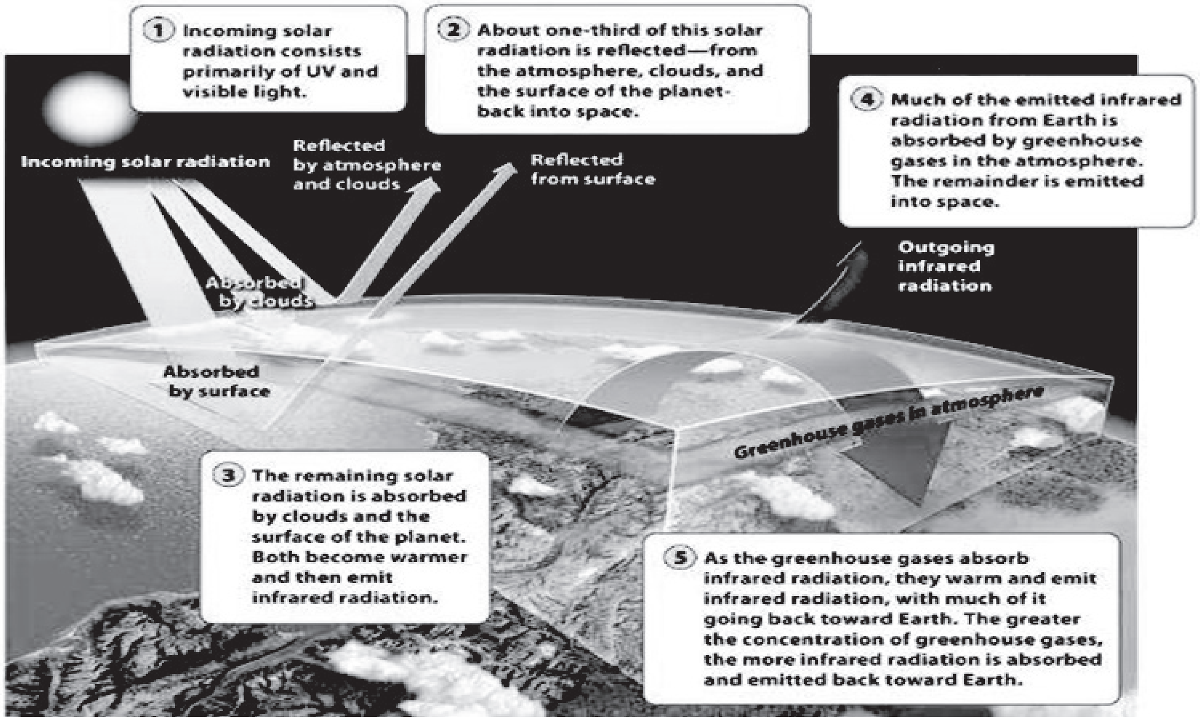
The Context-Changing Climate

Climate change is the name given by scientists for the gradual change in climate due to increase in temperature of the Earth's surface that has worsened since the industrial revolution. Over the past two decades the effect has become more distressing. During the entire 20th century, the average global temperature has increased by about 0.600°C. Using computer climate models, scientists estimate that by the year 2100, the average global temperature will increase by 1.400°C to 5.800°C. IPCC AR4 has categorically established that climate change is advancing rapidly with global warming as a prime causative factor.

According to the future scenario projections by IPCC AR 4 global warming is expected to intensify during the 21st century. Green house gases concentration in the atmosphere will be 45 per cent above the present level in 2100 under the most favourable set of hypotheses, and 260 per cent above it in the worst case. Without resolute mitigation, a global increase in temperature of 2–7°C relative to preindustrial levels and a rise of 0.1 to 0.9 metres in the sea level can be expected to occur by 2100 (Parry et al. 2007). The IPCC projections are supported and substantiated by other climatic models. A ten-year climate prediction model developed by the Hadley Research Center of the UK Meteorological Office predicts that the world is warming up faster than at any time in the past 100 years.

Due to the long lead times involved in climatic changes, global warming is expected to continue during the 21st century. Future projections indicate that there is increased confidence that some weather events and extremes will become more frequent, more widespread and/or more intense during the 21st century and impacts due to altered frequencies and intensities of extreme weather, climate and sea level events are very likely to change (IPCC, 2007c). A few examples of possible impacts of climate change due to changes in extreme weather and climate events to the mid- to late 21st century are (Parry et al. 2007):

- Warmer and fewer cold days and nights, warmer and more frequent hot days and nights. Over most land areas – virtually certain (greater than 99 per cent chance)
- Heat waves frequency increases over most areas – very likely (90–99 per cent chance).
- Heavy precipitation events frequency increases over most areas – very likely (90–99 per cent chance).
- Area affected by drought increases – likely (66–90 per cent chance).
- Intense tropical cyclone activity increases – likely (66–90 per cent chance).
- Increased incidence of extreme high sea level (excludes tsunamis) – likely (66–90 per cent chance).



Science of Climate Change

Climate Change: Disasters-Security Nexus

Climate Change and Disasters

The United Nations defines disaster as *a serious disruption of the functioning of the community or society, causing widespread human, material, or environmental losses which exceed the ability of the affected community or society to cope using its own resources*. Climate has always been linked with disasters, hitherto, through climate variability manifesting in extreme weather events such as cyclones, storms, floods, droughts, heat waves, windstorms, etc., with potential for catastrophic loss of human lives, damage to infrastructure and environment. These short-term climate fluctuations and extreme weather events have been the most frequently occurring hazards and in combination with social vulnerability have been responsible for the vast majority of disaster losses worldwide. CRED categorises these disasters resulting from climatic variability and other climatic and meteorological causes as hydro-meteorological disasters The hydro-meteorological disasters resulting from climate variability and other climatic and meteorological causes are also commonly referred as 'climate disasters' in disaster studies.Climate disasters have always been a recurring theme in human history, and are on a rising trend.

- **Trends – 20th Century:** Over the 20th century, climate-related disasters were seven times as frequent as those including geophysical hazards globally, and accounted for nine times as many deaths and caused economic losses that were three times higher (UNDP, 2007b).
- **Trends – 21st Century:** In the 21st century over the past three decades, climate-related natural disasters occurred five times as frequently, killed or affected seventy times as many people and caused twice as much damage worldwide as did earthquakes and volcanoes. In the past decade, weather-related natural hazards have been the cause of 90 per cent of natural disasters and 60 per cent of related deaths, and have been responsible

for 98 per cent of the impacts on disaster-affected populations, the majority in areas of developing countries (IFRC, 2005).

Climate Change and Increasing Disasters: Is There a Link?

A number of experts link these current trends in extreme weather events with the increase in the global mean temperature. The CRED report states that 'there is increasingly conclusive evidence which confirms that global climate change will have an impact on the occurrence and magnitude of extreme events'. CRED report also surmises that the current trends are consistent with the predictions of IPCC AR4, in that Asia and also West Africa are already suffering from more severe and frequent floods (Sapir, 2008). The future projections by IPCC AR4 also indicate that there is 'increased confidence that some weather events and extremes will become more frequent, more widespread and/or more intense during the 21st century and impacts due to altered frequencies and intensities of extreme weather, climate and sea level events are very likely to change' (IPCC, 2007c; Parry et al, 2007).

Also, there is evidence now that climate change, with present developmental trends, will not express itself in through slow shifts in average conditions, but will manifest at an unprecedented rate with increased variability, frequency of extreme events, long-term implications and possibility of abrupt change, fuelled largely through anthropogenic causes. Under such trajectory these two processes do have the potential to coalesce generating destructive forces which could cause mega disasters unless urgent, radical and resolute mitigation actions are not implemented.

Disasters and Security

To understand how disasters impact security, an analysis is required that goes beyond the disaster period to look at root causes of vulnerability, inequality, grievances and resource scarcities. Much literature exists on what causes disasters and it is well accepted now that disasters are not natural phenomena, but 'acts of society' and are caused by vulnerability at different levels, viz., ecological, economic, social, human and political, and are rooted in developmental failures (DFID, 2005).

Security, on the other hand, in simple terms, is 'lack of conflict', extant or potential. Conflicts do not occur unexpectedly and there many obvious causes of conflicts. But behind the immediate factors that trigger conflicts, analysis reveals deeper causes, such as territorial demands, socioeconomic inequalities, economic interests, the defence of political ideologies, burgeoning nationalism and the struggles of ethnic minorities, racism and arms proliferation, that is, vulnerable human conditions.

Both in analytical and practical terms, studies (Nel, 2008; Bhavnani, 2006) have illuminated the interconnectedness and the interface between disasters and security through vulnerable conditions as depicted in Fig 1. Hazards become disasters only through societal vulnerabilities; societal vulnerabilities above threshold of tolerance lead to conflict; disasters exacerbate existing vulnerabilities and generate new ones thus creating conditions ripe for conflict. This interface, viz., reinforcing pre-existing vulnerabilities and creating new insecurities for individuals, families and communities, is a toxic cocktail and is the principal conjunction between disasters and security.

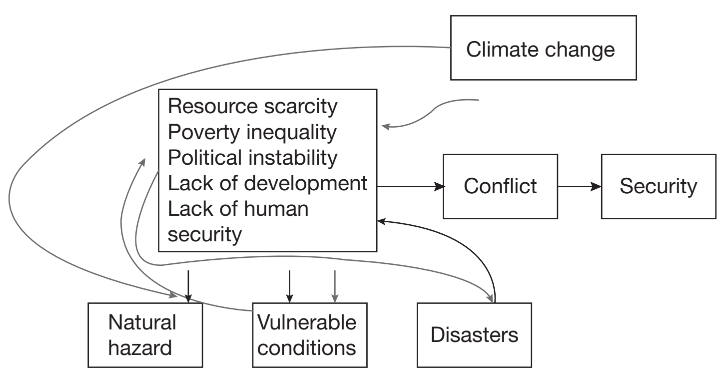


Figure 1: Climate change, disaster and security nexus

Climate Change, Disasters and Security: The India Context

Climate Change in India

For the Indian subcontinent, the projected changes by IPCC, based on the General Circulation Model (GCM), project warming of 2–4.7°C, with the most probable level being around 3.3°C by the year 2100 (A1B scenario) (Solomon et al, 2007). Warming is expected to be more marked in the winter half of the year (3.6°C) than in summer (2.7°C), and stronger in the north than in the south. Most scenarios project a decrease in precipitation during the inter dry period and an increase for the rest of the year. At the same time, an increase in heavy rain events is probable, particularly in the north of India. The global sea level rise of 0.1 to 0.9 metres is particularly expected to be high in the Indian Ocean, especially on the west coast.

Assessments by Indian Scientist using the Hadley Centre Regional Model (HadRM2) climate models show similar outputs and indicate that over the Indian region the temperatures will increase by 3°C to 4°C towards the end of the 21st century. The warming may be about 2.1°C to 2.6°C in the 2050s and 3.3°C to 3.8°C in the 2080s (DEFRA/GoI, 2005a). The different models/experiments generally indicate the increase of temperature to be of the order of 2–5°C across the country. In case of mean annual temperature, the increase is of the order of 3°C to 6°C. The warming is projected to be widespread over the country, and relatively more pronounced over northern parts of India. While the rainfall is projected to increase, there would be variations in the spatial pattern, with some pockets showing increase and others experiencing decline in rainfall.

The projected climate change will affect India particularly severely. Its consequences include a rise in sea level, threatening areas such as the densely populated Ganges delta, changes in the monsoon rains, the melting of the glaciers in the Hindu Kush-Karakorum-Himalaya region (crucial for the water supply in the dry seasons) and the foreseeable increase in heavy rain events and intensity of tropical cyclones (Parry et al, 2007). The thousands of glaciers located across the 2400 km of the Himalayan range are at the epicentre of an emerging crisis.

Likely Impact of Climate Change on Disasters in India

India is among the world's most disaster-prone areas. India supports 1/6th of the world's population on just 2 per cent of it landmass. Nearly 59 per cent of India's land area is prone to earthquakes of moderate to very high intensity, over 40 million hectares (12 per cent of land) is prone to floods, close to 5700 kms of its 7516 km coast line (about 8 per cent), is cyclone prone and exposed to tsunamis and storm surges, 2 per cent of land is landslide prone and 68 per cent of India's arable land is affected by droughts. Of the 35 states and Union Territories, as many as 27 are disaster prone.

The global disaster trends are alarming, singularly so in India. At aggregate country level, India ranks third with 21 significant disasters recorded (China recorded 38, followed by the USA which recorded 31). In terms of victims India ranked third with 7.3 million victims after China, 88 million, and Philippines, 8.6 million. China, the USA and India also remained the countries reporting the highest damages (China – 13.5 billion US$, the USA – 5 billion US$ and India – 3.3 billion US$) (CRED, 2007). The available data for 2007/08 also has India reporting third highest number of significant disasters, viz., 18 as against 22 reported by the USA and 20 by China. In terms of victims India ranked the second highest recording 1103 deaths, mainly due to floods, as against Bangladesh which recorded 5534 (Cyclone Sidr and floods) (ISDR/CRED, 2008). A scrutiny of the past records of 100 years too indicates that India figures in the first 10 in the world in terms of fatalities and economic losses in a variety of disasters.

These trends are likely to exacerbate in future with climate change. The projected increase in precipitation and rainfall, the glacial meltdown and rising sea levels will affect India particularly severely, creating conditions for more hazardous events and will lead to increase in incidence of floods, cyclones and storm surges. Though it is not possible to predict the future frequency or timings of extreme events but there is evidence that the risk of drought, flooding and cyclone damage is increasing and will continue to do so. Climate change is also likely to threaten India's food security, increase water stress and increase occurrences of diseases especially malaria.

Lack of availability and access to technological and financial resources coupled with a high dependence on climate-sensitive sectors – agriculture, fisheries, forestry – have made India highly vulnerable to climate change. A large and growing population, densely populated and a low-lying coastline, and an economy closely tied to its natural resource base, further intensify this vulnerability.

India's Options

- Three questions
  - What is in India's best interest?
  - Is there justification for the position in climate change negotiations that these interests dictate?
  - Does India have the leverage necessary to defend this position?

What Will Serve Its Best Interests?

- Worth taking voluntary mitigating actions that are costless or reduce costs
- Binding commitments in a post-Kyoto agreement are not in India's interest
  - With 300 million people living in abject poverty, growth cannot be compromised.
  - With 40 per cent of the households without ANY electricity, India needs to tap all possible sources of energy.
  - The cost in terms of adaptation forgone will be large.
  - Given the existing stock of emissions and large emissions by the rich countries, India's own mitigation will have virtually no impact on global warming – India could eliminate all GHG emissions and still will do nothing to global warming.

Is 'No Mitigation' Justified?

- India ranks 137th among emitters on per-capita basis. Freezing its emissions at current levels or less would deprive India of any chance of eradicating poverty. Almost any social justice criterion would come out against developing countries being denied room to grow sufficiently that they can eradicate abject poverty in order to allow developed countries to more or less maintain their ultra-high living standards.
- The exemption to the developing countries from mitigation commitments is enshrined in the UNFCC which explicitly recognises that 'the largest share of historical and current global emissions of greenhouse gases has originated in developed countries, that per capita emissions in developing countries are still relatively low and that the share of global emissions originating in developing countries will grow to meet their social and development needs'.
- While virtually all analysts club China and India together in climate change discussions, their emission profiles and magnitudes are vastly different. India is simply not a 'big league emitter' as is evident from following figure.

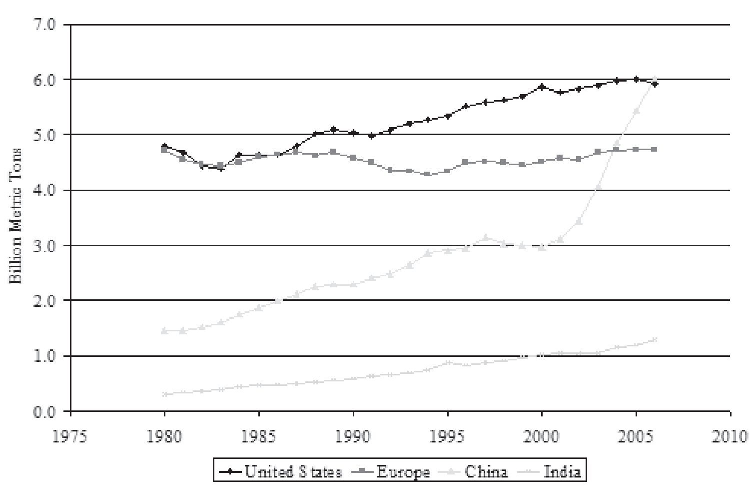


Figure 2: Total CO_2 emissions from the consumption and flaring of fossil fuels, 1980–2006

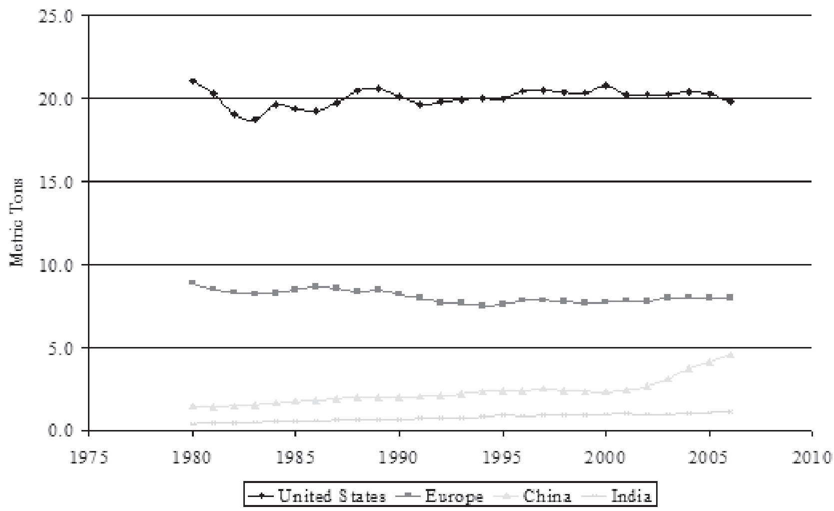


Figure 3: Per-capita emissions of CO_2, 1980–2006

Is 'No Mitigation' Feasible

- WTO rules and the possibility of retaliation allow India to combat pressures of unilateral actions.
- UNFCCC cover can be effectively used to delay commitments.
- India must undertake research studies that can persuasively make the case that by 2040 it can eradicate poverty and build up adaptation capabilities that will allow it to undertake mitigation subsequently.
- India must also produce research studies to argue the position that mitigation by developed countries alone is possible without the fear of leakage.

Recent Initiatives of the Indian Government

- Revisiting national missions, creation of new missions and enhancing of targets, etc.

Mitigation Initiatives

- Renewable energy target 175 GW and National Solar Mission from 20 to 100 GW
- Kochi Airport worlds' first airport powered by solar energy
- Solar-powered toll plazas
- Delhi Metro and other MRTS
- National Smart Grid Mission and Green Energy Corridor for efficient transmission and distribution network
- Revisiting national missions, creation of new missions and enhancing of targets, etc.

Adaptation Strategies

- Paramparagat Krishi Vikas Yojana – organic farming
- Pradhan Mantri Krishi Sinchayee Yojana – efficient irrigation
- Neeranchal – watershed development
- Namami Gange
- National Initiative on Climate Resilient Agriculture (NICRA)
- Bureau for Water Use Efficiency
- Lifestyle and culture of sustainability

Climate Finance Policies

- National Adaptation Fund
- Reduction in fossil fuel subsidies
- Coal cess increased from INR 50 to INR 200 per ton
- Tax free infrastructure bonds introduced for renewable energy

Recommendations

The country needs to have improved scientific understanding, capacity building, networking and broad consultation processes across every section of the society.

- **Integrated Risk Management Framework:** In India disaster management is being addressed by the National Disaster Management Authority (NDMA) as the apex body for addressing policy issues and for laying guidelines. Climate change is being addressed at various levels, by the Ministry of Environment and Forests, the Ministry of Science and Technology, the Ministry of External Affairs as well as by the Prime Minister's Office. There is wide divergence among these entities. There is an urgent need to bring climate change and disaster communities on a common platform, and develop an integrated risks management framework or model for the challenges of climate change and increasing disasters, which are intrinsically linked through societal vulnerability.
- **Adaptation and Mitigation:** Both adaptation and mitigation have been key levers in disaster risk reduction and climate change strategies. An integrated risk management framework needs to build on these two vital strategies. India has many mitigation projects for disasters, viz., earthquake, flood, drought mitigation, etc., but adaptation is largely spoken about only in discussions. This must change. The key levers of adaptation include poverty reduction, progressive change in economic structures, shifting away from primary (agriculture) livelihoods into (secondary and tertiary) knowledge-based forms of economic activity that are less vulnerable to direct impacts of risks, changes in land use and cropping patterns, etc. and enhancing the resilience of people.
- **From Structural to Non-structural Mitigation:** The Ninth Five-year Plan (19972001) of India saw the beginning of a gradual shift away from purely structural measures towards other forms of non-structural mitigation. In the Ninth Plan it was observed that in addition to the progress made in implementing structural flood protection measures, flood forecasting and warning systems had played a great role in mitigating the loss of life and enabling the protection of movable property. Lessons from past efforts towards flood control indicate that structural actions often increase long-term vulnerability. There has been a gradual shift from purely structural measures to non-structural measures for flood mitigation. This is reflected in the Tenth Five-year Plan of the Government of India, although much of the shift still remains on paper.
- **Future Climate Change-Disaster Scenarios – Impact Assessment:** Impact assessment of climate change-disaster security nexus is complex as it includes geophysical and socio economic aspects. However tools used for these assessments need to be continuously evolved. Climate change research, monitoring and modelling is an emerging area in India and the assessments are in their nascent stage. Identifying and using appropriate tools for integrated assessment with adequate data inputs can lead to improved projections with reduced uncertainties. There is a need to enhance technical and institutional capacity. Though India has a large science and technology institutional base in many areas relevant to climate change, these have to develop a shared vision, integrated approach and networking for synergistic assessment relevant to policy making.
- **Climate Change/Disaster Risk Indices (CCDRI):** Quantitative indices are an important tool in risk management. UNDP has developed a Disaster Risk Index (DRI) with a global level of observation and a national level of resolution allowing comparison between countries with respect to three types of hazards, viz., earthquakes, cyclones and floods (India ranks highest risk prone to floods with China a close second; for cyclones India ranks second with China leading, and for earthquakes India is ranked 10^{th}) (UNDP, 2004). With the confluence of climate change with disasters, development of climate change-induced disaster risks indices needs to be initiated.
- **Climate Change Modelling:** India has presently evaluated the outputs of 10 General Circulation Models (GCMs), and only one regional model, viz., HadRM2 with a resolution of 50×50 km. Regional climate modelling has to be strengthened and it

is desirable to acquire/develop and set up more Regional Climate Models (RCM) to ascertain their simulation accuracy of the current India climate, and then use the appropriate RCM for more robust projections.

- **Vulnerability Atlas:** A vulnerability map of India has been developed by the Building Material Council and Technology Promotion (BMCTP) showing multi-hazard zones based on earthquakes, wind and cyclones and floods. The vulnerability atlas needs to be revised in the context of the climate change projections and extreme weather events that India has faced in the last few years and also in the past on intermittent basis.
- **Climate Change to 'Climate Affairs' – A Multi disciplinary Approach:** Climate change has become a dominant issue, important to governments, corporations, public and humanitarian organisations. Thus there is a need to make climate science usable by the public as well as the policy makers at all levels of social organisation. This can be done by fostering a multidisciplinary approach to climate issues for purposes of awareness. 'Climate affairs' and not climate change should be the way to educate how climate knowledge can improve the quality of climate-sensitive decisions. Climate affairs encompass climate science, climate policies, and laws, climate economics and climate ethics and equity.
- **New Approach to Vulnerability:** There have been changes in the concept of vulnerability recently, and this requires a new approach. Trends in India show that rescue and rehabilitation do not solve problems, prevention and planning are required. Communities must be made more resilient. Strategies and policies must cope with climate change and adaptability and increasing vulnerability. The top-down approach has been left with very minimal impact. A proactive risk reduction bottom-up-driven approach is required and the government should work as a facilitator, for which political will is necessary.
- **Development as a Tool for Reducing Risk:** The conventional view has been to consider disasters and climate change as a barrier to development and simultaneously developments as a threat to climate change. However development can be the driving force to overcome challenges and risks of climate change. Disaster and climate change are increasingly being considered as a development constraint; hence, mainstreaming them into the development policy is all the more pertinent in the current context.
- **Logical Approach to the Disaster Management Cycle:** Until recently the focus of disaster management was on relief and rehabilitation. This focus has shifted to prevention, mitigation, preparedness, response and recovery. The logical approach to the disaster management cycle should be mitigation as the first priority; rehabilitation and reconstruction must also include mitigation in the disaster risk reduction cycle. In a non-disaster scenario, planning, prevention, mitigation and preparedness are all required to address hazard risks and vulnerability reduction. Only this will be relevant in the context of development and environment sustainability
- **Centre-State Relations, Policy Issues:** The broader and deeper geopolitical dynamics of centre-state relations continue to influence both official perceptions and policies towards climate change-disaster management. In many, if not most, cases the allocation of responsibility among key agencies within each state and between states and the central government in India is both highly politicised and far from clear.
- **International Cooperation:** Climate change and disasters know no boundaries, and will spread across geographical divides. If international cooperation, as opposed to competition, is strengthened in response to the threat of climate change and increasing disasters, international stability, governance and development could also benefit.
- **Climate Change – Need for Single Authority:** In India, on climate change, different ministries feud over turf. Ministry of Environment and Forests, the Ministry of Science and Technology, the Ministry of External Affairs, the Planning Commission, as well as the recently appointed office of the Prime Minister's special envoy are all addressing climate change from their perspectives. The integrated

climate change and disaster risk management framework proposed above needs to be put under one authority/ministry.

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Early Warning Systems in an Era of Climate Change and Innovation

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ABSTRACT: The presentation is informed by the results of a study, supported by a UNISDR/WMO/WB collaboration to find what lessons were learnt from the 2017 hurricanes in the Caribbean that would inform planned EWS investments in the region.

The general conclusion was that the changing hazard and social landscape require a revisit of the approach to early warning systems design, operations and assessment and the disruption of the entrenched silos approach to EWS development in the Caribbean. Irma and Maria have unearthed the mismatch in the pace and diversity of technology uptake between the institutional actors and the targeted communities of their services.

Additionally, whilst the modelling and science of risk knowledge are advancing the pace of its application for operations and response planning is lagging. There is recognition of the need to build the synergies between science and application but the conversion of a shared need is not being converted to a change in the EWS architecture or programming process.

The changing dynamics of the threats, the communities and technology are altering the EWS landscape. EWS policy and practice can benefit from more investment in evidence-driven considerations. Involving higher educational institutions and the private sector in providing the evidence. This is no longer a consideration but a necessity.

The findings of the study are used to offer a proposition for a Caribbean Early Waring Alliance to promote a more integrated and goal-driven Caribbean EWS programme.

KEYWORDS: climate change, early waring alliance, systems design, operations, assessment

Introduction

The 2017 Atlantic Hurricane season has been identified as the deadliest and costliest season in the history of the Caribbean region with the highest total Accumulated Cyclone Energy (ACE), and the highest number of major hurricanes since 2005. The three major storms Harvey, Irma and Maria impacted several islands and resulted in billions of dollars in damages with over 100 deaths. The value of uninsured losses from Irma is estimated between USD 7 and 15 billion, with the British Virgin Islands alone accounting for USD 3.6 billion. In Dominica, Maria led to damages that amounted to USD 931 million and losses of USD 382 million, equal to 226 per cent of the island's GDP.

In Puerto Rico, damages from the combined impacts of Irma and Maria were placed in the region of USD 94 billion. Equally noteworthy was the rapid onset of these events which challenged the hurricane readiness culture in the Caribbean.

This is the context which generated acute interest at the national, regional and international levels to look at the lessons to be learnt for early warning from these unfamiliar and unprecedented events.

Among those whose attention triggered and who expressed a desire to pursue the lessons learnt was the Climate Risk and Early Warning Systems (CREWS) Steering Committee. During its fifth meeting in Bonn, Germany, in November 2017, the CREWS Steering Committee called for the initiative "Lessons Learnt

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on Early Warning Systems Following the Caribbean 2017 Hurricane Season" to be undertaken to identify experiences, critical gaps and major lessons learnt.

The findings of this initiative are expected to guide and rationalise larger Early Warning Systems (EWS) investments initiative to strengthen EWS in the region. The Study is part of three inter-related assessments to address the various elements of the Early Warning Systems lessons from hurricanes Irma and Maria.

Purpose of the Expert Review

The Review sought to assess the "Communicating Warnings & Responding to Priority Needs" of the CDEMA system in the aftermath of hurricanes Irma and Maria. It was part of a tripartite expert review focused on Early Warning Systems. Early warning (EW) is "the provision of timely and effective information, through identified institutions, that allows individuals exposed to hazard to take action to avoid or reduce their risk and prepare for effective response", and is the integration of four main elements – risk knowledge, monitoring and predicting, dissemination of information and response (UNISDR, 2006).

The Review was undertaken during the period May 28-June 4, 2018.

The assessments were undertaken against the backdrop of the projected expectations for an above normal 2017 hurricane season and warnings disseminated on the events. The assessment focused on three tiers – the National System, the local level (community) and within a priority sector, Shelter.

The intent was to ascertain whether any reviews or enhancement of operational procedures were initiated based on the season forecast, how meteorological warnings and their likely projected impacts were received, shared with key constituents and the key actions taken by institutions and communities.

It is expected that the outputs of these reviews and consultations will generate findings that will help to guide current and future investments to building robust comprehensive EWS and contribute to recovery processes.

Approach to the Study

These included authorities of National Disaster Office (NDO), meteorological professionals, shelter managers and representatives of district or community-based entities. The nature of the engagement was influenced by the time constraints for the delivery of outputs. It included a mixture of representative stakeholder focus groups, individual and agency interviews (Appendix I). In addition to the 28 persons listed in Appendix 1, data was also generated from four regional/international organisations working in EWS in the CDEMA system and four meteorological offices primarily through the online questionnaire.

The target countries of the study were Antigua and Barbuda, British Virgin Islands and Dominica. A mixture of data collection methods was utilised and included literature reviews, administration of specific target group questionnaires online and in hard copy, focus groups and issues triangulations.

Limitations of the Study

The study was initiated with the primary purpose of determining whether hurricanes Irma and Maria had surfaced any new issues or lessons to inform a EWS project concept that was being developed for the Caribbean. The time allocated for the study was defined by the project defined scheduled. The two weeks from initiation to presentation of initial findings drove the issues scanning to the assignment. The recovery environment and dislocation of persons and institutions, impacted by the events, informed the purposive and convenience sampling approach used in the study.

The small numbers in the targeted informants are reflective of the generally small numbers of persons in the national disaster offices.

The outcome is that the allocated time for the study did not align with process required for full pursuit of the study objectives. The exercise was more akin to a Rapid Review.

Key Findings of the EWS Review

The findings of the EWS review are presented around the broad areas of a) Monitoring and Detection, b) Risk Knowledge, c) Preparedness and d) Dissemination and Warning. The intent is to recognise the connectedness of the four elements of EWS. The status and effectiveness of early warning systems are as dependent upon dissemination/communication and response capacity as it is on the existence, coverage, quality, spatial scale and 'skill' of the warning mechanisms. Where appropriate, efforts are made to show the interconnectedness between the actors and actions in the EWS value chain.

Monitoring and Detection

It was generally among all of the EWS actors in the Review that the warnings were timely. However, there is need for institutional strengthening of the meteorological services and other elements of the related early warning systems. Strategic planning is now only an emerging practice in this community. Additionally, staff welfare management in emergency situations is weak or missing. Irma and Maria highlighted the challenges of providing multi-island monitoring and forecasting services, especially when there is more than one event and varying levels of threat in their service spaces. These constraints were amplified by the limited familiarity with the local environmental peculiarities in the communities outside the national boundaries in which they operate.

A call was made for greater use of the existing decision support technologies, such as Dewetra, in the preparedness planning for hydro-met threats by practitioners in the meteorological and disaster management communities. The need for improved coordination of the work of key EWS was expressed strongly. Seven actions are below to help in mitigating the constraints and challenges surfaced by the meteorology community. However, there will need to be consultation on the scope of these challenges and the prioritisation within a service enhancement programme.

- Explore options for enhancing staffing of meteorological offices during intense forecasting periods.
- Examine options for access to a Communications Specialist, or support services, during the hurricane season or in periods of high demand for public information sharing and messaging.
- Revisit the communications toolbox to ensure service delivery in emergency for the local and external communities.
- Review and enhance the use of social media options for deepening information reach. This is critical to sustaining the position of meteorological service as the primary place of choice for warning products for all demographics.
- Broaden and accelerate training in the use and decision-making support tools in the meteorological and national disaster offices.
- Strengthen strategic and resilience planning of meteorological organisations. The need of continuity of operations in the midst of crisis is indispensable.
- Develop a model staff welfare management for the met services and promote its adoption.

Risk Knowledge

Risk knowledge is the baseline for the understanding about risks (hazards and vulnerabilities) and helps to drive preparedness, response planning and public education and information.

There is evidence of efforts to use risk knowledge in response planning, shelter selection and public education. The efforts are dispersed over several hazards, at varying scales and different actors and suggest the need for a more integrated approach within a national programme.

What is emerging here is the need to re-think of the design and delivery of early warning systems in an environment of changing climate. The components intervention approach does not sufficiently generate the interfacing issues of the EWS Triangulate – scientists and technocrats, policy makers and users.

Preparedness

Preparedness is the critical link between risk knowledge, the putting in place of systems to minimise the consequences of impact and seeking to inform and guide the behaviour of the potentially threatened. The areas included here are i. information receipt and dissemination, ii. timeliness of information, iii. receiving and actioning warning information, iv. communications failure and management.

The basic elements for the generation of risk knowledge and its application to the minimisation of loss of life, injury and damage to property exist. More risk mapping is required, and so too is its use, in the elements of the Early Warning System. Particular attention must be paid to the wider and more effective use of the developments in information communication technology in enhancing the means and products for information sharing, education and community engagement.

The national disaster system is playing catch up with the diverse agile sourcing options the population is using to obtain risk and warning information.

The emergency communications architecture is fragile and will require short-term investments to improve redundancy. The reasons for communications failure suggest weaknesses across key areas of the EWS architecture in the three study countries. Included in these are the suitability of the NEOC physical facilities, the redundancy in the communications systems and the continuity planning of the energy and communications utilities for the nature of the current and projected hydro-meteorological threats.

The shelter management review suggests that the issues and constraints are generally common and can benefit from a regional approach to action. The need to revisit the policy and practice of shelter management in the Caribbean is screaming for action. With the projection for more frequent major and extreme events the review and enhancement of shelter management and shelter management policy need to be addressed with urgency.

The picture painted of shelter management is one of complacency and neglect of a key link in the Early Warning System agenda. It exposes the limitations in the components approach to EWS interventions which is still common practice in the Caribbean and reinforces the call for an integrated approach to EWS programming and practice. Three broad recommendations are proffered as embryonic and essential steps in changing the shelter management landscape in the Caribbean.

- Address with urgency the absence of national shelter management policy. Whilst the focus of this review is set against the backdrop of a hurricane other hydro-meteorological, geo-physical and anthropogenic hazards can also generate shelter needs.
- Revisit the assumptions which underpin shelter management policy and programming in the Caribbean given the reality that shelterees arrive late at shelters and generally unprepared for shelter living.
- Evaluate the shelter management value chain, identify weak links and initiate actions to strengthen these. The issues, comments and recommendations in Table I can provide guidance for the areas to be analysed.

Lessons identified but not learnt.

A comparison of the issues surfaced in this review was made with those of EWS studies since 2010. The results suggest that the rate of learning is slow. Business as usual is the status. Climate change and its realisation in the Caribbean requires a bold change in the way of thinking and new ways of working.

Conclusion and Recommendations

The changing hazard and social landscape, influenced by changing climate, require a revisit of the Caribbean approach to early warning systems design, operations and assessment. The entrenched silos approach to EWS development in the Caribbean needs disruption to accommodate an integrated EWS agenda. Irma and Maria have unearthed the mismatch in the pace and diversity of technology uptake between the institutional actors and the targeted communities of their services.

Additionally, whilst the modelling and science of risk knowledge are advancing the pace of its application for operations and response planning is lagging. There is recognition of the need to build the synergies between science and application but the conversion of a shared need is not being converted to a change in the EWS architecture or programming process. The issues raised in earlier studies are marginally addressed.

The changing dynamics of the threats, the communities and technology are altering the EWS landscape. EWS policy and practice can benefit from more investment in evidence-driven considerations. Involving higher educational institutions and the private sector in providing the evidence is no longer a consideration but a necessity.

The Irma and Maria events provide another opportunity to pull the change triggers for new thinking and practice in EWS in the Caribbean. The recommendations offered below can provide institutional and operational ingredients for EWS transformation.

A. Improved EWS Architecture

- Undertake an EWS stakeholder mapping and related engagement strategy to help clarify roles, responsibilities and mandates of different institutions/bodies engaged in EWS. This is both urgent and important if duplication is to be minimised and efficiency of resource use achieved. One of the first steps in rationalisation process is to invest more effort in the integration or harmonisation of EWS programmes of national and regional actors. The CDM Harmonization Council (CDMHC) is well placed to provide the platform for such an exercise.
- Establish, with urgency, a facility to harmonise EWS enhancement interventions around a common Early Warning Vision for the Caribbean.
- Revisit the funding mechanism with a view for improved predictability as a central platform for EWS enhancement.
- Prioritise work to enhance redundancy in the emergency communications, including the mix of traditional and other warning methods.
- Broaden EWS programmes beyond disaster preparedness to exploit or build synergies with disaster risk reduction and climate change adaptation.

B. Standards, Products and Services

- Invest more in developing and promoting standards for performance in all areas of EWS to include shelters, shelter management and relief services.
- Introduce displacement and tracking tools and services to respond to emerging needs in the EWS system.
- Pilot the introduction of a smart shelters concept designed around the ingredients of adaptiveness, hardened facilities, use of alternate energy, water harvesting and conservation options.

C. Researching and Re-thinking EWS

- Research the use, reach and impact of social media in the Caribbean and options for enhancing these to include the review the governance arrangements around the development and introduction of new products and tools in EWS. A focus area could be improving capacity and capability to disseminate warning messages at local level after hazard impacts in environments of extensive destruction and disruption.
- Explore, through a more inclusive ESSC, the establishment of EWS Evidence Base Working Group to draft a framework for deeper involvement of HEIs in EWS. Some areas to be considered include methods to capture and integrate data from diverse sources and means to inform policy development and the better understanding of the social elements of EWS.
- Re-think the conceptualisation of EWS in an era of change to better embrace the principle of adaptivity.

Role of Public Perception in Climate Change in India

Vaishani Kapoor[a] **and Vandana Yadav**[a]

ABSTRACT: With the phenomena of climate change, there is a rapid increase in global temperatures and erratic global climatic conditions, resulting in melting of glaciers leading to sea level rise. Hence, this further mis-balances the equilibrium of earth creating extreme disaster type situation for the flora and fauna to thrive on soil and water. Now, the field of Disaster Management is moving towards Disaster Risk Reduction and resilience, therefore the public becomes an integral part of this process. Public plays an important role in controlling the factors that contribute to global climate change. In countries like India, where a large percentage of the population belongs to the middle class and lower class, it is even more important to take into account the public's understanding of this phenomenon and the disasters linked with it. As per the findings of our study, the public, especially the lower classes do not have enough or any understanding of climate change contributors like air pollution and thus have no idea about the disasters that it leads to. When the public is not aware of these issues then how can it contribute to the measures taken to control or curb them? Another consequence of this ignorance is that they are prone to becoming a victim of the health hazards caused by climate change. The study also proposes measures in this context which can lead to effective DRR. The Intergovernmental Panel on Climate Change assessment reports suggests that now there are two methods to fight against climate change, 1) adaptation and 2) mitigation. Mitigation measures like risk transfer, public awareness through different channels can be used to strengthen the people's preparedness and increase their contribution in curbing climate change.

KEYWORDS: people's perception, climate change, events, industrialisation, urbanisation

Increased greenhouse gases and increased carbon emission due to industrialisation and urbanisation have resulted in global warming (increased global temperatures). IPCC (Intergovernmental panel on climate change) scientists have predicted the temperature rise to about 1.8–5.4 degrees since 1990. The climate change is a repercussion of global warming, putting the world at the risk of climate change events. In the year 1992 in Earth Summit in Rio, the efforts to control the climate change were started and the United Nations Framework Convention on Climate Change was held and the treaty was adopted by the nations to stabilise the greenhouse gases, by limiting the anthropogenic intervention to climate change and climate risks. And every year negotiations were made to control the carbon dioxide and methane emissions. The Paris Agreement of the year 2015 again was an international agreement to fight climate change, aiming to keep the global temperature rise well below 2 degree Celsius in this century and to make efforts to limit it below 1.5 degree Celsius. It also made the countries to voluntarily pledge to cut down the emissions through "nationally determined contributions".

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Introduction

Increased greenhouse gases and increased carbon emission due to industrialisation and urbanisation have resulted in global warming (increased global temperatures). IPCC (Intergovernmental panel on climate change) scientists have predicted the temperature rise to about 1.8–5.4 degrees since 1990. The climate change is a repercussion of global warming, putting the world at the risk of climate change events. In the year 1992 in Earth Summit in Rio, the efforts to control the climate change were started and the United Nations Framework Convention on Climate Change was held and the treaty was adopted by the nations to stabilise the greenhouse gases, by limiting the anthropogenic intervention to climate change and climate risks. And every year negotiations were made to control the carbon dioxide and methane emissions. The Paris Agreement of the year 2015 again was an international agreement to fight climate change, aiming to keep the global temperature rise well below 2 degree Celsius in this century and to make efforts to limit it below 1.5 degree Celsius. It also made the countries to voluntarily pledge to cut down the emissions through "nationally determined contributions".

Global warming and climate change have drastically reduced the groundwater levels and have increased the sea-water level, disturbing both the equilibrium of plains as well coastal and marine ecosystem. Recurrent forest fires are killing animals of the forest as well as the tribal population living there. With climate change and receding ground water levels, many rivers are going extinct endangering the agricultural produce and causing other problems too.

There has been increase in the number of heat waves in many countries like Japan and Britain, and many European countries and the USA have witnessed forest fires on a large scale. In Japan, around 168 deaths happened due to temperatures rising up to 40 degree Celsius, and the country declared heat waves as a natural disaster. The increase in intensity of the heat has also increased the death toll of people as well as animals. Places close to Arctic Circle also witnessed temperature as high as 33 degree Celsius.

The developing countries like India are busy in the race to develop themselves and that is why their contribution to control the carbon emissions is marred by their developmental processes. Even less is the awareness of the masses in such countries due to lack of awareness and education. In such a scenario, it is important to check how public perceives climate change and what steps can be taken for risk reduction to their health.

Literature Review

Public Perception of Climate Change

Public perception is an important factor in the climate change debate. Public plays a huge role in contributing to the control measures for climate change. But sadly, there are very few perception studies that have been conducted with regards to climate change. These too have been mainly carried out in developed and industrialised countries while the developing countries lag far behind in this research (Adelekan & Gbadegesin, 2005). Most of these studies focus on the health impact of climate change and how the public perceives it to be. It can even be said that the extant studies on public perception of climate change are limited to the impact on health due to heat waves and air pollution. As per a study, it has been said that the perception of climate change-induced human health risks is a multifaceted construct that carries a social dimension as well (Armah, et al., 2015).

Many researches have established that climate change affects the human health. Even a report by IPCC clearly states that climate change is a contributing factor to the global increase in diseases and deaths. The direct effects include – thermal stresses, death/injury in climate change-induced hazards like floods and storms, strokes. The indirect effects include changes in the "ranges of disease vectors, water-borne pathogens, water quality, air quality, and food availability" (Armah, et al., 2015). High heat wave has been found to have high mortality rates and one of the main reasons for this has been attributed to the gaps in risk communication which ranges from the type of risk messages to be transmitted to the dissemination procedures and how users perceive and respond to the messages. In the process of implementation of risk communication here emphasis is on developing partnerships between stakeholders and engaging the public and concerned authorities in direct dialogue (Chowdhury, Haque, & Driedger, 2012).

The public risk perceptions of climate change are considered to be multidimensional in nature and they are a combination of (1) cognitive, (2) emotional, (3) subconscious, (4) sociocultural and (5) individual factors (Chowdhury, Haque, & Driedger, 2012).

There are different approaches that have been adopted by the researchers to study the risk perception of the public. The anthropology/sociology approach is based on the hypothesis that risk perceptions are produced by society and supporting social institutions. The cultural theory goes deeper in this approach and hypothesises that perceptions are constructed by institutions, cultural values and ways of life. The social context includes the personal, political and historical circumstances (Chowdhury, Haque, & Driedger, 2012). The psychometric research categorises an extensive range of factors into three high order factors: "(1) the degree to which risk is understood, (2) the degree to which it evokes a feeling of dread, and (3) the number of people exposed to the risk. Usually, those who are vulnerable are understandably more risk averse than those with more material resources" (Armah, et al., 2015).

Health Impacts Due to Climate Change

The negative impacts of climate change are exceeding and there have been evidence in the recent past in change of frequency of extreme climatic events directly and indirectly, impacting the masses. Heat waves, high precipitation levels, increase in temperature, increase in the frequency of hurricanes and cyclones are a few examples of these extreme events (A Haines, 2006).

In this paper the authors have mentioned the mortality rates due to heat waves have relatively increased and the most vulnerable are the elderly who suffer from cardiovascular to cerebrovascular problems and problems in respiration.

Heat waves in most cases originate in the urban or peri-urban areas and this effect is called urban heat island effect where there has been massive increase in the temperatures of their surroundings due to climate change resulting in various health diseases. Heat waves can lead to increase in concentration of air pollution levels increasing death tolls.

Increase in the number of floods, storms and droughts has also impacted people from giving them physical injury, to giving them emotional trauma. The data for all the people's death in all the following events especially in European countries also suggest that climate change and the related phenomena have increased manifold affecting the human health quantitatively as well as qualitatively.

WHO did a study in which the analysis for the increase in number of diseases due to climate change was observed which suggested that climate change is not limited to increase in mortality rates but rather has become a catalysing agent and making people move towards disability or leading their lives with disabilities. Hence, climate change and public health should be given more importance and measures should be taken to curb the ill-effects of climate change for better public health. WHO has also given measures to control the death tolls by investing more in mitigation and adaptation strategies which should be cost effective and should be done keeping in mind the low-income countries (A Haines, 2006).

Anthony J McMichael (2008) has also explored the impacts of climate change on the health of public and has cited the empirical study articles which have again proven the increase in death and ill effects of climate change. This problem is further to be solved by doing better researches in curbing carbon emissions and investing more on adaptation strategies especially in low- income economies as they are the most vulnerable.

Here mitigation refers to primary prevention (reducing greenhouse gas emissions) and adaptation entails interventions to lessen adverse health effects (Anthony J McMichael, 2008).

Figure 1 summarises the main pathways by which climate change can affect population health. The several main climatic-environmental manifestations of climate change are shown in the central section. The right-hand boxes, from top to bottom, entail an increase in complexity of causal process and, therefore, in the likelihood that health effects will be deferred or protracted (Anthony J McMichael, 2008).

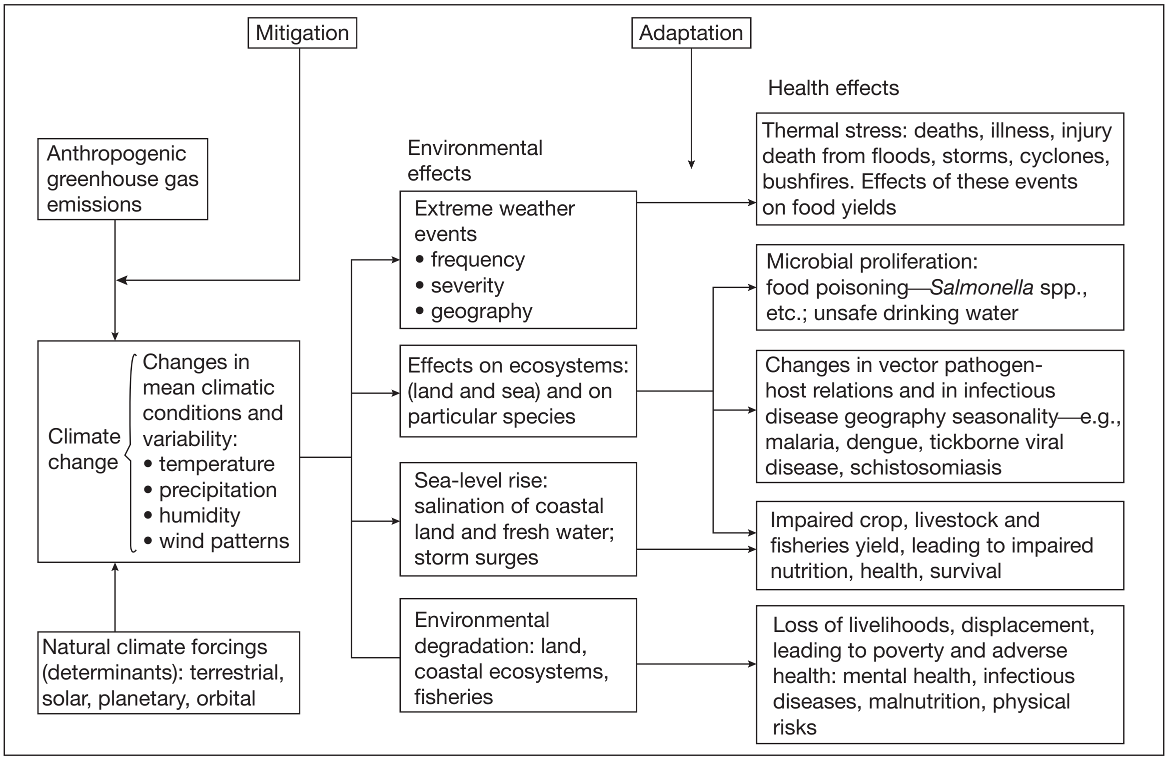

Figure 1: Schematic summary of main pathways by which climate change affects population health

Barriers to Public Heath Adaptation

Public health adaptation is usually considered as any short- or long-term strategies which can potentially reduce adverse health impacts or enhance resilience in response to observed or expected changes in climate and associated extremes. Public health adaptation to climate change is crucial and is inevitably needed to address the adverse health impacts of climate change over the next few decades. This paper shows that public health adaptation essentially can operate at two levels, namely, adaptive-capacity building and implementation of adaptation actions (Cunrui Huang, 2011).

Adaptive capacity represents the set of resources available for adaptation, as well as the ability to utilise these resources effectively and efficiently. And in most cases it is a prerequisite for adaptation actions and to implement them. The adaptive capacity can be different for different countries for instance for small island nations or the ones which are economically weak. There are a few factors which determine the adaptive capacity of individuals or a country which includes per capita income, healthcare coverage, level of access to information, which if high can result in higher adaptive capacity for health risk against climate change (Cunrui Huang, 2011).

The constraints which are there in the public health adaptation include (Cunrui Huang, 2011):

- **Uncertainties of future climate and socioeconomic conditions:** Since there are uncertainties in the climate projection and it is dynamic in nature, depending on the carbon emission, land use and so on public health adaptation cannot be generalised and predicted. Further because of varied socio-economic conditions, change in demography or economic status can hinder public adaptive capacity.
- **Financial challenges:** The countries which are financially weak are not able to handle health risks and invest in health adaptive capacity. This can be seen in the case of developed and developing countries where the developed countries have a

strong health system in place improving health adaptive capacity.

- **Technological limits:** New technologies can be beneficial in improving the health status of a country and can be beneficial in observing adaptive climate change. And in dearth of the technology for instance even internet, it can obstruct the development of a robust health system let alone adaptive capacity.
- **Institutional arrangements:** A set of rules is needed for any organisation to work and hence in government organisations too it is required for political and social mobilisation as well as for funding. The adaptive capacity depends on how strong the institutional arrangement is in a country and how strong their political will is.
- **Individual cognition:** Public perception and their respective cognition also matter and public health adaptive capacity can be limited because of their thinking, which in this case would be their ignorance or lack of awareness to act in a certain extreme event.
- **Social capital:** Collective initiatives for adaptation can enhance resilience and their shared responsibility for their community can increase their adaptive capacity. A low level of social capital can induce more vulnerability decreasing public health adaptive capacity.

Risk Transfer

Asia-Pacific region is one of the most disaster-prone regions. Also, it accounts for the highest number of people living below poverty line. Any major disaster sets the people on the margins, back to square one. In such scenario, there is an urgent need for mechanisms to transfer the risk of loss that people face through innovative mechanisms like insurance cover on the lines of microfinance. Under the Sendai Framework for Disaster Risk Reduction 2015–2030, risk financing, insurance and risk transfer are highlighted under priority 3 on investing in disaster risk reduction for resilience (Disaster risk transfer mechanisms: issues and considerations for the Asia-Pacific region, 2017).

According to Economic and Social Commission for Asia and the Pacific Committee on Disaster Risk Reduction:

"Risk transfer is the process of formally or informally shifting the financial consequences of risks from one party to another. Insurance, for example, is a well-known form of risk transfer, where coverage of a risk is obtained from an insurer in exchange for on-going premiums paid to the insurer to cope with losses after major disasters".

Risk transfer is one of the risk management approach aimed at building long-term resilience of countries, vulnerable populations and communities to loss and damage, including in relation to extreme and slow onset events as well as sudden onset events. It aims at helping the small businesses and houses with low income by providing them with easily accessible insurance for life and health. Sometimes it also covers the loss of small-scale assets, livestock and crops in the event of a disaster. With drastic weather and climate change, people face various difficulties like in the drought season or flood season when all the crops are destroyed; farmers take rash decisions like committing suicide. Hence, it becomes necessary to provide the poor people with economic safety as well as to save their lives.

It was also acknowledged by the Indian Prime Minister in the "Asian Ministerial Conference on Disaster Risk Reduction in 2016", which called for increased investment in disaster risk reduction through contingency planning, that risk coverage for all, from poor households to small- and medium-sized enterprises to multinational corporations to nation states, is needed to act as the basic building block of resilience at the household level. Insurance is used as a risk management tool, as it provides many benefits to stakeholders – ranging from regions, national governments and communities, to households and individuals. It helps in restarting the local markets after the disasters. And as risk transfer tool is designed to transfer the risks to the third party, re-stabilising and reinsuring company and capital market, it also helps the government by managing budget volatility by transferring the risks to international financial market.

The Sendai Framework for Disaster Risk Reduction 2015–2030 emphasises on the risk financing, insurance and risk transfer under priority 3 on investing in disaster risk reduction for resilience.

Sustainable Development Goals also have specific targets for which disaster insurance plays a significant role, including targets: reducing the exposure of the poor to climate-related extreme events and disasters, strengthening capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and strengthening resilience and adaptive capacity to climate-related hazards and natural disasters.

Paris Agreement (article 8) also talks about specific action areas to enhance understanding; action and support with respect to disaster reduction are outlined, such as risk insurance facilities, climate risk pooling and other insurance solutions. And these three international agreements highlight the value of risk transfer and financing for disaster risk management. But literature on risk transfer also suggested that alone these tools would not suffice to address some of the dire effects of climate change, which again points to the need for a holistic approach to managing climate risks (Warner, K., et al., 2012). Further it was also observed that risk transfer is not very effective in various slow onset disasters such as melting of glaciers or salinisation.

The National Disaster Management Plan 2016, aimed at reducing loss of lives and assets due to disasters drawing from the Sendai Framework for Disaster Risk Reduction, tries to make India disaster resilient and reducing the risk to lives and assets of the people. As of now, the government of India is the sole-insurer for maintaining relief funds. The plan also aims to bring the private sector for microfinance and insurance to cover the vulnerable populations mainstreaming SFDRR.

Loss and Damage

The whole loss and damage debate started with the small developing nations, not being able to bear the losses (such as loss to territory, critical infrastructure, income and livelihood forced displacement, etc.) caused by climate change, despite all the mitigation and adaptation measures. Hence a mechanism was needed to reduce the impacts by using actions including regional risk pooling, livelihood protection policies, insurance platforms, hazard mapping, early warning systems and robust contingency funds (Dr Adelle Thomas, Bahamas-based scientist).

There has been increase in the number of sudden-onset disasters (cyclones, forest fires, etc.) as well as slow-onset events (such as sea level rise, melting of glaciers, etc.). These climate change issues were often been solved with the approach of adaptation (planting trees, strengthening flood barriers, using new crops of varieties, etc.) and mitigation (the impacts of greenhouse gases by reducing the carbon emissions). Further there were also limitations to adaptation, and hence loss and damage approach came into existence, to curb the societal and financial damages. Hence, loss and damage is an approach to curtail the impacts of climate-related stressors apart from reducing greenhouse gas emissions as well as adaptation to climate change.

The Warsaw International Mechanism for Loss and Damage promotes the implementation of approaches to address loss and damage associated with climate change impacts, in a comprehensive, integrated and coherent manner. It has been established to assist the developing countries that are particularly vulnerable to the adverse effects of climate change by (Approaches to address loss and damage associated with climate change impacts in developing countries, n.d.):

- Enhancing knowledge and understanding of comprehensive risk management approaches to address loss and damage;
- Strengthening dialogue, coordination, coherence and synergies among relevant stakeholders;
- Enhancing action and support, including finance, technology and capacity building.

Methodology

A survey was conducted in collaboration with the organisation AIDMI, to find out the people's perception on heat waves and air pollution and their awareness about the issue. The survey had 20 questions each which covered the overall knowledge of people about heat waves/air pollution, their effect on health and household income and the steps taken by government to alert the public and tackle heat waves, and the measures that public can take to deal with these issues. These two surveys were conducted in the city of Lucknow and Varanasi. The method for sampling was snowball sampling method. A mix population was considered for the survey. A sample size of 80 was taken for the survey.

Mitigation Measures for Climate Change

Since climate change is only a result of several factors that are contributing in changing the environment therefore the measures that can be taken to reduce the risk are related to these factors. Risk transfer, as discussed earlier is a measure to check the losses incurred by the people. But what can people do to limit their footprints on the changing environment are discussed below.

Measures to Control Air Pollution

The following key strategies can be followed to control air pollution and its impacts in the city.

- **Air quality monitoring and alerts:** Since there are already CAAQMS in the city and ambient air quality is being monitored in various places, therefore when the air quality level becomes unhealthy or poor as per the defined categories, then an alert should be sent to the public so that people can take proper precaution like using masks while going out.
- **Involvement of stakeholders:** The following departments should be passed guidelines for controlling the pollution:
  - **Vehicle emission control:** Road transport organisation (RTO) should check the pollution under control certificate for all the vehicles in the city and cancel the registration of those which are not following the norms.
  - **Road dust and other fugitive emission control:** Nagar Nigam, LDA, Aawaas Vikas. Certain norms like use of v-nets and sprinkling of water to control the dust emission during drilling or other construction activity should be followed.
  - **Biomass burning:** Municipality for garbage burning and Agriculture Department for field biomass burning. Stop burning of residue in the fields.
  - **Construction and demolition activities:** Urban development authority and other development authorities like LMRC for Lucknow metro.
  - **Garbage segregation:** The public should be asked to segregate the garbage into recyclable and non-recyclable or wet and dry and then throw it. Dustbins all across the city should be installed and cleaned regularly. Restriction on burning the plastic waste. Open air landfills should be situated far away from the city and any residential area.
  - **Plantation:** Forest department should be involved to plant and take care of more and more trees.
- **Involving the health department:** There should be training programmes to train the staff about respiratory and other air pollution-related illnesses. Awareness through posters on city buses and autos can be spread about general precautions that can be taken for prevention.
- **Involvement of NGO:** NGOs can carry out awareness programmes in schools and societies about air pollution and can make people work individually on reducing pollution.
- **Awareness:** Steps that can be taken individually should be posted in public like at parks, bus stops, on buses and public should be promoted to take these steps for example:
  - Carpooling or use of public transport to decrease the number of vehicles on the road.
  - Plantation drives in the city. Plantation of one tree outside everybody's home.
  - Say no to plastic.
  - Use cycles for short distances. A public rent system for cycles can be started through an enterprise or by government itself to promote use of cycles.

– The concept of green homes should be brought into discussions. Green and blue infrastructure will help in decreasing the use of ACs and refrigerators.

Measures to Cope Up with Heat Waves

- Install Pyaaus during the summer season at various spots for easy access of drinking water to people and reduce the use of plastic water bottles which create non-biodegradable waste.
- Increase the road side plantation of trees, widen the dividers to have space for planting trees on the divider. Plant trees on the sidewalks of the road to increase shade.
- Make strict laws to restrict vehicles which emit a lot of pollution. Recently, the UP government made police do checks at petrol pump for wearing helmet. The same can be done for vehicles that do not have no pollution certificate.
- Make bus stops as sites of shade and resting.
- Use temples and libraries as cooling centres. Install water coolers or pyaaus for people.
- Training programmes for hospital staff on heat illnesses. Training to ASHA workers and NGOs as well.
- Regular data update on cases of heat waves fatality.
- Use of ambulances and buses to create awareness regarding heat among general public.
- Involvement of NGOs in schools to create awareness among students.

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Individual Behaviour and Perceptions in Disaster Management and Climate Change Adaptation: A Literature Review

Shiva Sai Kiran Pothula[a]

ABSTRACT: Most scholarly work has examined disaster risk and management from the dimensions of resource management, social capital and collective action and identified most significant determinants of adaptation through empirical research. However, empirical research on adaptation has so far mostly not addressed the importance of measurable and alterable psychological and behavioural factors in determining adaptation – a factor largely neglected in previous climate change research. In the light of this gap, this study aims to systematically examine the current literature with an emphasis on the individual behaviour and perceptions. This article provides a review of climate change beliefs, risk perceptions regarding potential climate change impacts and attitudes towards climate change adaptation. The review adopts a systematic literature review examining literary contributions to the field. The search strategy for these papers involved selecting a database, keywords identification, backward search and evaluation. Firstly, Google Scholar has been selected as the online database because it includes a broad range of publications with a focus on the chosen area and identifies literature across different publishers. Secondly, the most suitable keywords and search criteria have been identified to extract the representative subset from the database. Thirdly, a backward search has been chosen to identify the research on evolution of the key concepts and identify works of prominent researchers in the field. Finally, an evaluation was undertaken to limit the amount of literature identified by keyword search to only those articles relevant to the topic on hand. The literature review then broadly conceptualises what is known about the interaction between individual and disaster management and highlights the significance of individual behaviour and perception for climate change adaptation. This review also attempts to identify potential areas where new knowledge may be needed for further research.

KEYWORDS: climate change, public policy, social dilemmas, human cooperation

Introduction

During the latest years of this century, disaster management and climate change adaptation have emerged into important phenomenon, specifically, in the developing countries such as India. Addressing these issues and subsequent adversities is one of the most pressing tasks facing our planet and its residents (American Psychological Association, 2010), and across the world, decision-makers are facing the challenge of adapting to a changing climate. Even though global climate change is fundamentally a biophysical phenomenon, the recent and accelerating warming of the earth's climate is largely attributable to human activity (anthropogenic forcing). However, its impacts are arbitrated by psychological and social processes and can be limited primarily by human activity.

Most scholarly work has examined disaster risk and management from the dimensions of resource management, social capital and collective action

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and identified most significant determinants of adaptation through empirical research. However, empirical research on adaptation has so far mostly not addressed the importance of measurable and alterable psychological and behavioural factors in determining adaptation – a factor largely neglected in previous climate change research. In the light of this gap, this study aims to systematically examine the current literature with an emphasis on the individual behaviour and perceptions. This article provides a review of climate change beliefs, risk perceptions regarding potential climate change impacts and attitudes towards climate change adaptation.

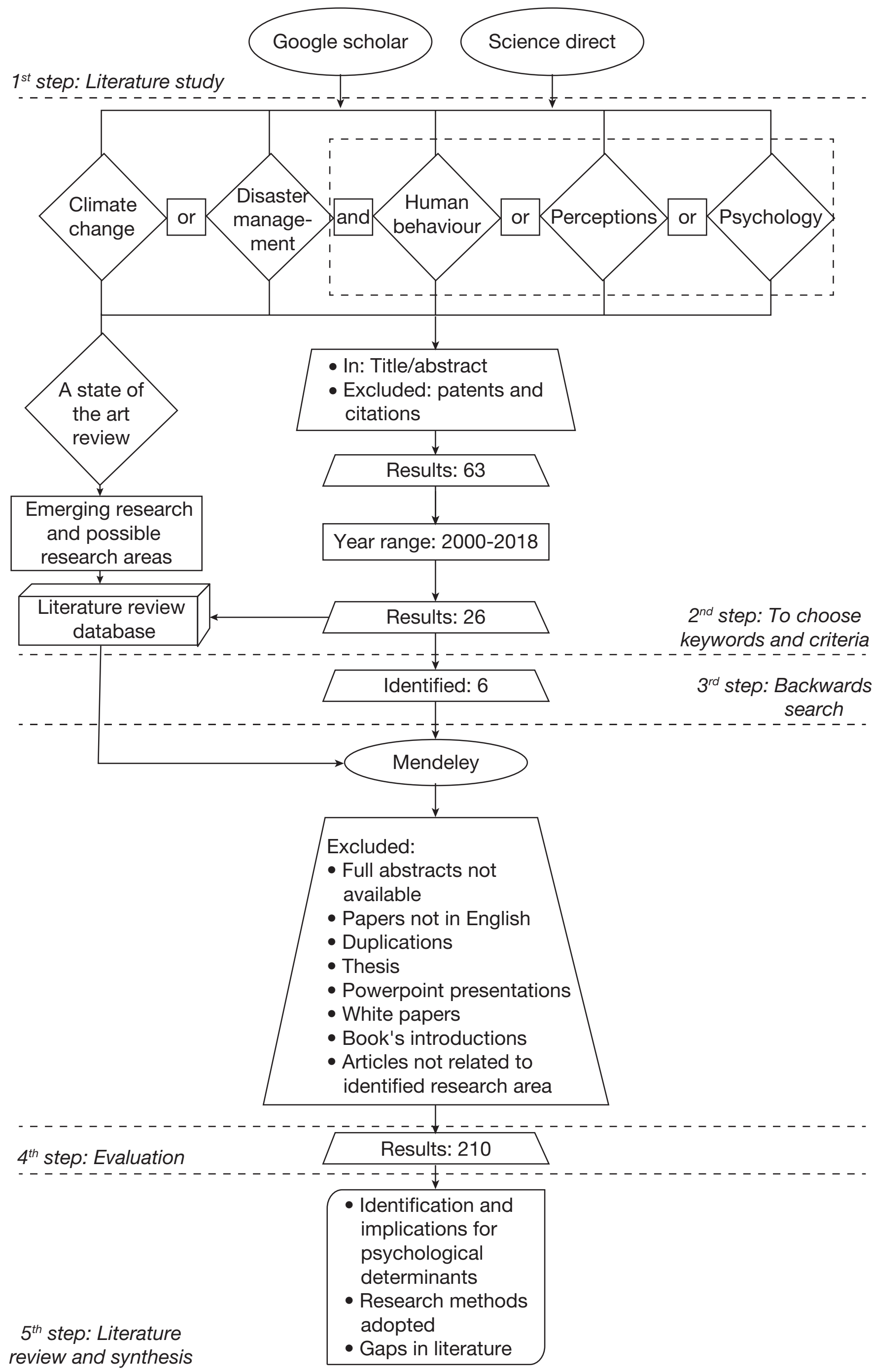

Figure 1: Literature review methodology

The review adopts a systematic literature review examining literary contributions to the field. The search strategy for these papers involved selecting a database, keywords identification, backward search and evaluation. Firstly, Google Scholar has been selected as the online database because it includes a broad range of publications with a focus on the chosen area and identifies literature across different publishers. Secondly, the most suitable keywords and search criteria have been identified to extract the representative subset from the database. Thirdly, a backward search has been chosen to identify the research on evolution of the key concepts and identify works of prominent researchers in the field. Finally, an evaluation was undertaken to limit the amount of literature identified by keyword search to only those articles relevant to the topic on hand. The literature review then broadly conceptualises what is known about the interaction between individual and disaster management and highlights the significance of individual behaviour and perception for climate change adaptation.

This review also attempts to identify potential areas where new knowledge may be needed for further research. This article provides a review of climate change beliefs, risk perceptions regarding potential climate change impacts and attitudes towards climate change adaptation. Given that climate change is, at least in part, deep-rooted in human behaviour, whether or not psychological science can offer novel and useful solutions to climate change is an obvious question (Lange, Joireman, & Milinski, 2018).

Methodology

This literature review partially adopts a methodological model proposed in a study about the importance of rigour in documenting the literature search process (Vom Brocke, J., Simons, A., Niehaves, B., Plattfaut, R., & Cleven, 2009). In order to clearly define the scope of this literature review, the author refers to an established taxonomy (Cooper, 1988) that includes six characteristics for literature review: (a) focus, (b) goal, (c) organisation, (d) perspective, (e) audience and (f) coverage. In order to choose the key concepts on which to base the literature review, the author began the study on the topic at hand by looking at journal articles and reports by institutions.

This review focuses on a core set of 20 peer-reviewed papers and reports directly relevant to public perceptions of climate change risk and adaptation. The literature search strategy included database, keyword, backward and forward search, as well as an ongoing evaluation of sources. To conduct this literature search process, the author evaluated the following search strategy steps: (a) to choose the database source; (b) to choose keywords and search criteria; (c) to choose if to apply backward and forward search and (d) to evaluate the literature subset suitability (see Figure 1).

Behavioural Responses to Climate Change

Human behaviour is integral not only to causing global climate change but also to responding and adapting to it. Given that climate change is, at least in part, deep-rooted in human behaviour, whether or not psychological science can offer novel and useful solutions to climate change is an obvious question (Lange et al., 2018). Some researchers argue that psychological research should apprise efforts to address climate change, to avoid misinterpretations about human behaviour and motivations that can lead to ineffective or misguided policies (Clayton et al., 2015). In this section, we examine behavioural responses from two dimensions; human perceptions of climate change and behavioural drivers of climate change adaptation.

Human Perceptions of Climate Change

There is great variability in public understanding of climate change and will to support action (Whitmarsh, 2011). Psychological research shows that much variety in understanding can be attributed not to what we learn about climate change but to how, and from whom, we learn the sources of our information and how we evaluate those sources (Clayton et al., 2015). In general, direct experiences of events related to climate change are more powerful than second-hand information in informing attitudes and behaviour (Riordan & Jaeger, 2001; Whitmarsh, 2008). This leads to ideologically polarised populations in several countries. For example, at least in the USA and UK, this polarisation is to be linked far more to political ideology and worldview than to any other factor and that polarisation has increased over time (Kahan, D. M., Jenkins-Smith, H. & Braman, 2010).

Many contemplate climate change risks and thus of the benefits of mitigating them as both considerably uncertain and as being mostly in the future and geographically distant. The costs of mitigation, on the other hand, will be encountered with certainty in the present or near future. Emotional reactions to climate change are likely to influence perceptions of risk. Yet, emotional reactions to climate change risks are likely to be disagreed and muffled because climate change can be seen as a natural process, and global environmental systems perceived as beyond the control of individuals, communities and, quite possibly, science and technology (American Psychological Association, 2010). There is, however, significant variability in people's reactions to climate risks, much of which is mediated by cultural values and beliefs (Ã, Borgstede, & Biel, 2004). This distress caused by the overwhelming political, ethical and social implications of climatic change can lead climate change messages to be ambiguous and rejected. Further research in this area can lead into two directions.

Behavioural Drivers

Human actions that influence climate change include those resulting from demands to accommodate population growth and region-specific types and patterns of consumption. Psychological approaches can help conceptualise and better understand psychosocial predictors of these driving forces. Psychologists can provide behavioural analyses of consumption by focusing on behaviours that contribute the most to climate change. Individual predictors of consumption include ability (e.g., income, skills) and motivation (e.g., connection to nature, perceptions of needs versus luxuries, core psychological needs) to engage in consumption. Contextual predictors of consumption, often mediated by individual-level predictors, include the opportunities and constraints afforded by contexts (e.g., physical infrastructure, climate – driving characteristics of where a person lives) and motivators of consumption primed by contexts.

In seeking to determine whether climate change mitigation strategies are effective, researchers and policy-makers typically use energy consumption as an indicator (Whitmarsh, 2010) and energy saving as motivator. Psychological concepts complement such analyses by examining non-economic predictors of adoption and use of these technologies, including cognitive and motivational factors, such as values and beliefs, and social factors, such as norms and public commitments (Ã et al., 2004; Ajzen, 1991; Trafimow, 2009). Research shows that these factors differ in relative importance for different types of behaviour, such as household adoption, use and maintenance of consumer technologies and behaviour in different domains.

With some types of behaviour, research has shown that intrinsic factors (e.g. values) are often more important than extrinsic ones (e.g. incentives). It is important to recognise that many behavioural decisions are influenced by factors outside conscious awareness. To the extent that behavioural choices are made in conscious response to the threat of climate change, the factors discussed in the previous section on perceptions will be relevant; however, a great deal of environmentally relevant behaviour is driven by forces such as norms, habits and default options (Whitmarsh & Neill, 2010).

Conclusion

The psychological perspective is uniquely placed to understand individual- and household-level factors in socio-ecological systems and can provide important input towards a multi-level approach integrating natural sciences, social sciences and the humanities. Researchers concerned with understanding and responding to climate change typically acknowledge that multiple disciplinary approaches are necessary but do not always act on this recognition. It is time to develop effective ways to integrate psychological research into these efforts. To successfully communicate about risk, change behaviours that contribute to climate change, understand the impacts of climate change and facilitate adaptation, it is necessary to consider individual capabilities, cognitive processes, biases, values, beliefs, norms, identities and social relationships and to integrate understanding at this level into broader understanding of human interactions with a changing climate.

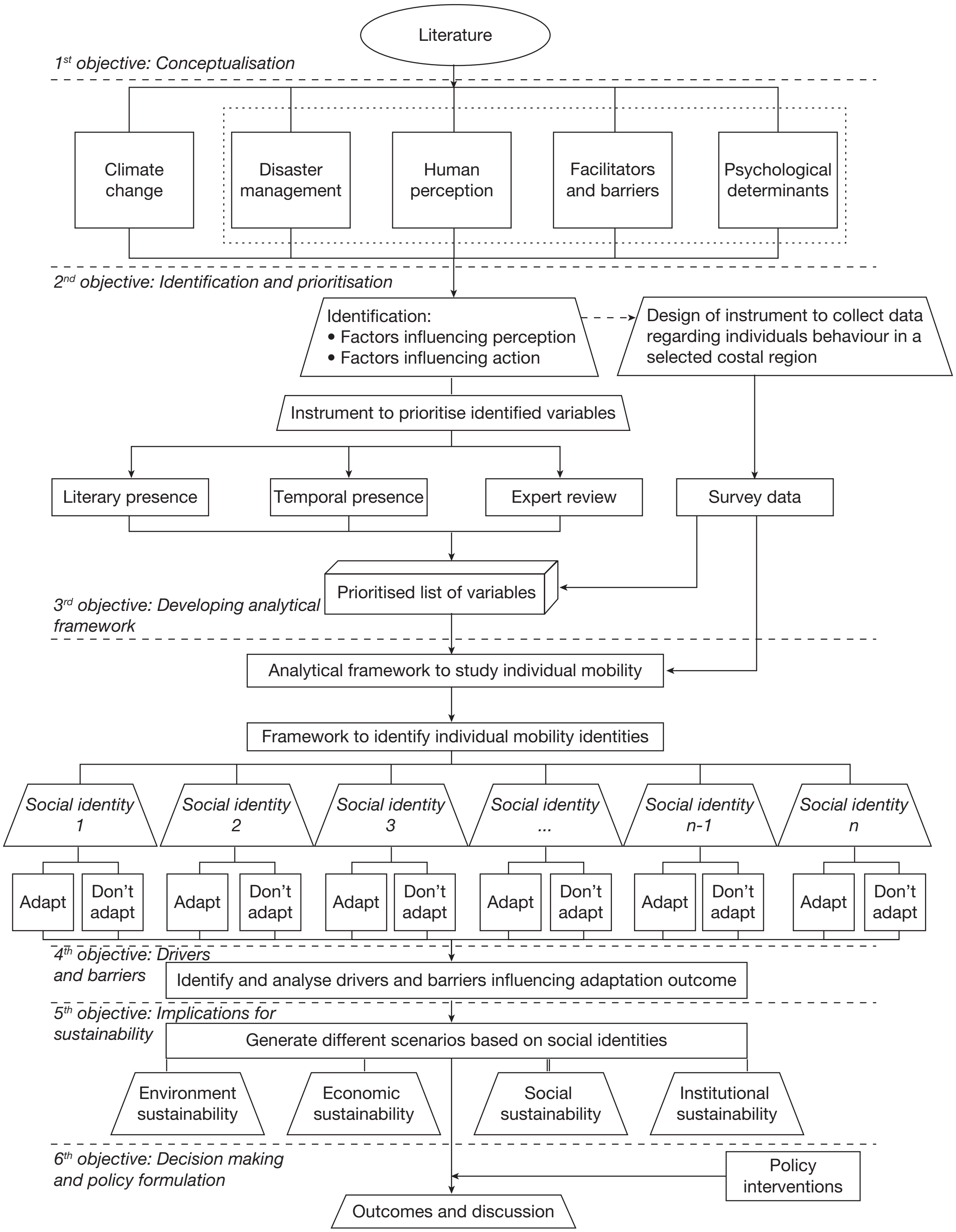

Figure 2: Research agenda and methodology

Adapting to and coping with climate change is an ongoing and ever-changing process that involves many intrapsychic processes that influence reactions to and preparations for adverse impacts of climate change, including chronic events and disasters. Psychological processes include sense making; causal and responsibility attributions for adverse climate change impacts; appraisals of impacts, resources and possible coping responses; affective responses; and motivational processes related to needs for security, stability, coherence and control. These processes are influenced by media representations of climate change and formal and informal social discourse involving social construction, representation, amplification and attenuation of climate change risk and its impacts. These processes reflect and motivate intrapsychic responses (e.g. denial, emotion management, problem solving) and individual and community behavioural responses. Individual and cultural variation influences all aspects of the process, providing context, worldviews, values, concerns, resilience and vulnerability.

Research Agenda

First, this evidence from the literature indicates a need to further examine relevant social identities and to develop educational and policy interventions and communications tailored to the values and possible misperceptions of specific audiences (Clayton et al., 2015; Poortinga, Spence, Whitmarsh, Capstick, & Pidgeon, 2011; Riordan & Jaeger, 2001; Whitmarsh & Neill, 2010). Second, we need more research into the ways known information processing biases affect responses to climate change. Further research could study the role of non-financial factors influencing high-impact household behaviours that could mitigate climate change, particularly the adoption of environmentally friendly technologies and the ways in which these factors interact with monetary incentives. More work is needed by psychologists in collaboration with political scientists and sociologists to illuminate the gap between individual action and societal impact by identifying the circumstances in which individuals take action, alone or collectively, that can bring about large-scale policy changes (see Figure 2).

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VII Technological Disasters

CBRN Incident Management

Col Ram Athavale[a]

ABSTRACT: India is prone to many natural and manmade disasters. While natural disasters occur randomly or perennially, manmade disasters impact our daily lives in a dangerous manner. Toxic wastes, industrial pollution, smog, all cause daily casualties. Chemical, Biological, Radiological or Nuclear (CBRN) risks and threats, whether natural, accidental or terrorist related, loom large on all nations of the world. CBRN emergencies occur as a result of occupational exposure, fire, industrial explosions, release of toxicants, and wastes, and are caused either by ignorance, negligence, incompetence, accident, or malicious intention. The consensus is that the international community is not yet prepared to address the full scope of (CBRN) threats and risks.

The emergence of state-sponsored terrorism, proliferation of chemical/biological weapons, availability of materials and scientific weapons expertise, and recent increases in less discriminate attacks, all point toward a growing probability of occurrence of CBRN mass casualty incident. India has already seen the Bhopal gas tragedy, the radiation incident at Delhi and the many biological threats like Swine Flu, Bird Flu and Plague. Rapid industrialisation, huge amount of toxic chemical trade, ineffective site security and vulnerable supply chains have all led to proliferation and smuggling of such dangerous materials. Preparing the nation to address CBRN threats is a formidable challenge, but the consequences of being unprepared could be devastating. The public health infrastructure must be prepared to prevent illness and injury from radiological, biological and chemical terrorism, especially a covert terrorist attack. With emerging infectious diseases, early detection and control of radiological, biological or chemical attacks depends on a strong and flexible public health system at the local, state, and central govt levels. Primary health-care providers (govt and private) throughout India must be vigilant because they will probably be the first to observe and report unusual illnesses or injuries.

While some countries are well aware of the CBRN risks and national vulnerabilities they lack basic education on health, safety and disaster management matters. Public health and personal hygiene are either ignored or not followed due to lack of funds, resources and institutional support.

Awareness of CBRN threats and risk mitigation measures is necessary at all levels There is an urgent need to educate and train all concerned stakeholders in CBRN risks and threats and the need to adopt risk mitigation measures. Recent trends show enhanced interests of terrorists groups in CBRN material. Syria and Iraq are glaring examples where industrial grade toxic chemicals have been used to cause large numbers of casualties.

Global threat patterns are increasingly moving in the CBRN realm. India needs to urgently understand the magnitude and complexities of such threats and put in place a sound mechanism to prevent these. Failing prevention, our response must be swift and adequate enough to limit escalation isolate the incident and effectively mitigate its impact.

The main paper would aim to highlight these CBRN threats and likely disasters and suggest methodology to build resilience towards these.

KEYWORDS: CBRN emergencies, crisis prevention, management, international support

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Introduction

India is prone to many natural and man-made disasters. While natural disasters occur randomly or perennially, manmade disasters are impacting our daily lives in a dangerous manner. Toxic wastes, industrial pollution and smogs are all causing daily casualties. Chemical, Biological, Radiological or Nuclear (CBRN) risks and threats, whether natural, accidental or terrorist related, loom large on all nations of the world. CBRN emergencies occur as a result of occupational exposure, fire, industrial explosions, release of toxicants and wastes. These are caused by ignorance, negligence, incompetence, accident or malicious intention. There appears to be consensus that the international community is not yet prepared to address the full scope of (CBRN) threats and risks.

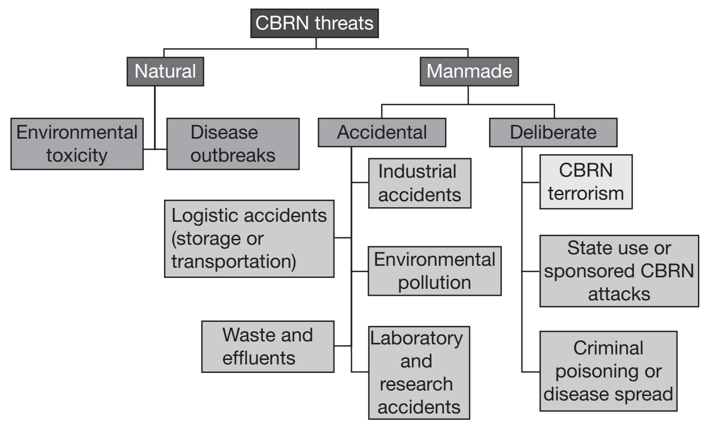
CBRN Threat Matrix

The emergence of state-sponsored terrorism, proliferation of chemical/biological weapons, availability of materials and scientific weapons expertise and recent increases in less discriminate attacks all point towards a growing probability of occurrence of CBRN mass casualty incident. A terrorist attack involving the use of CBRN materials could inflict large numbers of casualties and would represent a major incident for the emergency services. Administration and response forces could get overwhelmed unless proper planning and preparations are made.

India has already seen the Bhopal gas tragedy, the radiation incident at Delhi and the many biological threats like swine flu, dengue, bird flu and plague. Rapid industrialisation, huge amount of toxic chemical trade, ineffective site security and vulnerable supply chains have all led to proliferation and smuggling of such dangerous materials. The recent nerve agent poisoning of Sergei and Yulia Skripal in the UK and the public poisoning of Kim Jong Nam at a crowded Kuala Lumpur airport terminal raises fears of similar large-scale threats to general unassuming public. The paranoia created/generated shall have many repercussions.

Preparing the nation to address CBRN threats is a formidable challenge, but the consequences of being unprepared could be devastating. The public health infrastructure must be prepared to prevent illness and injury that would result from chemical, biological and radiological terrorism, especially a covert terrorist attack. With emerging infectious diseases, early detection and control of chemical, biological and radiological attacks depend on a strong and flexible public health system at the local, state and central government levels. In addition, primary health-care providers (government and private) throughout India must be vigilant because they will probably be the first to observe and report unusual illnesses or injuries.

CBRN threats and risks can be summarised as under:



While some countries are well aware of the CBRN risks and national vulnerabilities to these, situation in the country inhibits taking positive action towards risk mitigation. Some countries lack basic education on health, safety and disaster management matters. Public health and personal hygiene are either ignored or not followed due to lack of funds, resources and institutional support.

Awareness of CBRN threats and risk mitigation measures is necessary at all levels. While speaking to top Government officials from a developing country on CBRN risk mitigation needs, someone remarked that his country does not possess nuclear weapons and so why are we talking of CBRN risk mitigation. There is an urgent need to educate and train all concerned stakeholders in CBRN risks and threats and the need to adopt risk mitigation measures. Recent trends show enhanced interests of terrorists groups in CBRN material. Syria and Iraq are glaring examples where industrial-grade toxic chemicals have been used to cause large number of casualties. High visibility events like large public rallies, national and international sporting events, religious festivals and cultural extravaganzas are all highly vulnerable to CBRN terror strikes.

Preparing for CBRN Threats

A nation needs to first identify its National CBRN Strategy. This is aligned to the National Security Strategy and the National Health Strategy. The steps to empower a nation for CBRN resilience are as follows:

- Developing a National CBRN Strategy
- Assessment and analysis of CBRN threats and risks – risk mapping
- Mapping of CBRN-related capacities and capabilities – gap analysis
- Developing a National CBRN Action Plan for gap closure
- Training and equipping of stakeholders
- Awareness generation/enhancement programme – CBRN security culture
- Developing a CBRN response/consequence management plan
- Capacity building and capability development
- Training and equipping of response teams

Key Focus Areas: A CBRN consequence management plan should be based on the following five focus areas, with each area integrating training and research:

- Preparedness and prevention
- Detection and surveillance
- Response and mitigation
- Medical management
- Crisis command and communication

Stake holders: Contrary to common belief, there are a number of stakeholders in such incidents other than the Government agencies:

- Government
  - Intelligence agencies
  - Internal security
  - Disaster management
  - Ministries and organisations for industries, environment, customs and border control, law, health and transport (aviation, shipping and land based)
  - Armed forces
- Industry – factories and wholesalers
- Logistic agencies (storage and transport)
- Waste management agencies
- Medical and health care – public and private
- Civic bodies and NGOs
- Citizen
  - Working class
  - Small businesses
  - Students
- Media

Areas Requiring Emphasis: The Indian Government and other agencies including international agencies have begun a lot of work towards increasing resilience against CBRN incidents: however, certain areas which need more emphasis are as follows:

- Proliferation prevention (internal and external) – A lot needs to be done to secure our borders and material that is coming in and going out of the country. CBRN scanners, sound intelligence and comprehensive pacts with other countries are required.
- Streamline incident prevention measures – surveillance, risk zoning, strict enforcement measures, networking and crime prevention. Strong apex structure and synergy amongst the various agencies involved is the need of the hour.
- Enhance first response capability:
  - More CBRN trained NDRF Battalions – extend the concept to SDRFs to increase footprint and reduce reaction times.
  - Equipment – this is a major shortcoming. We need capacity building in state-of-the-art equipment for detection, protection, decontamination and medical management of CBRN casualties.
- Improving health infrastructure – wider footprint, greater density and surge capacity handling.
- Networking of Government and private agencies – resources, expertise and network of private NGOs, emergency management organisations and medical services need to be synergised with Government programmes.
- Communications, especially in interior areas.
- Media involvement. Develop and engage media as responsible stakeholders. Irresponsible media

coverage and urge to hit public with 'Breaking News' needs to be controlled. CBRN incidents have a huge psychological impact even on the 'worried well'. Media should aim to prevent and reduce panic and paranoia and help boost the resilience of the community.

- Logistics (warehousing, storage and handling and transportation) is a major concern and needs special attention.
- Awareness enhancement – education, drills, creation of Citizen Emergency Response Teams (CERT) in localities, industries, companies, colleges and institutions. Community involvement is a crucial aspect as more often than not, the local citizenry will be the first responders.

While the Indian Government and other agencies including international have begun a lot of work towards increasing resilience against CBRN incidents, a lot still needs to be done, especially the areas of stakeholder awareness, enforcement of legislations, public resilience and response efforts.

Medical management pre and post a CBRN incident is vital to saving lives. Medical infrastructure and human resource capabilities need to be trained and oriented to handling CBRN casualties. Such incidents have a mass impact, and hospitals and medical infrastructure need to develop surge capacities and work on such contingencies.

Inculcating a culture of safety from CBRN risks in various walks of life as well as in the basic social infrastructure is the need of the hour. This would call for a radical change in our thinking at all levels. The schools to begin with and later the colleges and universities as well as the professional colleges and institutions have to build this concept in their curricular and extra-curricular activities. Social organisations and the governmental administrative system at all levels have to incorporate these safety concerns in their work-ethics, work-manuals and procedures.

The Way Forward

To effectively prevent, counter and combat CBRN incidents, there is a need to synergise efforts of all concerned agencies. The aspect is dealt in three heads of Comprehensive Management, System Essentials and International Support.

Comprehensive Management: The state needs to evolve a comprehensive programme to cover all aspects of crisis prevention, management and consequence management. Focus should be on the following:

- Regulations based on international standards
- Life cycle safety – source to disposal and destruction
- Threat or vulnerability identification
- Establishing controls to prevent threats
- Surveillance, intelligence and early warning
- Preparedness for response
  - First responder – situational response
  - Medical response
- Containment
- Decontamination
- Resumption of safe operations or activity

System Essentials: While planning CBRN security to installations, Government infrastructure and public places, some key issues that need to be taken note of are listed below:

- Detection systems at airports, ports, border posts and cargo handling areas – controlled access system integrated with CBRN sensors.
- Perimeter security scanning for CBRN threats including stand-off detectors and meteorological sensors at critical infrastructure.
- CBRN detection systems integrated with situational awareness and hazard mapping system – integrated into security control station.
- Immediate protection means – personal protection kits (PPKs) for responder teams.
- Segregated HVAC system with CBR filters and clean chambers for temporary housing at important Government and public buildings.
- Casualty management and evacuation measures – casualty bags, resuscitators, CBRN ambulances and enabling hospitals for surge capacity handling.
- Decontamination equipment for on-site and detailed decontamination facilities including casualties.

International Support

While the Indian Government has its task cut-out, international support is essential to ensure the containment of the threat. Areas that seek international cooperation are as given below:

- Proliferation prevention
- Sharing of CBRN intelligence
- Expert assistance – best practices – seminars and workshops
- Industry participation – CBRN mock drill culture – awareness enhancement
- Technology sharing and availability of 'state-of-the-art' equipment
- Medical and health care

Conclusion

Global threat patterns are increasingly moving in the CBRN realm. India needs to urgently understand the magnitude and complexities of such threats and put in place a sound mechanism to prevent these. Failing prevention, our response must be swift and adequate enough to limit escalation to isolate the incident and effectively mitigate its impact. Analysis clearly indicates the growing possibility of CBRN incidents/terrorism in the Indian subcontinent. We need to be extra vigilant and fully prepared to prevent and deter and, if faced with, respond effectively to CBRN incidents.

Peril of Uranium Mining – An Emerging Disaster: A Case Study of East Singhbhum, Jharkhand

Priya Namrata Topno[a]

ABSTRACT: India is a mineral-rich country having a favourable geographical set-up. Mining sector is one of the core economic driver of the country. Uranium is a rare mineral used to generate nuclear energy and weapons. Uranium ore is found in small quantities in soils and rocks, which varies from place to place. East Singhbhum district of Jharkhand is the major uranium production centre having the mine site, plant and dumping ground called tailing pond. The main deposits are located on the lands belonging to tribal people. These people co-existed with the nature, but due to lack of awareness and education, they fell into the trap of country's developmental programme. Mining for the national cause has turned out to be disastrous. The hazardous nature of radioactive ore and mill waste pose serious and unidentified health risk and environmental impacts.

Radon gas is continuously released in the atmosphere from the mining sites and tailing pond, having irreversible health effects. Wind carries the dust particles from the tailing pond and mine site to long distance, that are inhaled by the tribal community residing in the vicinity, and they get deposited on the agricultural ground and also leach into soil and aquifers. This leads to higher level of health hazards. The unaware communities are paying a huge cost.

The objective of this paper is to understand the threats and risk associated with uranium mining in Jharkhand and to identify if there is any coping measure adopted by the tribal community who are directly impacted. This paper is based on the primary observation and secondary literature including both primary and secondary sources of data.

KEYWORDS: uranium mining, tailing pond, radiation, disaster, health risk, tribal community

Introduction

The nation celebrates its status of being a nuclear armed superpower. The country is proud of the shining missiles and possessing nuclear weapons but does not feel ashamed of the way it has treated the very people who made it happen.

Uranium mining process generates a wide range of risk from every day hazard to health risk by releasing harmful gases and dust that affect the health of tribal people. Not enough attention has been given to the communities residing nearby the mining site and tailing pond.

Very few people are actually aware of the different aspects of nuclear energy, uranium mining and its impact. Nuclear energy is going to be the focus of governments in the future. Uranium mining too is fast becoming a phenomenon all over. Hence, awareness on these issues is very important for Jharkhand in general and India in particular. Uranium waste is very dangerous for mankind. It takes around 100,000 years to dispose of uranium waste (Kiro, 2013).

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A recent study in Jaduguda and Turamdih, Jharkhand, on mining hazard and the accumulated risk has provided the opportunity to discuss the issue in both general term and specifically as it affects the surrounding areas.

Mining as a Disaster

Uranium mining is a subset of bigger environmental disaster and the most destructive industries. Mining strips billion tons of materials from earth, much of it is hazardous. It creates mountains of waste, environmental pollution and health hazards and leads to displacement and rehabilitation. Mining was taken up as a developmental work which has caused much damage to the indigenous people (Jojo, 2001). Uranium mines and tailing ponds have contaminated water with radiation and other heavy metals which are yet to be cleaned up (Energy Net, 2019). The uranium mining is a slow-onset disaster and its effect is seen after a long period of time.

Chemical, Biological, Radiological and Nuclear (CBRN) includes both weaponised or non-weaponised chemical, biological, radiological and nuclear materials that can cause great harm and pose significant threats. The non-weaponised materials refer to the dangerous goods (DG) or hazardous materials (HAZMAT) and also include contaminated livestock, water and crops (CEEP, 2019).

An accidental CBRN incident is an event caused by human error or natural or technological reasons, such as spills, accidental releases or leakages. These accidental incidents are usually referred to as DG or HAZMAT accidents. An intentional CBRN incident includes criminal acts such as the deliberate dumping or release of hazardous materials to avoid regulatory requirements. This incident differs in nature because there are unique implications relating to federal/provincial/territorial responsibilities, public safety, public confidence, national security and international relations.

CBRN incidents may include some of the following characteristics: potential for long-term effects, creation of an extremely hazardous environment, relative ease and cheapness of production, need for specialised detection equipment, need for timely, efficient and effective mass decontamination systems and need to establish early those who are affected and those at risk (CEEP, 2019).

Though uranium mining has not yet visualised as hazard, it has created huge risk to people residing in the vicinity of mine site and tailing pond. The impact can be seen in longer duration affecting entire ecosystem. The exposure by the contaminated ionising radiation can be by three ways:

- *External contamination:* when airborne radioactive materials such as dust and aerosols land on skin or clothes.
- *Internal exposure:* when a radionuclide is inhaled, ingested or otherwise enters into the bloodstream.
- *External irradiation:* when body is exposed to penetrating rays from an external source (GDPC, 2017).

Materials and Methods

The objective of this paper is to understand the threats and risk associated with uranium mining in Jharkhand and to identify if there is any coping measure adopted by the tribal community who are directly impacted. This paper is based on the primary observation and secondary literature including both primary and secondary sources of data. The data used will be the responses from the villagers residing near the mines, plant and tailing pond. Apart from this, various articles, case studies, documentary print and electronic media will be considered.

Study Location

Half of the world's uranium is found in Australia and Canada. Uranium mining is expanding everywhere. Uranium is mined for nuclear power and nuclear bomb, but very little is known about its effects. Nuclear chain reaction produces nuclear waste and contaminates the environment (Biegert, 2019). It has a leading position with respect to mining and other industrial activities in Jharkhand State. Jharkhand is the producer of uranium ore which is used as fuel for nuclear power reactors. The state consists of four underground mines, one opencast mine and two processing plants and a by-product recovery plant located in East Singhbhum district (GOI, 2018).

Jharkhand is located in the eastern region of Indian peninsular plateau. It is the 28th state of the Indian Union that came into existence on November 15, 2000, by the Bihar Reorganization Act. The word 'Jharkhand' means the 'land of forest' or 'bushland'; it has forest and hilly tract. Jharkhand is enclosed by Bihar towards north, Chhattisgarh and Uttar Pradesh towards west, Odisha towards south and West Bengal towards east. Jharkhand covers a geographical area of 79.70 lakh hectare and lies on the Chhotanagpur Plateau, a north-eastern portion of the Peninsular Plateau of India. This plateau is sub-divided into the Ranchi and Hazaribagh plateaus. The uneven region consists of succession of plateaus, hills and valleys drained by many rivers. Jharkhand is one of the richest areas in the entire country, rich in mineral deposit and forest. The state is a larger producer of fuel minerals; it is the 'red carpet' for industrial investments.

East Singhbhum district is situated at the extreme corner of Jharkhand. It has a leading position from the industrial growth and mining quarrying. Singhbhum means 'land of lions'. It is located between 22˚12' to 23˚ 01' North latitude and 86˚04' to 86˚54' East longitude. The entire district is rich in minerals such as iron, copper, ore, uranium, gold and kynite (GOI, 2016).

The power that gets generated using nuclear energy has its genesis in Jharkhand. The largest deposits of uranium ore are found at Jaduguda. Since 1960s, the nuclear lobby of the country rushed to exploit the ore (Wankhede, 2017). Uranium mining in Jharkhand state is leading to mass poisoning and slow deaths for tribal people. It is the slow-onset, manmade disaster (Bose & George, 2013). Uranium Corporation of India Limited (UCIL) was founded in the year 1967 with its headquarters at Jaduguda, East Singhbhum district of Jharkhand, where the first underground uranium mine is situated. It is a Public-Sector Undertaking (PSU) under the Department of Atomic Energy (DAE) for mining and processing of uranium (Wankhede, 2012; Vengurlekar, 2017). Growing demand of uranium ore led to reopening of old mines and developing new mines in East Singhbhum region. Hill at Banduhurang village in Jharkhand is converted into open-cast mine to extract uranium ore (Subramanian & Chattopadhyay, 2006). Turamdih mine and mill, Banduhurang open-cast mine and Mohuldih mine are the latest formed mines adding to Jaduguda, Narwapahar and Bhatin mines (Bose & George, 2013).

Minerals and Mining in Jharkhand

India is a mineral-rich country and has favourable geographical set-up similar to Canada, Australia, Brazil, South Africa, Chile and Mexico. The geographical environment is yet to be fully explored, assessed and exploited. Mining is one of the core sectors of Indian economy. It provides the raw materials to many industries. India is blessed with rich mineral resources, and Jharkhand has large deposits of minerals which act as solid launching pad for mining and mineral-based industries. It has a major portion of nation's mineral reserve.

Mining is a major economic activity, and industry is the backbone of the manufacturing and infrastructure sector of economy. The raw material that goes into industries includes thermal, iron and steel, petroleum and natural gas. India's mining sector is the third largest producer of coal (676.52 million tonnes in FY18) and steel (102.34 and 104.98 million tonnes of crude and finished steel in FY18), fourth largest producer of iron ore (210 million tonnes in FY18, has 8 per cent of world's deposits of iron ore), fifth largest in coal reserve in the world (308.802 billion tonnes FY16), seventh largest bauxite reserve (2908.85 million tonnes in FY17), sixth largest producer of zinc and produces 98 different types of minerals (Make in India, n.d.; IBEF, 2018). India produces 95 minerals, four fuel-related minerals, 10 metallic minerals, 23 non-metallic minerals, 3 atomic minerals and 55 minor minerals (building and other minerals) (IBEF, 2018).

Jharkhand is blessed with natural gift of immense mineral potential and natural resources. Mines and mineral industries are the main drives of Jharkhand's economy. Jharkhand ranks third in terms of mineral production in the country and holds about 40 per cent of mineral wealth of India (GOJ, 2016; Momentum Jharkhand, n.d.). Jharkhand has a wealthy treasure of iron ore (26 per cent of India's reserve), coal (27.3 per cent of India's reserve), copper ores (18.5 per cent of India's reserve), cobalt (20 per cent), apatite (17 per cent), steel, mica, uranium, bauxite, granite, limestone, silver, graphite, magnetite and dolomite and is trying to exploit plenty of mineral resources (Jharkhand Tourism, n.d.; IBEF, 2018; Momentum Jharkhand, n.d.).

Jharkhand state occupies first position in coal reserve, second position in iron ore reserve, third position in copper ore reserve and seventh position in bauxite reserve and is the sole producer of prime coking coal, limestone, dolomite, manganese, mica, china clay, graphite, soap stone, fire clay, coal bed methane, uranium, phosphorite, apatite, quartz, feldspar, gold and pyroxenite (GOJ, 2016). Jharkhand is one of the richest mineral zones in the world and boasts 40 and 29 per cent of India's mineral and coal reserve. Due to the presence of large mineral reserve, mining and mineral extraction are the major industries in the state. The strategic location of the Jharkhand state provides an advantage to the industries as it is located close to market and ports of eastern India (IBEF, 2018).

Background and History of Uranium Mining

The exploration and mining of radioactive ores in Jharkhand began in the year 1967 under the UCIL. Uranium was considered as a rare, radioactive and unstable element found naturally in low concentrations in soil, rock, surface water and groundwater. Uranium is the heaviest element existing in the form of uranium ore in the earth's crust.

Uranium mining is a process of extraction of uranium ore from the earth surface through the conventional open pit or opencast mining and underground mining. The deposits are often located in the areas where the indigenous or tribal community resides. After the extraction of uranium ore from the ground, it is sent to the processing plant where extraction of uranium from the ore takes place. Concentrated uranium oxide (U_3O_8) having 74 per cent purity is produced which is also known as 'Yellow cake' along with mine tailings and contaminated waste water.

Underground mining is done by digging a tunnel and using shafts to access and remove the ore. This proves to be very dangerous for the mine workers due to the highest level of exposure to the radon gas. The ore is mined as it is identified with the help of shaft that is sunk in the vicinity of the ore veins, and cross-cuts drive horizontally to the veins at various levels. Various tunnels also known as drifts are driven along the veins. The tunnels are driven upwards, also known as raises, and downwards, also known as winzes, through the deposit. Raises are used to develop the stopes from where the ore is mined from the veins and extracted. Stoping has two methods: first is the "cut and fill" or open stoping method where the extracted space is filled with waste rocks and cement, while the second is 'shrinkage' method from which sufficient amount of ore is removed through chutes and a hole is left. Open cast or open pit mining is done where the overburden is drilled and removed and the exposed ore is blasted and excavated using loaders and trucks.

The ore is processed in the mill which is mined and brought from the Jaduguda, Bhatin, Narwapahar, Bandhuhurang and Bagjata mines. The ore of different sizes is crushed, and undergoes a two-stage wet grinding process. The ground ore in slurry form is thickened and leached in leaching pouches under controlled pH and temperature conditions. The leached liquor is filtered and undergoes an ion-exchange process where the uranyl ions get absorbed in the resin. The liquor is then washed and treated with magnesia to get the yellow cake (magnesium di-uranate). Yellow cake is thickened, washed, filtered, dried and packed in drums and the final product is sent to Nuclear Fuel Complex, Hyderabad, to process it as nuclear grade fuel. The processing is done in such a way the effluent discharge is minimum with high recovery of product.

Threat due to Uranium Mining

The indigenous people have occupied the areas rich in mineral resources (Jojo, 2001). They have always been the victims of all mineral extraction losing their lands and livelihoods, suffering from unknown diseases, violation of human rights and facing the threat due to the adverse impact of anthropogenic environmental degradation. Among all the mining activities, uranium mining is the most dangerous. The opencast uranium mines emit radiation the most as compared to the underground mining. Uranium being a toxic metal produces the radioactive materials (alpha, beta and gamma rays) during the decay process.

Uranium milling produces huge amounts of sludge, dust and radiating stones kept in special ponds or piles known as tailings which are usually abandoned. This tailing contains about 85 per cent of radioactive materials present in the ore and heavy metals such as arsenic, polonium, radium and chemical reagents. The tailing pond emits dangerous radon gas which is carcinogenic in nature. These components spread into environment by wind, erosion, seepage and leakage; it also contaminates the groundwater supplies and pollutes the air. The fine dust particles spread radiation in a large radius because the particles travel longer distance and then seep into agricultural products like grass, vegetables and the livestock which are consumed by the local community. The toxic materials cause severe health disorders like urogenital disorders, leukaemia or cancer and other deformities. The effect can be seen after 15–40 years of exposure to the fine dust or gas, though the diagnosis of the cause of lung cancer, tumours and skin diseases is difficult.

The mine waste of uranium is associated with the contamination of the surrounding environment which poisons air and water and proves to be dangerous to humans, animals and vegetations. The primary risk of uranium mining is due to radiation, which is exposed to the fauna through inhalation and ingestion of the radioactive particles in various forms. This radionuclide is known to be carcinogenic and causes different kinds of cancer.

The mine waste is being dumped on the fields and grazing grounds (Bose & George, 2013). The unaware native residents of Jharkhand never knew the repercussion of these activities (Wankhede, 2017). Tribals trusted the government and were trapped for the name of employment. They were used for their physical labour to dig and load the ore for transportation to the surface, as uranium mining is labour intensive. The people were subjected to radiation for prolonged period of time; they worked with no protective clothing which spread the contamination even to their families (Wankhede, 2012). The life expectancy of uranium workers and their families is getting reduced, and children are born with incurable genetic disorder (Wankhede, 2017). Tailing pond, where the sludge is deposited, is also highly radioactive, which seeps through the ground, overflows during monsoon and blows as dust during summer and enters the ecosystem through food chain, air and water. Unknowingly, the local tribal have invited the evil through this mining project.

According to Jojo and Sonowal (2003), Jaduguda has suffered from various health impacts due to the existing uranium mines. The mining operations have adversely affected the groundwater table, and the effluent discharge from the mine site has seriously polluted the underground water resource and streams of these regions. The water pollution has adversely affected the fishes and aquatic life. The radioactive wastes from the uranium mill and tailing ponds at Jaduguda flow into Subarnarekha River and its tributaries compelling millions of people living along the river to drink the radioactive and chemically contaminated water.

These cases show how peoples' lives are being affected due to the uranium mining. They are paying the cost of their life for the nation's development. National nuclear programme is built upon the life of the people, as it deteriorates the living conditions of the tribal community residing near the uranium mining areas. Though the lives of the people have become traumatic, scattered and painful, yet the national nuclear programme is not going to stop. India wanted to be a super power by 2020 by destroying its own resources.

Mining and Its Aftermath Effects

Generally, a community does not get exposed to high doses of radionuclide that may cause acute effects. Rather, the exposure of low doses may result in increased risk of long-term effects. Though radio-nuclide may directly affect the community, it can also contaminate the vegetation and water. Processing of uranium requires a huge amount of water resources. And it leads to long-term impact on environment. Uranium mining affects the air quality due to the exposure of radon gas and uranium dust and also contaminates the surface and groundwater. Uranium mining can cause ecological disasters, as mining and milling produce lots of dust and radon gases. The radon gas is released after mining which is radioactive, and the waste is produced after milling the ore which is then collected as tailings.

The effect of uranium mining is disastrous. Most of the uranium-producing countries have no adequate environmental health and safety legislation and adhere to the International Atomic Energy Agency's safety guide (Thorpe, 2019). Radiation from the uranium mines has harmful effects from generation to generation. Many countries like Brazil, Colorado, Texas, Australia Namibia and other countries have documented the terrible health hazards, water contamination and other pollution problems. The tailing contains uranium, thorium, radium and polonium and emits radon-222. In less developed countries, there is no set limit of emission from the dumps and it's monitoring (Thorpe, 2019).

Through the literatures it has been found that health hazard and uranium mining go hand in hand. Uranium mines are located in different places in India; Jaduguda, Jharkhand, is the first place where uranium mining was started.

Health and Environmental Risk

Radiation does a great harm to the living cells and disrupts the cell's genetic instructions (Jojo, 2001). Nuclear radiation has caused dramatic increase in cancer among the indigenous peoples over past 52 years. The waste product after the uranium extraction is dumped in the huge pond. The radioactive gases released from the processing and dumping site have directly affected the workers, fishes and wildlife.

Uranium mining poses the radiation hazard to the public. There are mainly three types of exposure of the radiation from the surrounding of uranium tailing ponds, plant and mine site.

- Uranium mining and milling operations produce gases having radioactive elements and dust that are being inhaled.
- The water discharged from the mines contains radioactive elements. It exposes radiation when consumed by humans.
- Gamma rays are exposed through the tailing ponds or mine tailings (IDPD, 2004).

Exposure to uranium radiation on a regular basis for a prolong period of time increases the risk of acute radiation syndrome (ARS). Every day, the local community is exposed to natural radiation that comes from many direct and indirect sources such as soil, water, air and food. These elements contain radionuclides in nature which are inhaled and ingested by people. Radiation generated from the radionuclide damages the tissues or organs. The damages depend on the dose rate that is exposed to the sensitive tissues and organs. When the threshold level of exposure exceeds, it results in acute effects on tissues or organs such as skin redness, hair loss, radiation burns or ARS. When the dose rate is low for the long period of time, it can greatly damage the cells which in long run leads to be carcinogenic and can cause cell mutation. This proves to be greater risk for workers since they are more sensitive to radiation. The exposure of radioactive elements can cause lung cancer, skin cancer, bone cancer, leukaemia, kidney damage and birth defects. The local inhabitants experience high rate of lung, stomach and skin cancer, leukaemia, blood disease, kidney disorders and respiratory illness due to the radioactive gas released from uranium waste.

Moreover, uranium ore emits radon gas which is a potential threat to health due to its radioactivity. Inhaling high concentration of this gas is carcinogenic to humans. Therefore, radon leads to lung cancer risk (Stacy, 2012). The radioactive dust and contaminated groundwater lead to suspicious deaths. Radioactive material when kept exposed to the environment as nuclear waste may lead to slow onset of radiation. The communities residing in close vicinity to the Nuclear Processing Plant (NPP), mines or tailing ponds are eternally exposed to radionuclides. These particles come in contact when they are deposited on clothes or skins and can affect the internal organs when inhaled, ingested or absorbed through open wounds.

The water bodies which are the major lifeline of the tribal community have been affected by uranium mining. The Runkini river dried due to the dumping of the waste leading to scarcity of water. This is leading the community to consume contaminated water (Sonowal and Jojo, 2003). The effects of long-term ingestion of contaminated groundwater affect the kidney function; the intake of elevated levels of uranium in water may lead to progressive or irreversible renal injury and even affect bones.

In Jaduguda, the lands were taken by UCIL that once belonged to the tribal community which were very fertile. In these lands, the tailing ponds have been constructed which are one of the sources that lead to radiation exposure. Chatikocha, Dungridih and Turamdih villages are situated very close to the tailing ponds about 40, 60 and 20 metres, respectively, away from the pond. There are possibilities that the wind can easily blow the waste dust and radon gas across the villages and the vast area of agricultural land of Subaranarekha valley. During the monsoon, the tailing pond overflows into the fields and river.

In the year 2006, there was a pipe burst which led to leakage of waste; the toxic sludge killed many fishes, frogs and riparian life. This leak reached to Subaranarekha River and severely contaminated the water resources. In 1986, the tailing pond burst open and the waters flowed towards the villages. The study of radioactive contamination around Jaduguda uranium mines by Hiroaki KOIDE of Kyoto University, Japan, confirms that the amount of air-gamma dose exceeds 1 mili Sievert (1 mSv) per year in Jaduguda and reaches 10 mSV/years around tailing ponds. The strength of pollution in the tailing ponds is 10–100 times higher than the place without contamination, and radon emanated from tailing ponds spreads contamination (IDPD, 2004).

When the extracted ore is transported to the processing plant in trucks, the transportation safety measures are not appropriate and are not followed according to the standards. These raw ores of uranium are being taken by trucks/dumpers. The ores are being taken openly or partially covered by tarpaulins, which are a non-protective coverage, and thus they fall down along sides of the road which comes in direct contact with human, livestock as well as environment and make people and animals vulnerable to the health hazards. This also contaminates the soil that affects the vegetations. Uranium concentrates are left carelessly at Rakha Mine railway station. According to Prof. Tilman Alfred Ruff, vice-chairman and member, Board of Directors of the IPPNW, the uranium waste is disposed openly near the villages which are exposing them to the radiation (IPPNW, 2008).

As mentioned by Nitish Priyadarshi, a geologist and environmentalist, the radioactive waste will get mixed with the soil, and in the long run, it will create health-related problems to both humans and animals. Villagers of Tilaitand have stopped using water from the wells and ponds; they have also said that the wastes from tailing ponds had destroyed their crops. One of the villagers said that by using the contaminated water they have become sick and have witnessed it on the plants and animals too. As stated by the NGO, Paryavaran Chetna Kendra, the fruits are becoming seedless; in the case of kendu locally known as Tiril/Tend/Kend (*Diospyros melanoxylon*), the seeds are getting deformed and the leaves are turning white in colour instead of green. The impact is seen on trees growing in the vicinity of UCIL and tailing ponds. Fishes and frogs have developed unknown diseases and started dying due to the contaminated water; there are many cases of deformities of animals as well as their deaths. Small animals like rabbit, mice and monkeys are disappearing. Buffaloes and cows are being born with deformities. People have noticed the deformities in cows born without tail. Fishes were discovered with unknown skin diseases. Now, the radioactive materials have entered the food chain of humans too.

A local plant known as Thethar/Amori is affected by radiation which contains radium, radon and polonium in it. The nearby locations are also affected by the radiation which is not openly declared by the government because it will create chaos among the residents.

According to the villagers, the water bodies have been contaminated but the actual reason is unknown. These days the awareness has been provided by the NGOs working in the area; this enabled the people to know the source of contamination. They add further that the water bodies are so much contaminated that while taking bath or washing clothes in the water bodies it does not produce foam. The aquatic ecosystem is affected severely. Even though, the local communities are forced to use the contaminated water bodies for taking bath, washing clothes and irrigating fields because they do not have any alternative source. The utilisation of the water from the well is prohibited by the company (UCIL), since it contains 40 per cent of uranium in it; still the people are using the water for other domestic purposes except cooking and drinking. One of the villagers said that there is abnormal size of vegetable (radish and turnip) growth which is restricted to consume. The vegetable growth is so pathetic that even the cattle are not consuming it.

The people residing along the side of tailing pond of Turamdih mention that the water colour turns into yellow. In Jaduguda, people reported that if water is kept in container for long period, then the container becomes oily and greasy and turns yellow in colour. The cattle also suffer from unknown diseases; they are born with deformities. There are three tailing ponds at Jaduguda and one in Turamdih where tons of radioactive wastes are dumped from all over India. These tailing ponds are uncovered and are exposed to the human beings, animals and the entire ecosystem in direct as well as indirect manner. Tailing ponds are earthen in nature, and the embankments are made of pervious clay which leads to seepage and overflows during rainy season, contaminating the groundwater table and water bodies. During summer days, the tailings become dry and look like silver ground and wind blows the fine dust particles towards the villages. It does not even have proper fence; sometimes animals while grazing enters the pond.

Conclusion

Uranium mining was initiated for the development of the country but has turned into a disaster for the tribal community. Mining activities destruct the forest, disrupting the lives and livelihoods of people. The tribals pay the biggest price for the development. The rapid destruction of resources, impact upon socio-economic and cultural heritage of the indigenous people and environmental destruction have greatly affected the entire stretch.

The communities residing near the mines, plant and the tailing pond belong to the scheduled tribes and are unaware of the negative impact of the uranium mining. The indigenous community bear the burden of mining and are victims of the contaminated environment. They are directly affected by the contaminated water, soil and air. The processed waste disposal site is surrounded by the villages, located at less than 5 km distance. These people have additional risks as they cannot afford to bear the cost of the disease they face. Most of the workers are in contractual jobs and thus they don't have access to the company's medical support. Many suffer from these unknown diseases which are difficult to be diagnosed by the local doctors. Many get perished due to lack of awareness of the cause of sickness and inappropriate medicines given. These vulnerable groups of the society become more vulnerable as they reside in the land of mineral resources.

The impact of nuclear and radiological hazards can potentially be very high and the response and coping mechanism can be lengthy and differ from other hazards in several ways (GDPC, 2017). People do oppose the project but they do not have voices. Being a marginalised section of the society, they also do not have any coping mechanism of their own to avoid the risk generated by the uranium mining. There is no specialised monitoring equipment placed in the villages near the mine site and tailing pond to measure the radiation level.

Thus, the routine risks of radiation have a huge threat upon the tribal community affecting their physical health as well as the surrounding in which they live. The grave environmental and health impact of uranium mining and radioactive waste disposal makes the tribal community more vulnerable. Therefore, the company and the government should have a risk reduction approach to minimise the risk and vulnerability of the tribal community.

Recommendations

Few recommendations are as follows:

- Radiation measuring instruments must be installed in the vicinity of mine site and tailing pond.
- Regular monitoring must be done to identify which particles (alpha, beta, gamma rays) are emitted.
- A radiation-specific hospital must be constructed solely for radiation-affected patients, facilities and instruments for immediate decontamination, diagnosis, treatment and specialised doctors must be available.
- The community awareness much be generated and resettlement provisions must be provided.
- The treatment cost must be subsidised for the tribal community as they have been and still are the forced victims of the human-induced techno-developmental hazard.

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Urban Fire Risk Assessment

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ABSTRACT: This paper discusses the urban fire risk assessment for all types of occupancy groups of buildings and enhances the five-step assessment of potential activities. It aims to fire safety management in an organised and methodical approach detailing every aspect of risk assessment. It considers the identification of the fire hazard by identifying the potential sources of ignition, fuel and oxygen, with identification of the people who shall be at risk within the premises and nearby areas. Evaluation of the fire risks and people helps for removal and reduction of the risk through the corrective and effective measures through detection and warning, fire fighting escape routes with lighting facilities along with an appropriate display of signs and notices with its maintenances. This paper also emphasises on the importance of maintaining all the significant findings and the actions taken for minimising removal of fire risk. Also, the emergency plan helps in taking actions during the fire incidences with the training of the occupiers. The most important aspect of the risk assessment is reviewing the assessment from time to time for the least chances of fire occurrences ensuring fire safety.

KEYWORDS: urban fire, fire risk assessment, fire safety, fire hazard management

Introduction

Urban areas are constantly increasing in urban population resulting in high-density urban area developments. These areas of the dense population contribute to increased vulnerability to urban fires comprising buildings of all occupancy groups. The frequency of fires is increasing as urbanisation accelerates (Fang & Wang, 2018).

The fire has a high potentiality of fast destruction to lives and heavy loss of property. Constant technological development accelerates the risk factor and the installed preventive with protective measures faces challenges to maintain the risk factor to the reasonable bound. As a result, the risk of heavy losses is increasingly threatening the existence of the built environment in the community. Therefore, fire safety is one of the major concerns for the development of a country.

Efficient management of fire safety is essential to ensure that fires are unlikely to occur, and if they do occur, they are likely to be controlled or confined immediately, effectively and safely or that, if a fire grows viciously, everyone in the built environment is able to move to a place of total safety easily and immediately.

Fire disaster mitigation planning and management become challenging and the complexities are to be assessed to mitigate fire prevention and protection. The management, prevention and mitigation of urban fire risks are the priority actions within the framework of urban safety. Fire risk assessment with two main factors: the vulnerability and capacity for mitigation of the areas, as well as the areas with a fire history (Safety Section, 2013), are to be evaluated for mitigating fire disasters.

The risk assessment helps to ensure the functional/operational effectiveness of fire safety provisions – fire safety procedures, preventive and protective measures – and the risk assessment also identifies the issues of prerequisite consideration.

Urban Fire

Fires in cities or towns are urban fire. This fire occurs in two places of urbanised areas, namely, indoors and outdoors. Outdoor fires deal with the forest fires

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or wildfires and indoor fires deal with the fires in the confined spaces of buildings which are generally termed as building fires or house fires. Urban fires have the potential to rapidly spread to the adjoining structure. These fires damage and destroy the neighbouring built environment of buildings housing residential, educational, commercial activities along with the transportation vehicles. Therefore, the loss of buildings and infrastructure poses a significant risk from urban fires.

Fire Risk Assessment

A fire risk assessment is a scientific procedure of identifying the fire hazard within the built environment considering the activities carried out there and the probabilities of a fire to initiate and its potentiality to cause harm to the occupants and the people nearby in the neighbourhood (Shin Hayashi, 2006). It aims to determine whether the prevailing fire safety measures – precautionary and preventive – are adequate to assure safety to overall risks presented or if it requires any additions or alterations (Safety Section, 2013).

Fire hazard is the risk of exposure to a fire or its products and its effects. The hazard is the high probability of occurrence (likelihood) of fire, and severity of the possible fire is high leading to vulnerability. The potential harm from a fire hazard depends on the potential growth of a fire starting from the hazard and then the potential consequences leading to the vulnerability in terms of life loss and/or property loss (Safety Section, 2013).

The fire risk assessment aims to identify the fire hazards, minimise the risk of those identified hazards triggering harm to least rationally easible and decide the control measures by providing additional or alteration of fire safety measures to be installed alongwith the managing provisions essential to safeguard the safety of occupants in the built environment if a fire ignites.

A fire risk assessment helps to determine the probability of fire ignition and the consequences from fire to the occupants of the premises and the people in the immediate vicinity.

The fire risk assessment procedure comprises five key steps:

Step 1 – Identification of fire hazards
Step 2 – Identification of people at risk
Step 3 – Evaluate, remove, reduce and protect from remaining risk
Step 4 – record the findings, plan for an emergency, inform, instruct and train the users
Step 5 – review the assessment

Step 1 – Identification of Fire Hazard

Ignition of fire takes place when fuel, heat and oxygen unite in favourable condition. The chances of uniting these three elements can be controlled to avoid the fire to ignite. Therefore, identification of fire hazard can be categorised as identification of ignition sources, fuel sources and oxygen sources.

Identification of Ignition Sources

Identify the probable ignition sources in the built environment by locating the probable sources of heat which could get sufficiently heated to ignite the existing combustible materials. The indicators of heat sources can be anyone from:

- Smoker's materials such as cigarettes, matches and lighters if smoking is permissible within the built environment
- Open flames of candles and lamps
- Sparks from burning materials
- Heaters (portable or installed) – electrical, gas or oil based
- Heat from boilers
- Electrical kitchen appliances – toasters, cookers, hot plates, etc.
- Electrical domestic appliances – dishwashers, clothes washing machine, TV, CCTV, etc.
- Electrical and gas installations for various uses – plant rooms, lift rooms, meter room, etc.
- Frictional heat generated from powered equipment

- Inferior quality of electrical networks, accompanied with surpluses and damaged cable
- Arson, etc.

Identify Sources of Fuel

Any material which burns is fuel for a fire. The material igniting easily becomes the fuel source and becomes heat source for other materials to catch fire. The bulk quantity of combustible materials aggravates the hazardous vulnerability. Some of the common 'fuels' are:

- Textiles, furniture, clothing, beddings, etc;
- Waste paper – newspapers, magazines, cardboard, etc; stored for recycling collection
- Paper products for packaging, stationery, etc.
- Refuse containers and waste storage
- Flammable liquified products such as petrol, diesel paint, varnish, thinners, adhesives, spirits, cooking oils, etc.
- Flammable chemicals like cleaning products, mosquito and insect killers, photocopier chemicals, etc.
- Flammable gases like LPG, CNG, paraffin, etc.
- Temporary structures and seasonal decorations and religious decorations
- Stored materials and high piled or racked storage

During alterations, repairs and redecoration in the premises, combustible materials are possibly stored in the escape routes or in the rooms which are vacant. Careless storage of these products or by deactivating of fire safety installations during the working hours also contributes to the risk. Therefore, particular care has to be taken in such conditions.

Identify Sources of Oxygen

Atmospheric oxygen is always available abundantly (E. Chuvieco, 2010) for fire through the natural ventilation system of windows and ventilators and doors in the built environment. Powered air conditioning arrangements and air handling arrangements are installed in enclosed spaces of structures for conditioned ventilation. In many buildings, as per the requirement of the activity within, combined systems – natural and mechanical air conditioning ventilation system – are installed in the building. From these ventilation systems, oxygen can be easily available for fire also. Oxygen is also available in different materials which are used or stored in the built environment as some oxidising chemical materials which provides oxygen for fire and further to continue burning, oxygen cylinder storage used during welding processes and pyrotechnics (fireworks) which consist oxidising materials.

Step 2 – Identification of People at Risk

In case of fire occurrences, life safety is the prime objective of fire safety. All threats regarding life safety of occupants have to be identified during the fire risk assessment (P. Code and P. Use, 2013). Persons in the built environment of the building and around the immediate vicinity are to be identified. Identification of people at different locations in different situations is essential. Identified locations can be of permanent nature like persons working at workstations or at uncommon places around the built environment. Old aged people and visitors like customers, contractors, maintainers, etc. are also to be identified. Fire risk assessment includes identification of all people who use the premises who may be at risk such as people asleep who are slow to respond; people in isolated areas for maintenance services like catwalks; people who are unfamiliar with the built environment, for example, cyclical maintenance employees, visitors and clients; specially abled persons or people who are not able to leave the built environment speedily; people having linguistic problem; all people in the immediate neighbourhood of the built environment; also, domesticated animals are to be considered for identification.

Step 3 – Evaluate, Remove, Reduce and Protect from Remaining Risk

Evaluation of risk from the hazard is essential. Removal of hazards, wherever it is practicable, helps to reduce the risk. Risk generated by the other neighbouring buildings is also to be taken into consideration.

Evaluate, Reduce or Remove the Risk of Fire Occurrence

The probabilities of ignition of fire can be low with few ignition sources. Good housekeeping keeps the combustible materials away from the heat sources, and therefore, the three elements are unable to have combustion. Generally, fire occurs in one of the ways – accidentally when lighted cigarettes are not extinguished properly or when lighting displays are knocked over; by careless maintenance of electrical installations, or accumulation of waste packaging is permitted near a heat source, or by storage of LPG cylinders next to an electrical fire or other heat source; and arson – intentional attempt to set up fire in immediate proximity of buildings in rubbish bins.

Removal of identified fire hazards is the optimum solution to reduce the risk (P. Code and P. Use, 2013). If not practicable to remove it, then reduce the quantity of the hazardous materials for minimising the loss. Removal or reduction of fire risk is possible by removal or reduction of the ignition source, fuel source and the oxygen source. Actions of removal or reduction of risk should be ensured so that the risks are not replaced by other hazards or risks. Replacement of flammable substance with toxic or corrosive substance is risky which may injure people in other ways.

Evaluate, Remove or Reduce the Risks to People

Evaluation of actual risk to those people in the built environment needs to evaluate ignition point of fire and its spread from various locations (P. Code and P. Use, 2013). Fire spread has to be identified and evaluated to enlist the threat to people. Fire spread occurs by three methods – convection in which temperature rise due to fire in the building becomes the heat source for the spread; conduction in which transfer of heat through material leading to temperature rise; and radiation in which air is heated through radiation similar to an electric bar heater which heats a room.

Smoke is a byproduct of fire containing toxic gases which are harmful to mankind. Technological development produces modern fittings in the buildings which generate thick and black smoke and obscures vision. Smoke causes difficulty in breathing and also blocks the fire escape routes. It is essential to ensure that the provided escape routes are operable and functions effectively evacuating every person to the place of total safety before smoke liberation.

Having evaluated all the risk and measures taken, it is unlikely to conclude that there is no further risk. Fire incidences are unpredictable, and the threat from fire is constant in every built environment presenting the risk to people and property loss. Therefore, we need to reduce the risk factor to the minimum practicable possibility by confirming that adequate fire safety arrangements are installed in the premises along with adequate public address systems instructing the people for safe escape and action to be taken in the case of a fire. Automatic fire detection system alerts the occupants for an early and safe escape (N. D. Hansen, F. B. Steffensen, M. Valkvist, G. Jomaas, and R. Van Coile, 2018).

Reduce fire risk by eradicating or minimising the quantum of combustible substances or heat sources. Also, reducing the number of the users by limiting the population density, educating them through awareness programme, increasing the number of trained personnel, controlling the risk areas by the experts, etc. are some of the possible alternatives to ensure fire safety.

Removal or reduction of fire risk and protection against the remaining risk should consist the fire safety installations as per the regulation. These fire safety installations can be manual or automatic or can be a combination as per the investigation. Automatic installations are reliable and hence preferred.

Fire Detection and Warning Systems

Fire detection at an incipient stage and warning by a modest shout of ‘fire’ or simply manually operated devices are needed for further action of fire safety. Manually operated alarm systems are functional in low-density built environments and are effective if the occupants are aware of the escape routes and preventive measures. In high-density premises, a fire could advance to the level that escape routes could be blocked before the fire is discovered. Automatic detection systems are effective in such premises with regular mock drills and also at places where human services are less. Provision of automatic detection and alarming system also depends on the risk factor of the built environment (P. Code and P. Use, 2013) where the activity handles, manufactures, stores or uses a low flash point or highly flammable hazardous substances.

Firefighting Equipment and Facilities

Firefighting equipment actively reduces the risk of incipient fire developing into a large one like a fire in a waste-paper container. Appropriate use of fire extinguisher at an incipient stage of fire significantly reduces the risk to the people in the built environment by permitting people to assist other users who are at risk (N. D. Hansen, F. B. Steffensen, M. Valkvist, G. Jomaas, and R. Van Coile, 2018). Enough number of portable extinguishers are to be provided for the respective fire risk at the internal and external locations. Fixed firefighting equipment operated by trained staff is to be installed as per the regulations. The operation of these permanent installations requires trained staff, and untrained people should not be expected to handle it. However, all employees should be aware of its location on the premises and its operations.

Escape Routes

Once a fire is noticed and alarming signals are given, the users should be able to move to a place of total safety without any assistance or assistance of rescue team (N. D. Hansen, F. B. Steffensen, M. Valkvist, G. Jomaas, and R. Van Coile, 2018). However, few specially abled persons and others with special assistance like old aged and children may require help for safe evacuation. Staff for them should be designated, and generally, they are taken care of by their family members or neighbours. Provision of escape routes should consider factors such as occupant load in the premises; type of escape route with its number of exits; travel distance with escape time; the type of construction (Jun-tao Yang & Ye Chen, 2014) of the built environment with its age; phased evacuation or delayed evacuation; evacuation with assistance and assembly or gathering points.

Emergency Escape Lighting

Escape routes are to be sufficiently lighted and ventilated for efficient evacuation process. The mental state of the evacuators undergoes a shock regarding threat towards life loss and property loss. Evacuation in such condition is challenging, and hence sufficient ventilation and light are essentially required in the escape routes. Generally, natural lighting systems are more effective, but in a case where the escape routes are of internal tower type, where there is no provision of the window or in the case during night periods, then back up provision helps to provide emergency escape lighting. Emergency escape lighting is significant for safe evacuation.

Signage Systems and Notices

Signage system helps the occupiers to identify the location of escape routes, firefighting equipment and emergency communication systems. Pictogram signage systems are easily understood and also help people with language problems (P. Tofiło, M. Konecki, J. Gałaj, W. Jaskółowski, N. Tuśnio, and M. Cisek, 2013). Notices are essential to provide directions on how to use any fire safety apparatus, the actions to be taken in case of a fire and support for the fire safety and rescue team to locate the position of hydrant valves or electrical cut-off switches. All signage system and notices are to be situated adequately so that they are easily visible and understood.

Installation, Testing and Maintenance

Regular checks, periodic servicing and maintenance are essential irrespective of the size of the built environment and help in identifying the defects in the equipment as soon as possible. The checks and tests depend on the risk factor and size of the premises at intervals as daily checks; weekly tests and checks; monthly tests and checks; six-monthly tests and checks and annual tests and checks.

Step 4 – Record, Plan, Inform, Instruct and Train the Users

A written record of fire risk assessment helps for effective fire safety management. It is a good practice to record the findings and actions to be taken (M. Srivanit, 2015).

Record the Significant Findings and Actions Taken

Significant findings are to be recorded on which further actions can be taken, as an output of the assessment and particulars of anyone at specific risk. Details of findings shall include identified fire hazards, the actions taken or to be taken to reduce or remove the chance of a fire taking place as precautionary actions, identified persons at risk within the premises and in immediate vicinity, the actions deployed or to be taken to control fire and smoke spread as protective measures, the actions to be deployed by the occupiers in case of fire, emergency plan and the nominated staff to carry out. The findings of the fire risk assessment aid to develop the emergency plan, the instructions, information and training to be provided; the coordination and cooperation strategies incorporating other designated staff and the maintenance arrangements and testing of the firefighting installations.

Emergency Plans

The aim of an emergency plan is to confirm that the users of the built environment know what to do in case of fire incidence so that the premises can be safely evacuated (M. Srivanit, 2015). An emergency plan should be on the basis of fire risk assessment and be available for the users, the service providers and administering authority. It is a good practice to keep the records.

Inform, Instruct, Cooperate and Coordinate

All occupants and staff of the built environment should be kept informed and instructed about the fire safety immediately after occupying the premises. Also, the maintenance staff who works beyond the working hours. All the service providers should be instructed and informed about the fire safety arrangements immediately and instantly. The information and instruction should be based on the emergency plan which should include the significant findings from fire risk assessment, the corrective procedures to be followed to minimise the risk, actions to be followed by the staff in case of fire, the identity of the nominated fire safety personnel and any special provision for risky areas of the premises.

Fire Safety Training

Fire safety training should be given to the occupiers of the built environment (M. Srivanit, 2015). The training programme should be based on findings of fire risk assessment and should explain the emergency procedure, duties and responsibilities of the personnel or staff. This training should be conducted during normal working hours ensuring each one's participation and repeated periodically. It should be easily understandable to the users and other people who may be present and with no language difficulty. This training should be tested by mock drills.

The fire safety training should inculcate the actions to be taken on noticing fire, the procedure of raising alarm, actions to be taken after hearing an alarm and the procedure of calling the fire service authority. The evacuation method for all occupants of the built environment to reach a gathering place of total safety should be an essential part of training. The location of various firefighting equipments with its appropriate use for controlling or extinguishing the fire at its incipient stage should be participated by the users. The importance of keeping the escape routes free from obstruction and fire doors closed to avoid the spread of fire, heat and smoke should be explained. The fire safety personnel should be trained to cut off the power supply and stop working of machinery in the event of a fire. Handling of highly flammable materials should be trained for safe operations. The importance of housekeeping should be explained and ensured as this is generally overlooked and many times this is the cause of the fire.

Step 5 – Review

A constant monitor is essential in fire safety management's action to implement the fire risk assessment. The effectiveness of the actions is to be assessed continuously to control the fire risk. The fire risk assessment should be reviewed and revised whenever it is practicable or required. There is no specific timescale for review (The Regulatory Reform, 2005). Reasons for review can be changes in work activities, that is, occupation type, alterations in the interior of the building with a change in furniture and layout, additions and alterations to the building. The substantial changes to type and quantities of storage materials, hazardous materials within the premises. A substantial increase in the number of occupants in the built environment and the presence of specially-abled people and disabled people due to some reason should be the reason for revision. The failure of any fire detection and alarm system and suppression systems like a sprinkler system or mechanical ventilation systems should be the major cause for revision as it ensures life safety to the occupants.

It is not essential to modify the fire risk assessment for every insignificant modification, but if a change is significant to introduce new hazards, then the revision is essential to keep the risks under control. Revision of the assessment is also significant on the occurrence of fire or 'near miss' indicating the inadequacy of the existing risk assessment. The good practice is to identify the cause of any fire incidence and then review and, if needed, modify the risk assessment. Records of testing, maintenance, training, etc. are beneficial aids in a review procedure (The Regulatory Reform, 2005).

Common Drawbacks in Fire Risk Assessment Process

As with any assessment process, there are certain common drawbacks which are to be avoided (The Regulatory Reform, 2005). The generic assessment process is to be avoided in case of site-specific assessments. Risk assessment with inappropriate practices of reconsideration in an attempt to justify that a decision already taken may result unsatisfactory. Failure to recognise all hazards, consider all probable consequences and hierarchy of controls and implement control measures can result in failure of fire risk assessment. Failing to convey the results of risk assessment to those who are involved in the risk factor can be dangerous. Involvement of a team should be encouraged for assessing the risk. A team approach should focus on pooling the knowledge, skills, expertise and experience of various persons with different perceptions to ensure inclusive coverage of all fire hazards.

Conclusion

Fire safety is one of the most important safety issues. Fire safety management should address to control or minimise the threat of injury or death of the users or any person in the immediate vicinity. Unlike most of the other disasters, a fire disaster has the potential to injure a vast number of people. A fire has a constant threat to huge life loss or property loss. The discussed fire risk assessment shall have its impact on other safety issues and vice versa. Therefore, good fire safety management is essential to ensure that fires are unlikely to occur, and if it occurs, it is likely to be controlled or confined immediately at its incipient stage effectively and safely. And if the fire is not possible to be controlled, then all the occupants of the built environment are able to evacuate easily and immediately to a place of total safety.

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Numerical Studies on Development of Fires Inside the Large Size Enclosure

Deepak Sahu[a], Jaspreet Chawla[a] and Sangeeta Garg[a]

ABSTRACT: Fire behaviour inside the room has been investigated with the help of Fire Dynamic Software. The mode is ISO 9705 room size (3.6 m × 2.4 m × 2.4 m) and door of size (0.8 m × 2 m) and in addition to roof opening (0.5 m × 0.5 m) created to study the effect of door opening and ceiling vent in development of fire inside the enclosure. A fire source is heptane fuel of size 0.5 m^2 located at the corner of rear wall. Several sensors are placed to continuously monitor the heat release rate (HRR), mass loss rate of fuel with time and velocity of the inlet air and product gases. Temperatures at different locations are also continuously monitored to note the effect of ventilation on fire behaviour. In FDS (Fire Dynamic Simulator), Smagorinsky form of LES (Large Eddy Simulation) is used to predict the turbulent in under-ventilated spaces. Maximum value of heat release rate (HRR) is 2015 kW and 1997 kW predicted in Tests 1 and 2, respectively; thereafter it is decreased with time due to depletion of oxygen inside the room in both ventilation conditions. Maximum temperature at ceiling is found in the range of 835–840 °C at rear location above the fire source, while it is decreased in direction of rear to front of room with magnitude of 150–180 °C due to cooling effect. In both ventilation conditions, fire is self extinguished after 80 s; at this time, the concentration of oxygen is below 0.12 mol/mol inside the enclosure. The time of occurrences of flashover is found to be very short, approximately 20 s, where maximum heat fluxes are predicted in the range of 30–35 kW/m^2 at ceiling and at floor is predicted to be 10–12 kW/m^2.

KEYWORDS: FDS, ventilation, temperature, velocity, heat flux

Introduction

Over the years, incidents of fire accidents in industries are increasing rapidly. Causes of fires are diverse and include both accidental and prolonged human ignorance. Failing to plan is planning to fail! This enables us to look for intervention methods and techniques to study the behaviour of fire and development of strategies to control the flammability of ignition sources and prevent the further growth of fire. Fire growth and spread rate inside compartment depend on several parameters such as compartment geometry, type of fuel and its placement inside the corridor/chamber, etc.

Zhang et al. (2014) carried out study to design the smoke exhaust system in a busbar corridor, which is extremely important for electrical power transmissions. They analysed 24 possible conditions to predict the design of smoke design system to optimize it. They took into account five factors, that is, the heat release rate (HRR), height of building, the air change rate (ACH), the exhaust outlet positions and the airflow inlet positions. They observed that height and air flow inlet positions affected the exhaust system.

Zhang et al. (2015) analysed CFD simulation studies on a two-level corridor model. In the first case, fire was placed in the lower corridor and in another case, fire was placed at the upper level. The second case was

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found to be more dangerous, because of buoyancy and air flow through the doors, smoke descends and creates a more hazardous situation. They designed the critical velocity of air flow required to control the spread of smoke using Froude modelling.

Zhou et al. (2017) experimentally worked on a 15 m long, 0.5 m wide and 0.75 m high corridor and scaled the model to carry out simulations on larger scale (4:1). They took into account three different sizes of fuel trays to evaluate the HRR and smoke spread inside the corridor. They found that the larger trays led to more HRR, which subsequently to more vertical temperature. However, temperature declines along the length of the corridor.

Wua et al. (2018) conducted reduced-scale numerical simulations (1:4) for a tunnel fire without train blockage. Experiments were conducted to measure the smoke layer length under different conditions. Variations in three parameters are studied: HRR, longitudinal ventilation velocities and ambient pressure conditions. They observed that the smoke layer decreases with increase in ambient pressure conditions, keeping the ventilation velocity and HRR constant.

This work is focussed on to simulate the fire behaviour in a ISO 9705 room of dimensions 3.6 m (length) × 2.4 m (width) × 2.4 m (height) with and without ceiling opening conditions. FDS code is used to numerically measure the HRR and mass burning rate and temperature at the different locations at ceilings and at vent.

Numerical Studies

FDS model numerically solves a form of the Navier–Stokes equations appropriate for low-speed, thermally driven flow with an emphasis on smoke and heat transport from fires.

Geometry and Domain Creation:

The first step of the model is to create the geometry of the problem. In some cases, internal flow is disturbed by boundary of the domain. Therefore, the domain is from the door opening to maintain the free boundary condition. The meshing of computational domain is based on characteristic fire diameter as had been described by McGrattan et al. (2010). A study was carried (He et al. 2008) to investigate the effect of extension of computational domain on the accuracy of FDS. The grid sensitivity analysis shows that the predicted results are sensitive to the size of the cells (McGrattan et al. 2010). The size of mesh cell. *x* is based on characteristic fire diameter *D* (McGrattan et al. 2010), defined as

$$D^* = \left(\frac{\dot{Q}}{\rho_\infty C_p T_\infty \sqrt{g}} \right)^{2/5} \quad (1)$$

where $\dot{Q}$ is heat release rate (kW); ρ_∞ is ambient air density (kg/m^3); C_p is specific heat of air (kJ/kg K); T_∞ is ambient temperature (K) and g is gravitational acceleration (m/s^2). The value of $\frac{D^*}{\delta x}$ more than 10 is recommended for mesh near to fire source and at vent (Cai and Chow 2014).

Selection of Physical Sub-models:

In Hydrodynamic Model, turbulence is treated by means of the Smagorinsky form of Large Eddy Simulation (LES). LES is a technique used to model the dissipative processes (viscosity, thermal conductivity, material diffusivity) that occur at length scales smaller than those that are explicitly resolved on the numerical grid. LES studies helps to understand the turbulent mixing of the gaseous fuel and combustion products with the local environment condition. In fact, experiences have shown that the best results are obtained when the Smagorinsky constant Cs is set as low as possible to maintain numerical stability (McGrattan et al. 2010).

Combustion Model is based on mixture fraction (of fuel and air) concept and estimates the extent of combustion in under-ventilated spaces. In combustion, the mixture fraction is defined as the (mass) fraction of the gases present in the fuel stream.

In Radiation Transport model, the solution of the radiation transport equation for a gray gas is solved using finite-volume method for convective transport.

In the past several numerical studies have been conducted to study the behaviour of fires. The numerical simulation studies (Cai and Chow 2014) on room fires were conducted for different grid sizes and free boundary conditions were selected to analyse the effect on predicted results. Wang et al. (2018) studied the control of smoke and CO transportation in fire using Water Mist Curtain (WMC) system. The WMC system could effectively decrease the temperature of the protected zone, and even under a low working pressure, smoke entrained in the WMC become stable and fall to the floor during the early stage after discharging of the WMC. Newman et al. (2004) derived scaling relationships for characterising room environments. Experimental studies of growing enclosure fires were conducted to test previously derived scaling relationships. The validated correlations enable to estimate the transient combustion product distributions if transient heat release and temperature measurements are available.

Model Design

In present study, a model is ISO 9705 room size (3.6 m × 2.4 m × 2.4 m) and door of size (0.8 m × 2 m) and also provide the roof opening to predict the effect of roof opening on development of fires inside the compartment/chamber. Pyrolysis model is incorporated to study the rate of evaporation of liquid fuels on burning, which is a function of the liquid temperature and the concentration of fuel vapor above the pool surface. Clausius–Clapeyron relation is used to correlate the volume fraction of the fuel vapour above the surface with liquid boiling temperature (McGrattan et al., 2010).

$$X_F = \exp\left[\left(\frac{-h_v W}{R}\right)\left(\frac{1}{T_s} - \frac{1}{T_b}\right)\right] \qquad (2)$$

The fire source is created inside the confined area and allowed to burn initially. Sensors are thermocouples, velocity probe and heat flux metre for prediction of temperature, velocities and heat fluxes, respectively, at various points inside the confined area to study the fire profile inside the chamber.

Figure 1 shows the test model having dimensions 3.6 m × 2.4 m × 2.4 m with a door opening of 0.8 m wide and 2 m high and a ceiling vent at the centre of dimensions 0.5 m × 0.5 m. The room walls of thickness 0.1 m are made of cemented bricks. The ceiling and floor are of thickness 0.1 m and is made of concrete. Fire source is kept at the corner of the room at the distance of 0.3 m, having the area of 0.5 m^2. Heptane taken as fuel for the fire source is allowed to burn initially inside the room, and fire profile on combustion is studied. The details of the test model and simulation are summarised in Tables 1 and 2.

Table 1: Summary of Test Conditions

Test No.	1	2
Ventilation condition	Door opening (0.8 m wide and 2 m high) and ceiling vent (0.5 m× 0.5 m)	Door opening (0.8 m wide and 2 m high)
Size of room	3.6 m × 2.4 m × 2.4 m	3.6 m × 2.4 m × 2.4 m

Table 2: Details of Simulation Parameter

Parameters	Test 1	Test 2
Initial temperature (°C)	20	20
Simulation type	LES, Transient	
Computational domain	4.3 m × 3.1 m × 3.1 m	
Total simulation time (s)	120	
Cell size (m)	0.07 × 0.07 × 0.07	
Total cell	121,500	
Turbulence	Smagorinsky model	
Smagorinsky constant	0.2	
Radiation loss fraction	0.25	
Fire source	Pyrolysis of heptane (0.5 m2)	
Test 1	Cell size	
Sim.1	0.11 m × 0.11 m × 0.11m	
Sim.2	0.09 m × 0.09 m × 0.9 m	
Sim.3	0.07 m × 0.07 m × 0.07 m	

Sim: Simulation

Thermocouple tree (A) having four thermocouples (TF_1-TF_5) are placed above the fuel surface at x = 0.55 m, y = 0.55 m with increment of 0.4 m height. Thermocouple tree (B) is kept at centreline of door at x = 3.6 m, y = 1.2 m with increment of 0.2 m, in total nine thermocouples are fixed to measure the doorway temperature. Further, two thermocouple trees (C, D) are kept at the two corners, one near the entrance 'C' at x = 3.3 m, y = 2.2 m with increment of 0.3 m height, in total seven thermocouples are fixed, and another rack 'D' at rear of room at x = 0.3 m, y = 2.2 m with increment of 0.3 m, in total seven thermocouples are fixed to measure the temperature along the height of room at rear and front of room. A total of four thermocouples are fixed at different locations at a height of 0.2 below the ceiling to measure the temperature of hot gas layer. Also, Oxygen and CO sensor are fixed at different locations to measure the concentration with time and different locations during fires. Oxygen sensors (Oxy 1 to Oxy 5) are fixed at location x = 1.2, y = 0.6 with increment of 0.3 m height. Further, sensors are placed to continuously monitor the HRR and mass loss rate of fuel with time inside the room. Velocity of the inlet air is also continuously monitored to note the effect of ventilation on fire behaviour.

Results and Discussion

Figure 2 shows the fire behaviour in ISO 9705 room size (3.6 m × 2.4 m × 2.4 m) and door of size 0.8 m × 2 m and roof opening (0.5 m × 0.5 m). Grid analysis has been done on Test 1 to understand the effect of grid sensitivity on simulation studies. The predicted values of heat release rate and ceiling temperature are shown in Figure 2. The results of heat release rate and ceiling are found more stable in case of sim.2 and sim.3, while its deviated more in case of sim.1. Therefore, sim.3 condition is considered for further study.

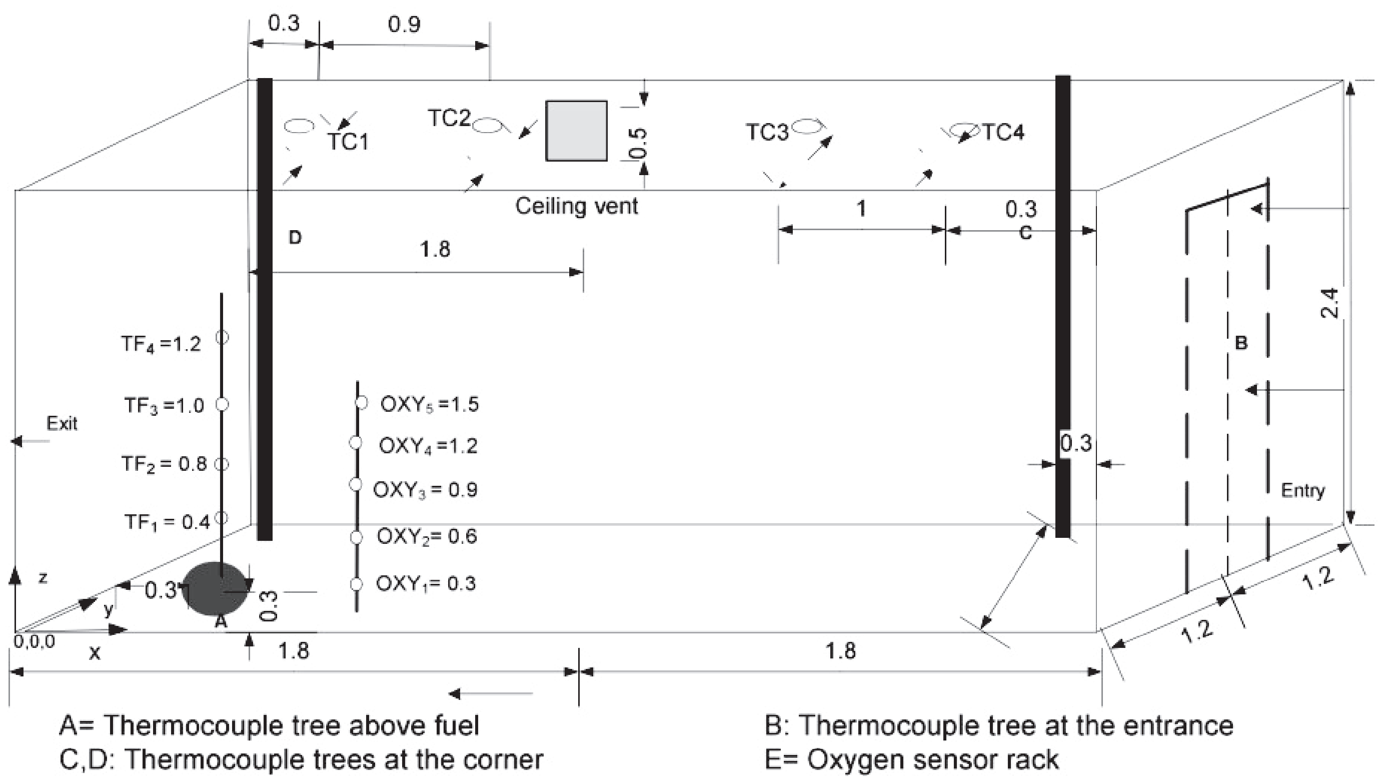

Figure 1: Schematic of fire test model

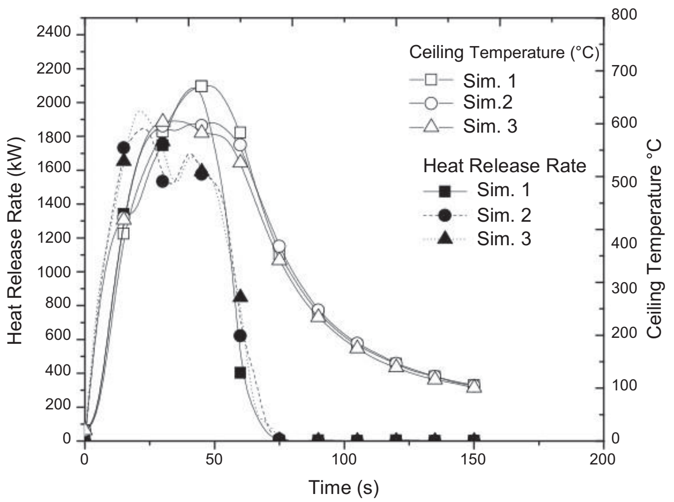

Figure 2: Heat release rate and ceiling temperature under different grid in case of Test 1

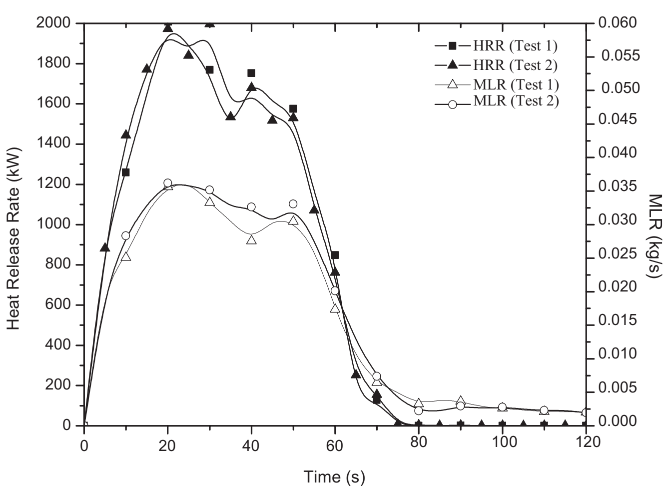

Figure 3: Variation of HRR and MLR with time in Tests 1 and 2

Figure 3 shows the heat release rate and mass loss rate with time in case of Test 1 and Test 2. The growth of fire is increasing rapidly in short period of time, 20 s, before achieving its maximum. Maximum value of heat release rate (HRR) is found to be 2015 kW and 1997 kW in Tests 1 and 2, respectively, and thereafter is decreased with time. Similarly, profile of mass loss rate is predicted in Tests 1 and 2. Fire inside the compartment is mostly affected by hot gas layer and radiated heat towards the fuel surface, therefore, enhancing the burning rate. In Tests 1 and 2, at the start burning of fuel is increasing rapidly by heat feedback. The enclosure vents (doors, windows, leakage areas) may restrict the availability of oxygen needed for combustion.

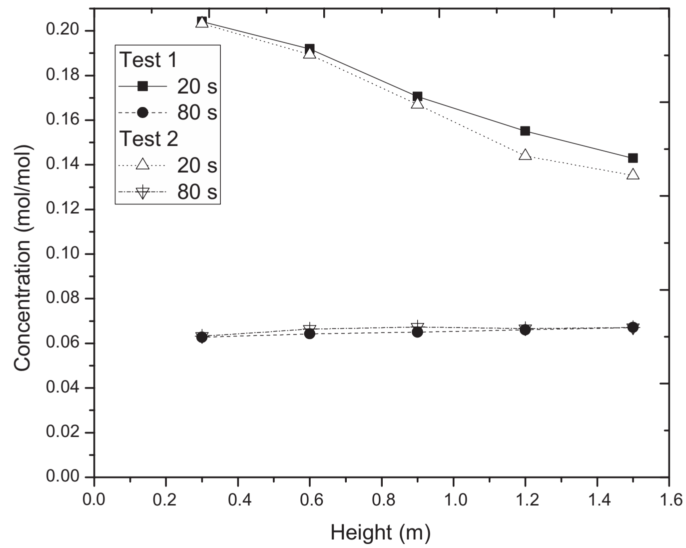

Figure 4: Concentration of Oxygen gas inside room under different ventilation conditions

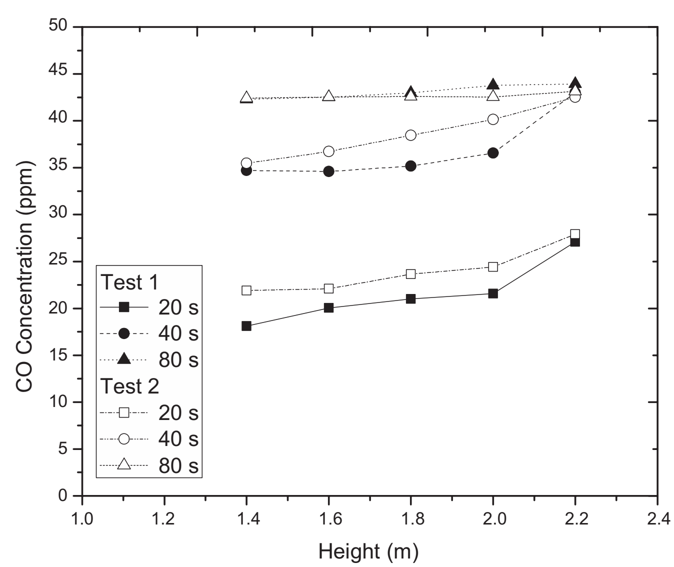

Figure 5: Concentration of CO inside the room under Tests 1 and 2 conditions

Figure 4 shows the oxygen profile inside the room under Tests 1 and 2, it is inferred from the profile that the oxygen is depleted with time and height of room. This profile is similar to heat release rate profile; oxygen concentration is found 0.12 mol/mol at time 60 s at a height of 0.3 m from floor and continuously decreased with time and height. Further, the oxygen concentration is not replenished with inlet air to maintain the combustion of heptane fuel; fire is self extinguished after time 80 s from ignition in both test conditions. Figure 5 shows the concentration of CO at different time and height of room. Concentration of CO is increased with time and height due to depletion of oxygen and incomplete combustion in both ventilation conditions. The smoke can significantly reduce the visibility, thus reducing the possibility for the people to reach escape routes.

Figure 6 shows the ceiling temperature with time and at different locations of room in Tests 1 and 2. The temperature profile is found to be similar in both conditions. Temperature is found to be maximum at 835 and 840 °C at rear location TC1 above the fire source, while it is decreased in the direction of rear to front of room with magnitude of 150–180 °C due to cooling effect in Tests 1 and 2, respectively. It is clear that the temperature profile is non-uniform in both test conditions. Figure 7 shows the variation of temperature at different heights and time in Tests 1 and 2. Initially, at time 20 s, it is clear from this figure that the temperatures at various depths are quite uniform showing the stratification of the hot gas layer at a height of 0.6 m above the floor in both vent conditions. However, after time 40 s, it is found that the smoke descent to room and filled completely, therefore, no stratification layer found in both test conditions. Figure 8 shows the variation of temperature with height in rear and front location.

It is inferred from this figure that temperature distribution is not uniform in rear to front of room.

Doorway temperature profile is shown in Figure 9; the maximum temperature is found to be 593 and 600 °C at a height of 1.8 m from floor. The doorway profile is distinguished into fresh air inlet and outlet of product gases from room; initially it resulted at a height of 0.6 m from floor at time of 20 s. Thereafter, there is no layer separation found in both ventilation conditions due to filing of smoke in entire room.

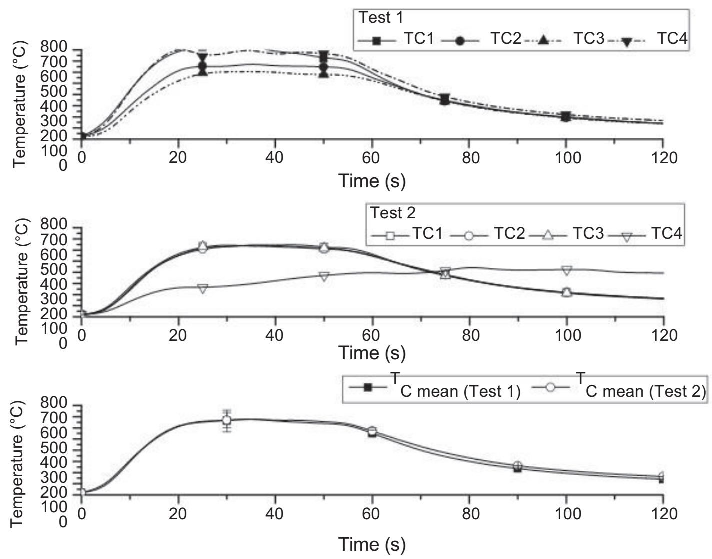

Figure 6: Variation of ceiling temperatures at 0.2 m below the ceiling at different locations

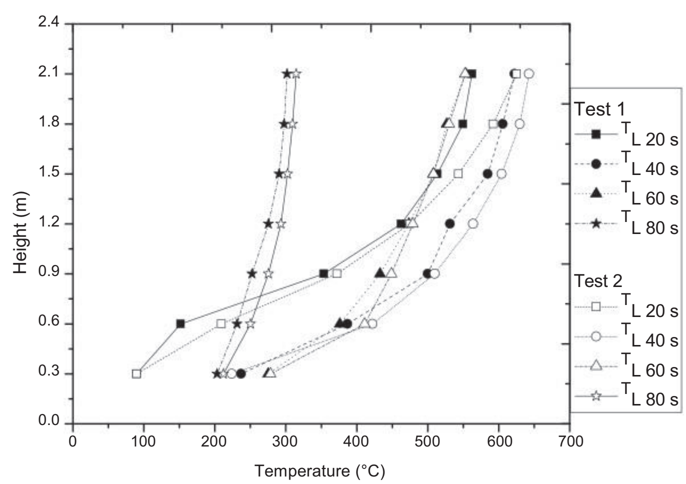

Figure 7: Variation of temperatures along the height of room under different ventilation conditions

Figures 10 and 11 show the heat flux distribution towards the compartment surface at time 20 s in Test 1 and Test 2 conditions, respectively. The maximum heat flux is predicted to be approximately 35 and 40 kW/m^2 at rear wall and ceiling surfaces in Test 1 and Test 2 conditions, respectively. The heat flux at floor and lower portion of room is approximately 10–15 kW/m^2. It represents the flashover condition inside the room; flashover is the state of fire between the growth and the fully developed fire. In this state, total combustible material is involved in a fire. Flashover occurs whenever the compartment temperature reaches approximately 500–600 °C or radiation reaches approximately 15–20 kW/m² to the floor.

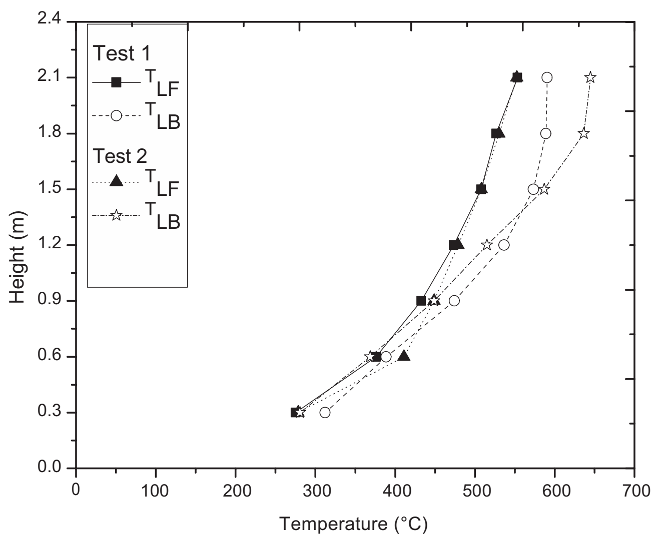

Figure 8: Variation of temperature with height in rear and front location in Test 1 and Test 2 conditions

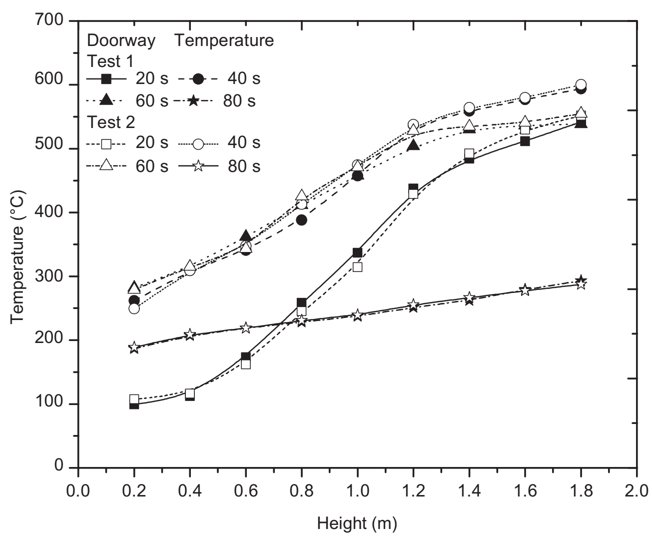

Figure 9: Doorway temperature profiles with height under different ventilation conditions

The compartment surfaces are made of concrete; its comprehensive strength is constant up to 300 °C, thereafter strength decreases with the increase in the temperature. For ceiling temperatures above 400 °C, spalling of concrete starts occurring. It is important to prevent or delay the occurrences of flashover so that spalling of concrete from the safety point of view can be avoided.

Figures 12 and 13 show the velocity field (U velocity) at time 20 s at Y = 1.2 m in Tests 1 and 2, respectively. Maximum velocity is found to be 2.2 m/s and 2.9 m/s at upper zone of compartment, and air inlet velocity is found to be 1.2 and 1.6 m/s in Test 1 and Test 2 conditions respectively; uniform layer is predicted in both test conditions at time of 20 s.

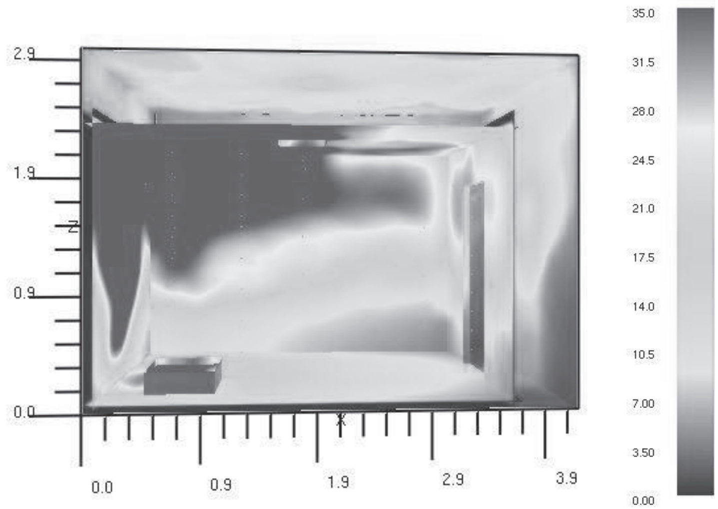

Figure 10: Heat flux field (kW/m²) at different surfaces of room in Test 1 at time 20 s

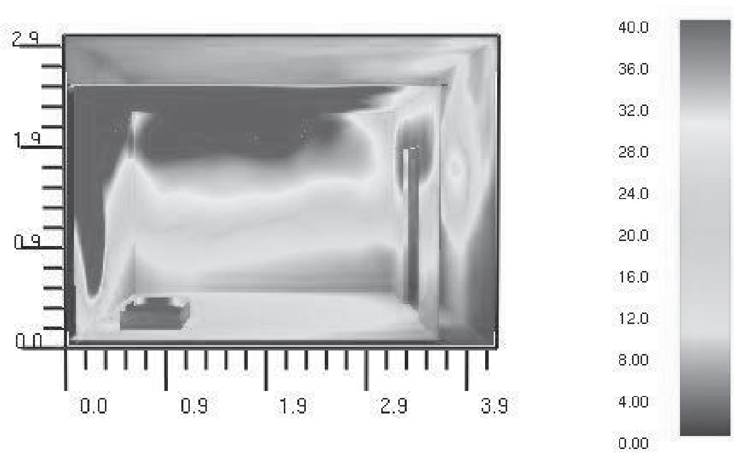

Figure 11: Heat flux field (kW/m²) at different surfaces of room in Test 2 at time 20 s

Figure 14 show the flame temperature with time and height above the pool in Test 1 and Test 2 conditions. Temperature in case of Test 1 is found in the range of 650–600⁰C at 20 s and 580–620 s in Test 2, in these period, heat release rate found its maximum.

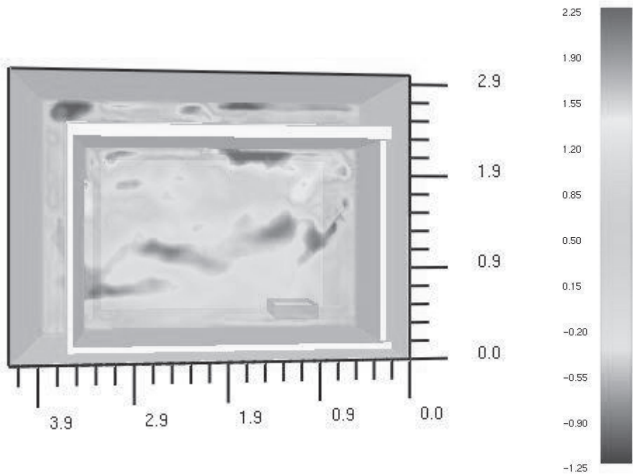

Figure 12: Velocity field (m/s) inside the room at y = 1.2 at time 20 s in Test 1

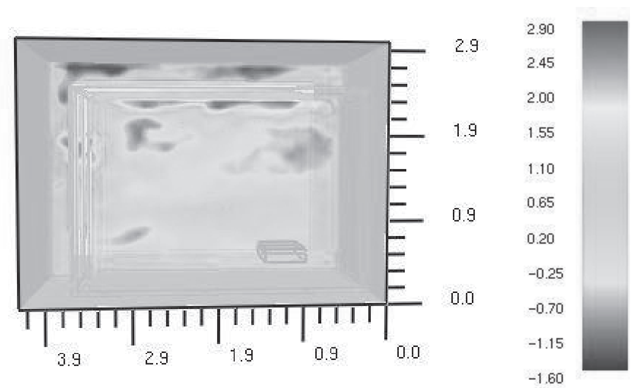

Figure 13: Velocity field (m/s) inside the room at y = 1.2 at time 20 s in Test 2

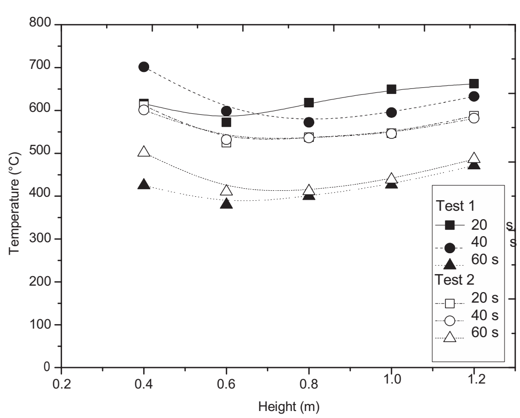

Figure 14: Variation of temperatures above the pool surface in Tests 1 and 2

Conclusion

In this study, a model of room of dimensions 3.6 m × 2.4 m × 2.4 m with a door opening of 0.8 m wide and 2 m high and a ceiling vent of dimensions 0.5 m × 0.5 m has been created to predict the behaviour with and without ceiling vent conditions. The thermal environment and concentration of product gases are changes significantly in both vent conditions. Maximum value of heat release rate (HRR) is 2015 kW and 1997 kW predicted in Tests 1 and 2, respectively; the oxygen availability gets depleted below 0.12 mol/mol after time period of 60 s and burning rate is decreased rapidly and fire is self-extinguished in both conditions. Before self-extinction of fire, fire reached the flashover at time 20 s. This study helps in understanding the fire behaviour in ceiling ventilation condition. The results will be useful in the design of fire protection systems, that is, sprinkler, fire detector, alarm and evacuation system inside the industries and residential areas. The provision of ventilation though helps to control fire but initially increases the supply of oxygen and enables more burning. This study is useful for understanding the fire behaviour under roof or door opening conditions which helps in designing of evacuation system inside the industries/residential area during emergency.

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An Effective and Way Forward Approach for Road Safety Acquisition of Knowledge: Correlative Study for Patna

Sunil Kumar Chaudhary[a]

ABSTRACT: Road safety has been a matter of great concern for the developing countries and the situation has become worsened particularly in India. Under the umbrella of India, various cities are lying that are facing the common problems of road safety. All modes of transportation and eventually all users including rider, drivers, passengers and pedestrians are the common players of road environment in Patna apart from that the majority of the population travels in public transport. According to a study, three Es of transportation including Education, Engineering and Enforcement should be correlated with each other for an effective, efficient and balanced system. The road users are not well-aware of the basic, standard and updated road safety knowledge that ultimately brings no prolonging effect on the Engineering and Enforcement subsidiary. The paper reveals the collected information based on the designed questionnaire capturing the features of limited road safety knowledge of drivers and riders in continuation with the traffic crash-dependent factors. Based on the analytical facts and figures, the research study focused on major recommendations transferring the acquisition of engineering and enforcement measures with the initiation of fundamental understanding of prevention of crashes.

KEYWORDS: safety, enforcement, road user, India

Introduction

Inadequacy of traffic planning is rising day by day, and due to this reason, people lose their precious lives or suffer temporary and permanent injuries. Investigation has shown that many domestic rules and regulation for traffic safety are just only at the documented stage, but people in general are not aware of its existence. Awareness programmes and training sessions for the targeted road user should be the stringent approach; it might be helpful for the fulfilment of several issues including understanding for traffic laws, safety signs, vehicle ordinance and manufacturing details and road/environmental conditions. Patna is one of the most important cities of India and famous city in terms of population, economic potential and geo-strategic location. Based on the statistics, the population of Patna is tremendously increased in last decade, because people migrated all around Bihar to Patna. They need to live with the miserable conditions of traffic and transportation. It is linked with the inadequate system master planning resulting in the unfortunate mishaps of traffic accidents. Patna is enriched with the number of locations that are to be nominated as the black spots of the city carrying a meaningful percentage of minor, serious and fatal injuries.

Scope and Objectives of Entire Research

The scope of this work for the relevant study is restricted to the strong manipulation of road safety acquirement of knowledge. The study is focused on the development and generation of ideas for the

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stakeholders at micro and macro levels. The following are some of the concerned objectives of this research paper:

- Identification of traffic safety problems on selected arterials of Patna;
- Idealising the correlation factor between three Es of transportation through detailed survey methodology;
- Highlighting the significance of road safety awareness;
- Formulisation of effective transport planning based on incident prevention.

Incident Approach and Traffic Safety Analysis

The respective approach is associated with the solution for the problems which are not readily available as innovative work needs to be done to arrive at new policies and design. It is quite evident that the understanding and scientific approach might be shared internationally but it needs to be moulded based on the location-specific and context sensitive. The identified treatments are to be enlisted on short-term as well as long-term planning.

Injury Control Trends (Mitigation Between Developed and Developing Countries)

According to a study of crashes related to developed and developing countries, the percentage of road users killed is categorised. In the available data, India's situation is embedded for having a clear perspective. The idea is more enhanced in Table 1.

On the overlook of the data presented in Table 1, it can be predicted that riders and pedestrians or passengers are the vulnerable road users for the city of Patna. This proves that the majority of low-income population is willing to ride but due to the negligence and lack of subsequent knowledge leading towards traffic crashes.

Practical Condition of Road Safety on Major Arterials of Patna

Alost more than 15 arterials or major locations of respective towns are surveyed during the whole research in order to achieve all road and safety parameters. For illustration, the idea is visualised through the following figures:

Table 1: Percentage of Road Users Killed

Countries	Pedestrians	Riders	Four Wheelers	Others
Australia	18 %	10 %	65 %	7 %
Japan	28 %	21 %	41 %	10 %
Malaysia	15 %	57 %	18 %	10 %
The Netherlands	10 %	12 %	56 %	22 %
Norway	15 %	12 %	65 %	8 %
Thailand	10 %	73 %	13 %	4 %
USA	12 %	5 %	80 %	3 %
Patna, India	**48 %**	**36 %**	**14 %**	**2 %**
Bandung, Indonesia	33 %	41 %	17 %	9 %
Colombo, Sirilanka	39 %	35 %	14 %	12 %
Pakistan	42 %	35 %	14 %	9 %

On the respective locations, two important issues are focused that are inadequate road maintenance problems and lack of engineering measures. The system needs to show demand oriented by strong routine and periodic maintenance. Moreover, the horizontal curves are hazardous for the riders due to slippage effects. Special warning signs are to be posted on these locations, while super elevation design philosophy should be on a prior basis.

Figure 1: Deficient junction with no safety measures

Figure 2: Sharp bends requiring curve warning sign and chevrons

Figure 3: Unprotected hazardous location inviting danger

Figure 4: Broken poles, low height wire inviting danger

Figure 5: Inadequate earthen shoulder

Figure 6: Trees on sharp curve obstruct sight distance

Figure 7: Run off the road

Normally, the horticulture action is imposed within the limited time slots but it is to be furnished in the dawn and daylight timings in which high traffic intensity is present. Unprotected hazardous location inviting danger Warning Sign & Chevrons. A number of other problems are gathered from the surveyed locations including lack of pedestrian facilities, parking facilities, absence of signified traffic signs, improper and absence of road furniture, insufficient illumination and road distresses, etc.

Research Methodology with Analytical Facts and Figures (Road and Human Contributory Factors)

At the initial steps of research, a detailed questionnaire was designed including the basic and traffic-related questions (as shown below). It was designed in a manner to expect from the respondent two major entities that are basic road safety knowledge at the level of beginner and crash prevention control for his/her entire life. The locations visited are Patna city, Ashok Rajpath, Agam kuan, Kankarbag, New By-Pass, Frazer Road, Exhibition Road, Gandhi Maidan, S.P. Verma Road, Station Road, Boring Road, Bailey Road, Anishabad, Danapur and Phulwarisharif. The locations are selected on the basis of past knowledge and severity of arterial depending on the existing traffic stream.

Some interesting facts could be furnished from the analysed data. First of all the highest level of education is graduation as responded while only 5 per cent are agreed to use on personal protective equipments. Not only that, almost 50 per cent responded lying in the category of having initial knowledge of road safety. This leads towards the issue that the majority of road user is not sentient of traffic rules and regulations despite educational background. Keeping in view of the gravity of issue, road safety should be the part of curriculum at different stages of education. According to the data, more than 90 per cent persons agreed on the negligence of obeying traffic signs and in the same way direct relationship of more than 50 per cent is achieved on the contributory factors of careless driving and ignoring traffic signs.

Table 2: Design Questionnaire with Assign Code

Traffic Survey Questionnaire (Patna)					
S. No.	**Questions**	**Question Code**	**Answer Description**	**Number of Persons Lying in Following Section**	**Total Number of Persons**
1.	Age group?	A	18 to 25 (Years)	115	450
			26 to 32 (Years)	95	
			33 to 39 (Years)	70	
			40 to 46 (Years)	53	
			46 to 52 (Years)	55	
			52 to 58 (Years)	62	
2.	What is the highest level of education you have completed?	B	Metric	115	450
			Intermediate	60	
			Bachelor	180	
			Masters	92	
			PhD	3	

(*Continued*)

Table 2: (Continued)

Traffic Survey Questionnaire (Patna)					
S. No.	**Questions**	**Question Code**	**Answer Description**	**Number of Persons Lying in Following Section**	**Total Number of Persons**
3.	Do you have valid driving license?	C	Yes	370	450
			No	80	
4.	How many hours you drive daily?	D	1 Hour	122	450
			2 Hours	190	
			3 Hours	134	
			4 Hours	4	
5.	Type of vehicle?	E	Motor car	288	450
			Motor cycle	162	
6.	Mostly when you drive?	F	Peak hours	388	450
			Non peak hours	62	
7.	Are you aware about traffic signs and symbols?	G	Basic	206	450
			Moderate	229	
			Excellent	15	
8.	Are you regularly followed traffic signs and symbols?	H	No	0	450
			Sometime	439	
			Every time	11	
9.	Are you using personal safety equipments during driving (Helmet, Seat Belt, etc.)?	I	Yes	22	450
			No	428	
10.	Are you using personal safety equipments during driving (Helmet, Seat Belt, etc.)?	J	Yes	388	450
			No	62	
11.	If yes, injury type?	K	Minor	190	388
			Moderate	166	
			Major	32	
12.	If yes, injury type?	L	Yes	290	388
			No	98	

(*Continued*)

Table 2: (Continued)

Traffic Survey Questionnaire (Patna)					
S. No.	**Questions**	**Question Code**	**Answer Description**	**Number of Persons Lying in Following Section**	**Total Number of Persons**
13.	Causes of accident?	M	Careless driving	132	388
			Ignoring traffic signs and symbols	88	
			Mental distractions from work	44	
			Taking shortcuts	97	
			During overtaking	27	
14.	Have your any family member or relative or friend died in road accident?	N	Yes	28	450
			No	422	
15.	Which type of vehicle he or she was using when accident occur?	O	Car	12	28
			Motor cycle	16	

Policy and Framework Evaluation for Road Safety

Currently India has not organised any computerised data bank which keeps record of all the road accidents. Statistics for road crashes are based on the data provided by police agencies which is underreported. There is an immense need of policy and framework evaluation for the pre and post crash phase. It is quite apparent from the author's statistical data that there is a quite risky operating traffic in Patna city, the reason behind is that either domestic traffic policy is not appropriately put into practice or it might be outdated due to the highly populated and crowded traffic. The whole dilemma is associated with the primary factors such as research, education and communication and secondary factors such as judicial action and accident control.

Balanced between Three Es of Transportation

As mentioned earlier, three Es of transportation need to be prioritised including Education, Engineering and Enforcement, which is the main objective of this research study. Aims and objectives for these entities are clearly defined as follows:

Education: Road users are to be introduced with their rights and limitations securing from the hazardous condition while providing a safe room for others as well.

Engineering: Following the standard practices and improvement for all engineering works with the provision of safe and smart route network. Preventing violation of the rules of the road by the road users by organising a very effective enforcement agency.

Recommendations

With the orientation of title, the way forward steps and recommendations include micro- and macro-level processes as follows:

- Road crash is not an infrastructure problem or human issue; it should be taken as public health problem and on prior basis.
- Road crashes for different areas of Patna should be categorised on the basis of road, human and vehicle contributory factors.
- Black roads and black spots of the entire city should be focused based on the severity indices.
- Organisations should play a vital role in order to collect road accident data. In this connection, standard practices should be adopted.
- Impact studies (before and after) should be prepared for future perspective while data should be monitored and checked on equal intervals.
- Public-private partnership programmes should be introduced for traffic accident data collection and manipulation.
- As per the existing structure, the local community police working on crash prevention should join hands with private agencies in order to achieve better accuracy.
- Road safety should be the part of curriculum at different levels of Education.
- Computerised and strict Enforcement action should be applied.
- New and updated Engineering standards should be designed prevailing the nature and traffic conditions of India.
- Each road user should be given the adequate importance while providing the infrastructure facilities.
- Efficient and effective emergency response vehicle (ERV) system could be furnished.
- Emergency centres should be deputed at approachable locations while they are to be identified based on the severity of area.
- Road safety policy formulation is the integrated step that provides the broader umbrella to above-discussed points.

Conclusion

- Traffic and road safety condition in India is an issue in which very few organisations and people are willing to do fruitful action for the future advancement.
- Research exemplify that there are many obstacles due to which safety is not put into practice. In this incongruous condition, education and enforcement both are important stages.
- Experts, professionals and foreigners should play important roles in the effective training sessions.
- Government should also provide adequate safety policies and train people.
- Regulatory bodies such as Ministry of Information and Broadcasting, Traffic Police Patna, Motor Vehicle Inspection Patna and City District Government Patna should plan and design a structure to review and judge the safety performance and level.

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VIII Other Disasters

Chir Pine and the Forest Fires

Hari Krishna D. V.[a], J. P. Maithani[b] and Taniya Bhatt[a]

ABSTRACT: Forests constitute the largest, complex and most important natural resources (Dr. Satendra 2014). It is also very important to understand how sensitive forests are as a landform to various physical factors and how these physical factors are influenced by human activities. Some living organisms are so sensitive to the ecology that if there is a little disturbance in ecological balance, then they may not survive. Forest fires are as old as the forests themselves. The Chir (*pinus roxburghii*) forests are located in between the altitude of 900 and 1800 m. Most of the population of Uttarakhand are concentrated in this area. And most of the fires also occur here, below 900 m in the Sivaliks and above 1800 m in the Deodar, Fir and Oak areas are less frequent. Chir pine forests are of great economic importance to the people, supply constructional timber, provide railway sleepers to put under the railway tracks, furniture for households and provide supplies of resin to the resin and turpentine industry. The whole processes involve a large number of labour creating employment opportunities for local people. There is also an argument by J.S.Mehta, saying the longer the area is protected from fire successfully, the greater will be the damage if a fire occurs, because of heavy accumulation of inflammable Chir needles. Most of the area of the Chir forest is under resin tapping; this increases the fire hazard and is more dangerous because the resin channels easily catch fire and it will be difficult to control it because of the resin in the channels.

KEYWORDS: forest fire, vulneribility, impact, chir pine, environmental responsibility, network management

Introduction

Fire is a good servant, but a bad master. Forests constitute the largest, complex and most important natural resource mostly dominated by trees or continuous forest with trees usually growing to more than about 7 m in height and able to produce wood. In the recent past, as a result of developmental activities, particularly in the sensitive regions, the environment has been very adversely affected, resulting in exponential increase in the fragility of land mass.

More than 90 per cent of the forest fires all over the world are due to anthropogenic activities (Satendra and Kaushik 2014). Conversion of the forest land to agricultural land or for plantation is the reason for it. Sometimes forest fires are caused intentionally by the people to promote the growth of grass, clear the areas for shifting cultivation, clear forest floor for NTFP collection, etc. and also for hunting wildlife or to encroach on the forest land. The Chir (*pinus roxburghii*) forests are located in between the altitude of 900 and 1800 m.

Most of the population of Uttarakhand are concentrated in this area. And most of the fires also occur here, below 900 m in the Sivaliks and above 1800 m in the Deodar, Fir and Oak areas are less frequent.

The fires in the forest are in some of the following ways beneficial too. Fires in forests are not unnatural to them. Most of the fires are very useful and essential for good natural forest development and regeneration. Even in historic time, till now forest fires have been ignited and burned naturally, but these are usually of low intensity. These low-intensity fires in the past kept the forest floor free from the natural annual build up of the litter, that is, tree needles, dead grass, leaves and twigs, thick brush and dead trees. Fire may at times also stimulate flowering, increase the branching behaviour, seed production and seedling establishment (Satendra

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and Kaushik 2014). Fires destroy biodiversity directly and have more indirect long-term impacts. Forest fires in Himalayan states have been regular and historic features that are causing adverse ecological, economic and social impacts. The forest fires destroy biodiversity directly and induce secondary hazards too, like landslides and floods as long-term impacts. During April 2016 forest fires were widespread covering most of the forested regions of the state and the numbers of fires observed were unusually high (Jha and Thumaty 2016). The 2016 major forest fire was handled by National Disaster Response Force in three districts Almora, Chamoli and Pauri Garhwal (Uttarakhand Forest Fire- APR. 2016 n.d.).

Chir pine forests are of great economic importance to the people, supply constructional timber, provide railway sleepers to put under the railway tracks, furniture for households and provide supplies of resin to the resin and turpentine industry. The whole processes involve a large number of labour creating employment opportunities for local people. But Pine forests are only of a little use to the locals. Pine was in adequate of firewood, because of the fast burning. It is useful only for commercial purposes as timber and its by-products, pulp and resin, but these benefits the outsiders only (Weber 1988).

"Living in the Himalayas for several years, I have been painfully aware of a vital change in species of trees, which is creeping up and up the southern slopes, those very slopes that let down the flood waters in to the plains below. This deadly changeover is from Banj (Himalayan Oak) to Chir pine. It is going on at an alarming speed and it is not a matter of deforestation, but change from one kind of forest to another, it is not taken sufficiently seriously."

–Mirabehn's (Gandhiji's disciple) article in Hindustan times – 'Something Wrong in the Himalaya'

Then in the end arguments and solutions are discussed.

Forests

"Forests constitute the largest, complex & most important natural resource mostly dominated by trees or continuous forest with trees usually growing to more than about seven metres in height & able to produce wood. This includes both closed forest formations where trees of various storey and undergrowth cover a high proportion of the ground and open forest formations with a continuous grass layer in which tree covers at least 10 per cent of the ground. It is also defined as the land with tree crown cover (stand density) of more than 20 per cent of its area" (Satendra and Kaushik 2014).

Food and Agriculture Organisation (FAO) of United Nations defines the forest in a bit technical way as

"Land with a tree canopy cover of more than 10 per cent and area of more than 0.5 hectare".

Sensitivity

It is also very important to understand how sensitive forests are as a landform to various physical factors and how these physical factors are influenced by human activities. Some living organisms are so sensitive to the ecology that if there is a little disturbance in ecological balance, then they may not survive. Mushroom, lichens, algae and moss are among the highly sensitive species. Lichens consume nutrients from the air, and polluted air may kill them. After a forest fire, the carbon ash disseminates in the air. Fresh moss that is growing on the trees inside the forests that too during the summers denote that the temperature is cooler inside. Mushrooms indicate high level of moisture around. But forest fires increase the overall temperature and make the forest devoid of moisture.

Some species indicate the micro-ecological health of the forest or ecosystem, and hence if they stop growing, then it is to be understood that the forest health has been adversely affected (Rath 2013).

In ecologically more sensitive and destabilised areas like Himalayas and Western Ghats, the impact of deforestation/degradation has been more severe. In the recent past, as a result of developmental activities, particularly in these sensitive regions, the environment has been very adversely affected, resulting into exponential increase in fragility of land mass.

In these sensitive areas, the impact of deforestation has been more severe, which directly or indirectly affect the lower plains of the country, as well. Deforestation in Himalayas has increased the severity of floods during rainy season and reduced stream flows and dried up springs during summer seasons. The increase of soil erosion has reduced water carrying capacity of the rivers resulting into shallowing of riverbeds leading to floods in the plains and also affects the process of underground water recharge system.

Increase in the temperatures will result in shifts of lower altitude tropical forests and subtropical forests to higher altitude temperate forests, resulting in the extinction of some temperate vegetation types. Decrease in rainfall and the resultant soil moisture stress will result in drier teak-dominated forests replacing Sal trees in central India. Increased dry spells may also place dry and moist deciduous forests at increased risk from forest fires (Durgadas n.d.). The increase in forest fire in the Garhwal Himalaya badly affects the Oak/Baanj (*Quercus leucotrichofolia*) regeneration, and this is naturally replaced by Chir/Pine. This has been noticed in many forest areas of Chamoli Garhwal.

Causes of Forest Fires

Global Scenario

More than 90 per cent of the forest fires all over the world are due to anthropogenic activities (Satendra and Kaushik 2014). Conversion of the forest land to agricultural land or for plantation is one of the reason for it. The two important types of practices for the conversion in the tropical regions are:

- **Shifting cultivation:** This is the practice where a piece of forest land is chosen and cleared, the fell trees are then burnt, and the residual ash supplies enough nutrients for the crop to be cultivated. This area is used for agriculture for few years until the decline starts. After this the land is left for natural regeneration and a new area is searched for.
- **Permanent conversion:** With the pressure from increasing population, the forests are cleared and occupied for reasons like resettlement, agriculture, etc. These practices also usually follow clear felling and then burning. The resettlement in Tarai belt of Uttarakhand and UP is an example.

Other causes for initiating forest fire include collection of NTFP too. In some tribal practices to celebrate ritual customs, forests are ignited. Road construction is a developmental activity that has been a factor for increase in the incidents of forest fires. The roads gave access to the forests, where people can easily come and ignite. Also fires are initiated by picnickers, grazers, tourists, etc, because of negligence. Throwing burning cigarette butts, camp fires, cooking food within or near the forest areas are examples of negligent activities that cause fire.

India

Foresters use forest fires as a tool in scientific forest management because certain species regenerate under the light fire conditions. But uncontrolled fires are one of the major causes of degradation of forests. Sometimes forest fires are caused intentionally by the people to promote the growth of grass, clear the areas for shifting cultivation, clear forest floor for NTFP collection, etc and also for hunting wildlife or to encroach on the forest land.

Himalayas

Among the many ways by which injury is caused to flora of Garhwal and Kumaun region, fire is by far the most dangerous and supposed to be enemy number one of the forests (Mehta 1996).

The Chir (*pinus roxburghii*) forests are located in between the altitude of 900 and 1800 m. Most of the population of Uttarakhand are concentrated in this area. And most of the fires also occur here, below 900 m in the Sivaliks and above 1800 m in the Deodar, Fir and Oak areas are less frequent.

There is also an argument by J.S. Mehta, saying the longer the area is protected from fire successfully, the greater will be the damage if a fire occurs, because of heavy accumulation of inflammable Chir needles. Most of the area of the Chir forest is under resin tapping; this increases the fire hazard and is more dangerous because the resin channels easily catch fire and it will be difficult to control it because of the resin in the channels (Mehta 1996).

Timber mafia is also a key perpetrator in the case of forest fires (S 2016).

Natural Causes

Natural Causes of forest fires include lightning, friction between stones, rubbing of clumps of dry bamboos and volcanic eruptions (Satendra and Kaushik 2014).

Benefits of Forest Fires

The fires in the forest are in some of the following ways beneficial too. Fires in forests are not unnatural to them. Most of the fires are very useful and essential for good natural forest development and regeneration. Even in historic time, till now forest fires have been ignited and burned naturally, but these are usually of low intensity and controlled. These low-intensity fires in the past kept the forest floor free from the natural annual build up of the litter, that is, tree needles, dead grass, leaves and twigs, thick brush and dead trees. Fire may at times also stimulate flowering, increase the branching behaviour, seed production and seedling establishment (Satendra and Kaushik 2014).

But fire's effect on all types of forests is not equal. While same fire is beneficial for one ecosystem, it may be dreadful for another, depending upon the climatic conditions and type of vegetation.

Soil heating due to the fire changes its physical, chemical and microbial properties. Prescribed burning is used as a way to put the fire back, in a specific unit of land. Fallen trees and logs left to rot on the forest floor decay at a very slow rate. Large logs may even take more than 100 years to decompose.

Pine needles decompose very slowly. It takes more than a year for 10 per cent of the pine needles to decay. As a result, year after year, pine needles continue to build up until they are eliminated by a fire. This implies that natural recycling is a very lengthy and time-consuming phenomenon in forest. Now, fire is the best process to intensify this natural process. Faster recycling occurs during a smaller time frame. In the burned area, nitrogen and other nutrient remains are leached back into the soil as rain soaks the ground. This is nature's way of rapidly feeding nutrients to the soil.

But, unfortunately, when there is too much fuel on the ground and it is burned, an intense severe fire occurs, where these benefits are missing. Intense fire tends to scorch the ground and kill the trees. In brief, the forest needs both slow recycling from decomposition and fast recycling from fires. The heavy fire affects the top soil, and this results in fire-induced soil erosion and causes micro landslides in the Himalayas.

Thus, forest fires are not always harmful. Small and controlled fires in the form of prescribed burning are very essential and useful.

In the absence of fire, vegetative changes may result in fuel loads far exceeding safety levels, which would pose a serious threat to forest if ignited. The small-scale controlled fires provide social and ecological benefits too, like reducing risk of catastrophic forest fire, improving silvicultural opportunities, increasing habitat opportunities for wildlife, enhancing biodiversity and so on.

"Fire is a good servant but a bad master" the saying is true for forest fire too. Limited and controlled forest fires have been useful and essential for healthy growth of the forests. But uncontrolled forest fire may destroy the healthy thick forest cover within no time.

Impacts of Forest Fires

Fires destroy biodiversity directly and have more indirect long-term impacts. There is an argument that the dark carbon dust emitted by the fires deposited on Himalayan glaciers could hasten their melting. This could also affect the hydrology of the rivers that are a source of water for human populations in north India. The average temperature of northern India saw increase of 0.2°C (The devastating effects of the Uttarakhand fires 2016). The changed forest canopy, soil and water conditions along with land use practices induce secondary hazards like landslides and floods too.

Severe forest fires damage the forest canopy and the plants below, as well as the soil. This results in increased runoff after intense rainfall or rapid snowmelt, which can put homes and other structures below a burned area at risk of localised floods and landslides. Forest fires also loosen the soil and accelerate the soil erosion in the slope of hills, now because of which soil depth is reduced and also the water conserving capacity.

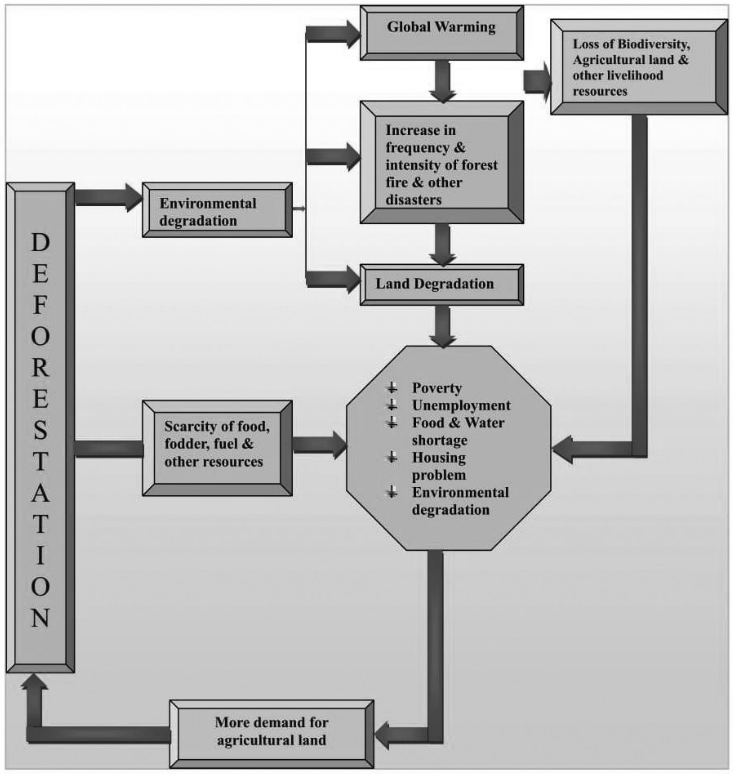

Figure 1: Impacts of forest fire (Satendra and Kaushik 2014)

Indian Forests Vulnerability to Fire

The availability of the three essential components (fuel, oxygen and heat) for fire is not uniform throughout the country's forests, depending on the tree species and the climatic conditions; the situation of the fires is different in different forest areas. For example, the coniferous forests of the Himalayan region is very prone to forest fires because of the presence of fir (*Albies* spp.), spruce (*Picea smithiana*), *Cedrus deodra, Pinus roxburgii, P. Wallichiana,* etc.

As much as 64.29 per cent of the Recorded Forest Area (RFA) is prone to fires, said the India State of Forest Report 2015 published by the Forest Survey of India (India State of Forest Report 2015).

The most vulnerable stretches of the world to forest fire are the youngest mountain ranges of Himalayas (Satendra and Kaushik 2014).

Forests in eastern Himalayas are less prone to the forest fires than the forests in western Himalayas because they have greater rain density. One more reason for the alarming increase in the forest fires in the Himalayas is the large-scale expansion of Chir forests.

Himalayan States

Forest fires in Himalayan states have been regular and historic features that are causing adverse ecological, economic and social impacts. The forest fires destroy biodiversity directly and induce secondary hazards too, like landslides and floods as long-term impacts.

According to an estimate by Forest Survey of India (FSI), 1.45 million ha of forest is affected by fire annually with 6.17 per cent of the forests prone to severe fire damage. In 2016 between February and June, there have been widespread and unusually high incidences of forest fires in Uttarakhand, Himachal Pradesh and Jammu Kashmir.

History of Forest Fires in Himalayan States

Forest fires in the Himalayan states have been a regular feature. Major fires have been recorded in the years 1911, 1921, 1930, 1931, 1939, 1945, 1953, 1954, 1957, 1958, 1959, 1961, 1964, 1966, 1968, 1970, 1972 and 1995. Some fires during 1921, 1930 and 1942 have been associated with popular movements too, against the then British government's forestry policies and for independence (Dobriyal 2017). Forest fires are also used as a tool to settle the scores with the Forest Department (Satendra and Kaushik 2014).

2016 Massive Forest Fire

Uttarakhand usually shows forest fire activity from February to June, with a peak in fire incidence in May and June. During April 2016 forest fires were widespread covering most of the forested regions of the state and the numbers of fires observed were unusually high (Jha and Thumaty 2016). The 2016 major forest fire was handled by National Disaster Response Force in three districts Almora, Chamoli and Pauri Garhwal (Uttarakhand Forest Fire- APR. 2016 n.d.). The fire was so disastrous; it affected the reserve forests of Corbett Tiger Reserve and Kalagarh Tiger Reserve, Rajaji Tiger Reserve, Kedarnath Musk Deer Sanctuary. The worst affected districts are Almora, Chamoli, Nainital, Pauri, Rudraprayag, Pitoragarh, Tehri and Uttarkashi (Goswami 2016). This incident smashed nearly 4000 ha of forest cover across the 13 districts, killed 9 and injured 17 people besides damaging the biodiversity and the forest ecosystems beyond repair (Forest Fires and Its Effects on Environment, Forests, BioDiversity and Wildlife and Remedial/Preventive Measures 2016).

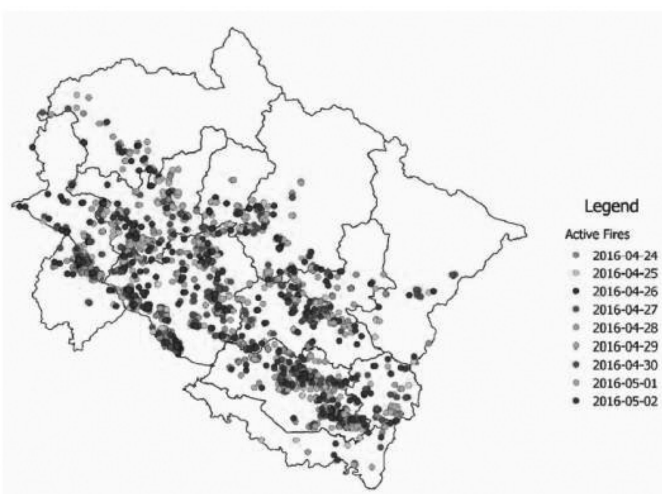

Figure 2: Spatial distribution of cumulative forest fire locations in Uttarakhand, India, during 24 April–2 May 2016 (Jha and Thumaty 2016)

Uttarakhand

Uttarakhand was formed on November 9, 2000, as the 27th State of India. It is located at the foothills of the Himalayan mountain ranges; it is largely a hilly state and has international boundaries with China (Tibet) in the north and Nepal in the east. On its north-west lies Himachal Pradesh, while on the south is Uttar Pradesh. It is rich in natural resources especially water and forests with many glaciers, rivers, dense forests and snow-clad mountain peaks.

It is blessed with a rare biodiversity; 175 rare species of aromatic and medicinal plants are found in the state (Dhyani n.d.).

Forest fires in Uttrakhand have been regular and historic feature of the forests. Every year forest fires in Uttarakhand causes great loss to the forest ecosystem, flora and fauna and economic wealth. Forest fire is one of the major disasters in the forests of Uttarakhand. High temperatures with no atmospheric moisture were one of the important reasons, for forest fires in Uttarakhand. The ground and surface fuels mostly don't ignite till the moisture content drops very low (less than 20 per cent) (Satendra and Kaushik 2014).

Pine invasion can be seen all over the state; this is an alarming situation that is indicating the future environmental degradation. The Chir forest has infested many agricultural fields too, which resulted in abandoning of cultivation due to lowering of productivity.

There are many indigenous and endangered species which are adversely affected due to forest fires.

Chir Pine

Chir pine forests are of great economic importance to the people, supply constructional timber, provide railway sleepers to put under the railway tracks, furniture for households and provide supplies of resin to the resin and turpentine industry. The whole processes involve a large number of labour creating employment opportunities for local people.

Gymnosperms are a taxonomic class which includes plants whose seeds are not enclosed in an ovule, in contrast we usually see in popular fruits like mangoes, apples, etc. Gymnosperm means ‘naked seed’. Gymnosperms have needles. Examples are pines, cedars, spruces and firs (Angiosperm or Gymnosperm? n.d.). Some kinds of gymnosperms are weedy in nature. They invade disturbed areas or abandoned agricultural land. Pines and junipers are the notorious invasive species which make the land unusable (Tripathi 2008).

Distribution and habitat	Afghanistan, Bhutan, India (North West Himalaya to Assam, Arunachal Pradesh), Pakistan. The Chir Pine (*Pinus roxburghii* Roxb.) is named after William Roxburgh, is native to the Himalaya. It generally occurs at lower altitudes than other pines in the Himalaya, from 500 to 2000 m, occasionally up to 2300 m.
General description	A large evergreen tree, nearly deciduous in dry localities, usually not exceeding 30 m in height, rarely 55 m. A girth of 3 m has been recorded in favourable conditions. Branches up to middle age whorled, crown elongated to pyramidal shaped afterwards becoming spreading or umbrella shaped.
Bark	Reddish-brown, thick and deeply fissured at the base of the trunk, thinner and flaky in the upper crown.
Leaves	Are needle-like, in fascicles of three, very slender, 20–35 cm long and distinctly yellowish green.
Flowers	Are monoecious (individual flowers are either male or female, but both sexes can be found on the same plant) and are pollinated by wind.
Scales	Woody with a curved beak.
Cones	Ovoid conic, 12–24 cm long and 5–8 cm broad at the base when closed, green at first, ripening glossy chestnut-brown when 24 months old.
Seeds	8–9 mm long, with long membranous wing and are wind-dispersed.

Uses

Edible uses	Seed: Raw or cooked. It has a strong flavour of turpentine and is only eaten as a condiment, emergency food. A sweet edible manna exudes from the bark and twigs; it is actually a Manna, Seed gum. Vanillin flavour is obtained as a by-product of other resins that are released from the pulpwood.
Medicinal uses	Antiseptic; diaphoretic; diuretic; rubefacient; stimulant; vermifuge. The turpentine obtained from the resin of all pine trees is antiseptic, diuretic, rubefacient and vermifuge. It is a valuable remedy used internally in the treatment of kidney and bladder complaints. It is also very beneficial to the respiratory system and so is useful in treating diseases of the mucous membranes and respiratory complaints such as coughs, colds, influenza and TB. Externally it is a very beneficial treatment for a variety of skin complaints, wounds, sores, burns, boils, etc. The wood is diaphoretic and stimulant. It is useful in treating burning of the body, cough, fainting and ulcers.
Other uses	Charcoal, dye, herbicide, ink, lightning, resin and construction

Major indigenous uses	Part used	Frequency of use		
		Quite frequently	Sometime	Rarely
1. Timber	Wood	*		
2. Fuelwood	Wood, bark	*		
3. Edible and source of oil	Seeds		*	
4. Religious purpose	Twigs	*		
5. Decoration	Cones		*	
6. Treatment of asthma	Forest		*	
7. Pandawa festival	Tree	*		
8. Livestock bedding	Leaves	*		
9. Resin	Resin		*	
10. Lighting	Resinuous wood			*

Figure 3: Uses of Chir pine (Kala 2004)

Out of five pines occurring naturally in India, which are, *Pinus roxburghii* Sargent, *Pinus wallichiana* Jackson, *Pinus gerardiana* Wall., *Pinus kesiya* Royle ex Gord and *Pinus armandi* French, only *Pinus roxburghii* Sargent is tapped commercially for (Krishnamurthi 1969).

The Uttarakhand hills in the northern India are one of the best habitats of Chir pine forests (Kala 2004). The Britishers started the resin industry in the Kumaon region. Other forests are now being felled to make way for the Chir (Weber 1988).

Pine forests are only of a little use to the locals. Pine was in adequate of firewood, because of the fast burning. It is useful only for commercial purposes as timber and its by-products, pulp and resin, but these benefits the outsiders only (Weber 1988).

The forest areas are dominated by pine. Formation of plant story such as top, middle and lower is absent in the pine forests. Pine forests are usually pure. No other species reach the top canopy.

The leaves of the Banj tree which fall down create a fertile black mould, in which a thick mass of bushes, creepers and grasses (undergrowth) develop; this lets all the rainwater to get absorbed. Some of this gets evaporated while percolates down to lower altitudes feeding the springs. The Banj forest is an ideal shock absorber for the monsoon rains. The Chir has just the opposite effect of this, the needles that fall down creates a smooth, dry carpet and this absorbs nothing, this also prevents the development of any undergrowth, so when the torrential rains come it washes away everything (Weber 1988).

Occurrence of annual fire is one of the major reasons for degradation of the forest. Inflammable condition prevails during the days of hot weather. The Chir forests are highly inflammable and the dry leaves burn very quickly and the fire spreads very fast. Pine needles decompose very slowly; they take more than one year for 10 per cent of the pine needles to decompose. So, year after year, pine needles continue to build up until they are eliminated by fire (Satendra and Kaushik 2014). Burning makes the Chir to spread upward in Oak forests. At higher elevation degraded Oak forests are encroached upon by the pine. Oak forests are not inflammable but suffer from fire spreading up from the Chir forests. Green leaves of Oak catch fire and burn out quickly (Terrestial Biodiversity Report 2009).

Discussions

Indicator of Drought?

An *indicator* is a thing that indicates a state or level of something.

The drought manual of India in its page 10, on the impacts of droughts, says that the drought may lead to loss in forest cover. It also says that the drought increases the hazard of fire. There are many works stating the direct relation between the drought conditions and the dryness – causing forest fire.

In a two-day workshop of United Nations Food and Agriculture Organisation – Regional office for Asia and the Pacific on "Forests and Droughts" in Bangkok, the scientists report said that the droughts during the dry season would have serious implications such as tree loss and forest fire.

Moisture content of the soil plays an important role to suppress a fire (John J Keetch, 1968). In this book, he also refers to the dry branches and plants which catch fire as fuel; when the fuels are dry, they burn deeply and damage excessively. The history and experiences over the years establish association of forest fires with dryness and drought. The effects of drought are not confined to deep organic layers of soil only; the dried out organic material comes to the top shallow soil too.

Drought being a slow disaster and chronic, its onset cannot be noticed, the progression of the drought conditions into turning up as a disaster is unrecognised. An article by the State and Federal fire control officers in United States of America (Keetch n.d.) said that an extended drought has indirect effects on fire behaviour characteristics like rate of spread and intensity – because more fuel is available for consumption. The litter on the forest floor becomes very dry, the high temperature there and low humidity produce blow-up conditions for forest fires (Tannehill 1947). These references say that forest fire can be an indicator of a forest drought.

Clear Chir Forest?

On August 13, an article in The Times of India, an Indian daily (Sharma, To prevent forest fires, Uttarakhand seeks to chop lakhs of Chir pine trees 2015), said that the forest department is planning to clear out the Chir forests as it plays a major role in spreading the forest fires and said that it is also no good for the environment. The proposal has been made for removal of the Chir trees wherever they are in large numbers and was sent to the Ministry of Environment, Forests and Climate Change. There are officials who also say that the Chir is not an indigenous species and were brought from other places like other invasive species like lantana (Sharma, Are pine trees squeezing out other flora? 2015). The presence of Chir in the Indian Subcontinent is immemorial, but the mass regeneration happened at British times for the sake of tapping resin (Dobriyal and Bijalwan, Why cutting down Chirpine is not a solution to Uttarakhand forest fires 2015). This article in Down to Earth also agrees with the established fact that the Chir pine needles are inflammable and one of the causes of fires in the forests, but it is not the only source of fire hazard. The article also mentions the advantages of Chir and also the problems associated with it. Many ecological and economical problems also arise because of this large-scale removal at once; gradual replacement of Chir with the broad-leaved indigenous species like the Banj and Oak is a better solution. Better forest management and fire management strategies can be implemented rather than felling thousands of trees. Involving the locals and planning with them yield the best solutions.

Conclusion

Fires are not very new to any forests; they are as old as the forest themselves. The research was devised to find out the reasons for people to start the fire in spite of forests giving them a lot. The materials that people get from the forests are useful for their subsistence and also when sold give them an economic support, to know about the other losses that the fires bring and also to study what the Government, NGOs are doing to find a solution. The forest fires cause lot of damage to the ecology and the economy also. Forest fires occur because of various natural and human made reasons. Many authors had already found out that most of the causes are anthropogenic only. So it is us the humans to be held responsible and the change should come from here. Lack of environmental responsibility is the main reason for people to intentionally start fires for the momentary needs. But these temporary actions by the people are for their survival only; poverty doesn't allow them to stop what they are doing. For example, most people put fire to the forests to start new germination of grass, which is fodder for the cattle. They also lack awareness and skill about the better forest management methods and techniques like control burning. It is the duty of the Government and its allied bodies to educate the masses and to instill the environmental responsibility in the people. People should also be trained in the best practices to put out the fire and also the Van Panchayats system should be given enough powers so that they can plan for themselves, the approach should be bottom up, not top down. The forest community or the villagers around the forest believe that the forest policy have snatched their traditional rights related to the forest in result the emotional, cultural relation with forest have been degraded so it's time to restudy the impact of present forest policy – so that the feeling of Chipko will again take place. As the community is the first responder to any disaster that happens and they are the ones who are directly getting affected, they should plan for themselves. Existing networks of schools and other educational institutions, self help groups, NGOs and CBOs should be utilised to strengthen the human and social capital to fight against the inferno.

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Developing a Methodology for Estimation and Mapping of Air Pollution Disaster Risk Based on Social Vulnerability

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ABSTRACT: Air pollution is one of the largest causes of mortality and morbidity rates in the world, making it necessary to address air pollution from a disaster studies perspective. Despite the international interest in the study of socio-economic effects on risk to air pollution, very little studies have been carried out in Asia and especially India. In this study, aerosol hazard, followed by the social vulnerability index, was calculated to estimate the air pollution risk for Mumbai city. This methodology helped in delineating the areas as high, medium and low risk to air pollution in a GIS platform. This paper thus provides a tool to decision makers to identify areas and population at severe risk of air pollution so as to execute mitigation measures accordingly. It also helps identify the precise factors that can help in targeted equitable mitigation strategies for air pollution. The study concluded that social vulnerability estimation and GIS-based spatial mapping can help identify the high air pollution risk areas that need immediate actions by decision makers.

KEYWORDS: air pollution risk, aerosol hazard, social vunerability, mapping

Introduction

Globally, 3 million people die due to ambient air pollution (WHO, 2012). Air pollution is the fifth largest cause of death in India (NYT, 2014). Aerosols ($PM_{2.5}$ and PM_{10}) are one of the most hazardous components of air pollution that contributes to high mortality and morbidity rates. They are used as proxy to poor air quality in most of the studies (WHO, 2016). Aerosol pollution, though a major hazard, is often overlooked because the impact is usually visible only after sometime and there are no sudden casualties. Long-term exposure to PM_{10} is strongly related with ischemic heart disease, cerebrovascular disease, COPD, lung cancer and acute lower respiratory infections (Maji et al., 2016). $PM_{2.5}$ can more easily enter the blood stream and travel through the body to the brain, where it affects children's brains. It has also been strongly linked to Parkinson's and Alzheimer's among older adults (UNICEF, 2017). Air pollution monitoring from ground stations are resource intensive, difficult or expensive and hence data for only few points are available. A surface or contour map of pollution for the whole region can be created using spatial interpolation techniques in GIS (geographic information system) using fewer points (Kumar, 2016).

Urban regions are increasingly facing challenges in air pollution due to high population density, high energy demand, developmental activities (like infrastructure and construction projects), large number of industries and huge number of vehicles (Maji et al., 2016). An estimated 65 per cent of the world population is projected to be living in cities by 2025 (O'Neill, 2003). Human settlement patterns, behaviours, pollutant sources and composition differ vastly across local, national and international scales, hence examining exposure in a variety of geographic regions is desirable (O'Neill, 2003).

Social inequalities make people more vulnerable to various disasters. The Health Assembly emphasised

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that the root causes of air pollution and its adverse impacts are predominantly socio-economic in nature, and there was a need to address the social determinants of health related to development including poverty eradication, as an indispensable element for sustainable development and for the reduction of the health impact of air pollution (WHO, 69th world health assembly). Socio-economic processes that deliver the risk differently to different groups have been given insufficient attention in traditional risk assessment models (Schwartz et al., 2011).

Public policies that intend to protect populations vulnerable to air pollution through cost-effective, targeted equitable mitigation measures need help from studies that include both air pollution and socio-economic variables. This will help in making a more informed decision (O'Neill et al, 2003). Researchers (Dey et al., 2012) have emphasised the need for local scale cohort studies to be carried out in the Indian sub-continent. Environmental inequity is the disproportionate effect of environmental degradation on people and places (Cutter et al. 1995). Poverty and deprivation in early childhood influence the health and development which can have consequences throughout life (Dueguen, 2010). Social vulnerability is partially dependent on social inequalities. A study observed that neighbourhood socio-economic deprivation increases the mortality risks associated with air pollution (Wong et al, 2008). Researchers have highlighted the need for study in variations of effect modifiers which is a complex system of social, economic and environmental factors (Bell, 2013).

The huge disparity among the urban population is in terms of availability of various resources like health-medical support, education, infrastructure facilities, etc., that makes them highly vulnerable to various disasters. People or region fall into one of the three categories: environment, economy and society, and when they suffer from air pollution, these attributes would manifest in three forms of vulnerability: exposure, susceptibility and adaptability. In risk perspective, these three dimensions can be grouped as biophysical and social vulnerability to produce overall place vulnerability (Ge et al, 2017 (a)). Exposure here is not just the spatial exposure but also involves features that involve social and institutional parameters which will increase the defenselessness of humans or assets and result in greater damage (Ge et al, 2017 (b)). It is characterised by structures, population and economy (Birkman et al., 2006). Susceptibility is a capacity leading to higher risk at a given exposure level, due to biological intrinsic factors that can modify the effect of a specific exposure. It is the fact of being exposed (WHO, 2003). A system's ability to respond, adjust and cope with the adverse consequences of an event in terms of behaviour, resources and technology is called adaptability of the system (Ge et al, 2017 (b)). People with high social vulnerability would either not recover or take a longer time to recover from a disaster as they do not have safety nets like insurance and additional financial resources as compared to people with low social vulnerability. Hence, it is necessary to identify such vulnerable population and focus air pollution mitigation measures accordingly. A number of factors contribute to vulnerability, namely, age, gender, education, financial status, occupation, resident type, green cover, etc. Some of these factors help increase while some decrease the vulnerability, hence identification of these factors that modify social vulnerability and mapping them to aerosol risk is necessary for effective air pollution disaster management.

GIS has a wide variety of applications. Set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes (Burrough et al., 1998). In the field of air quality research, a number of studies have been carried out to map areas with high pollution concentration using GIS (Briggs et al., 1997, Lim et al., 2005). Chattopadhyay et al. (2010) used GIS technology to study the seasonal variations of SO_2, NO_2 and RSPM. Another area where GIS is used is in risk and vulnerability mapping in disaster studies. Spatial database and modelling, risk assessment and analysis can all be managed together in GIS (Matejicek, 2005). GIS systems can be informative and visually illustrative of the geographic patterns of inequity (O'Neill et al, 2003). The objective of this work is (i) Estimating and mapping aerosol hazard, (ii) Identification of social vulnerability factors, mapping and estimation of social vulnerability index. (iii) Estimating and mapping the air pollution risk in a GIS environment.

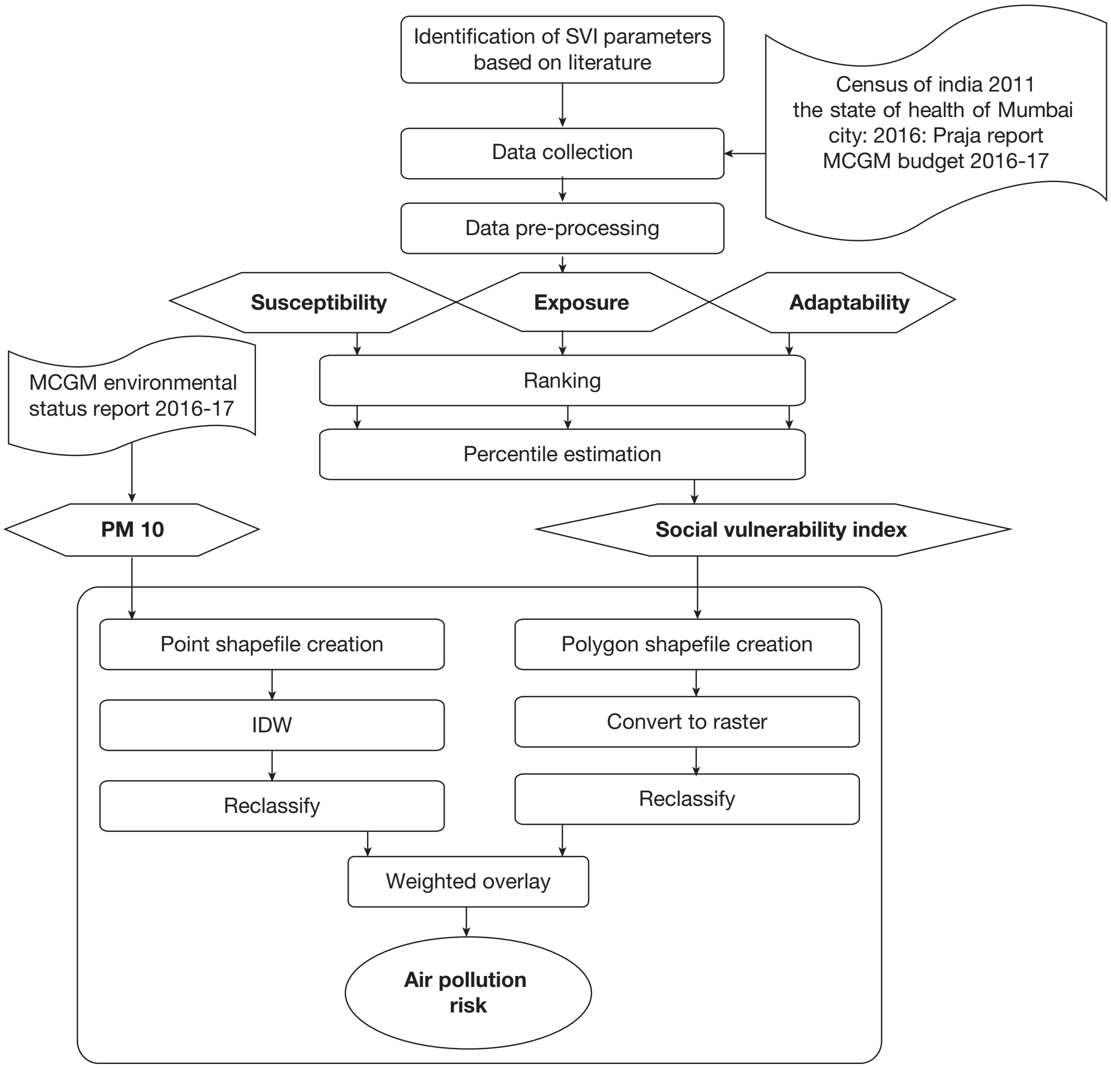


Fig i: Methodology for air pollution risk estimation and mapping

Methodology

To achieve the above objectives the following methodology was followed (Fig i):

In this study, an attempt has been made to include the different dimensions of vulnerability; economic, social, institutional, physical under the umbrella off social vulnerability. The indicators have been classified into three dimensions, namely, susceptibility, exposure and adaptability. The indicators belonging to 'susceptibility' or 'exposure' tend to increase social vulnerability, while those for 'adaptability' tend to decrease social vulnerability. With these indicators, a composite score of social vulnerability can be evaluated and be named as social vulnerability index (SVI) (Ge et al., 2017).

Materials and Method

Study Area

Mumbai, being the economic capital of the country, has always been under tremendous stress due to the large migrant population influx and this high population density has put more number of people at risk due to aerosol pollution. Mumbai's population is 22 million (based on the 2011 census). Out of this, 41.3 per cent people live in slums which create a huge difference in their socio-economic conditions. Kumar et al. (2016) showed that the economic loss due to PM_{10} and NO_2 for Mumbai for 2012 was Rs. 509 billion, which is 4.24 per cent GDP of Maharashtra state.

Fig ii: Ward map of Greater Mumbai (MCGM, 2016)

The City of Mumbai is a conglomerate of seven islands. Apart from being the financial and economical capital of the country, Mumbai is also the most industrialised city (UBAIR, 1997). The study area comprises Mumbai city and Mumbai suburban districts called as Greater Mumbai. The study area comprising both the districts is divided into 6 zones consisting of 24 wards. Being a coastal megacity, Mumbai enjoys the land sea breeze that helps in better air circulation and also dispersal of air pollutants to some extent. However, now the city is undergoing major restructuring in terms of developmental and infrastructure projects which have significantly increased the aerosol pollution in Mumbai. The entire population of Mumbai city within the 24 wards (around 22 million based on the 2011 census) will be considered for the study.

Hazard Estimation and Mapping

Technological approaches are the simplest way of capturing the risk in the form of objectively measurable units by applying weights to the negative effects (Vasvari, 2015). Air quality mapping based on interpolation from dispersion models underestimate the PM concentrations as dispersion models have large uncertainity and require additional meteorological data. Hence, monitored air quality is preferred (Kumar, 2016). Air pollution data was collected from SAFAR for Mumbai city. System of Air Quality and Weather Forecasting and Research – 'SAFAR' for Mumbai was launched and dedicated to country on June 23, 2015. It provides location-specific information on current and one to three days forecast for air quality and weather parameters along with UV index in a public friendly format along with health advisories (MCGM, 2016). In Mumbai, SAFAR has installed nine monitoring stations in the region of Greater Mumbai. This records air pollutants, namely, PM_{10}, $PM_{2.5}$, ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), benzene, toulene, xylene, mercury, etc. which are quantified and displayed on LED boards in terms of Air Quality Index (AQI) along with health advisories. However, in this study only (PM_{10}) has been considered.

In this study, annual concentration for air quality (PM_{10}) has been studied for the year 2016. The year 2016 was selected as SAFAR data for this period and the comparison data for MPCB stations were available. Annual averages of air pollution data were calculated for all the locations. Interpolation techniques in GIS like inverse Krigging and Inverse Distance weighted (IDW) give data with spatial variation and good correlation with the ground stations; these can be used for air quality management studies, among these Krigging and IDW gave better results than Spline (Kumar et al., 2016). However, IDW has been used here as the data with Krigging does not include the whole city; only some wards are interpolated due to lack of enough stations. Interpolation using IDW with power (p) value 2 was carried out in arc-GIS environment for all 24 wards of Mumbai city. The results are generated in the form of colour-coded maps.

Table i: Details of Indicators for Assessing Social Vulnerability Index

Dimension of SVI	Characteristic	Indicator	Units of Measurement	Type of Impact
Susceptibility	Age	Below 6 years	%	+
		Above 6 years	%	+
	Gender	Females	%	+
	Literacy	Illiteraters	%	+
	Economic status	Below poverty line	%	+
Exposure	Employment	Non-main workers	%	+
	Household type	Slum population	No. of households	
	Population density	Density	%	+
Adaptability	Budget for activities to reduce air pollution	Includes budget for green cover, parks, primary health care and emergency management	Number	-
	Green cover	Trees	Number	-
	Availability of hospitals	Government hospitals	Number	-
		Government dispensaries	Number	-

Social Vulnerability Index Estimation and Mapping

As the study tries to understand which socio-econo-demographic factors are required to develop a social vulnerability index to estimate the risk due to aerosol pollution, a number of independent variables are involved. Data for all the social variables was obtained from 2011 census data and other secondary sources like MCGM environmental status report, MCGM annual Budget 16–17, Health status report 16–17 by Praja, etc. These were the most recent and complete dataset available. The social vulnerability index was divided into three categories, namely, exposure, susceptibility and adaptability. Exposure and susceptibility will increase social vulnerability, while adaptability will decrease it. The indicators that increase vulnerability will be shown by a '+' sign, while those that reduce vulnerability will have a '–' sign (Ge, 2017). The social factors that will be considered are Susceptibility: age, gender, literacy, poverty, employment, inhabitant type: migrant, permanent resident; Exposure: employment, household type, population density; Adaptability: green cover, availability of hospitals and budget for activities to reduce air pollution.

Details of Variables:

Age: In South Asia over 12 million babies live in areas where the outdoor air pollution is at least six times higher than the international limits, putting them under high risk of potential poor brain development (UNICEF, 2017). Though all children are at risk, the youngest children are at most risk (UNICEF, 2017). Hence, child population below the age of six has been included in this study.

Gender: Females are more susceptible due to physical weakness and differential access to resources (Cutter, 2000). Women are slightly at higher risk than men for an increase in PM_{10} concentration (Bell et al., 2013). Hence, females have been taken as an indicator.

Literacy: Education is associated with income and poverty (Flanagan, 2011). Hence, it is an important indicator. A person age seven years and above who cannot both read and write with understanding in any language is taken as illiterate (Census, 2011). The indicator here is the percentage of Illiterates.

Below Poverty Line (BPL): Economic status of households or individuals is directly related to the level of vulnerability due to natural hazards. The vulnerable groups have inadequate access to critical and basic socioeconomic infrastructure, including communication networks, utilities and supplies, transportation, water, sewage and health care facilities, which increases their exposure to risk (Winrock, 2008).

Employment: A person who works for more than six months is a main worker (Census, 2011). In this study, the percentage of non-main workers have been considered, which included persons who are not employed in any economical activity (non-workers) and those who worked for less than six months (marginal workers) of the reference period.

Household Type: High levels of air pollution compounds the risk of children living in urban slums as they are already under threat of infectious disease due to lack of clean water and sanitation (UNICEF, 2017). Slum dwellers could be more susceptible to air pollution-induced respiratory diseases due to high pollution exposure, poor living conditions, less awareness, lack of knowledge, indoor cooking and poor resistance (Haque, 2017). Hence, the slum population have been considered.

Population: Higher population increases the exposure to air pollution risk.

Adaptability Factors: Budget allocated towards air pollution reducing activities, green cover, and availability of medical facilities have been recommended as some of the important strategies for air pollution mitigation in most of the researches. Hence, these three variables were included. After selecting the above variables, they were preprocessed so that they can be compared on the same scale. Since the social factors like age, gender, education, occupation, etc., are all in different scales, they were normalised. This was done by converting them into ranks (1–24), where 24 indicates high and 1 indicates low. The SVI was developed using the method developed by Flanagan, 2011. To estimate the social vulnerability, each of the 10 variables, except budget per capita, density of trees and density of hospitals, was ranked from lowest to highest where the highest rank indicates contributing to high social vulnerability. Budget per capita, density of trees and density of hospitals were arranged from income was ranked from highest to lowest because, these indicators help reduce the vulnerability. A percentile rank was then calculated for each ward for all the 10 indicators. A percentile rank is defined as the proportion of scores in a distribution that a specific score is greater than or equal to. Percentile ranks were calculated by using the formula:

$$\text{Percentile Rank} = (\text{Rank-1})/(\text{N-1})$$

where N = the total number of data points, and all sequences of ties are assigned the smallest of the corresponding ranks.

The percentile was then summed to estimate the susceptibility, exposure and adaptability. These three domains were then again summed to estimate the social vulnerability index.

Risk Estimation and Mapping

To develop an aerosol risk map, the social vulnerability index and hazard maps from the previous two steps are integrated together in GIS. They were first reclassified and then using weighted overlay function were integrated together. This map will delineate areas with high, medium and low risk to aerosol pollution. The mapping gives us the exact areas at risk under each category as well as their spatial distribution.

Results and Discussion

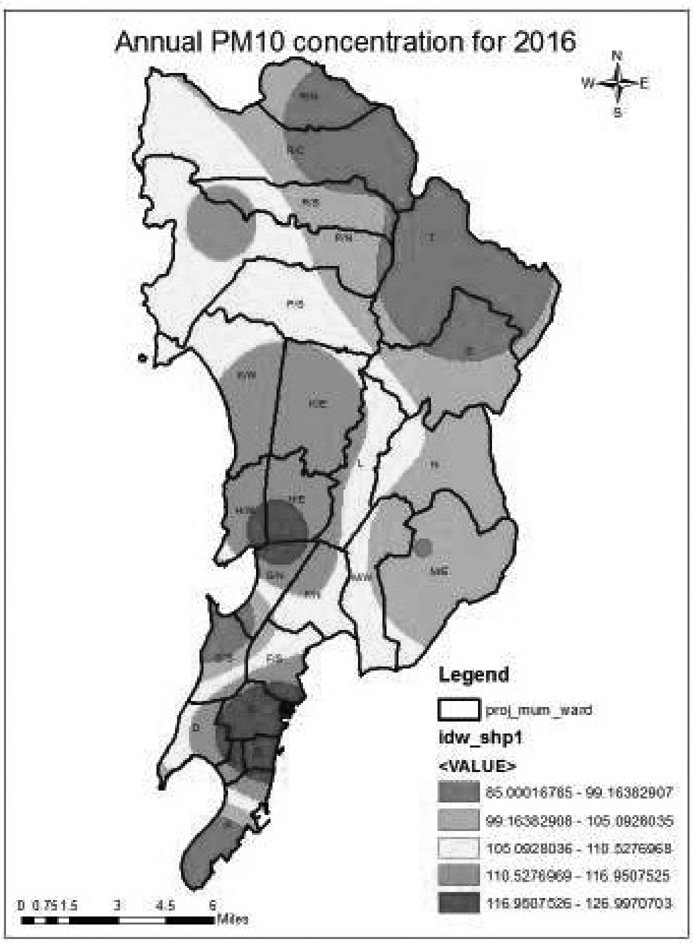
Hazard Estimation and Mapping

Interpolation results of annual concentration of air quality data was compared with the MPCB stations for validation of the IDW technique, since the annual averages of all the stations were above the CPCB prescribed standard of PM_{10} standard. It was divided into five classes from low 85.00 to severe 126.99.

The air pollution map based on PM_{10} concentration indicate that severe pollution concentration was found in parts of wards H/W, H/E, G/N, A, B, C, D, E and F/S. Comparison of the results were done with the MPCB air quality station data. It was found that it accurately predicted for Bandra station while for the Sion station the interpolation was under predicted. Since no more data was available and based on the work of Kumar (2016) for the same region, IDW interpolated data was considered to be correct.

Social Vulnerability Estimation and Mapping

All the three dimensions were represented in five levels of intensity. This was based on natural breaks (Jerkins) in the data. The minimum and maximum values across the three dimensions (susceptibility, exposure and adaptability) were found in almost the same wards. Percentile ranking and mapping helped in delineating areas of high and low susceptibility, exposure and adaptability. The susceptibility of ward C-Marine lines (0.5) was found to be the lowest, while it was highest at ward M/E-Mankhurd (4.3). Mankhurd followed by Andheri-west, Kurla and Kandivali were identified as wards with severe level (3.26–4.35) of susceptibility. The low susceptibility (0.48–1.91) wards identified were Marine line, followed by Mulund, Bandra, Sandhurst road and Grant Road. Exposure of ward C-Marine lines (0.0) was found to be the lowest, while it was highest at wards Goregaon (1.8) and Bhandup (1.8). Goregaon, Bhandup followed by Ghatkopar, Andheri east and Chembur were identified as wards with severe level (1.43–1.78) of exposure. The low exposure (0.04–0.26) wards identified were Marine lines, followed by Sandhurst road and Grant Road.



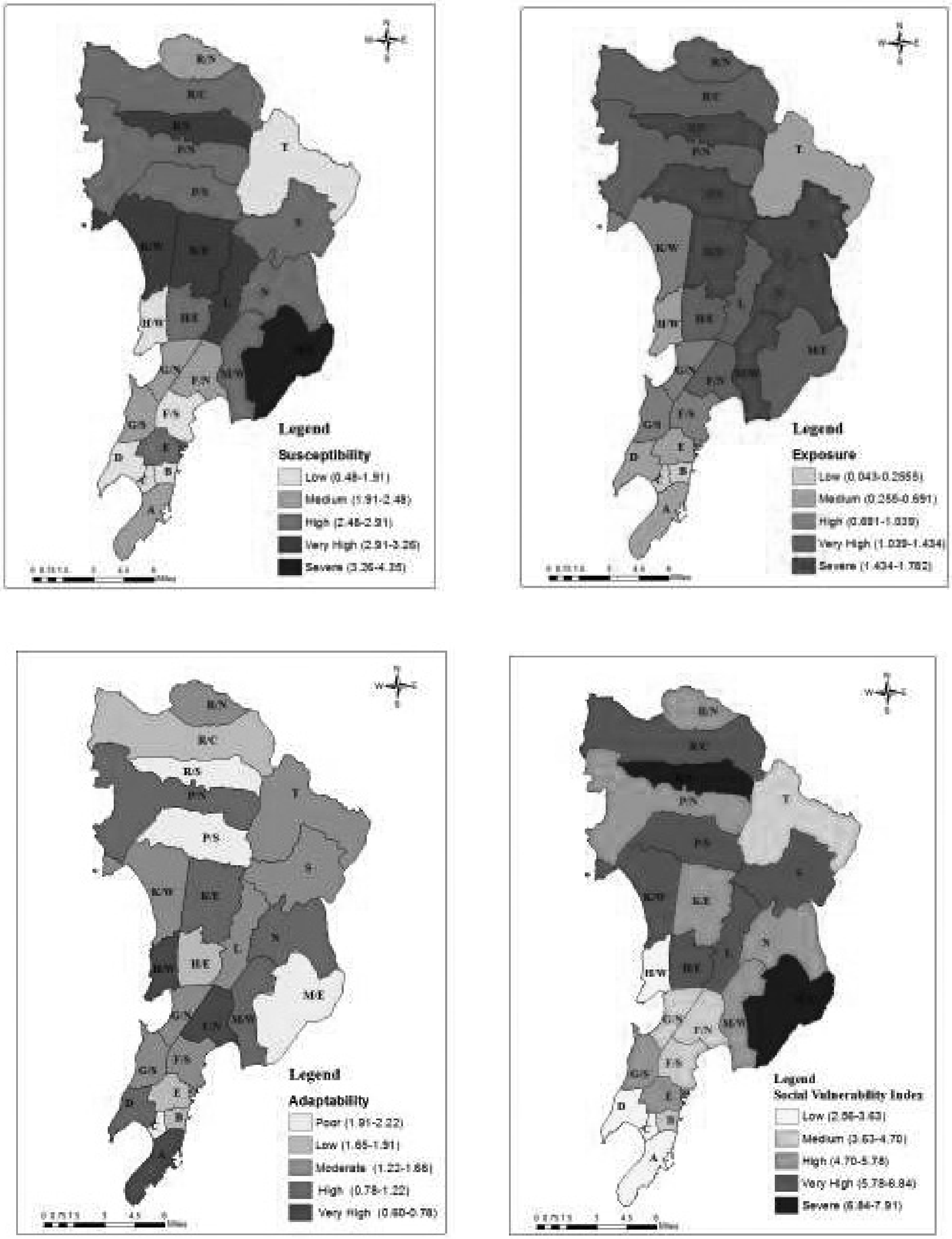


Fig iii: Map of susceptibility (a), exposure (b), adaptability (c) and SVI (d)

However, since the relationship of adaptability is inverse to social vulnerability, high adaptability values means it contributes to more social vulnerability and hence is actually least adaptable. Since the data here was calculated in terms of percentile rank, the lowest values in adaptability actually indicated it is more adaptable than the areas with high adaptability values. In this capacity, the adaptability of ward Colaba

(0.6) was found to be the lowest, while it was highest at ward Mankhurd (2.2). Hence, Mankhurd followed by Kandivali, Marine lines, Goregaon, Byculla and Borivali and Chembur were identified as wards which are poorly adaptable wards. The low adaptability wards identified were Marine lines, followed by Matunga, which indicates that these wards are most adaptable wards.

On summation of the three dimensions, the SVI was derived which was also divided into five levels of intensity. The SVI values ranged from low (2.56–7.91). SVI of ward C-Marine lines (2.6) was found to be the lowest, while it was highest at wards Mankhurd (7.9). Mankhurd followed by Kandivali were identified as wards with severe level (6.84–7.91) of SVI. The low SVI (2.56–3.63) wards identified were Marine lines, followed by Bandra, Grant Road and Colaba. Fig. 2 shows the comparison of the dimensions and their effect on SVI. It can be seen that for Andheri east though it had very high susceptibility and severe exposure values, the medium adaptability value helped in reducing the overall SVI for Andheri east to class of high SVI instead of very high or severe class.

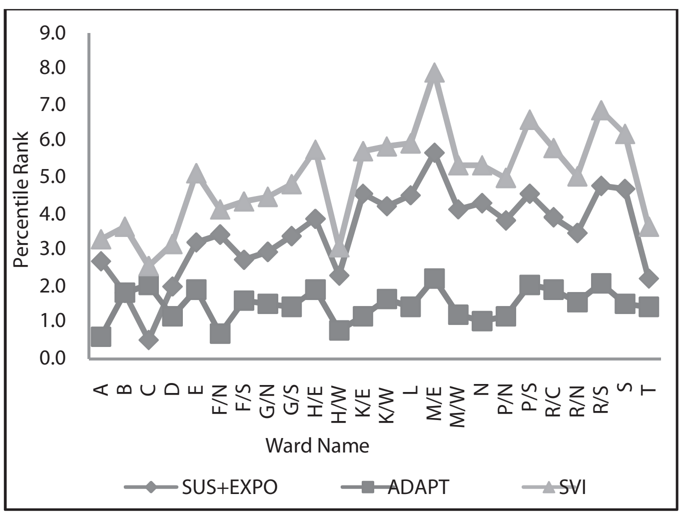


Figure iv: Comparison of three dimensions and their effect on the SVI across the wards

Risk Estimation and Mapping

The risk map helped in delineating the areas of severe risk and low risk to air pollution based on the hazard and SVI. The low risk areas identified were in ward A; it was followed by moderate risk in some parts of wards A, D, R/N and the whole of ward T. Severe risk was found in some parts of H/E ward and R/S ward. It can be easily visualised that the areas under very high risk and low risk are exactly the areas identified in the social vulnerability map.

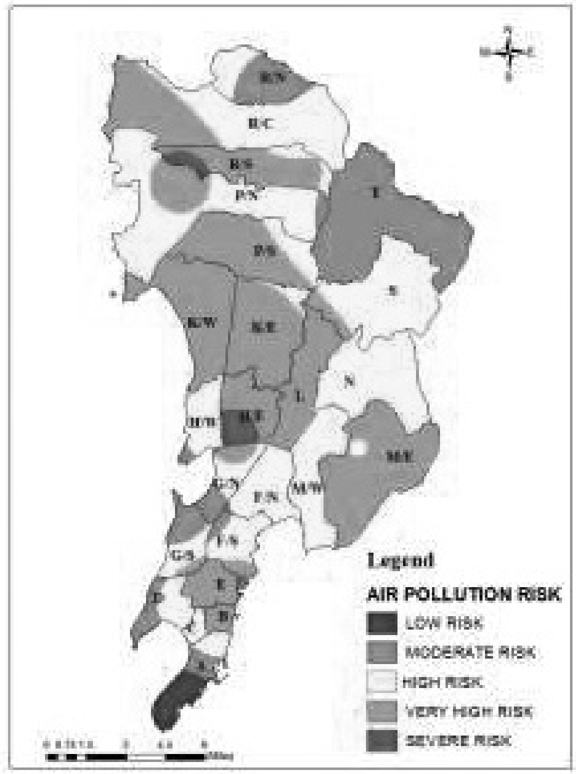


Fig v: Air pollution risk map

Conclusion

This study approaches the problem from a disaster science perspective. This has helped to delineate the high-risk and low-risk zones based on hazard zonation and social vulnerability. From a policy standpoint, consideration needs to be given to the social factors that have led to the disparities in air pollution (Kathuria, 2007). In the end, it would be worthwhile to suggest introducing a comprehensive framework for slum development with focuses on their health and habitation so that they could be brought under mainstream city living (Haque, 2017). During mitigation and planning for emergencies, identification of socially vulnerable communities help to provide those residents increased assistance over the course of a disaster (Flanagan, 2011). This research has shown that places with high air pollution concentration do not always coincide with high socially vulnerable areas, hence along with hazard social vulnerability assessment should also be carried out to understand the risk due to air pollution. The GIS-based spatial maps in the view of regulators helps direct attention to specific places where attention may be needed to address environmental health concerns, while from a stakeholder communities' point of view these spatial maps would help identify areas that need to educate and engage with residents to address air pollution problems (Sadd et al, 2011).

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PART III DISASTER RESPONSE

IX Disaster Response

Robust and Effective Disaster Response Force to Enhance Disaster Resilience in India

Brigadier Kamal Singh Chauhan (Retd)[a]

ABSTRACT: Disasters have been happening since the existence of living beings on the earth. No amount of scientific and technological advancements can prevent occurrences of natural disasters. However, some countries prone to such disasters have achieved a great deal of resilience by developing a robust and effective response system to disasters. There are several instances from prehistoric period to modern time where loss to lives, economical damage and environmental degradation could be minimised to a large extent through application of robust and effective response system. Though effective disaster warning and disaster information dissemination system, and quick decision-making process is a prerequisite to any meaningful disaster response, ultimately a cutting-edge disaster response force makes the difference.

Existing institutional framework for disaster management in India is aimed at creating and developing a proactive, participative, multidisciplinary, multisectoral and integrated civilian structure for disaster management including the response to disasters. This apparently should have reduced involvement of the Armed Forces, but they invariably continue to be the first responders in all major disasters in India and in neighbouring countries. The combined capabilities of the National Disaster Response Force (NDRF), central police force (CPF), Civil Defence and State Disaster Response Force (SDRF) have proved to be grossly inadequate to effectively respond without ab-in-to, overwhelming deployment of the Armed Forces in search, rescue, evacuation and relief operations during any major disaster. Thus, supposedly the last respondents, that is Armed Forces always turn out to be the first respondents without any exception.

In India, under the provisions of aid to civil authority, the Armed Forces have always been called upon to assist the civil administration even during various disasters, as and when felt necessary by civil authorities. National Disaster Management Act 2005 has further provided the legal mandate to civil authorities to employ the Armed Forces in disaster response. National Policy on Disaster Management issued in 2009 has also outlined the significance of capacity and capabilities of the Armed Forces in response to disasters. Certain Guidelines issued by National Disaster Management authority on various natural and manmade disasters including chemical, biological, radiological and nuclear emergencies arising accidently or otherwise have further amplified the specific role and responsibilities of the Armed Forces. However, in many other guidelines the role of the Armed Forces is just not mentioned. Similarly, National Disaster Management Plan 2016 also lacks specificity of role and responsibility of the Armed Forces. This dichotomy if addressed would facilitate better preparedness, coordination and integrated response to disasters.

In view of the above, it is essential to revisit the institutional framework for disaster management with regard to organisation, development, coordination, employment and command and control of disaster response forces. In this paper attempt will be made to analyse various aspects in this regard to generate alternative models for having a robust and effective disaster response system to make India more disaster resilient.

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KEYWORDS: institutional framework, disaster management authorities, disaster response force model, disaster resilience

Introduction

Disasters have been associated with human being since the inception of life on the earth. Along with the physical, social, economic and scientific evolutions, disaster coping mechanisms have also been evolving right from pre-historic period. The world has moved from purely reactive response to a proactive and holistic disaster management (DM) era, with integrated approach. The credit goes to various international initiatives right from declaration of International Decade for Natural Disaster Reduction to Sendai Framework, and serious commitment displayed by the member states in general, and India in particular. Fast pace of technological development also plays a significant role to boost up the modern disaster management approach and practices. As per the studies conducted by the Centre of Research on the Epidemiology of Disasters (CRED), Asia is the most disaster-prone continent, and India is one of the most disaster-hit countries in the world (ADSR, 2013). Hence, in line with the international initiatives, India took a big leap forward by enacting National Disaster Management (DM) Act 2005, which brought in a paradigm shift in the country's disaster management approach. It paved the way for holistic and integrated disaster management encompassing prevention, mitigation, preparedness, response and recovery to build back better or bounce forward. Capacity development and preparedness play a fundamental role in effective disaster response, which substantially contributes towards disaster resilience (National Policy on DM 2009, 7).

The DM Act 2005, besides providing legal mandate for establishment of disaster management authorities at national, state and district level, and for creation of financial framework, also provides for constituting National Institution for Disaster Management (NIDM) for capacity development, and National Disaster Response Force (NDRF) for the purpose of specialist response to disasters or disaster-like situation (DM Act 2005, 21–22). There is no mention of the role of the Armed Forces for disaster response in the entire Act, except that the Chief of Integrated Defence Staff is included as one of the members in the National Executive Committee (DM Act 2005, 7). However, Section 35 (f) of the DM Act, without any amplification, mandates the Central Govt to take measures with regard to the deployment of the Armed Forces in disaster management. This Act, thus, provides an additional constitutional authority to Central Govt to deploy Armed Forces in any manner for disaster management. National Policy on Disaster Management 2009 acknowledges the fact that though conceptually the Armed Forces are required to be employed to assist the civil administration only when situation overwhelms the civilian resources, practically, the Armed Forces owing to their speed of operational response and the resources at their disposal have been playing a major role as an immediate responder in all major emergencies and disasters. National Policy on one hand acknowledges that the Armed Forces form an important segment of national response capacity; however, on the other hand, it seeks the role of Armed Forces more as the trainers on specialised aspects, such as CBRN, heli-insertions, rescue at high altitude, watermanship, and training of paramedics, than the responders (National Policy 2009, 13). As per National Policy, only NDRF, State Disaster Response Forces (SDRFs), Fire and Medical Services, Police, Civil Defence, Home Guards, NCC, NSS and NYKS are the first and key responders, and not the Armed Forces. The Policy also calls for role reduction of the Armed Forces in view of the deployment of NDRF in disaster response (National Policy 2009, 26).

Guidelines on various disasters, issued by NDMA since 2007, also carry forward the national intent of reducing the role of the Armed Forces in DM. Thus, the role of the Armed Forces has been included in the Guidelines on Medical Preparedness and Mass Casualty Management, Biological Disasters, Nuclear and Radiological Emergencies, and Chemical Disasters only, and not for any other disaster (Guidelines on various Disasters). National Disaster Management Plan (NDMP) 2016 too excludes Armed Forces from institutional arrangements for disaster response, except for connecting the Integrated Defence Staff to National Emergency Operation Centres (NEOCs)

(NDMP 2016, 96). Thus, the existing framework for disaster management in India has introduced a huge role clarity gap and integration deficit between the Armed Forces and newly found responders and civil administration. This dichotomy has also been analysed and amply highlighted by Dagur in his paper on "Armed Forces in Disaster Management", published in the *Journal of Centre for Land Warfare Studies* (Dagur 2008, 6–8). However, paradoxically, the Armed Forces have remained the first and major responders in all major disasters, whether it was Leh Mudslide in 2011; Floods in Uttarakhand in 2013, Jammu and Kashmir in 2014, Chennai in 2015, and Kerala in 2018; or Nepal Earthquake in 2015. In this regard, views of Mahalingam bringing out many shortcomings and questioning the adequacy of the existing disaster response framework, in his article published in *Times of India*, are pertinent (Mahalingam 2013). Yamunan also highlighted in his article, published in *The Hindu*, that better preparation and coordination by civil administration with the Armed Forces could have avoided delay in rescue operation during Chennai Floods in 2015 (Yamunan 2015).

Analysis of Prevailing Practices and Thought Process on Disaster Response Force

Looking at the global scenario, there are accepted and acknowledged trends of deploying the Armed Forces for disaster management as part of military operations other than war (MOOTW). Depending upon the respective peculiarities and political dispensation, countries employ military for disaster response either exclusively or in combination with other civil responders. In the USA, Ministry of Defence has delegated the basic responsibility of disaster response to the US Army. Corps of Engineers play a leading role in Public Work and Engineering as a part of their national response plan. There are well laid down instruction and SOPs for integrated response, which are activated on declaration of national disaster by the President. For localised disasters, area commanders on receipt of emergency request initiate actions to save lives, and to prevent destruction and damage to property. Russia has dedicated 23,000 troops along with aviation, engineers, communications, transports and other assets which remain deployed in nine regions under Emergency Command (EMERCOM). Similarly, China's disaster response force is purely based on People Liberation Army (PLA). In Austria armed forces have been delegated the responsibility of assisting the civil administration in all major disasters and accidents (Shabab et al. 2015, 154). Australia, Canada, the UK and Japan have also been deploying their armed forces for disaster response with great success.

Notwithstanding, there have always been opposing views regarding deployment of armed forces in disaster response, one supporting the enhanced role, and the other discouraging the same for different reasons. At the onset of Hurricane Katrina, in 2005, there were initial debacles in response, which prompted a massive swift deployment, and diligent response by the armed forces. In the aftermath, the President remarked that now it was clear that disasters of such magnitude required more federal authority and enhanced role for the armed forces, who have enormous capability for a successful logistic operation in a very short notice. The US conference of Mayors also acknowledged that the enhanced role of armed forces in disaster response would accrue many advantages. However, to avoid undue risk to civil liberties, democratic nations have constrained and restricted military use in disaster response through legislations. For example, Posse Comitatus Act 1878 puts restrictions on employment of federal military and National Guard as a police force. Similarly, Canadian Emergency Management Act 2007 though supports the employment of armed forces it also provides complete freedom and ensures fundamental rights of the citizens during national emergencies. Some of the academic literature and emergency practitioners are also critical of managing disasters in a military manner. For example, the US National Emergency Management Association (NEMA) does not favour the enhanced military role in response to disasters. Opposition to the lead role of military in disaster response also stems from the view that hierarchal command and control structure is not effective in handling complex disasters, since they may not take into account the culture, expertise, authority and concerns of the local population (Etkin, Mc Bay, and Trollope 2011, 11–12).

The general belief brought out by Etkin and others that command and control-based management approach of armed forces makes them bureaucratic is not true during crises and emergency situations. Rather, at times civil emergency managers may adopt a bureaucratic approach which was amply visible during Hurricane Katrina, where senior civil emergency managers were instrumental in turning down the aids from Red Cross Society and other agencies for want of procedural compliance (Etkin, Mc Bay and Trollope 2011, 13). Etkin and others also recommended that military must be involved in disaster management since they are also significant stakeholders of the society, besides having special expertise and resources. They cited the results of survey of the views of emergency managers carried out by Etkin and Nirupama, in 2009, to ascertain their preferences for command and control-based approaches or community-based approaches, in all the four phases of DM, that is, mitigation and prevention, preparedness, response, and recovery. The survey result showed a significant preference for command and control-based approaches during response phase and for community-based approaches during recovery phase of the DM cycle (Etkin, Mc Bay and Trollope 2011, 15). Etkin and others through a conceptual model, further concluded that it is absolutely essential to involve armed forces for liaison, coordination, need assessment and planning in all the phases of DM cycle including mitigation and preparedness. They cited the role of corps of Engineers of US Army in mitigation phase. During localised emergencies also, armed forces should be involved in liaison and planning to enable integrated and coordinated response in case of escalation of emergency (Etkin, Mc Bay and Trollope 2011, 20).

Australian Civil Military Centre, in a paper on Civil Military Response, observed that despite the opposition by some humanitarian organisations, the armed forces will keep having an enhanced role in disaster response, owing to their ability and capacity for quick response on a much larger scale than the civilian actors. Employment of armed forces will also continue for disaster response due to political compulsions. This paper cites the example of employment of Japan's Self Defence Forces in response to earthquake, tsunami and nuclear accidents in 2011. Immediately after the earthquake, out of 2,30,000 troops 1,70,000 troops were mobilised by Japan in response to this multi-hazard disaster. Armed forces established joint command of ground forces and responded swiftly in a well-coordinated manner, besides coordinating the response of about 20,000 US troops. This was in absolute contrast to the disaster response to Kobe Earthquake in 1995, when the local government and the Prime Minister showed reluctance to employ Self Defence Forces (ACMC Paper 5/2012, 3). However, Fischer, while acknowledging the lead role of the armed forces in disaster response in the wake of Japan tsunami, brought out that armed forces lack capability in terms of equipment and training. He also highlighted the coordination problem between civil and military actors during disaster response (Fischer 2011).

As per the analyses in the said AMC paper, the role of armed forces is the most essential and accepted during response phase; however, the need and acceptance diminish in recovery phase. It is also clearly brought out that the effective response capacity development necessitates preparedness by both military and civil disaster management agencies. Though, disaster reduction measures involve many long-term activities, but there are certain activities such as identification of evacuation routes and setting up early warning system in consultation with the communities, which will entail involvement of the armed forces also. Thus, there will definitely be some overlap of responsibilities in the mitigation phase as well. It is further observed in this paper that armed forces are better trained in preparedness activities, such as scenario-based contingency planning, training, mock drills and exercises than their civilian counter parts involved in disaster management. Therefore, preparedness must include joint coordination mechanism to avoid chaos during the response phase. This paper also brings out likely challenges in future disaster response. These challenges include response to disasters in urban areas infested with insurgency and criminal gangs, and may call for dominant role by the armed forces in response phase. Similarly, disaster response in conflict zones, and in a situation where natural and technological disaster overlap, will require overwhelming military involvement (ACMC paper 5/2012, 5–7).

Scolobig et al. also stressed the need of considering possible cascading effects of one hazard leading to another, such as earthquake leading to landslides/

tsunami or any industrial accidents, while planning and preparing for enhanced response capacity (Scolobig et al. 2013, 7). Arcala Hall and Cular brought out in *South African Journal of Military Studies*, that the deployment of armed forces for disaster response is generally of a short duration and hence unlikely to have any adverse impact on civil-military relationship, which is one of the apprehensions leading to reluctance in deployment of armed forces in disaster response (Arcalla Hall and Cular 2010, 64–66). Alexander, while deliberating in detail about disaster and emergency planning for preparedness response and recovery, emphasised the significance of scenario-based planning catering for different hazards as per geographic locations and sectors (education, health and hospitals, fire, collapse of structures, transport, etc.). He further stressed the need of detailed planning for recovery phase also, besides planning for response during the preparation phase (Alexander 2015, 15–23). Since Armed forces are trained for such deliberate and detailed contingency planning, it is advantageous to involve them along with civil emergency managers in preparing the joint contingency plans for response and recovery phases, during preparedness phase, in order to enhance disaster resilience.

Despite creation of NDRF, SDRFs and re-organisation efforts to make Civil Defence, Home Guards, Fire Services, Youth Organisations, and NGOs more effective in disaster management, Indian Armed Forces will continue to be embroiled in disaster response due to following reasons. One, since Army is deployed across the country even in far flung and inaccessible areas, most of the time they will be able to reach and respond much before the arrival of other responders. Two, every major disaster has huge political implications. Hence no political dispensation will take a chance to avoid employment for armed forces or prefer a graduated response, that is waiting for situation to go beyond the capabilities of other responders (Raj, Alok 2008, 169–170). Three, owing to proven capabilities of Indian Armed Forces in disaster response in all the major disaster in the past, public has tremendous faith, hence deployment of Armed Forces gives them assurance and hope for speedy rescue and relief (Dey 2017, 155). Four, other responders including NDRF are at best capable of handling localised disasters and not the major disaster. Shri Arjun Katoch, an international disaster adviser to various countries, remarked one day during a round table conference jointly organised by Vivekananda International Foundation (VIF) and Policy Perspectives Foundation (PPF) on 06 May 2016, in the presence of MoS (Home), that NDRF is best suited for localised disasters, and Armed Forces will be invariably required to respond during major disasters (VIF and PPF 2016, 14). Five, in the case of mass causality events (MCE) emanating from CBRN emergencies, only Armed Forces have the capability to respond. However, even Armed Forces are apprehensive of their excessive employment in assisting the civil authorities, which distract them from focussing on their primary task. Hence judicial employment is recommended (H, Shivananda & Gautam 2012, 108).

Though the Indian Armed Forces have vast exposure and experience of responding to various disasters, lack of specific equipment, training and expertise essential for disaster response has been felt for a long time; and the same was acknowledged by the high-power committee (HPC) on disaster management in 2001. The HPC has recommended dedicated component of personal and equipment at the battalion level, besides fully equipped centres having heavy equipment in all of the Army Commands for disaster response. HPC also recommended employment of TA for disaster response besides incorporating the Border Road Organisation (BRO) in DM plan (Report of HPC 2001, 168). However, instead of implementing these recommendations the NDRF was created vide DM Act 2005. Creation of NDRF is undoubtedly a good step towards specialised response to disasters. NDRF has played an important role in various localised and major disaster in India as also during Nepal earthquake and Japan tsunami (Patel, Bhagat, and Bhatt 2017, 3). But the NDRF response capacity is limited in terms of personal, equipment, training, mobility and logistics. Therefore, it may be appropriate to consider NDRF, SDRFs and other civilian response forces in supplementary role and not as a replacement to armed forces in major disaster response. Somehow, the institutionalised disaster response sought in the Act, National Policy, various guidelines on DM, issued by NDMA, and National Plan lacks clarity on this particular aspect. Hence the most potent component of disaster response, that is the Armed Forces, is not properly involved and integrated in preparedness and response phases of the DM cycle (VIF & PPF 2016).

Commenting on the existing capabilities of the NDRF, Shri O.P. Singh, DG NDRF, during the said round table conference on India's Disaster Response Mechanism, brought out the organisational deficiencies of NDRF. Similarly, Shri Arjun Katoch, an expert in DM, mentioned during the same conference that NDRF lacks modern training facilities and technical equipment of international standard, besides lacking in technical leadership and exposure to function in close coordination with the Armed Forces. He also highlighted the weaknesses of the Indian disaster response management to include absolute lack of response capacity of the community as a first responder, negligence of Fire Services and Civil Defence, non-involvement of Red Cross, NGO in disaster preparedness and response phases, and legal constraints in linking the corporate social responsibility (CSR) funds. In the said conference, requirement of training of responders on Medical First Response (MFR), Collapsed Structure Search and Rescue (CSSR), Hospital Preparedness for Emergency (HOPE), and Swift Water Rescue (SWR) were also highlighted. The need for well-trained SDRFs in all the states was considered vital for quick response to disasters. At the beginning of this conference Shri Kiren Rijiju, MoS of Ministry of Home Affairs, stressed the need of high-end technology to enhance disaster response capacity (VIF & PPF 2016, 9–11).

Response survey of senior officers of Armed Forces, civil officials, DM experts and NGOs carried out by Alok Raj in 2008, to ascertain the state of coordination between civil administration and Armed Forces, revealed significant findings. Majority of the responders were of the view that civil administration does not share essential inputs and updated data related to local hazard mapping, vulnerability profile and existing DM mechanism with the Armed Forces. Civil administration doesn't maintain the updated contact details of Armed Forces, which at times result in delayed response. Majority of them also felt that deployment of Armed Forces gets delayed due to the graduated response philosophy, at times, and hence Armed Forces should be deployed ab-in-to in anticipation. Most importantly majority of them felt that joint mock drills and exercises are never carried out. Hence coordination between civil/administration and Armed Forces needs substantial improvement (Raj, Alok 2008, 173). Kumar also brought out that lack of preparedness and coordination of civil administration with the Armed Forces delayed response during Kosi River Floods 2008, which devasted a huge area in Bihar (Kumar, Satish 20182, 126). Similar observations were made by Krishna and Damle in a study carried out by them to assess the deficiencies in coordination between Armed Forces and civil administration, which adversely effected disaster response during J&K Floods in 2014 and Chennai Floods in 2015. In this study also, responders were drawn from across the spectrum of the stakeholders in these disasters, including civil response forces, civil administration, affected communities and the Armed Forces (Krishna & Damle, 13240–13243).

While reassessing India's disaster management preparedness H. Shivananda and Gautam brought out certain constraints and challenges that Armed Forces face in disaster response. They mentioned that Armed Forces have to often respond without any proper information and data base of civilian resources in terms of skill, essential services and forecast of probable disasters; and in absence of emergency preparedness, and joint drills. They also brought out the requirement of disaster specific training for the armed forces. Even Gen. S. Padmanabhan in his book 'General Speaks', brought out that Armed Forces need specific training and equipment for disaster response, based on his experience in Bhuj Earthquake in 2001 (H. Shivananda & Gautam 2012, 11). Singh and Tandon also, stressed that disaster managers must have a clear understanding of the capabilities and operational methodologies of the Armed Force to enable optimised disaster response. They also brought out that role clarity in respect of Armed Forces and civilian response forces is essential to avoid duplicity. Importance of coordination and training was also stressed by them (Singh & Tandon 2015, 2906–2907).

Findings

From the foregoing deliberations the following facts emerge:

- Presently, the disaster response capacity at the community level, who are supposedly the first responders, is negligible in India.

- Apprehensions against the deployment of armed forces in disaster response are unfounded. On the contrary, public and disaster managers prefer armed forces response to disaster, owing to their capabilities and experiences. Disaster response by the armed forces is the main stay in major disasters across the world.
- Despite creation of NDRF at national level, and SDRFs at state level, Armed Forces will remain involved in response to major disasters in a lead role.
- Existing institutional framework in India lacks role clarity for Armed Forces in disaster response, which has led to their non-involvement in planning and coordination during preparedness phase of the DM cycle. This results in lack of integration of Armed Forces with other civilian response forces during response phase.
- NDRF is gradually acquiring specialised capabilities, but their response capacity along with other civilian response forces such as, SDRF, Civil Defence, Police Force in all likelihood will remain inadequate to manage major disaster response on their own. However, their response capacity may be adequate for localised disasters where involvement of Armed Forces can be avoided.
- As of now, NDRF has organisational shortcomings in terms of personal, equipment, training and specialised leadership.
- Civil Defence and Fire Services are in the state of neglect.
- There is hardly any exchange of information/data, and coordination between civil administration/ civil response forces and Armed Forces during preparedness phase.
- There is hardly any worthwhile joint planning and training by the Armed Forces and civilian response forces during the preparedness phase of DM cycle.
- Judicious deployment of Armed Forces for a short duration in disaster response will not distract them from their primary role, and also will not have adverse impact on civil military relationship.
- Armed Forces also need disaster response-specific equipment and training.

Recommendations for Robust and Effective Response Force Model

In view of the above findings, following recommendations if implemented, India's Disaster Response Force will become very robust and effective, which will consequently enhance the disaster resilience of the country:

- Response capacity must be developed at community level, which is a long-drawn process. Joint efforts by NDRF, SDRF, Police Force, Civil Defence, and youth organisations to enhance disaster awareness in rural and urban areas, will go a long way in enhancing response capacity and resilience at community level.
- Organisational shortcomings of the NDRF must be overcome through priority. Requirement of additional specialised equipment and training must be met at the earliest.
- Civil Defence must be revamped, Fire Services must be reorganised and re-equipped, and SDRFs should also be organised and trained on the line of NDRF. All the civil response force entities should be integrated under the leadership of NDRF during preparedness phase of the DM cycle, and during response phase for response to localised disasters only.
- To avoid duplicity of efforts and to ensure synergy in search, rescue, and relief operations, all the civilian response forces should be grouped and employed in the form of joint composite task forces, preferably under the leadership of Armed Forces during response to major disasters.
- Existing Institutional framework for DM must be revisited and amended to ensure involvement of Armed Forces during preparedness phase, and their integration in response to major disaster.
- Information/data sharing with the armed forces by civil administration on regular basis will enhance the preparedness of the Armed Forces, hence the same must be ensured.
- Scenario-based joint mock drills, and exercises for area-specific disasters at state, district and city level

must be conducted regularly for disaster response. All stakeholders including elements of civilian response forces and Armed Forces must participate. Planning and the coordination for the same must be done by the office of respective disaster management authority/executive authority at state, district and city level.

- Disaster-specific equipment and training for the Armed Forces as recommended by HPC on DM, must be ensured.
- The responders must be trained on MFR, CSSR, SWR and HOPE.
- Mass Causality Management and Biological Disaster Management should be planned in detail and efficacy of the same should be checked through simulated computerised models.
- Technology must be exploited to ensure mobile telephone-based effective disaster warning dissemination system. Technology should also be used for data sharing and exchange of information on real or near real time basis.

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Effectiveness of TOT Workshop on Psychosocial Care in Disaster Management for National Disaster Response Force Personnel

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ABSTRACT:

Introduction: India is a country where it is surrounded with sources of potential harm or situations with a potential to cause loss all around us. We could encounter both major disasters like tsunami, cyclone, earthquake, floods and we could be living close to the industrial area which is potential threat to the environment. National Disaster Management Authority (NDMA) aims at instilling a culture of preparedness among all stakeholders and training of different stakeholders is the most important tool. Further the efficient disaster response will depend primarily on effectiveness of training and re-training of specialised Disaster Response Forces. NDMA has been recommending all the states to train at least one battalion equivalent out of their state armed police units as Disaster Response Force on the lines of National Disaster Response Force (NDRF).

Methods: The objective of the study is to find out the effectiveness of Training of Trainers (TOT) workshop on psychosocial care in disaster management among middle level officers of National Disaster Response Force (NDRF) from different battalions. The study adopted quasi experimental design with post only research design. There were 25 participants who were part of the training programme. The content of the programme includes the disaster resilience, need, importance, techniques and role of the NDRF personnel in provision of psychosocial care in disaster management. A semi-structured questionnaire consisting of socio demographic profile, Overall evaluation of workshop, psychosocial aspects in Disaster Management was developed for assessing the effectiveness of the programme. Descriptive statistics was carried out to analyse the data.

Results: All the participants were at the rank of commandants in different battalions of NDRF. Majority of the participants found the content of the programme from very good to excellent, very well structured and organised. Overall impression of the programme was reported as very good to excellent by most of the participants.

Conclusion: Preparing the NDRF personnel on integration of psychosocial care services in disaster management would equip them to deal with the psychosocial issues effectively. There is also a high need to train all the battalions of NDRF for effective and efficient disaster response force, which result in reducing the psychosocial impact on survivors of disasters.

KEYWORDS: training of trainers (TOT) workshop, psychosocial care, national disaster response force personnel, efficiency

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Introduction

Disasters are unpredictable events, which extremely disrupts the functioning of a community or society and causes losses to human, material and economic or environment that exceed the community's or society's ability to cope using its own resources (IFRC, 2018). The word "Disaster" is derived from the Greek word called (dus)- "bad" (aster)- "star". The root of the word disaster is "bad star" in Greek and Latin from an astrological theme (Ministry of Home Affair Government of India, 2009). A country like India has the high degree of socio-economic vulnerability which makes it one of the most disaster-prone countries in the world. According to the annual disaster report 2016 there were around 8733 death due to disaster. However, number of people affected by natural disaster in 2016 is very high (569 million). Asia tops the list of casualties due to natural disasters (Guha-sapir, Hoyois, & Below, 2017).

The Sendai Framework for disaster risk reduction 2015–2030 has four priorities for action, and one among them is strengthening disaster risk governance to manage disaster risk through prevention, mitigation, preparedness, response, recovery and rehabilitation (UNISDR, 2015). Over the last two decades paradigm shift from relief-centred post-disaster management to disaster risk reduction and disaster preparedness aspects. These consist of holistic, multi-dimensional integrated community approach of health promotion, disaster prevention, preparedness and mitigation. There are various psychosocial problems faced by the survivors of disaster through psychosocial care we enhance the restoration of social cohesion and infrastructure as well as the independence and dignity of individuals and groups. Psychosocial care serves to prevent developments of major mental illness and further social disruption (Rao, 2006).

Disaster preparedness in the policy level has attained through enactment and implementation of Disaster Management Act, 2005. There are various committee in disaster preparation which consists of multidisciplinary professionals like physical, geographical, engineering, environmental, social, health, psychological, management, and economic sciences and so on (Aitsi-Selmi, Egawa, Sasaki, Wannous, & Murray, 2015). The Disaster Management Act 2005 of India has statutory provisions for constitution of National Disaster Response Force (NDRF) for the purpose of specialised response to natural and man-made disasters. Generally psychosocial care training is provided in post-disaster situation to manage the damage caused by the hazard. Whereas, it should be given in the pre-disaster phases as part of preparedness. National Disaster Response Force is the first responder to any disaster, and it is involved in all the aspects of rescue and relief. Nevertheless, prevention reduces expense of resources multiple times than post response. Providing psychosocial care in disaster preparedness and disaster risk reduction is essential as per international and national disaster management guidelines (Baingana, 2008; NDMA, 2017). Therefore, providing psychosocial training to the NDRF personnel would help them in being sensitive to psychosocial problems and provide effective management at the initial phase of disaster.

Methodology

The National Institute of Mental Health and Neuro Sciences (NIMHANS), Bangalore, is the nodal centre for psychosocial care of the survivors of disasters in India. NIMHANS developed Training of Trainers (ToT) manual to train school teachers, healthcare workers and community-level workers on psychosocial care of the survivors of disasters. This manual consists of 40 sets of sessions from basic understanding of disaster to working with special populations (Sekar K, Dave AS, Bhadra S, et al. 2004).

The Disaster Management Act has statutory provisions for constitution of National Disaster Response Force (NDRF) for the purpose of specialised response to natural and man-made disasters. At present, National Disaster Response Force consists of 12 battalions, three each from the BSF and CRPF and two each from CISF, ITBP and SSB. Each battalion has 18 self-contained specialist search and rescue teams of 45 personnel each including engineers, technicians, electricians, dog squads and medical/paramedics. The total strength of each battalion is 1,149. All the 12 battalions have been equipped and trained to respond to natural as well as man-made disasters. Battalions are also trained and equipped for response during chemical, biological, radiological and nuclear (CBRN) emergencies. NIMHANS and National Institute of Disaster Management (NIDM), collaboratively conducted TOT workshop on psychosocial care in disaster management for NDRF personnel.

The objective of the current study was to assess the effectiveness of one such TOT workshop on psychosocial care in disaster management. The study adopted quasi-experimental with post assessment only research design. The ToT programme included 20 participants. The duration of the programme was five days. The content of the programme includes the disaster resilience and sustainability, impact, needs of the survivors, normal and abnormal psychological reactions, life event and family life cycle after disasters, vulnerable population, techniques of psychosocial care, and role of NDRF personnel in provision of psychosocial care in disaster management. Following are the semi-structured questionnaire consisting of socio-demographic profile, content, structure, organisation, usefulness, applicability, methodology used for training which was developed for assessing the effectiveness of the programme. Data analysis was done using the SPSS version 21. Descriptive statistics was carried out to analyse the data.

Results

Data of the 20 participants who attended the training programme were taken for data analysis. There were only male participants who attended the training programme. Table 1 shows socio-demographic details of the participants. The average mean age of the participants was 42±7.61 (M±SD), half the participants (50 per cent) were assistant commandant; there were participants from all 12 battalions.

Table 1: Socio-demographic Details of Participants **N** = **20**

		N	%
Designation	*Assistant commandant/ Executive*	01	05
	Assistant Commandant/ MO	01	05
	Assistant Commandant	10	50
	Deputy commandant	08	40

Table 2: Overall Evaluation of Workshop by the Participants **N** = **20**

	Very well (%)	**Well (%)**	**Moderate (%)**	**Average (%)**	**Unstructured (%)**
Structure and organisation	17 (85)	3 (15)	00 (0)	00 (0)	00 (0)
	Very much (%)	**Much (%)**	**Moderate (%)**	**Limited use (%)**	**Not at all (%)**
Programme useful in job	18 (90)	2 (10)	00 (0)	00 (0)	00 (0)
	Excellent (%)	**VG (%)**	**Good (%)**	**Fair (%)**	**Poor (%)**
Overall impression	16 (80)	4 (20)	00 (0)	00 (0)	00 (0)

Table 3: Evaluation of Usefulness of Workshop by the Participants **N = 20**

	Strongly agree (%)	Agree (%)	NA/D (%)	Disagree (%)
Programme help me in future jobs	12 (60)	8 (40)	00 (0)	00 (0)
Practical orientation	16 (80)	4 (20)	00 (0)	00 (0)
Inspires me for assignment related to DM	11 (55)	09 (45)	00 (0)	00 (0)
Benefited – interaction with fellow participants	16 (80)	4 (20)	00 (0)	00 (0)
Course and material usefulness	18 (90)	1 (5)	1 (5)	00 (0)

NA/D = Neither agree nor disagree

Table 4: Topics on Psychosocial Aspects in Disaster Management N = 20

	Excellent (%)	VG (%)	Good (%)	Fair (%)	NR (%)
Disaster and development conceptual framework	15 (75)	05 (25)	00 (0)	00 (0)	00 (0)
Evaluation and principles of psychosocial care and impact of disaster on survivors	17 (85)	03 (15)	00 (0)	00 (0)	00 (0)
Normal and abnormal reaction in disaster	17 (85)	2 (10)	01 (5)	00 (0)	00 (0)
Identifying circle of support for disaster survivors	18 (90)	02(10)	00 (0)	00 (0)	00 (0)
Technique of psychosocial care	18 (90)	02 (10)	00 (0)	00 (0)	00 (0)
Life events and family life cycles coping abilities	18 (90)	02(10)	00 (0)	00 (0)	00 (0)
Identifying the more vulnerable group	17 (85)	03 (15)	00 (0)	00 (0)	00 (0)
Recalling the childhood events and identifying the impact of disasters on children	20 (100)	00 (0)	00 (0)	00 (0)	00 (0)
Principles of providing psychosocial care to children in disaster	18 (90)	2 (10)	00 (0)	00 (0)	00 (0)
Social discrimination against women	19 (95)	1 (5)	00 (0)	00 (0)	00 (0)
Differential impact of disaster on men and women	17 (85)	03(15)	00 (0)	00 (0)	00 (0)
Body mapping and identifying of the women in difficult circumstances	17 (85)	03(15)	00 (0)	00 (0)	00 (0)
Strategies to work with women	16 (80)	03(15)	01 (5)	00 (0)	00 (0)
An overview of self-care strategies of holistic living	18 (90)	02(10)	00 (0)	00 (0)	00 (0)
Handling burnout	17 (85)	03(15)	00 (0)	00 (0)	00 (0)

VG = Very good; **NR** = No response

The overall evaluation of workshop among the participants is indicated in Table 2. Most of the participants reported that the programme was very well structured and organised (85 per cent) and (90 per cent) felt that workshop will help them in future job prospects. Participants reported overall the training was excellent (80 per cent).

The overall evaluation of workshop among the participants is indicated in Table 3. More than half of the participants strongly agree (60 per cent) and the rest (40 per cent) agree that workshop will help them in future jobs. Eighty per cent of them strongly agree that they had practical orientation to programme. Half of the participants strongly agree (55 per cent) that workshop inspires to take up assignment related to disaster management. Most (80 per cent) of the participants strongly agree that they have been benefited in the interaction with the fellow participants and 90 per cent of the participants strongly agreed that the course and the material were useful.

Table 4 indicates the evaluation of the topic covered on psychosocial aspects by the participants. Majority of the participants rated excellent with regard to the topics on disaster and development conceptual framework (75 per cent), evaluation and principles of psychosocial care and impact of disaster on survivors (85 per cent), normal and abnormal reaction in disaster (85 per cent), identifying circle of support for disaster survivors (90 per cent), technique of psychosocial care (90 per cent), life events and family life cycles coping abilities (90 per cent), identifying the more vulnerable group (85 per cent), recalling the childhood events and identifying the impact of disasters on children (100 per cent), principles of providing psychosocial care to children's in disaster (90 per cent), social discrimination against women (95 per cent), differential impact of disaster on men and women (85 per cent), body mapping and identifying women in difficult circumstances (85 per cent), strategies to work with women (80 per cent), an overview of self-care strategies of holistic living (90 per cent) and handling burnout (85 per cent).

Feedback about the Content of the Training Programme

Majority of the participants reported that the content of the training is very useful to psychosocial care in disaster management and participatory method of training gave better involvement and easy understanding during the course of training. They also reported that the training programme will help us better in terms of handling psychosocial problems during disasters situations. Participants even felt that training was interesting and it is useful for both workplace and for our daily life. Some of the participants like the group activity and some even said that topic of discrimination against women were influencing. Some of the participants felt that course was specially designed for NDRF personnel, which could have included how to extract maximum output from subordinates. Few participants said that the trainers could have finished the sessions on time.

Possible Ways of Utilising the Training Content in Their Workplace

Participants reported that they can utilise the training content in future disaster situation and can also practise things which they have learned during training. Some of the participants said that training helps them to understand the problems which are generally not visible in disaster situation like providing psychosocial care for children, women and old-age people. The psychosocial techniques can be utilised in future disasters at workplace. Some of the participants said that they can utilise the training to further train their people so that they may help people affected in disasters. This training programme can be utilised for dealing with their own personal and family problems. Some of the participants reported that they are totally unaware of the field psychosocial care, and in future they would implement the techniques which were taught in the training. Training on stress management can also be used in their workplace. Some of the participants thought as rescuers, it is not their duty to do psychosocial care and we may not have the time to do it during rescue operations. But post training I understood now, even during rescue phase we can start psychosocial care for disaster survivors.

Discussion

According to guidelines for disaster preparedness in PSSMHS there is need for capacity building at various levels, since the country needs huge volume of civic resources to deal with disaster situations (NDMA, 2008). NDRF is the specialised emergency response force in India to natural and man-made disasters and is also majorly involved in capacity development during the various preparedness activities for providing both sensitising the community about the psychosocial effects of the disasters and also provides psychosocial first aid (National Disaster Management Guidelines: Psycho-Social Support and Mental Health Services in Disasters, 2009). On the above, there is dearth of empirical evidence on psychosocial training effects in the preparedness aspects across the world. The present training programme helps to gain the knowledge about psychosocial care in disasters among the NDRF personnel. NIMHANS has been working on the psychosocial care for all most three decades (Dr. K. Sekar, Subhasis Bhadra, C. Jayakumar, E. Aravindraj, Grace Henry, 2005). There is dearth of research on training NDRF personnel on psychosocial care on disaster management. Hence the current work has been prepared to add evidence to the need for training on disaster preparedness for NDRF personnel.

In Andhra Pradesh newspaper article by express news service Express News Service reported that NIDM has started organising training and capacity-building programme on psychosocial care in disasters for NDRF and SDRF personnel. However, there is no evidence to substantiate how many personnel have been trained on psychosocial care in disaster (Express News Service, 2018). At Lok Nayak Jaiprakash Airport, Patna, a five-day training programme was conducted on handling airport emergencies to respond to CBRN (Chemical, Biological, Radiological and Nuclear) emergencies, medical first aid and initial psychosocial support from April 23–27, 2018. A total of 200 personnel were trained which will include one-week training of 50 participants representing various agencies responsible for operations and maintenance, emergency handling and sensitisation of 150 working level staff in a half day programme (Corporate Communications Directorate, 2018). Another training programme has been conducted by the National Disaster Management Authority (NDMA) on enhancing the preparedness of airport emergencies at Bengaluru from November 12 to 17, 2018. The specialised training programme concluded with a mock drill along with sensitisation of over 200 working staff of the Kempegowda International Airport, Bengaluru. The programme consisted of live demonstrations of detection and decontamination, including the use of Personal Protective Equipment (PPE) and Airport Emergency Handlers was trained to provide first-aid and initial psychosocial support for the victims (The Hindu, 2018).

Results of the effectiveness of school safety training programme conducted (Rajamanikandan S, U Harikrishnan, P James Ranjith, E Aravind Raj, 2018) among school teachers, Asha workers, community-level workers shows (pre-test score 1.93 (SD = 1.75), post-test score 11.13 (SD = 1.99) significantly improved participant's knowledge. Other training programme conducted among the 375 undergraduate medical college students in Madhya Pradesh (Sinha, Pal, Kasar, Tiwari, & Sharma, 2008) had a pretest and posttest design structured questionnaire which was administered for assessing the current level of knowledge, attitude and practice about disaster preparedness and mitigation. Results shows that the posttest mean score on the knowledge level was 8.77 per cent, which is highly significant. Though the current study does not have a pre- and post-test results as shown in the above studies, it clearly indicates the participants perception about the content and usefulness of the training programme. Since it is the first of its kind programme for the NDRF personnel on psychosocial care, this can be considered as a step forward in integration of psychosocial services through NDRF personnel.

Conclusion

The Training of Trainers workshop would help in imparting knowledge and changing the attitude of the responders towards the disaster survivors which would result in effective delivery of post-disaster services. Preparing NDRF personnel in the integration of psychosocial care services in disaster management would equip them to deal with the psychosocial issues effectively. It also helps in making the services available in the community and results in reducing the psychosocial impact on survivors of disasters.

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Search, Rescue and Evacuation: Present Status and Future Needs

Col Bhasker Gupta[a]

ABSTRACT: This research paper attempts to analyse, as part of disaster preparedness, how the mandated agencies of the Government (both at central and state level) – mainly the NDRF, Armed Forces, including the Coast Guard and other specialised Forces (CISF), some NGOs, Humanitarian/UN Agencies, PSUs, etc., work towards this specialised response. It tries to study their specific modes of disaster planning, to make their tasks efficient, responsive, participatory and transparent. It tries to understand the mechanics of the complex operations of search and rescue (SAR) and their types, SAR as practised in the world today and specific instances of recent SAR ops in India. It also looks at evacuation, glances at disaster technologies in vogue and also the worldwide organisations involved, then specifically looks at those of India and finally recommends some measures to make this formidable task effective, have a pan-India reach, so that each effort counts (in terms of number of lives saved) in a post-disaster situation.

KEYWORDS: disaster preparedness, search and rescue (SAR), relief and rescue, evacuation, disaster, response planning

Definition

Search and rescue (SAR) is the search for and provision of aid to people who are in distress or imminent danger. United States Coast Guard: "The use of available resources to assist persons or property in potential or actual distress." Canadian Forces: "Search and Rescue comprises the search for, and provision of aid to, persons, ships or other craft which are, or are feared to be, in distress or imminent danger". The general field of search and rescue includes many specialty sub-fields, typically determined by the type of terrain search is conducted over. These include:

- Mountain rescue;
- Ground search and rescue, including the use of search and rescue dogs;
- Urban search and rescue in cities;
- Combat search and rescue on the battlefield;
- Air-sea rescue over water.

History of SAR

One of the world's earliest well-documented SAR efforts ensued following the 1656 wreck of the Dutch merchant ship Vergulde Draeck off the west coast of Australia. Survivors sought help, and in response three separate SAR missions were conducted, however, without success.

On November 29, 1945, a Sikorsky R-5 performed the first civilian helicopter rescue operation in history, with Sikorsky's chief pilot Dmitry "Jimmy" Viner in the cockpit, using an experimental hoist developed jointly by Sikorsky and Breeze. All five crew members of an oil barge, which had run aground on Penfield Reef, were saved before the barge sank.

In 1983, Korean Air Lines Flight 007 with 269 occupants was shot down by a Soviet aircraft near Sakhalin. The Soviets sent SAR helicopters and boats to Soviet waters, while a search and rescue operation

[a] Indian Army

was initiated by US, South Korean and Japanese ships and aircraft in international waters, but no survivors were found.

In July 2009, Air France Flight 447 was lost in the middle of the Atlantic Ocean. An international SAR effort was launched to no avail. A third effort nearly two years later discovered the crash site and recovered the flight recorders.

In early 2014, Malaysia Airlines Flight 370 crashed under mysterious circumstances. Many nations contributed to the initial SAR effort, which was futile. In June 2014, the Australian Transport Safety Bureau commissioned the MV Fugro Equator to lead a three-month survey of the ocean bed, for which it had budgeted $60 mn; at the same time, Malaysia announced it had spent $9.3 mn to date on its search effort. This search has thus become the largest SAR so far with the largest budget.

Types of Search and Rescue

- **Ground (Lowland) SAR:** Ground SAR is the search for persons who are lost or in distress on land or inland waterways. People may go missing for a variety of reasons. Some may disappear voluntarily, due to issues like domestic abuse. Others disappear for involuntary reasons such as mental illness, getting lost, an accident, death in a location where they cannot be found or, less commonly, due to abduction. Such missions that occur in urban areas should not be confused with "urban search and rescue", which in many jurisdictions refers to location and extraction of people from collapsed buildings/other entrapments. In most countries, police is the primary agency for carrying out searches for a missing person on land. Some places have voluntary SAR teams that can be called out to assist these searches.
- **Mountain Rescue:** Mountain rescue relates to search and rescue operations specifically in rugged and mountainous terrain. Qualified and experienced trekkers/mountaineers do this type of search, aided by ground navigation and air support and admit that is among the most challenging of all SAR ops. In our case, the recent Siachen rescue of soldier Hanumantha, would be fresh in the reader's memory.
- **Cave Rescue:** Cave rescue is a highly specialised form of rescue for rescuing injured, trapped or lost cave explorers, and requires ultimate skills, perseverance and expertise. The recent rescue of young footballers from the Thai caves after 10 days of entrapment, would tickle everyone's memory.
- **Urban Search and Rescue:** USAR, also referred to as Heavy Urban Search and Rescue (HUSAR), is the location and rescue of persons from collapsed buildings or other urban and industrial entrapments. Due to the specialised nature of the work, most teams are multi-disciplinary and include personnel from police, fire and emergency medical services. Unlike traditional ground search and rescue workers, most USAR responders also have basic training in structural collapse and the dangers associated with live electrical wires, broken natural gas lines and other hazards. While earthquakes have traditionally been the most common cause of USAR operations, lately, terrorist attacks and extreme weather such as tornadoes and hurricanes have also resulted in the deployment of these resources.
- **Combat Search and Rescue:** Combat search and rescue (CSAR) is search and rescue operations that are carried out during war that are within or near combat zones. Again its quiet challenging, as this may have to be carried out from under the nose of enemy and under hostile fire.
- **Maritime Search and Rescue:** Maritime search and rescue is carried out at sea to save sailors and passengers in distress, or the survivors of downed aircraft. The type of agency which carries out maritime search and rescue varies by country; it may variously be the coast guard, navy or voluntary organisations. When a distressed or missing vessel is located, these organisations deploy lifeboats to return them to land. In some cases, the agencies may carry out an air-sea rescue (ASR). This refers to the combined use of aircraft (such as flying boats, floatplanes, amphibious helicopters and non-amphibious helicopters equipped with hoists) and surface vessels.

SAR in the World Today

Canada has the world's biggest SAR component, with the duties shared between the Canadian Coast Guard and the Defence Forces. It has assigned five aircraft squadrons plus three combat support squadrons with SAR roles. Some municipalities and provinces have their own SAR units, plus some volunteer non-profit associations that conduct SAR in the country. The USA was the first to develop the expertise and technology of SAR. Presently, countries like Israel, Germany, Russia, UK, Turkey also have a well-developed SAR network.

SAR in India

The Indian Air Force (IAF) provides regular relief operation for food and medical facilities around the world using its cargo aircraft most notably the Ilyushin (Il-76).

The most recent relief operation of the IAF was in Kyrgyzstan, where some 800 plus stranded Indians were airlifted out of the country during the ethnic strife/riots of Dec 2017.

- **Operation Sankat Mochan (2016):** An operation of the IAF to evacuate Indians/other foreign nationals from South Sudan during the South Sudanese Civil War of 2016.
- **Operation Insaniyat (2017):** A humanitarian assistance aimed to supply relief packages to Bangladesh for migrant Rohingya Muslims.
- During the 2010 Ladakh floods, two Il-76 and four Antonov-32 aircraft of the IAF carried 30 tonnes of load, which include 125 rescue and relief personnel, medicines, generators, tents, portable X-ray machines and emergency rescue kits. MI-17 and Cheetah helicopters were used to increase the effectiveness of rescue operations.
- During the 2013 Uttrakhand floods, Indian armed forces took part in rescue ops. By 21 June 2013, the Army had deployed 10,000 soldiers and 11 helicopters, the Navy had sent 45 naval divers, and IAF had deployed 43 aircraft including 36 helicopters. From 17 to 30 June 2013, IAF airlifted a total of 18,424 people, flying a total of 2137 sorties and dropping/landing a total of 3,36,930 kg of relief material and equipment.
- IAF participated in Operation Raahat and evacuated more than 4640 Indian citizens (along with 960 foreign nationals from 41 countries) from Yemen during the 2015 military intervention by Saudi Arabia and its allies in that country during the Yemeni Crisis.
- **Nepal earthquake 2015 – Operation Maitri (Amity):** Indian Army sent a contingent led by a major general to Nepal to oversee the rescue and relief efforts. IAF mobilised its, Ilyushin Il-76, 2x C-130J Hercules, 4x C-17 Globemaster transporters, 2x Advanced Light Helicopters and 8x MI-17 helicopters for Operation Maitri.

Relief and Rescue (Nepal Quake)

By afternoon of the quake (25 April), 10 teams from NDRF (450 personnel) and including several search and rescue dogs, had reached Nepal; 10 additional IAF planes soon departed to join them with further aid. In the immediate aftermath of the quake, India sent 43 tons of relief material, including tents and food.

By April 26, Operation Maitri had started. IAF evacuated over 500 citizens. Then they airlifted army's forward hospitals, teams of doctors, nurses, paramedics, engineering task forces, water, food, NDRF teams, medical personnel and equipment, blankets and tents. By evening, India had dispatched a further 10 tons of blankets, 50 tons of water, 22 tons of food items and 2 tons of medicines to Kathmandu. Nearly 1000 NDRF personnel were pressed into service, to evacuate Indian citizens through the road route. GoI deployed 35 buses to evacuate stranded Indians. Indian Railways provided one lakh bottles of drinking water to be delivered by IAF, with arrangements being made to supply another 1 lakh bottles every day.

By the morning of 27 April 2015, IAF had evacuated 1935 Indian citizens from Nepal using 12 aircraft sorties. Army was in the process of sending 10 engineer task forces with machinery to clear roads and debris. The troops had taken with them a further 10,000 blankets and 1000 tents were on standby, along with oxygen cylinders for distribution to medical teams. Spain sought India's help in evacuating its nationals and the Indian PM promised to help.

With weather improving by April 28, 2015, IAF and Indian Army teams fanned out to remote areas while continuing to transport essential items from various bases to Kathmandu and evacuating distressed persons to India. A 41-member medical team, along with medical supplies, was sent to Nepal from Rajasthan. The Sashastra Seema Bal dispatched about 40 vehicles, including ambulances and water tankers to Nepal from its border camps. GoI dispatched a further 220 tons of food packets and dry rations, 50 tons of water, 2 tons of medicines, 40 tents and 1400 blankets to Nepal.

- **J&K Floods 2014 -** Twenty-three aircraft of IAF and 26 helicopters were deployed, along with 6 teams of NDRF and 200 Marcos commandos of the Indian Navy

Rescue Operations

- Indian Army deployed 265 columns (approx 30,000 troops) along with 224 BAUTs/boats. As on Sep 12, 90,155 persons were rescued to safer places; 15 engineering task forces were deployed with necessary engineer stores and equipment. (Army – 72050 + Air Force - 17105 + Navy - 1000).
- NDRF deployed 22 teams (955 persons) along with 148 boats and rescued more than 36,101 persons. NDRF also recovered/retrieved 14 dead bodies. Twenty-five ton relief material was distributed at Karan Nagar, Charsu, Begumpura and Avantipura.
- IAF deployed 98 helicopters/aircraft (34 Transport aircraft + 64 helicopters). Army deployed 16 helicopters (6 ALH + 10 LH). About 1500 sorties were carried out by IAF, with 22,800 stranded passengers being airlifted and 7406 people being evacuated from Srinagar.

Relief Operations

Army established six relief camps in Kashmir Valley (BB Cantt, Avantipura, Old Airfield, Sumbal, Chattarga, Jijamata Mandir) and 13 camps in Jammu division. Essential commodities including food packets were air dropped daily for 10 days. Food packets, water and medicines were sent to all the affected areas. Eight thousand and two hundred blankets, 704 tents, 320 Red Cross tents, 533 tons cooked/ready food, 298 tons water, and 31500 food packets were sent by the Army. Thousand tents were sent by NDRF.

Two water purification plants, each having a capacity of purifying around 50,000 litres per day and six small water purification units along with operators were installed in the valley. Two large water purification units, each having a capacity of purifying 40,000 litres per day, were kept ready by the Red Cross Society at Delhi for ready deployment.

Medical Help

Ten lakh chlorine tablets, 5600 kg of ORS, 150,000 tablets of doxycycline, 65,800 bottles of Paracetamol syrup, 1,00,000 Ondansetron tablets, 72,000 Ranitidine injections and 50 lakh chlorine tablets were sent to the valley. About 80 tons of specified drug and non-drug items of medical supplies were also delivered to state. Army deployed 80 medical teams to provide medical aid. A 10-member clinical team comprising physicians, paediatricians and gynaecologists plus 20 doctors were positioned in Srinagar since Sep 8 to provide medical relief to the affected population.

Telecommunication

Eight tons (4T of Aircel + 4T of DOT) equipment was airlifted by IAF. BSNL communication connectivity was partially restored in the state by Sep 11, with the help of dedicated boats which were provided by the Army. AIRCEL partially restored 2G connections, for which a 250 KVA generator was airlifted by IAF. One hundred and thirty hand-held radio sets, 14 INMARSAT and one Exchange (ex-Leh) were provided by Army. NDRF also deployed 26 INMARSAT phones. Nine STD Booths were also established (three at base camps + six at relief camps).

Road Communication

BRO deployed five task forces (12 RCC companies, 5700 persons) at Srinagar Rajouri Akhnoor. Srinagar-Leh National Highway was opened and Jammu-Poonch cleared for traffic, with a bridge launched on Durangli Nalla.

Chennai Floods 2015

Indian Coast Guard, along with Indian Army, Navy and Air Force started the SAR ops in Kancheepuram district. IAF conducted 25 sorties in Tamil Nadu and in Andhra Pradesh, air-dropping 5000 kg of supplies and rescuing 25 stranded people before ceasing operations on Nov 20. Uninterrupted power supply had been restored in 671 of the 683 villages in Cuddalore district, with remaining panchayats were supplied with drinking water through tanker lorries.

Forty medical camps and 121 special camps for cattle stock had been constructed and 70 relief camps had distributed 58,000 food packets. Upwards of 5335 people living in low-lying areas evacuated, with over 90,000 food packets distributed in 101 relief camps. In Tiruvallur district, 18,501 food packets were distributed through 57 relief camps and 2958 people given shelter. In Kancheepuram district, people in low-lying areas had been moved to safety and 16,000 food packets distributed. Over 55,000 people across Tamil Nadu were screened for water- and vector-borne diseases by 402 mobile medical units. Overall 1.1 million people were rescued in the Chennai region.

Kerala Flash Flood 2018: HADR OPS by IAF

Many parts of Kerala were affected by landslides and floods. IAF responded immediately to the crisis in extending all possible assistance to the residents of Kerala through Humanitarian Assistance Disaster Relief (HADR) missions. Concerted efforts were made by IAF in rescuing stranded people from the flooded areas. Nearly 1000 plus ladies, children, elderly people and residents were winched from the rooftops of submerged houses to safety. Helicopters also dropped food and water packets to the stranded people. Five AN-32 transporters were deployed to transport 38 boats and 9 NDRF teams and their equipment from Arakkonam/Vijayawada to Calicut, along with two teams of Army Engineering Group from Bangalore and Hyderabad.

Transport aircraft from all corners of the country (C130J/C17) were flying in day and night to ensure relief material is available in relief camps. 974 T of relief material was airlifted to Kerala state. Twelve Rapid Action Medical Teams (RAMT) from Southern Air Command and Training Command were deployed at various places to provide medical assistance. RAMT has the capability to provide both medical and surgical emergency medical care. Additionally, 119 Doctors with 63 T of medicine/equipment were airlifted to Kochi/Thiruvanathapuram for further placing at various medical camps.

Operation Nistar-2018

Operation by Indian Navy using INS Sunayna to evacuate Indian citizens from Yemen Island of Socotra, who were stranded by Cyclone Mekenu.

Evacuation

This operation involves removing people from zones at risk of an imminent disaster to a temporarily safe location. Though common to cyclonic storms, evacuation is also a frequent requirement with technological/industrial disasters. For it to be effective, there must be a timely and accurate warning system, clear identification of escape routes, provision of transport, an established policy that requires everyone to evacuate when ordered and an education programme to make the community aware of the plan. Most evacuation ops are dovetailed with and generally follow the SAR ops and hence are not discussed separately.

Disaster Response Planning

Disasters typically involve widespread human, material, economic, or environmental impacts, which can exceed response capabilities for company facilities and offices. Planned response actions that incorporate qualified and trained internal and external responders are key to ensuring that both short-term and longer-term needs are addressed. Although specific vulnerabilities to disasters vary, no one is immune to their effects.

Disaster Response Staging Area

A disaster scenario typically requires external resources beyond the scope of a company's capabilities. In a major response, establishing a staging area (or areas) may be required to support an increase in activity and ongoing response operations. In selecting a suitable staging area, the following criteria should be considered

- Accessibility to impacted areas
- Location safety
- Proximity to secure parking, airports, docks, pier or boat launches
- Accessibility to large trucks and trailers that may be used to transfer equipment
- Accessibility to basic needs
- Accessibility to necessary utilities

In addition, the staging area should

- Be in a large open area in order to provide potential equipment storage and increased responder population
- Not interfere with equipment loading and offloading operations
- Have a dock/pier on site for deploying equipment if emergency is near shore or offshore
- Have moorage available for vessels to aid the loading/offloading of personnel, as necessary

Disaster Plan Considerations

Other key considerations to be included in a disaster management plan include

- **Communication Plan**: Should identify telephone numbers and radio frequencies used by responders. This may also involve activation of multiple types of communications equipment and coordination among multiple responding agencies and contractors.
- **Public Affairs Plan**: Contains guidelines for dealing with the media during an emergency. The Incident Commander will play a key role in providing the initial public assessment and taking the first steps to provide situational understanding.
- **Site Security Measures**: The potential for increased public attention created towards a disaster site may require additional security measures to be implemented. Several measures should be planned in advance to prepare security personnel for possible security events that may occur.
- **Waste Management Procedures**: Disposal plans should be in place to manage increased waste from the initial disaster, as well as from the increased activity surrounding the disaster. Waste management needs may be overlooked in the emergency phase of a response, which could result in delays and interruption of clean-up operations.
- **Demobilisation Plan**: These guidelines provide an organised set of procedures to help facilitate and expedite a return to normal operating conditions, and help to minimise costs by standing down response resources in a timely manner.

Disaster Preparedness: Saving Lives and Livelihoods

Over the past two decades, the number of recorded disasters has doubled from approximately 200 to over 400 per year. Nine out of every 10 of these disasters have been climate related. Current projections regarding climate change suggest this trend is set to continue and that weather related hazard events will become more frequent and more volatile. Patterns of drought and desertification are also intensifying. In addition, vulnerability is also growing in many countries. Increasing urbanisation, including growing concentrations of people in unplanned and unsafe urban settlements and exposed coastal areas, poverty, HIV prevalence, and inadequate attention to changing risk patterns, are placing more and more people in disaster-prone locations. Never before has the challenge “to substantially reduce the impact of disasters and to make risk reduction an essential component of development policies and programmes”, as spelled out in the Hyogo Framework for Action 2005–2015 (HFA) being more urgent or more compelling.

In 2005, shortly after the Asian tsunami, over 168 governments pledged to implement the Hyogo Framework’s three strategic goals:

- Integrate Disaster Risk Reduction (DRR) into sustainable development policies and planning,
- To develop and strengthen institutions, mechanisms and capacities to build resilience to hazards,
- To systematically incorporate risk reduction approaches into the implementation of emergency preparedness, response and recovery programmes.

To achieve these goals, the HFA outlined five specific Priorities for Action:

- Making disaster risk reduction a priority
- Improving risk information and early warning
- Building a culture of safety and resilience
- Reducing the risks in key sectors
- Strengthening preparedness for response

The framework also stressed that DRR is not just an issue to be addressed by humanitarians, scientists or environmentalists, but is also critical to sustainable social and economic development processes. Disasters undermine development achievements, impoverishing people and nations. In the absence of concerned efforts to address root causes, disasters represent an increasingly serious obstacle to the achievement of the Millennium Development Goals.

In Priority Five, strengthening preparedness for response at all levels, HFA highlighted the essential role that disaster preparedness can play in saving lives and livelihoods particularly when integrated into an overall DRR approach. Strengthened preparedness for hazard events is mainly concerned with two objectives: increasing capacity to predict, monitor and be prepared to reduce damage or address potential threats and strengthening preparedness to respond in an emergency and to assist those who have been adversely affected.

Guiding Principles for Implementing Disaster Risk Reduction(DRR)

Provision of assistance in disasters should be informed by the underlying humanitarian principles of neutrality, humanity and impartiality. The holistic and strategic approach of the Hyogo Framework is based on a number of further guiding principles outlined in detail in the ISDR document *Words into Action: Implementing the Hyogo Framework*. These include

- **Effective disaster risk reduction requires community participation:** Involvement of communities in the design and implementation of activities helps to ensure that they are well tailored to the actual vulnerabilities and to the needs of the affected people.
- **States have the primary responsibility for implementing measures to reduce disaster risk:** States have the power as well as the responsibility to protect their citizens and their national assets by reducing the losses from disasters.
- **DRR must be integrated into development activities:** Disasters undermine hard-won development gains, destroying lives and livelihoods and trapping many people in poverty.
- **A multi-hazard approach can improve effectiveness:** It involves translating and linking knowledge of a full-range of hazards into disaster and risk management. It will look not only at natural hazards, but also factors including political strategies, technical analysis, and operational capabilities and public understanding.
- **Capacity development is a central strategy for reducing risk:** This requires not only training and specialised technical assistance, but also the strengthening of capacities of communities and individuals to recognise and reduce risks in their localities.
- **Decentralise responsibility for DRR:** Many DRR activities need to be implemented at the provincial, municipal and local levels, as the hazards faced and the populations exposed are specific to particular geographic areas.
- **Gender is a core factor in disaster risk and in the reduction of risk:** It is evident from past disasters that low-income women and those who are marginalised due to marital status, physical ability or age, social stigma or caste are especially disadvantaged. On the other hand, women are often well positioned to manage risk due to their roles as both users and managers of environmental resources, economic providers and caregivers. Hence, it is necessary to identify and use gender differentiation information to ensure DRR strategies are effectively implemented through both women and men.
- **Public-private partnerships are an important tool for DRR:** Because the threats from natural hazards affect both public and private interests alike, private-public partnerships can offer opportunities to combine resources and expertise and to act jointly to reduce risks and potential losses and thus improve the resilience of communities.
- **DRR needs to be customised to a particular setting:** States vary greatly in their political,

socio-economic, cultural, environment and hazard circumstances. Measures that succeed in reducing risk in one setting may not work in others. Customising involves making use of others' experience, and then tailoring these to implement policies and activities that are appropriate for the local contexts.

Disaster Technologies

For SAR and evacuation to be effective, certain essentials are required – shelter, food and drinking water, communication, power supply, clearance and access, public information and security, health and sanitation, temporary subsistence supplies.

Technologies such as interactive maps, open databases, text bots, apps, telehealth services and drones have great potential to help people stranded in life-threatening situations and make first response teams more effective during disasters. Advancements in science and technology have made it possible to forecast disaster occurrences with specific locations, thus helping in initial stages; like remote sensing, satellite imagery and computer-based GIS systems.

Disaster Organisations

According to the Centre for Research on Epidemiology of Disasters (CRED), 337 catastrophes related to natural hazards were reported worldwide in 2014. They affected 94 countries. While this might seem huge, the number of natural catastrophes was the lowest. Floods were the most frequent, followed by earthquakes and then storms. These events call for a massive coordinated reaction within a very short notice because of their sudden occurrence and destructive nature. That's where disaster relief organisations come in-being amongst the frontrunners for helping disaster-struck regions. They often operate together with and sometimes next to local governments and the military. Some of these are listed below.

- **International Search and Rescue Advisory Group (INSARAG)** is a UN organisation, located in United Nations Office for the Coordination of Humanitarian Affairs (OCHA). This is a network of disaster-prone and disaster-responding countries and organisations, dedicated to urban SAR and operational field coordination. The duty to render assistance is covered by Article 98 of the UNCLOS. It aims to establish standards and classification for international USAR teams as well as methodology for international response coordination in the aftermath of earthquakes and collapsed structure disasters.
- **INSARAG Membership:** Any country or organisation with a stake in urban search and rescue may join INSARAG. Countries that wish to join identify a national focal point that acts as an interface with the INSARAG Regional Group and the Secretariat. INSARAG members are part of a worldwide knowledge-sharing network on collapsed structure rescue and operational field coordination. They are invited to annual meetings of the relevant INSARAG Regional Group and to participate in INSARAG working groups. The members are expected to have access to the Virtual OSOCC (Virtual On-Site Operations Coordination Centre) and the Global Disaster Alert and Coordination System (GDACS) on the internet, which provide alert notification in the event of a sudden-onset disaster and real-time information updates and coordination during ongoing disasters.
- **The United Nations High Commissioner for Refugees (UNHCR):** It was created in 1950, in the aftermath of the Second World War, to help millions of Europeans who had fled or lost their homes. The start of the 21st century has seen UNHCR help with major refugee crises in Africa, Middle East and Asia, besides using its offices to help many internally displaced by conflict and re-settling stateless people. UNHCR now has more than 16,765 personnel, working in 138 countries with a budget of US$ 6.54 billion (as of 2016). During its lifetime, UNCHR has helped over 50 million refugees to successfully restart their lives.
- **United Nations Disaster Assistance and Coordination (UNDAC):** It's part of the international emergency response system for sudden-onset emergencies. Created in 1993, it is designed to help the UN and governments of disaster-affected countries during the first phase of a sudden-onset

emergency. UNDAC also assists in the coordination of incoming international relief at national level and/or at the site of the emergency. Its teams can deploy at short notice (12–48 hours) anywhere in the world. Assessment, coordination and information management are UNDAC's core mandates in an emergency response mission. Specifically in response to earthquakes, UNDAC teams set up and manage the On-Site Operations Coordination Centre (OSOCC) to help coordinate international USAR teams responding to the disaster. UNDAC system is managed by the Field Coordination Support Section (FCSS) in the Emergency Services Branch of OCHA Geneva. The system comprises five regional teams: Africa, Asia, Europe, Middle East, Pacific and the Americas (including the Caribbean).

- **UNDAC'S emergency missions:** As of Dec 2016, UNDAC has conducted 268 emergency missions in over 100 countries. OCHA mobilises UNDAC teams mostly in the event of a natural disaster, when a disaster-affected country requests international assistance and requires additional international coordination resources. The deployment and detailed tasks of an UNDAC team are decided in consultation with the national Government and/or the Resident/Humanitarian Coordinator. It stays in the affected area for initial response, which can be up to 3–4 four weeks in a natural disaster.
- **UNDAC disaster response preparedness missions:** It is capable of undertaking missions to evaluate the national disaster preparedness and response capacity and plans upon request specific request from a Government. To date, UNDAC has carried out 31 such missions worldwide.
- **Worldwide Disaster Relief Organisations:** Listed below are 34 disaster relief organisations which are doing a good job in providing disaster relief. This list, though not exhaustive, to a large extent, underlines how greatly help is needed all over the globe.
- **Médecins Sans Frontières/Doctors Without Borders (MSF):** An organisation dedicated to helping people worldwide where the need is greatest, delivering emergency medical aid to people affected by conflict, epidemics, disasters or exclusion from health care.
- **Mennonite Central Committee:** MCC is a global, non-profit organisation that strives to share God's love and compassion for all through relief, development and peace. When responding to disasters, they work with local groups to distribute resources in ways that minimise conflict.
- **Direct Relief International:** Direct Relief is a humanitarian aid organisation. It's active in all 50 states and 70 countries and has a mission to improve the health and lives of people affected by poverty or emergencies.
- **International Red Cross:** From small house fires to multi-state natural disasters, the American Red Cross goes wherever they're needed, so people can have clean water, safe shelter and hot meals when they need them most.
- **Brethren Disaster Ministries:** One of BDM's primary fields of work is engaging in a network of volunteers to repair or rebuild damaged homes for disaster survivors who cannot recover on their own.
- **The Ananda Marga Universal Relief Team:** AMURT's mission is to help improve the quality of life for the poor and disadvantaged in the world besides those affected by calamities and conflicts.
- **The Nazarene Disaster Response:** Their vision is that Nazarenes would be empowered to respond in practical and tangible ways to their community in case of any disaster.
- **REACT International:** They will provide public safety communications to individuals, organisations and government agencies to save lives, prevent injuries and give assistance wherever and whenever needed.
- **All Hands:** All Hands is the world's leading disaster relief organisation powered by volunteers. Over last 10 years, they have enabled over 35,000 volunteers to donate 175,000 days impacting 500,000 people all over the globe.
- **City Team International Disaster Response:** City team is a Christian non-profit organisation that's compassionately serving the poor, the homeless and the lost in San Jose, Philadelphia, San

Francisco, Oakland, Portland and other parts of the world.

- **OXFAM:** Oxfam is an international confederation of 18 NGOs working with partners in over 90 countries, helping those who need it most after natural disasters strike their homes.
- **Billy Graham Rapid Response Team:** They train God's people for grief ministry. They also deploy crisis-trained chaplains to provide emotional and spiritual care to those affected by man-made or natural disasters.
- **ADRA:** ADRA Canada, part of a world wide ADRA network, has been working to end extreme poverty in some of the poorest communities of our world for three decades.
- **Hope Worldwide:** This international charity that changes lives by harnessing the compassion and commitment of dedicated staff and volunteers to deliver sustainable, high-impact, community-based services to the poor and needy.
- **NECHAMA:** A voluntary organisation that provides natural disaster preparedness, response, and recovery services nationwide. Through the years, they have brought comfort to disaster survivors by training and mobilising thousands of volunteers to help communities in the aftermath of floods, tornadoes and other natural disasters.
- **United Methodist Committee on Relief** (UMCOR)**:** A non-profit organisation dedicated to alleviating human suffering around the globe. UMCOR work includes projects in disaster response, health, sustainable agriculture, food security and relief supplies.
- **Plan India:** A member of Plan International Federation, it is a nationally registered independent child development organisation committed to creating a lasting impact in the lives of vulnerable and excluded children, their families and communities.
- **Save the Children:** 2015 presented the world with unprecedented challenges. Thanks to their incredible generosity, Save the Children responded to 99 humanitarian crises in 59 countries, directly reaching 13.8 million people, including 7.1 million children.
- **CARE:** CARE International is a global confederation of 14 member organisations working together to end poverty caused by conflict and natural disaster.
- **AmeriCares:** AmeriCares saves lives and improves health for people affected by poverty or disaster so that they can reach their full potential.
- **Global Giving:** It's the first and largest global crowdfunding community for non-profit. Since 2002, Global Giving has raised $230,218,366 from 536,778 donors who have supported 14,942 projects.
- **International Relief Teams (IRT):** Is a top-rated non-profit humanitarian organisation dedicated to alleviating human suffering worldwide and in the USA. IRT specialises in two complementary sets of activities: disaster response and building healthy communities.
- **Bill & Melinda Gates Foundation:** They work with partner organisations worldwide to tackle critical problems in four programme areas. Their Global Development Division works to help the world's poorest people lift themselves out of hunger and poverty which is often caused by natural disaster.
- **ICCO:** ICCO is the inter-church organisation for development cooperation. They work towards a world in which people can live in dignity and well-being, a world free from poverty and injustice.
- **Relief International:** A non-profit organisation whose sole mission is to reduce human suffering. They respond to natural disasters, humanitarian emergencies and chronic poverty. They are non-sectarian and non-political.
- **WHO:** The World Health Organisation helps protect those displaced by natural and man-made disasters from the ravages of disease.
- **Mission Aviation Fellowship:** MAF can be found in the hardest-to-reach locations, where people live isolated from the rest of the world, cut off from the most basic necessities. Their highly trained pilots manoeuvre Cessna/Kodiak aircraft through rugged terrain.
- **World Vision:** They're continuously building relationships. By planning and working alongside local leaders, they're finding solutions to change the future for kids and the next generation.

- **AMREF:** They are committed to improving the health of people in Africa by partnering with and empowering communities, and strengthening health systems.
- **Shelter Box:** By providing emergency shelter and tools for families robbed of their homes by disaster, they're transforming despair into hope.
- **Medical Teams International:** They provide medical and dental care, humanitarian aid and holistic development programmes to all people in need, regardless of religion, nationality, sex or race.
- **Humanitarian Coalition:** It strives to maximise Canadian fundraising efforts in support of members' assistance programmes for the survivors of international humanitarian disasters. By working together, the members seek to increase the awareness of needs, reduce the duplication of costs and take the guesswork out of giving for Canadians.
- **Global Medic:** They quickly respond to disasters with a Rescue Unit, Water Purification Unit and Emergency Medical Unit. Helping those who need it most.
- **Engineers without Borders:** A non-profit humanitarian organisation established to partner with developing communities worldwide in order to improve their quality of life.

Recommendations and Suggested Policy Changes

Recommendations

- **Training of SAR Teams: Towards an Improved and Effective SAR**

SAR involves location, extrication and initial medical stabilisation of victims trapped in confined spaces. It is considered a "multi-hazard" discipline, as it may be needed for a variety of emergencies of disasters, including earthquakes, cyclones, floods, dam failures, technological accidents, terrorist activities, avalanches & hazardous material releases. The events may be slow in their onset, for example, cyclones or sudden (earthquakes).

First responders cannot be expected to be amateurs. Training requirements are intensive and training to perform search and rescue is hazardous and should only be undertaken by competent individuals. Their training, under supervision of instructors skilled in the various functional disciplines, needs to be institutionalised. Standardisation of training, certification and further research and development in this regard need to be put on track for the purpose of organisational effectiveness.

Besides, training requirements could also be outsourced to private enterprises, like Rescue Training Associates (RTA) of the USA. Established in 1998 to improve disaster management and technical rescue training within the USA, it now travels throughout the world assisting local, state, federal and international clients in establishing emergency response and technical rescue training programmes. The team comprises active firefighters, Emergency Medical Team/Paramedic personnel, Hazardous materials technicians/Specialists, Fire Academy (NFA) and Emergency Management Institute (EMI) instructors, former military personnel and equipment manufacturer trainers. Their knowledge is founded on extensive experience in both civilian DM and specialised federal CBRN emergency response teams.

There is a need to encourage such ventures to come up in India too. The country has a repository of experience in handling a varied nature of catastrophes in all kinds of terrain. The vast pool of experts comprising scientists, academicians, government officials, military and paramilitary organisations, NGOs and private organisations, having dealt with combating disasters in the past, can be brought together on a single platform, to contribute to training and in synergising the efforts to streamline and develop mechanisms to fight disasters in future.

- **Cater for Emergency Support Functions**

Besides SAR, there would be many other support departments and ministries in States/Centre, keeping in view their roles in the realm of managing disasters. These roles must be made explicit and should not be left ambiguous. Once responsibilities are assigned, suitable organisational changes should be affected and adequate resources must be allocated to the departments and ministries. The USA, for example, has grouped resources into 17 Emergency Support Functions (ESFs), each headed by a primary agency, selected based on its resources and capabilities in the functional area. Other agencies are designated support agencies for one or more ESFs, based on their capabilities to support the functional area.

- **Build Local Capacities**

The focus of most recent initiatives and plans/projects is to enhance the capacities at international, regional, national and at best the state/province levels and very little is being attempted at local levels. Efforts to build local capacities at the village, block and local community levels are more important now than ever, especially after setting up of NDMA/NIDM and raising of NDRF. This would contribute not only towards improving resilience of the community but also provide a fillip to self-confidence and self-esteem of locals, in the long run. It would help bring in positive changes in the attitude and the behaviour pattern of the community towards responding to disasters.

- **Improve Readiness State of Stakeholders**

Preparedness aspects should lead to improving the readiness state of all the stakeholders to include individuals, organisations and the vulnerable communities. Some important aspects which would contribute towards better preparedness and readiness are as follows.

- **Training and Knowledge:** Training is an essential input towards creating the required expertise. Training not only imparts knowledge and skills needed for set of activities that are expected to be performed, but also brings about positive attitudinal changes. Whereas training of people from establishments like NDRF, Home Guards, Civil Defence and Fire and Rescue workers is taken care of by respective organisations, training of personnel forming part of vulnerable/affected local community needs to be streamlined.

  Though UNDP assisted programmes and projects have been put into action, the willing endeavours taken up by local administration and authorities at village, block and district levels would serve the purpose better, wherein self-reliant communities would be a more promising alternative. It is important that training objectives for each skill-set required for emergency functions and emergency support functions be laid down. Moreover, since first responders would be required to mobilise and reach the incident area immediately on occurrence, there would be no scope for any kind of orientation, after being deployed for the task.
- **Mock Drills and Rehearsals:** Rehearsals contribute tremendously towards understanding the nature of tasks while mock up drills and rehearsals are in fact a medium to generate and develop the essence of team work and provide an objective assessment of the preparedness and readiness state of the team. These should be organised and conducted in all earnest and endeavour should be to evaluate the performance to identify weaknesses/grey areas so as to provide an effective feedback for further training. These should be conducted periodically and in the utmost professional manner. District Collectors must be mandated to carry out mock up drills and rehearsals of the plans at least once in a year (a practical model practised in Gujarat is noteworthy). These rehearsals would ensure that plans are drawn, people are well trained and all resources required during crisis situations are readily available.
- **Integration of Stakeholders:** During the occurrence of any disaster, and immediately thereafter, the incident site would be flooded with myriad types of agencies working to deal with post-disaster activities. There would be certain tasks where diverse agencies need to operate in a manner so as to achieve synergy. It is therefore essential that necessary coordination is ensured as they need to be functioning in an orchestrated manner, rather than working in a compartmentalised manner. Vertical as well as horizontal communications among the various stakeholders are a must.

- **Build a Coordination Mechanism:** As discussed above, there would be a number of organisations pressed into action immediately after the disaster has occurred. Limited road space and vast equipment and infrastructure being used by them will further create crises of other nature if it is not well coordinated. There would be a need to allocate areas of operation, areas for establishing bases, relief camps, medical camps and for other such other activities. It would require well thought out SOPs. This is an area where NDMA and NIDM need to work further and chalk out a strategy to streamline procedures. The USA's National Incident Management Systems and Incident Command Systems (after being studied in detail) could be adapted to suit our requirements. These could be further evolved in times to come, as we learn from experiences

Suggested Policy Changes

- Keep adequate budgeting for these tasks, especially since most are unforeseen and give very little reaction time. This money has to be in-built as a contingency fund, with every State/District/City/Town and made available to the SAR coordinating agency on ground and without any delay or bureaucratic hassles.
- Pre-approvals/sanctions for deploying men and materials for such tasks, at the highest level, probably mandated to the respective District Commissioner.
- Concept of placement of Disaster Bricks-as enunciated by Armed Forces be practised and provisioned with the NDRF/State Disaster Forces.
- Delineation of responsibilities of NDMA, MHA/other Ministries be clearly spelt out and known to all concerned to facilitate smooth/prompt response.
- Applications of GIS and remote sensing should be encouraged in order to effectively analyse and interpret the available data for risk reduction.
- Best practices pertaining to disaster mitigation and management should be documented properly and be disseminated in vernacular language and pictorial format to the community at large.
- Specific courseware should be designed and be implemented by all educational institutions to inculcate education and knowledge among the school going children, NGOs and other Govt agencies.
- Coordination and knowledge networking among stakeholders, researchers, academicians, NGOs is imperative and should be done regularly by a nodal agency.
- Integration of disaster mitigation in universities/other courses, resulting in research outputs,with a positive impact on disaster mitigation efforts from time to time.
- Uniformity in bye-laws would result in several advantages such as updation, cost effectiveness of updation training, development of software for checking conformity.
- Involvement of private sector in disaster mitigation and management is imperative. Similarly, creating conditions for the development of insurance markets and encouraging use of other risk reduction financial instruments are a need of the hour.
- Microfinancing for poor is imperative in order to reduce the vulnerability to natural hazards and recovery from disasters.
- Towards long-term socio-economic and psycho-cultural rehabilitation, political and administrative support is essential. This needs a rehabilitation plan, ensuring participation of local, committed and trustworthy civil societies and the community at large.

Conclusion

As we have seen in this paper, search, rescue and evacuation are among the most challenging tasks, more so in a post-disaster situation. Hence the utmost skill, training and expertise is needed for the responders and rescuers to be up to this challenge. This is not the responsibility of the government alone and requires a community effort, at all levels, which is the need of the hour, especially in a disaster-prone developing country like India. NDMA has made a beginning, and together, with the help of Armed Forces/NGOs/Pvt sector, it is that this onerous task will be accomplished, because that will mean less lives lost, which translates into more lives saved, while facing future disasters. In this regard, we should be more than willing to take help of UN agencies or adopt models/best practises from Canada/USA, who are the pioneers of SAR and evacuation techniques in the world today.

Use of Emergency Departments in Turkey: Appropriate or Not

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ABSTRACT:

Objective: The study was carried out to detect frequency of inappropriate attendances to different-level emergency departments in different seasons.

Materials and Methods: Data were collected in two different intervals. The appropriateness of the patients in terms of emergency was evaluated by the physicians according to the Emergency Severity Index and some criteria. Other data were collected by face-to-face interviews with data collection tools developed by the researchers. Here we present preliminary data on the frequency of inappropriate use at different-level emergency departments and change of inappropriate rates over daily time period.

Results: A total of 13,221 emergency department admissions were evaluated. 51.4 per cent of the patients were female and 48.6 per cent were male. In the study 75.6 per cent of attendances evaluated as inappropriate. 80.3 per cent of emergency department visits to the first-level emergency departments, 74.8 per cent of emergency departments visits to second-level emergency departments and 71.4 per cent of attendances to the third-level emergency departments were found to be inappropriate. The difference between the rates of inappropriate use at different emergency departments levels was statistically significant ($p<0.01$). Inappropriate attendances to emergency departments were higher in the summer (77.7 per cent) than in winter (72.9 per cent) and between 18.00 and 23.59 were higher than other daily time period ($p< 0.01$).

Conclusions: Inappropriate use rates are increasing in the summer period. In the first-level emergency department. the inappropriate use is higher than the second and third-level emergency departments.

KEYWORDS: attendance, emergency department, health service, inappropriate use

Introduction

Emergency departments are special units in which life-threatening situations are taken under control. In these departments, it is essential to prioritise patients who have high level of urgency and to provide the necessary treatment and care as soon as possible. However emergency departments are often used for those health problems that do not require emergency treatment and care (Moskop 2010). In general, inappropriate attendance to emergency departments are defined as attendances which are made for health problems that occur without any accident and injury, do not require special emergency department services and can be treated at primary health care institutions (Carret 2009). With this general definition, various criteria determined by

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researchers are taken into consideration in determining the frequency of inappropriate use (Pines 2013).

The prevalence of inappropriate use of emergency services across the world varies between 4.8 per cent and 90 per cent. Depending on the differences in the descriptive criteria used (Durand 2011). In a study using the New York University Emergency Department Algorithm performed in the USA, the rate of attendances of health problems which were not required emergency care was recorded as 6.3 per cent (Raven et al. 2013). In a study conducted in France, attendances which were not urgent and were more suitable for primary care according to triage nurses evaluations were found to be 44.9 per cent (Gentile et al. 2010). In a study conducted in Sweden, patients who were not brought by ambulance, were not referred from another unit and could wait without any medical risk for at least one hour for physician evaluation were accepted as non-emergency patient and the rate of inappropriate attendances was found to be 23.5 per cent (Backman et al. 2008). In a study conducted in Australia, emergency department admissions were evaluated according to four different definitions and a more favourable attendances rate for primary care was reported as 10–25 per cent (Nagree et al. 2013). In a study conducted in Jordan, the suitability of emergency department admissions was evaluated according to HUAP and it was determined that 65.8 per cent of attendances made in one month period were not suitable in terms of emergency (Jerius et al. 2010).

Various factors play a role in choosing emergency departments for non-emergent health problems. Primary factors of these can be listed as: difficult access to primary health care services (Callen et al. 2008; Brim 2008; McHale et al. 2013), lack of health insurance (Hsia et al. 2013), believing that the health problem requires emergency care (Callen et al. 2008), not wanting to wait for a long time (Penson et al. 2012) and the lack of alternative service units to emergency services (Weinick et al. 2010).

Inappropriate use has an adverse effect on the provision of emergency departments services and on the beneficiaries of these services. It leads to increased workload, disruptions in diagnosis and treatment process, patient and employee dissatisfaction (Samaras et al. 2010). It also causes an increase in the cost of health services (Weinick et al. 2010). On the other hand, the use of emergency departments rather than primary care services for follow-ups such as blood sugar and blood pressure measurement prevents the adaptation of patients to the necessary lifestyle changes and regular drug use. This situation causes the patients to be deprived of the necessary health education, recurrent exacerbations of symptoms and decrease the quality of life of patients (Rodrigues 2015; Moskop 2010).

The preliminary data presented in here was gathered in scope of the project conducted in order to detect the causes and frequency of inappropriate attendances and relations between inappropriate attendance and overcrowding at different levels of emergency departments considering seasonal differences and to prepare educational tools. The project was funded by The Scientific and Technological Research Council of Turkey (TUBITAK).

Materials and Methods

Criteria for attendances to be considered inappropriate are set as to be in the fifth or fourth triage category of Emergency Severity Index, according to physician's examination, suitable for waiting safely for medical care and treatment for at least 24 hours without any life threat and organ dysfunction risks, having no referral from another health care institution, having accessibility to policlinics or family medicine and having no need for any surgical interventions. Since there are not any health services unit that provides services for health problems that require suturation and plaster-splint applications other than emergency departments of hospitals in our country, attendances for these medical services were not accepted as inappropriate use.

The research was carried out in Turkey. In order to determine the effect of seasonal differences on inappropriate use of emergency department, the data was obtained in two separate stages in the summer and winter. The study was conducted in three different levels of emergency department. In designated emergency departments, visits were evaluated in one week period during July and March. Data were gathered using questionnaire form designated by researchers.

The preliminary data obtained from the study were presented here.

Results

During the study period, 13221 attendances were evaluated. 43.3 per cent of (n = 5728) these attendances were made in the winter and 56.7 per cent of them (n = 7493) in the summer. 51.4 per cent of the patients were female and 48.6 per cent were male. The mean age was 43.5 ± 18.1 (Min 18; Max 98). In the study 75.6 per cent of attendances evaluated as inappropriate.

The rates of inappropriate attendances to different levels of emergency departments are shown in Table 1. The maximum number of inappropriate attendances was found to be at level I emergency department and the difference between emergency department levels was statistically significant ($p< 0.01$).

Table 2 presents the frequency of inappropriate visits by seasons. The incidence of inappropriate use was significantly higher in the summer period than in winter ($p <0.01$).

The change of inappropriate attendances rates over daily time period is presented in Table 3. The frequency of inappropriate attendances was found to increase as time progressed during the day. This change in the frequency of inappropriate attendance according to time periods was statistically significant ($p < 0.01$).

Table 1: Inappropriate Use Rates According to Emergency Department Level

ED level	Appropriate		Inappropriate		p
	n	%	n	%	
I. Level ED*	638	19.7	2604	80.3	p<0.01
II. Level ED	2015	25.2	5982	74.8	X2 = 61.004
III. Level ED	567	28.6	1415	71.4	
Totally	3220	24.4	10001	75.6	

*ED: Emergency Department

Table 2: Inappropriate Use Rates According to Seasons

Seasons	Appropriate		Inappropriate		Totally		p
	n	%	n	%	n	%	
Winter	1550	27.1	4178	72.9	5728	100	p<0.01
Summer	1670	22.3	5823	77.7	7493	100	X2 = 40.136
Totally	3220	24.4	10001	75.6	13221	100	

Table 3: Inappropriate Use Rates According to the Daily Time Period

Daily time	Appropriate		Inappropriate		Totally		p
	n	%	n	%	n	%	
00:00–5:59	366	41.3	520	58.7	886	100	
6:00–11:59	720	24.5	2214	75.5	2934	100	p<0.01
12:00–17:59	1030	23.7	3316	76.3	4338	100	X2 = 157.741
18:00–23:59	1104	21.8	3951	78.2	5047	100	
Totally	3220	24.4	10001	75.6	13205	100	

Discussion

When the emergency departments are used inappropriately, there are some problems related to emergency department services. In this study, it was determined that inappropriate use rates of emergency departments with different levels in different seasons in Turkey.

In the study it was found that 75.6 per cent of attendances were inappropriate. Inappropriate use rates were higher in summer (77.7 per cent) than in winter (72.9 per cent). Attendances to first-level emergency departments (80.3 per cent) were found to be more inappropriate than other levels (II. Level 74.8 per cent; II. Level 71.4 per cent).

The prevalence of inappropriate use of emergency departments in the world varies between 4.8 per cent and 90 per cent, depending on the differences in the descriptive criteria used (Durand et al. 2011). In a study using the New York University Emergency Department Algorithm in the USA, the rate of attendances for health problems which didn't require emergency care was recorded at 6.3 per cent (Raven et al. 2013). In a study conducted in France, the rate of patients who were not urgent and were more suitable for primary care according to the evaluation of triage nurses was found to be 44.9 per cent (Gentile et al. 2010). In a study conducted in Sweden, patients who were not brought by ambulance, who were not referred from another health care unit and who could wait without any medical risk for at least one hour for the evaluation of the physician were accepted as non-emergency patient and the rate of inappropriate use was found to be 23.5 per cent (Backman et al. 2008). In a study conducted in Australia, emergency department attendances were evaluated according to four different definitions and a more appropriate attendances rate for primary health care was reported as 10–25 per cent (Nagree et al. 2013). In a study conducted in Jordan, the suitability of emergency department admissions was evaluated according to HUAP and it was determined that 65.8 per cent of emergency department attendances made in one month period were not appropriate (Jerius et al. 2010). In Turkey, this rate varies between 19.5 per cent and 62.3 per cent (Edirne et al. 2008; Aydın et al. 2010). On these differences between countries, there may be effects on health care systems and social differences, as well as differences in the descriptive criteria used.

It was determined that the rate of inappropriate use was the most between 18:00 and 23:59. In Turkey, Ersel et al. showed that inappropriate use increased at 18:00–08:00 (Ersel et al. 2006). However in some study made in Turkey it was found that inappropriate use more frequent between 08:00 and 16:00 hours (Kose et al. 2011; Aydın et al. 2010). In other studies conducted outside our country, it is observed that inappropriate attendances are mostly in the daylight hours (Nagree et al. 2013; Tsai et al. 2010; McHale et al. 2013; Carret et al. 2007). Turkey has a higher rate of inappropriate attendances during working hours compared with other countries, which can be associated with the difficulties in accessing primary care services in other countries.

Conclusion

Inappropriate use rate was more in first-level emergency departments than other levels. Inappropriate attendances increase in summer compared to winter. In considering the problem of inappropriate use, it is important to consider the seasonal factors affecting the emergency department attendances and the variables related to the level difference.

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Emergency Preparedness Plan for Explosives Processing Area

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ABSTRACT: Solid rocket motors play significant part in ISRO launch vehicle programs. These motors ranging from diameter 1 m to 3.2 m classes are produced at SDSC SHAR to meet the requirements of PSLV, GSLV and GSLV Mk III class launch vehicles. Each launch vehicle handles these explosives ranging from 140 to 400 tons. Raw materials used for making these motors are highly sensitive to shock, impact, friction and electrostatic discharge. The major hazards during processing of explosives are explosion, fire, leakage of toxic chemicals and failure of high pressure systems (mechanical explosion). Based on the hazards of the raw materials, the layouts of the facilities are worked out based on the quantity distance criteria and protected with traverse/merlons, leak detection systems, fire suppression systems and escape systems and plan to minimise the damage in case of an untoward incident. An organised emergency preparedness plan also should be in line to manage any emergency scenarios. Emergency preparedness plan is prepared considering probable emergency situations related to process, natural calamities and security threats. The first and most important objective of this plan is to make the personnel involved in process and staff aware of all the emergency situations and keep them ready to react to such situation in shortest possible time without getting panicky. The emergency preparedness plan prepared for one of the explosives processing area is explained in this paper. This emergency preparedness plan deliberately covers organogram with roles and responsibilities, detailed action plan and facilities available to tackle the situation.

KEYWORDS: safety, organogram, emergency, emergency preparedness plan, emergency action plan

Introduction

Satish Dhawan Space Centre SHAR, the Spaceport of India is responsible for providing world-class launch infrastructure for Indian Space Programme. The solid motor production needs of the ISRO's launch vehicles are being addressed by two solid propellant processing plants established at SDSC SHAR. Composite solid propellant is a homogeneous mix of fuel and oxidiser in polymeric resin and curator. The processing facilities include hardware preparations, raw material processing, mixing, casting, non-destructive testing and magazine (storage). The raw materials used for processing the solid propellant are highly sensitive to shock, impact, friction and electrostatic charge. These harmful properties of raw materials/solid propellant make these facilities prone for fire, explosion and leakage of toxic chemicals. A well-planned facility layout, operational procedures (SOPs) will ensure safe and reliable operation in the production of solid rocket motors. However, the possibility of an inadvertent situation cannot be ruled out. Hence a structured emergency action plan is very much essential to handle any unforeseen situation. One such emergency plan prepared for the solid propellant processing plants is explained in this paper. This paper highlights the various hierarchies of controls and coordination teams along with roles and responsibilities to handle emergency situations that may arise in solid process plants.

Definition of Emergency

An emergency can be defined as "a situation that poses an immediate risk to health, life, property or

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environment and requires urgent intervention to prevent worsening of the situation". It may be the result of a fault in any of the activities of the organisation itself or may be caused by an external agency like lightning, wind, flood, sabotage, etc. An emergency is termed as *"on site"* when it confines itself within the facility/organisation and *"off-site"* when the emergency extends beyond its premises. An *emergency plan* is a detailed response plan describing how to react on a certain set of anticipated emergencies.

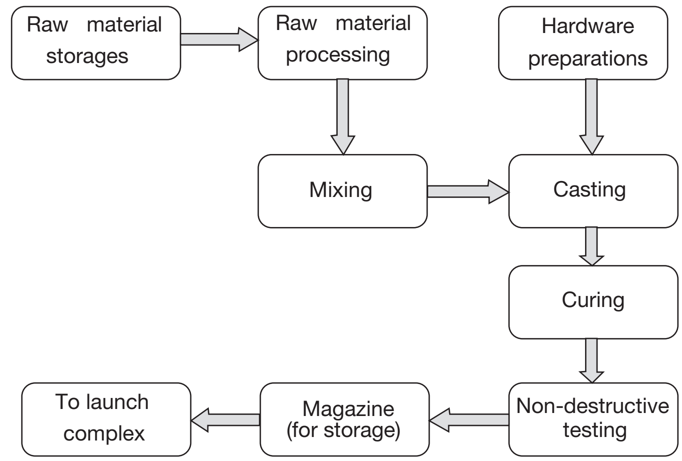
Objectives of the Emergency Preparedness Plan

The first and most important objective of the plan is to make the staff aware of all the emergency scenarios and keep them ready to react to such situation in a quick and effective manner without getting panicky. In addition, it will help to:

- Reduce the consequences following the incidence.
- Reduce the casualties, disabling injuries, property damages, damage to the environment, etc.
- Ensure the timely involvement and support of security force (CISF).
- Ensure the support of SHAR Fire Services(SFS), Medical and Public Health division, etc.
- Ensure the safe evacuation and rehabilitation of the staff from the affected area, especially in case of toxic releases.
- Reduce the interference of unauthorised personnel.
- Preserve of relevant records, materials, equipment, etc.
- Preserve the evidences for accident investigations for the identification of root causes.
- Make it possible to return to the normal conditions as early as possible.

Overview of the Solid Motor Production Activities

In order to manufacture the solid rocket motors, group of facilities start from storages (raw materials/hardware), process facilities and other auxiliary (Substations, DG Rooms, Fire pump house, etc.) facilities are available in this area.



The safe siting of process/storage/other facilities is so important to protect an exposed site from a potential hazard site for process hazards. The considerations followed before siting the facilities inside process area are UN Classification of explosives, quantity of material handled, type of facilities/ buildings planned nearby and intra-line & inhabited building distances arrived based on the guidelines of STEC.

- **Process Safety:** Propellant processing is hazardous and it is essential to minimise human intervention to the maximum extent possible. Process automation and fail-safe instrumentation systems were provided for taking utmost care for men, material and environment. Inbuilt safety systems like ventilation, relief valves, man limits and interlocks are established in non-hazardous buildings. Systems namely traverse/merlon, anti-static floorings, non-sparking tools, rupture discs in feed lines, explosion proof fittings/intrinsic safe devices and circuits and vacuum dust collection are provided in hazardous buildings.

- **Firefighting Systems:** Water-based fire protection systems (hydrant points, water monitors, deluge systems and sprinkler systems) are provided over the entire plant for suppression or controlling the propagation of fire in case of emergency situations including mandatory water storage and pumping capacities. Fire detection and alarm (FDA) and clean agent flooding systems are provided to control rooms and air handling units.

Emergency Scenarios

Emergency scenarios which have the potential to cause serious danger to personnel and/or damage to property are considered primarily for preparing the Emergency Preparedness Plan. Depending upon the process activities carried out, following are the scenarios considered.

- Explosion due to solid propellant or Al/AP powder/dust
- Minor fires not involving propellant (combustible materials, electrical, etc.)
- Minor fires involving less quantity of propellant (less than 1 or 2 kgs)
- Major fires involving propellant
- Forest fires near process buildings
- Leakage of toxic chemical
- Natural Calamities (tsunami, earthquake, cyclone)

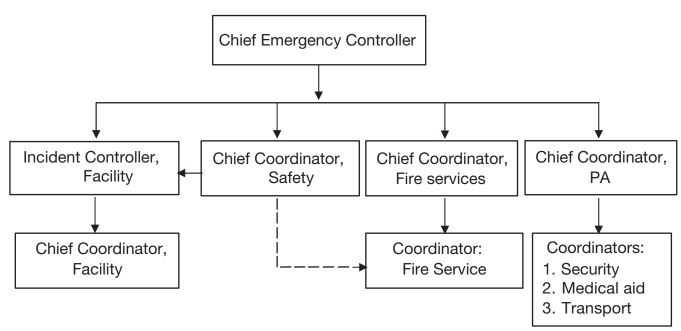
Organogram for Emergency

Whenever emergencies occur, tackling of the situation is possible only through an organised effort. An organogram is defined for the emergency with roles and responsibilities so that the activities during the emergencies can be coordinated efficiently and effectively.

The members of the emergency team, chief emergency controller, coordinators are identified as given below.

- **Chief Emergency Controller**
  The Chief Emergency Controller will be the supreme authority and will have the overall responsibility on handling the emergencies. Chief of the Process Plant (Deputy Director) will function as Chief Emergency Controller of all Emergencies in this area.
- **Incident Controller, Facility**
  Incident Controller will have the overall responsibility of handling the Emergency at the incident site. GM, Process will act as the Incident Controller of all emergencies in that facility.
- **Chief Coordinator, Facility**
  Chief Coordinator Facility will be responsible for giving technical advice and guidance regarding the facility to the Chief Emergency Controller and to ensure the availability of all support to the Incident Controller at the site.
- **Chief Coordinator, Safety**
  Head, Safety will be the Chief Coordinator Safety. Chief Coordinator Safety will be responsible for advising the Chief Emergency Controller on safety-related issues.
- **Chief Coordinator, Fire and Rescue**
  Head, SHAR Fire Services will be the Coordinator, Fire and Rescue services. He will be responsible for advising the Chief Emergency on firefighting and rescue-related issues.
- **Chief Coordinator, Plant Administration (PA)**
  Manager, PA will be the Chief Coordinator for arranging First aid for injured, mobilising the injured to hospitals and contacting Chief medical officers and treatment for the injured.

- **Emergency Teams at the Site**
  - *Security:*
    Leader of the team will be the Asst Commandant of SDSC SHAR.
  - *Fire & Rescue Service:*
    Leader of the team will be the Station officer, SHAR Fire Services.
  - *First Aid Team:*
    Leader of the team will be the Manager, PA and Medical Officer designated by Chief Medical Officer.
  - *Transport:*
    Leader of the team will be the Manager, PA and Manager, Transport designated by CEC.



Organogram chart for the emergency

Major Roles and Responsibilities

Teamwork is the backbone of any emergency plan. The success behind the efficient tackling of an emergency situation lies with the coordinated effort of the team members with their assigned roles and responsibilities. The Chief Emergency Controller along with chief coordinators will be the ultimate decision-making body during the execution of emergency action plan. Every chief coordinator is responsible to ensure that right type of trained people are deployed for the jobs to be done and the manpower under his control is always kept identified for deployment.

All members of the Emergency team should ensure personal safety while performing the duties.

- **Chief Emergency Controller, DD, SPP**
  Reach the emergency location on getting the firsthand information about the incident. Declare emergency after assessing the situation based on the information from the incident controller.

  Ensure the information is communicated to all employees through Emergency Siren/ public address system/available mode of communication.

  Ensure that chief coordinators have been informed about emergency and they reach the location.

  Ensure that the roles and responsibilities of all chief coordinators are carried out. Give necessary guidance and advice to the incident controller. Ensure that incident controller is getting all logistic support. Inform higher authorities (Director, SDSC SHAR).

  Declare the withdrawal of emergency once the situation comes out of the danger period. Ensure that the same information is properly communicated to all staff.

- **Incident Controller, GM, Process**
  He will immediately arrive at the incident location. Make a decision on the type of emergency and inform chief coordinator of the facility on actions to be performed. He shall ensure the evacuation of all the facility team members from the incident location and direct the facility in charge/supervisor to take a roll call to ensure any missing member.

  Ensure fire service and security are informed and their services are available at the site. Coordinate the security, safety, fire and rescue and first aid activities until the respective teams reach the site and take the charge.

  Establish communication with emergency location.

  Recommend the need for shutting down and evacuation of plant and areas likely to be threatened by the accident.

  Report all significant developments to Chief Emergency Controller.

  Continue the functioning as Incident Controller at the site until the situation is under control.

  Inform Chief Emergency Controller regarding the withdrawal of emergency as and when the incident is under control.

  Do necessary arrangements to preserve evidences that would facilitate any subsequent enquiry into the cause and circumstances of the emergency.

  Seek coordination from Technical Photography Facility (TPF) for photo/video coverage to record relevant information.

  Reports all significant developments to Chief Emergency Controller.

  Does necessary arrangements to preserve evidences that would facilitate any subsequent enquiry into the cause and circumstances of the emergency.

- **Chief Coordinator, Facility In-Charge**
  Pass the information about the emergency to the Chief Coordinators once he gets the information from incident controller.

  Give necessary guidance and advice to the incident controller.

  Ensure that incident controller and other chief coordinators are getting all logistic supports.

  Ensure easy recovery of the plant after the incident.

  Arrange for accident investigation to identify the root cause and take necessary actions for avoiding recurrence of such incidents.

- **Chief Coordinator, Head, Safety**
  Work in close association with Incident Controller in handling the emergency. Extend all the help in handling safety operations at the incident site. Ensure that the roles and responsibilities of Safety team are carried out.

- **Chief Coordinator, Head, SHAR Fire Services**
  Extend all the help in handling fire and rescue operations at the incident site.
  Ensure that the roles and responsibilities of Fire and Rescue teams are carried out.

- **Coordinator, Station Officer, SHAR Fire Services**
  Mobilise the firefighting system and rush to the incident location along with the fire crew on getting information.
  Review and arrange adequate resources (man power, water supply for firefighting, fire tenders, etc.) to tackle the situation.
  Seek the assistance of external fire services if required.
  Take necessary advice from chief coordinators safety and CISF. Report the progress of fire fighting activities.

- **Chief Coordinator, Manager, Plant Administration**
  Reach the incident location on getting the information.
  Make sure that all the coordinators are available at their respective offices, ready to provide any assistance to the Emergency team.
  Ensure that the roles and responsibilities of all coordinators are carried out.

- **Coordinator, Assist Commandant, Security**
  Arrive at the incident site on getting the information. Instruct his team to cordon off the area of accident.
  Take the lead role in evacuation along with the fire and rescue team.
  Control the external traffic till the arrival of police department personnel and later coordinate the activities with them.
  Ensure that alternate exit is identified, communicated and operated in case of situation under which the main gate cannot be used.

- **Coordinator, Medical Officer, SHAR**
  He will be responsible to give medical attention for the casualty and will function from SHAR hospital.
  He will arrange for rendering first aid at the site of accident with the help of trained first aid group. For this a list of staff trained in first aid shall be maintained. The staff should be given periodic training.
  Maintain a list of blood donors of the centre.
  Arrange ambulance/vehicles for transporting casualties to the nearest hospitals.

- **Coordinator, Manager, Transport**
  Keep the vehicles and drivers ready and send the vehicles as per the requirement of emergency management team.
  Ensure vehicles are not taken for any purpose not related to the emergency plan.
  Keep a contact list of local transport agencies and arrange for vehicle from outside agencies if required.
  Keep list of drivers and their phone numbers (including residential) and arrange the copy of that document at the suitable location during emergency.

- **Employees Other than the emergency team**
  Avoid spreading or listening to rumours. Do not cluster at the incident location.
  Move to the assembly points without creating panic as per the instructions received (including contract workers, casual labourers, trainees and visitors).
  Minimise the use of communication equipment and transportation facility, as they are more required at the emergency site.
  In the absence of the member of the emergency team, he/she will depute their powers to the immediately senior official of the plant whoever is present in station during at the time of emergency.

Emergency Action Plan

Action plan for the identified scenarios is given in this section. All the chief coordinators, Coordinators and task team members will perform their responsibilities and this action plan can be utilised in the form of a checklist to avoid the omissions of important actions.

- **Explosion due to solid propellant or Al/AP powder/dust**
  The major hazards in case of explosion are overpressure and thermal radiation effects. In solid process plant, explosion may occur during raw material processing, mixing and casting.

Action plan for the personnel identifying the incident and those who are present in the building and adjacent buildings.

Abandon the building and run to a safe location. Later move to the assembly points. Break the manual call point/ring the fire bell (if available in the nearby safe area). Inform the Facility in Charge (Incident Controller), Chief Coordinator Safety, Fire Service, PA and Security.

All employees of the nearby facility stop the operations, shut down the plant (if required) and must move to safe place or assembly points according to the instructions.

Each Facility in -charge will take the muster.

No employee other than emergency team shall go to the accident site. Follow the instructions given by the emergency team.

Return to the workplace as per the directions, once the emergency is withdrawn.

The seniormost officer available at the incident location will coordinate the activities until the arrival of the incident controller.

Once the first hand information is received by respective Incident Controller, fire and rescue team and security team will act according to their roles and responsibilities. Meanwhile if the situation is becoming out of control emergency will be declared by the Chief Emergency Controller and the emergency plan with all Chief Co-coordinators and Coordinators will come into action.

All the members of the emergency team will act according to the roles and responsibilities identified for them. Ensure the following during the execution of the plan.

Use water to douse fire in the adjacent areas.

Power supply to the area to be switched off before putting out the fire.

Ensure that power supply to the electrically powered fencing is switched off. Avoid spreading of fire and protect the nearby facility.

Electric supply to fire pumps/firewater replenishing system is not obstructed. Use the public address system to give instructions to the employees. Use firewater to fight fire in the adjacent area if any. Fight the fire from a protected position. Search the area for casualty

Cordon off the area

Arrange for traffic control.

Ensure that approach to the incident site is cleared to facilitate the movement of essential services.

- **Minor fires not involving propellant (combustible materials, electricals, etc.)**

Try to extinguish the fire using first aid fire extinguishers if non-propellant of mass quantity is not involved in the fire.

Use CO_2 or DCP type first aid fire extinguisher to put out the electrical fires in the incipient stage. Also ensure power supply to the area is switched off before starting firefighting.

Fight the fire from a protected position.

Inform the Facility in Charge (Incident Controller), Chief Coordinator Safety, Fire Service, PA and CISF gate.

Cordon off the area.

Return to the workplace as per the directions, once the emergency is withdrawn.

- **Minor fires involving small quantity of propellant (less than 1 or 2 kgs)**

Break the manual call point/ring the fire bell.

Use water-type first aid fire extinguisher/fire hose to put out the fire if very small quantity of propellant only is involved.

Fight the fire from a protected position.

Inform the Facility in Charge (Incident Controller), Chief Coordinator Safety, Fire Service, PA and CISF gate.

Cordon off the area.

Evacuate the building and move to the assembly points. If required, mobilise all fire fighting resources.

All employees of the nearby facility stop the operations, shut down the plant (if required) and must move to safe place or assembly points according to the instructions.

Follow the instructions given by the emergency team.

Return to the workplace as per the directions, once the emergency is withdrawn.

The senior-most officer available at the incident location will coordinate the activities until the arrival of the Incident Controller.

Once the firsthand information is received respective Incident Controller, fire and rescue team and security team will act according to their roles and responsibilities. Meanwhile if the situation is becoming out of control emergency will be declared by the Emergency Controller and the emergency plan with all Chief Coordinators and Coordinators will come into action.

- **Major fires involving propellant**

Run away from the area to a safe distance in case of the propellant fire. Later move to the assembly points.

ALWAYS GO AWAY FROM AREAS OF FIRE SPREAD.

USE EMERGENCY EXITS AND RAMPS IF INSIDE THE BUILDING.

Break the manual call point/ring the fire bell (if available in the nearby safe area). ENSURE THAT AUTOMATIC DELUGE/SPRINKLER SYSTEM IS WORKING. Inform the Facility in Charge (Incident Controller), Chief Coordinator Safety, Fire Service, PA and CISF gate.

All employees of the nearby facility stop the operations, shut down the plant and must move to safe place or assembly points according to the instructions. The muster will be taken by each Facility In-Charge.

No employee other than emergency team shall go near to the accident site.

Follow the instructions given by the emergency team.

Return to the workplace as per the directions, once the emergency is withdrawn.

The senior-most officer available at the incident location will coordinate the activities until the arrival of the Incident Controller.

Once the firsthand information is received respective Incident Controller, fire and rescue team and security team will act according to their roles and responsibilities. Meanwhile if the situation is becoming out of control emergency will be declared by the Emergency Controller and the emergency plan with all Chief Coordinators and Coordinators will come into action.

Ensure the following during the execution of the plan.

Use water to fight fire in the adjacent areas.

Power supply to the area is switched off before starting firefighting. Avoid spreading of fire and protect the nearby facility.

Electric supply to fire pumps/firewater replenishing system is not obstructed. Use the public address system to give instructions to the employees. Fight the fire from a protected position.

Search the area for casualty

Cordon off the area.

Ensure that approach to the incident site is cleared to facilitate the movement of essential services.

- **Forest fires near process buildings**

Break the manual call point/ring the fire bell (if available in the nearby safe area).

Inform the Facility in Charge (Incident Controller), Chief Coordinator Safety, Fire Service, PA and CISF gate.

Avoid spreading of fire and protect the nearby facility by using fire hydrants.

All employees of the nearby facility stop the operations, shut down the plant (if required) and must move to safe place or assembly points according to the instructions.

The muster will be taken by each Facility In-charge.

No employee other than emergency team shall go near to the forest fire. Follow the instructions given by the emergency team.

Return to the workplace as per the directions, once the emergency is withdrawn.

- **Leakage of toxic chemical**

Notify and evacuate the personnel in the vicinity of spill to safe area.

Inform the Facility in Charge (Incident Controller), Chief Coordinator Safety, Fire Service, PMO and CISF gate.

Open the doors and windows and ventilate in case of minor spill.

Secure the spill area by restricting access and posting “No Entry” boards.

Wear appropriate personal protective equipment (SCBA) in case of entering the spill area.

Confine and contain spill.

Cover spill with absorbent material.

Follow steps given under neutralising and clean-up spills.

Monitor for residual toxic chemical using portable leak detection system

- **Natural calamities (tsunami, earthquake, cyclone)**

As the process plant is located in a coastal area, the likelihood of the impact of natural calamities like tsunami and cyclone cannot be ruled out. Not all natural calamities can be predicted and prevented. A state of preparedness and ability to respond quickly will considerably mitigate the loss of life and property. These are the situation where more coordination with outside agencies like District Emergency Control team also is required. The directions from District authorities are to be followed. Following is the action plan in case of these situations.

Use the public address system to give instructions to the employees. Keep ready the rescue team.

Meanwhile declare Emergency by the Emergency Controller and be ready to execute the roles and responsibilities by the Emergency Team if required. Evacuate all the personnel (including colony) to the identified safe place as decided by Emergency Controller or Legal Authorities (District Collector). Arrange for traffic control.

Mobilise all the transportation facilities for the evacuation. Arrange for the food and shelter for the evacuees. Call for the external help if required.

Obtain supplementary materials or equipments for handling the emergency, if required.

Assembly Points in Process Area

Assembly points are options for initial assembly. Later move as per the directions of emergency team. The dedicated and well-marked safe areas of each facility are identified as emergency assembly points. In case of emergency and evacuation, staff is requested to assemble in identified locations, stay calm, take head count and wait for further instruction.

Emergency Telephone Numbers

Emergency contact numbers for attending these emergency scenarios are displayed in every facility and “In case of Emergency” display boards with dos and don’ts information is presented for better understanding of the personnel.

Conclusion

Based on the various probable emergency scenarios at process plant, the emergency preparedness plan has been prepared and documented. By organising the frequent mock drills the effectiveness of the emergency preparedness plan can be measured and re-verified.

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Development of a Device for Rescue Operation in Borewell Accidents

Tapash Jyoti Kalita[a], Priyanuj Mahanta[a], Sourav Sonowal[a], Abhishek Khongia[a], Surjya Tanti[a] and Maruk Alam Aziz[a]

ABSTRACT: In today's world, scarcity of water has been a major concern. Water resources are being constantly polluted by disposal of various types of wastes directly or indirectly into waterways. The growing demands for freshwater for livelihood is presently very high. Many places are already hit by severe draught due to scarcity of water. To meet this demand, borewells or boreholes are drilled deep into the ground in order to extract water. Some borewells are also drilled for mining operations as well. Presently, with the increase in construction of industries, drilling of borewell is frequent. The newly drilled borewells are potentially dangerous to children with the risk of them falling into it while playing nearby. Of late it has been an evident observation that cases of children falling into the borewell is concerningly high and the conventional rescue operations are either time consuming or compromising to the safety of the victim. On an average, the conventional procedure of rescuing the victim by boring a parallel hole beside the borewell consumes 15–20 hours. Practically, it is very difficult for the victim to survive in the dark and suffocating environment for such a long period, with decreasing probability of the survival of the victim. More often past situations are evident that victim survived only in few cases. By keeping in mind the value of precious time and to overcome other difficulties, we have designed a device to carry out rescue operations inside the borewell by providing basic survival needs to the victim and bring it back to the ground surface in minimum time without compromising with its safety unlike the prevailing ones. The design is simple and effective and mostly made of mechanical linkages. A mechanism is incorporated to put safeguards around the victim to prevent it from falling off once it is located. The device will also be equipped with oxygen supply, audio-visual support and light. Most importantly the device can quickly move through the well as it is operated from top of the well via cables. The capability of the device to travel past the victim with minimum space available without hurting the victim makes it efficient in securing the victim from beneath and to bring it back to the ground surface.

KEYWORDS: water scarcity, borewell accidents, safety, devices, rescue operation

Introduction

Agriculture holds above 70 per cent of India's total land area. Making our nation rank second worldwide in farm outputs. Ground water is the main component for all the agricultural activities. Hence borewells and boreholes are dug to meet the rising demand for water. These borewells are dug near household areas. It is often seen that the borewells are left uncovered becoming potentially dangerous for the children playing and roaming nearby. Kids fall into the borewells and get trapped. This unfortunate activity is seen to occur frequently due to inappropriate safety measures present near the site area. Also the children tumbling down are weak enough to rescue themselves from the borewells. The first ever rescue operation for such mischance included digging a parallel hole near the borewell and rescuing the victim via that pit. This time-

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consuming process remained to be the conventional method until new methods were introduced. However the newly introduced methods compromised with the victim's safety to an extent. The prototype of the robotic-based machines did not match the real life situations due to scarcity of space between the victim and the borewell wall.

Diagrams

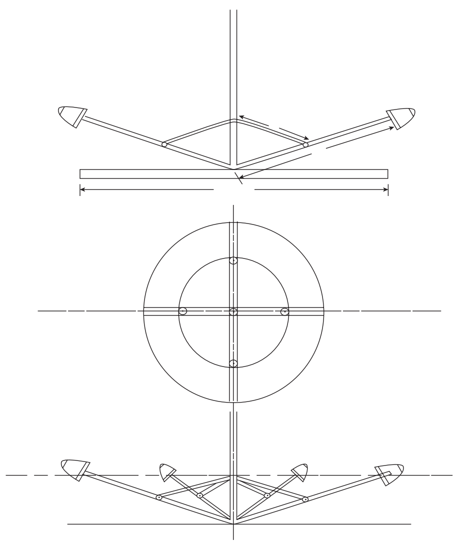

Figure 1

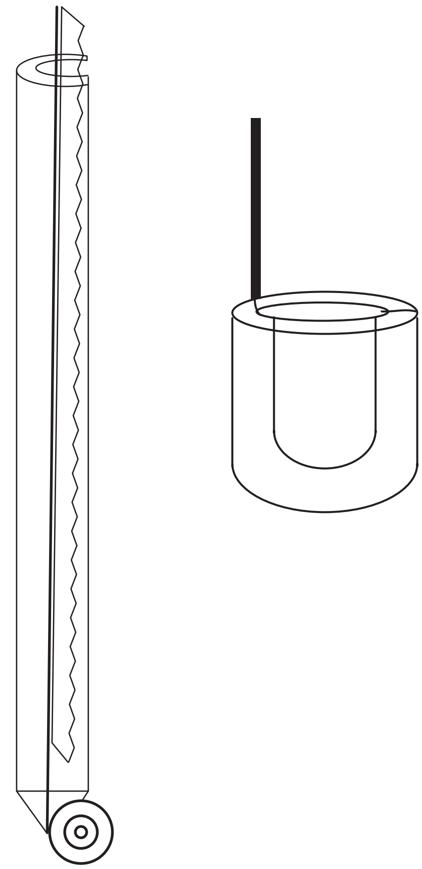

Figure 3

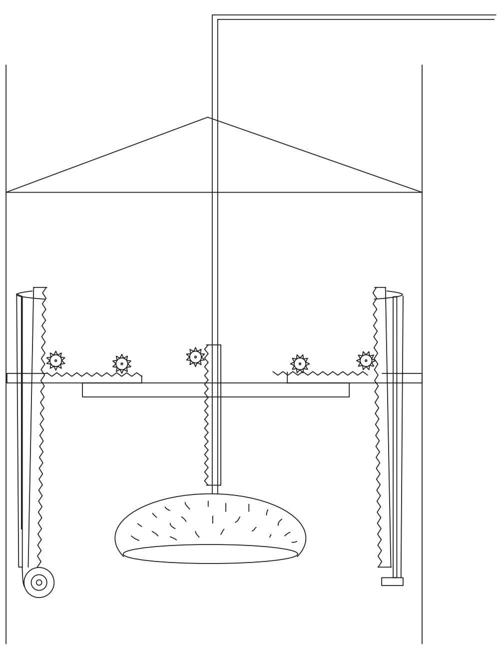

Figure 2

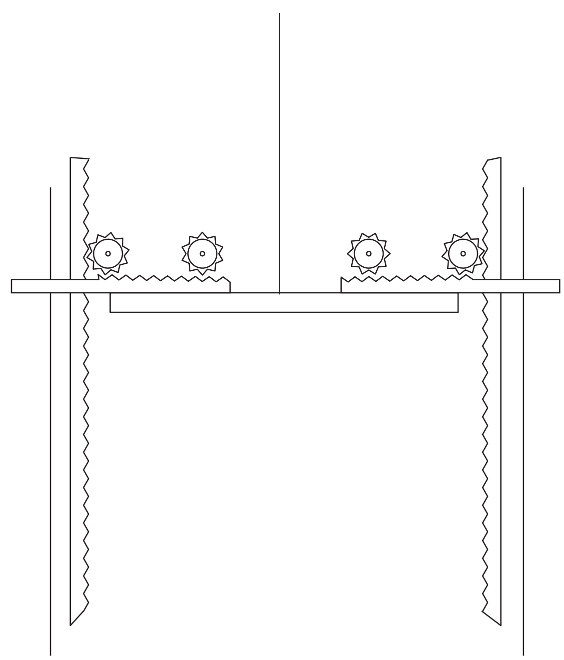

Figure 4

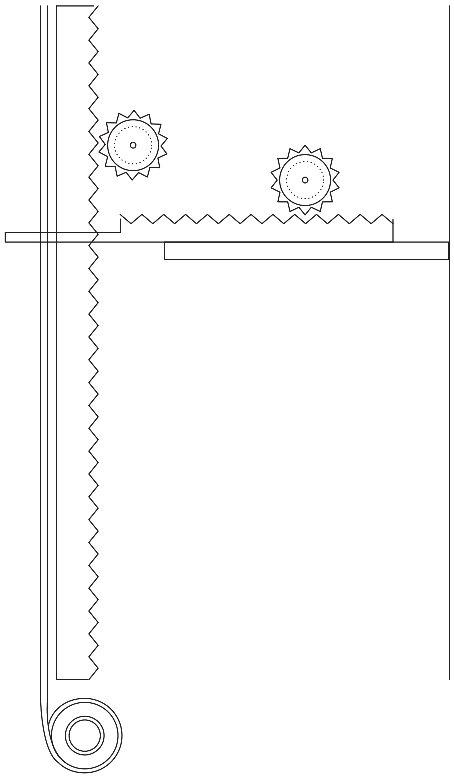

Figure 4 (Continued)

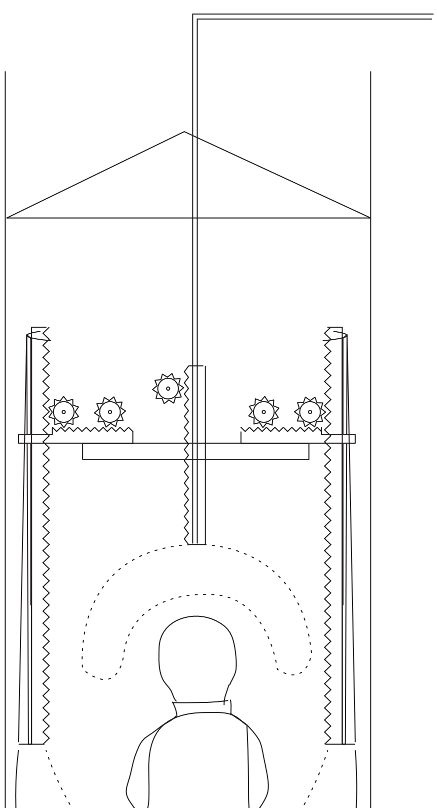

Figure 5

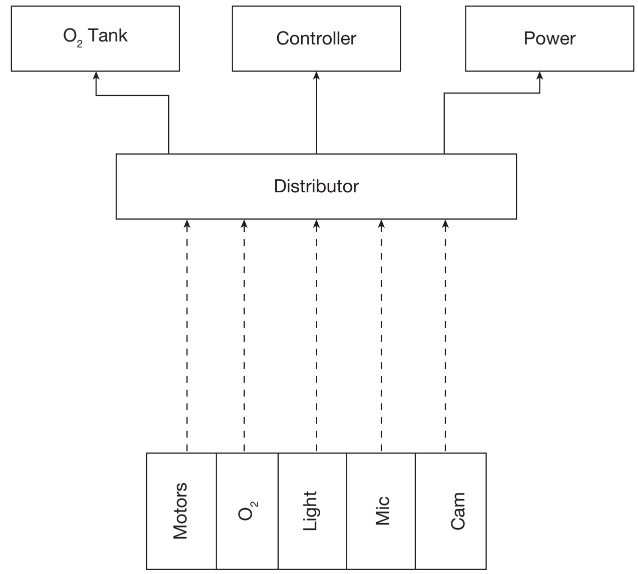

Figure 6

Discussion

Related Works

Following are the few of the works related to the systems introduced to rescue a child from Borewell:

- An instructor at TVS Community College in Madurai named M. Manikandan developed a borewell robot. The first prototype developed in 2003 however took 12 long years to come into practice. The robot has metal hands with a camera fitted. The personnel handling the remote control can monitor the robot's movements on a laptop and grab the victim and pull it up. However it compromises with the victim's safety.
- Shivam Bajpai, Abhinav Singh, Ravi Shankar Rai, Ashwani Sharma, CK Jha have designed a gripper-based robot. A rope is connected with the robot having electric wires attached to it. The pump hose is fixed at the upper plate can be adjusted accordingly with the robot movement. A camera is also positioned to view the victim's movement. A PCB controller is setup on the upper plate. A safety balloon gas tube is present in the gap between the borewell and the baby. Initially the air tube is present above the end. Once the safety balloon is

inflated using air compressor and exact pressure is reached the vacuum supply is cut off. The victim is then pulled up once the robot removed from the removed.

- Subhasis Saha has proposed a borewell rescue robotic machine which consists of a robotic arm that evacuates the victim from the pit. The robotic arm developed to grab the child is mechanical and hence very difficult to position in accordance with the position of the victim. This results in the possibility of the victim being harmed during the process. One other issue that rises while dealing with the robotic arm is that if it faces failure at the top of the well it can easily cause death of the victim as the mechanism is not fail safe.

Overview of the Device

The device is equipped with a mechanism to ensure the stability of the device. Its size can be adjusted according to the size of the borewell manually by hand (Fig. 1). The mechanism is connected to a circular plate. It contains another mechanism to adjust the diameter that can be covered by the soft bars (Fig. 4). The bars contain rack gears connected to two pinion gears for their up and down motion. Now to control the diameter that can be covered by the bars, two additional rack gears were provided whose axis are perpendicular to the axis of the bars.

These additional racks are connected to two separate pinion gears for their individual controls. Below the plate is a hemispherical cap to provide oxygen and support to the victim's head (Fig. 2). It is provided with soft fingers of rubber to make the support comfortable and harmless. The cap is attached with the plate by a bar containing a rack and pinion arrangement. The oxygen pipe passes through this bar. The lights are also placed below the plate. The mic is also placed inside the cap. There will be two cameras, one at the surface of the shell, which will also come with an attached light and other will be present inside the cup.

All the five pinion gears are connected to four separate DC motors of 3.5 rpm.

The pipe for the inflatable shell is present behind the rack and passes through one of the bars. At the end of this bar the deflated shell is carefully placed in such a manner so that it covers minimum area and can easily pass through the victim.

The bar is covered by a soft material to prevent any possible injury while moving past the victim. The deflated shell also contains a magnet to provide required attraction force later during the rescue process. Another bar also contains a magnet at its tip to attract the magnet present in shell. There is also an additional mechanical lock provided above the magnet for locking purpose. The device is attached with a nylon rope and once the victim is secured is used to pull out the device along with the victim safely using pulleys.

Working

At first the device will be inserted inside the borewell and moved near the victim manually with the help of the camera. Once it reaches the victim, the bars will be allowed to move past the victim very carefully with the help of the rack and pinion arrangement without hurting it. Once the bars moves past the victim, the fluid is allowed to fill up the deflated shell. Once the shell comes into its original shape, the magnet attached to it is arranged in such a way that it attracts the magnet present at the tip of the second bar. Once the magnets get attached, an additional lock will be used to secure the attachment.

Now the hemispherical cup will be allowed to move downwards where soft rubber fingers are present to secure the head and provide the victim with the oxygen supply and the mic support. Once the head is secured, now the shell will be pulled upwards slowly to the surface safely without hurting the victim (Fig. 5).

Conclusion

Of all the unfortunate happenings across the nation where a kid tumbles down a borewell, a very few of them are rescued alive. The proposed design doesn't compromise with the victim's safety and requires minimum space for the rescue process. It is well equipped with light and sound facilities enabling the proper contact between the victim and the rescuer. It reduces human efforts to a great extent and facilitates the rescue operation with least time consumption.

Hereby we consider that our proposed device will be effective enough, unlike the traditional machines, to save lives in the coming years.

Acknowledgements

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Theoretical Framework Using Gamification for Stakeholder Engagement in Disaster Operations

Abhishek Behl[a] and Pankaj Dutta[a]

ABSTRACT: The world is witnessing a gradual increase in natural disasters. Changing weather and increased human intervention has resulted in a drastic rise in the number of natural disasters. Studies related to Humanitarian Supply Chain and Disaster Relief Operations have gained prominence. An important contribution in disaster recovery is played by the stakeholders and various studies have addressed concerns related to the role of various stakeholders like government, NGO, military, telecom providers, international agencies, healthcare services, banking and financial services. Most of the studies have looked at disaster management from the viewpoint of Operations, Finance and Economics, Healthcare Management, Information Technology, Analytics, Human Resource Development, it is surprisingly that theories of marketing have not been explored in this context. One such theory is theory of engagement through gamification which has been widely applied in diversified domains. The present study proposes to integrate gamification in disaster relief operations. The study caters to a key research question: How can various stakeholders in disaster relief operations be engaged to achieve resilience? The motivation to address the concern of engagement is embedded in the issue of lagged linkages and communication between the stakeholders thereby resulting in delay in achieving normalcy. Data is collected from the stakeholders involved in a flood management in Kerela using a structured questionnaire. At least three responses from each stakeholder was collected totalling up a total of 205 responses. The responses were used to develop a framework which would ensure a higher engagement practice than what is currently being followed. The results also factors in the delays from every stakeholder's side which makes the framework much more robust in implementing. An alarming result is the relatively low score for recovery stage which causes dampening effect on the mitigation and preparedness stage of disaster operations. A recommendation from the study is to develop an application which could integrate elements of gamification to pump up the engagement of the stakeholders.

KEYWORDS: disaster management, stakeholder analysis, resilience, gamification, framework

Introduction

Humanitarian Supply Chain (HSC) management has grown with increasing number of natural disasters. Humanitarian Operations has gradually involved a large number of stakeholders, some of which behave and contribute differently. Coordination amongst themselves is a well-discussed debate in the humanitarian literature. While studies argue that there exist systems which help to coordinate among various stakeholders, the challenge lies in understanding their degree of engagement and more importantly sustained engagement. There has not been much written or worked in the area of sustainable engagement in the humanitarian context and the absence of which would lead to delays and lags in achieving resilience. Engagement is mostly used in the context of marketing and customers and in some cases with stakeholders as

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well, but majority of the studies discuss its implications in the case of a process which does not involve uncertainty. The present study draws upon elements from theories explaining engagement and discuss their role in HSC.

There has been a significant increase in the financial and the economic losses due to a natural disaster. The intensity of the disaster has increased over the years which has although resulted in lesser human causalities but higher financial losses. In today's dramatically expanding and connected world, it is worthwhile to focus upon innovation and disruption by improvising upon their networks and operations. Further spur in smartphone and internet usage is indicative of growth opportunities for several telecom subsectors, including wireless and broadband carriers, networks carriers and electronic device manufacturers. A major part of the disaster relief operations has now shifted its management from offline systems to online systems, especially app-based management systems. It has the potential to become one of the most sought after applications in the recent times (Carlson et al., 2018). This new mechanism provides agencies and affected individuals to be connected using a unifying platform and helps in systematic relief operations rather thereby increasing the efficiency.

The application is seen to permit the users to interact amongst each other and with the required stakeholders in order to achieve faster and efficient financial resilience. However, in this uncertain and stochastic situation, it has been observed and confirmed by the literature that while financial payments are made by the government or the non-government organisations, the role of citizens as financial donors is important and can help in achieving sustainable financial resilience. Crowdfunding and crowdsourcing are often used terminologies in this context and there have been umpteen work done in this area. However disaster relief operations for financial and economic aspects remain an unexplored area when looking from the lens of financial donorship made by citizens. Technology adoption and payment behaviour of people using mobile apps has been widely studied while citizen engagement in the process of community resilience needs significant attention. Therefore studies fostering rate of adoption and thereby engagement will give the service providers and affected citizens crucial information required for economic well-being (Shin et al., 2009). Such mobile apps are launched recently in Indian markets and examination of the acceptance of the application and more importantly its continued usage at this early stage is crucial for the prediction of the growth and development of cities and states which are struck by natural disasters every year. The factors contributing to the success of these mobile apps are targeting the right kind of audience and adequate engagement tactics. The factors also emphasise on the necessity for research on behavioural intention of the users for the purpose of targeting the right kind of audience through the utilisation of the right resource at the right time (Shin, 2009). While there have been some seminal studies in the past trying to capture closely similar objectives and finding out that cognitive attention and media content as some of the key variables for continued usage of these apps (Hennig-Thurau et al., 2015), in a setting like India which is graduating into an internet-dependent country, this study would be significant as Indian subcontinent is at the risk of being affected by natural disaster with a higher frequency. There is a need for deeper understanding about citizen's engagement after making a payment towards financial resilience of the affected areas. The present study intends to highlight and explore the reasons which might increase an individual's adoption of these services which will provide crucial and pertinent inputs in designing commercialisation strategies for these services.

Calder and Malthouse (2008) have discussed 'engagement' from two critical focuses; 'engagement with the advertising medium' and 'engagement with the advertised brand itself'. Gummerus et al. (2012) conducted an online survey of gaming Facebook community to find enhanced customer satisfaction and loyalty largely being influenced by three relationship benefits, namely social, entertainment and economic. Bitter et al. (2014) applying an extended model on theory of planned behaviour and social practice studied the engagement behaviour of consumer interactions through online social media with companies and brands on Facebook. Kumar and Pansaru (2016) established that push to better customer engagement behaviour leads to a positive impact on the performance of the firm. While Veirhof et al. (2010) stated that given the importance of customer relationship firms have started taking pro-active measures towards customer engagement. The survey results depicted that consumer's self-brand relationships and their conversations with friends over social media affected the behaviour. Trust, information privacy issues, age and gender had a moderating effect on the customer engagement behaviour.

Various studies have been undertaken which highlight the importance of citizen engagement and how behavioural intentions of a citizen is driven (Harmeling et al., 2017). Zeithmal et al. (1996) observe that evidence of service quality impact over customers' behavioural responses should be noticeable. In an empirical study examining the relationships concerning behavioural intentions, the results depicted strong influence of service quality over it. Several notable findings report that service quality, satisfaction and service value may have direct effect upon behavioural intentions (Cronin et al., 2000). An empirical investigation fusing innovation diffusion theory, cost and perceived risk into an extended technology acceptance model carried out by Wu and Wang (2005) find positive influence of perceived risk, cost, compatibility, perceived usefulness on behavioural intention to use mobile commerce. Venkatesh et al. (2012) further extend the Unified Theory of Acceptance and Use of Technology (UTAUT) to understand acceptance and usage of technology from the point of view of a consumer. The refined UTAUT2 uses three constructs such as hedonic motivation, price value and habit into UTAUT.

The objective of this research is to investigate the key constructs that have a bearing on individuals' behavioural intention to embrace and make use of the technology, and to assess the effect of these identified constructs on the user's sustained and prolonged engagement. The hypothesis related to each of the constructs for this study can be developed as follows:

The UTAUT model considers Perceived Expectancy of Performance (PEP) as one of the vital determinants of 'Intention to use'. PEP is one of the key identified antecedents of UTAUT model. The present study uses the operational definition of PEP as "the degree of perception of an individual that a process will better the performance of the individual" (Venkatesh et al., 2003). Various studies have proven that PEP positively impacts the intention to use a fresh technology and hence facilitate the adoption. Zhou et al. (2010) established that adoption of mobile technology and services is significantly impacted by PEP. A study carried out by Lu et al. (2004) pointed that PEP significantly impacts the BI for a mobile data service. The perception of the end users in such a technology has to be playing a key role towards the behavioural intention. It is therefore hypothesised:

H1. PEP has a significantly positive influence over BI

The Perceived Ease of Use (PEoU) is basically the extent to which a user of new system or technology has the faith or belief that the system can be used easily and there is no requirement of complex efforts in order to utilise the new technology or system. Which also means that to use a new form of a particular technology minimal efforts should be required. The construct PEoU has been derived from Technology Adoption Model (TAM) (Davis, 1993). The construct was also used by Venkatesh et al. (2003) in UTAUT model and was operationally defined as "the degree of ease experienced by an individual while using a technology". Ming et al. *(*2013) found that customer perception about electronic payments was closely linked to their behavioural traits towards the adoption of the technology in its early phases. Apps related to DRO therefore need to be designed on a user-friendly platform to enhance customer experience in the longer run. It is therefore hypothesised:

H2. PEoU has a significantly positive influence over BI

Venkatesh et al. (2012) define social influence (SI) as the level of belief or trust perceived by an individual regarding his or her joining the set of individuals who make use of the new technology or a new technological product. The origin of SI stems from TRA model which signifies a direct association between BI and SI. The relationship between BI and SI largely was also analysed in detail in Innovation Diffusion Theory (IDT). Studies have also highlighted that a significant role is played by the peer pressure and society in influencing a person to take a decision. The importance and significance of this construct is compounded many times in a rural set up where the society or people are mostly illiterate or functionally literate. While there are handful of studies which measure the satisfaction of people in society which would influence the degree of influence on the individual, it is worthwhile to test whether the existing societal setup influences behavioural intentions or not. Therefore, we structure the following hypothesis:

H3. SI has a significantly positively influence on BI

Facilitating conditions also play a significant role as they act as catalyst in the process of diffusion. Venkatesh et al. (2012) defined it as "degree of belief or trust an individual has regarding the existence of technical and organisational infrastructure to promote, support and enhance the usage of a system". While this qualifies for an external construct, it is equally important as incubator for hatching an egg. These conditions facilitate the process and therefore it is important to study the effect of them towards behavioural intention. There are multiple items which constitute the construct and it differs from situation to situation, but earlier studies have highlighted the positive effect of FC on BI. We therefore suggest that:

H4. FC has a significantly positive influence on BI

Hedonic Motivation (HM) is referred to as pleasure gained after using a particular technology (Brown and Venkatesh, 2005). It is often in close proximity to the sense of satisfaction which the users acquire after using a technology. Kim et al. (2007) found that HM proves to be a significant indicator for adoption rate of information technology. Studies have also categorised the construct as an antecedent to behavioural intention of customers. The present research can hypothecate along the same lines and the derived hypothesis can be:

H5. HM has a significantly positive influence on BI

The perceived Valuation of Service (VoS) is one of the constructs used to evaluate the behavioural intention of customers. Customers are always looking for a trade-off between the money they shell out and the quality of services they get in return. The balance of supply and demand factors is usually considered before opting for the service (Chang & Wildt, 1994). It could be hypothesised:

H6. VoS has a significantly positive influence on BI

Venkatesh et al. (2012) incorporated Usage Habit (UH) in the model and defined it as "Level of usage of any technology repeatedly as a result of continuous learning or requirement". Studies highlight that the higher is the frequency of usage of any technology the better is the adoption rate (Aarts & Dijksterhuis, 2000). Habit of an individual towards usage of a technology is a resultant of various factors but it forms a building block for future usage of that technology as well (Kim et al., 2005). It is thus hypothesised that:

H7. UH has a significantly positively influence on BI

Gamification as a Moderating Variable

Gamification is an approach which has been successfully used in engaging and retaining customers especially in a digital environment. The gamified approach helps to inculcate a sense of competition that motivates the users and recently achievement of personal and professional goals has also been added (Huotari and Hamari, 2017). A lot of companies have used gamified elements to engage their customers and churn revenue.

There are many studies examining the effect of gamification on usage intention (Wolf et al., 2018) and even impact of gamified services on firm benefits (Hamari and Kovisto, 2015; Jang et al., 2018), but there is a scarcity of literature explaining the impact of gamification on engaging citizens in a disaster relief scenario. There is a need to understand how and up to what extent can gamification be used to explain citizen retention in achieving financial resilience for disaster relief victims. The present study therefore uses gamification as a moderating variable.

H8. There is a moderating effect of gamification on the relationship between PEP and BI.

H9. There is a moderating effect of gamification on the relationship between PEOU and BI.

H10. There is a moderating effect of gamification on the relationship between SI and BI.

H11. There is a moderating effect of gamification on the relationship between FC and BI.

H12. There is a moderating effect of gamification on the relationship between HM and BI.

H13. There is a moderating effect of gamification on the relationship between VOS and BI.

H14. There is a moderating effect of gamification on the relationship between UH and BI.

Methods

The study uses structured questionnaire as a research instrument for data collection. The research instrument was developed by borrowing constructs and their respective items from existing scales in the areas of political science and information systems and was modified in the context of the present study (e-participation). The instrument was primarily developed into two segments: demography-based questions and theory-based items. Both the categories were used for either descriptive or inferential analysis. Reid and Levy (2008) and Malhotra and Gellata (1999) were used to adapt the items measuring attitude towards e-democracy. Items related to subjective norm was adapted from established literature while that of political belief was adapted from Mizrahi and Vigoda-Godat (2009). The items related to e-democracy outcome in the context of disaster relief operations were adapted and modified from Dubey et al. (2018). All the constructs were measured using a five-point Likert Scale where 5 denotes Strongly Agree and 1 denotes Strongly Disagree.

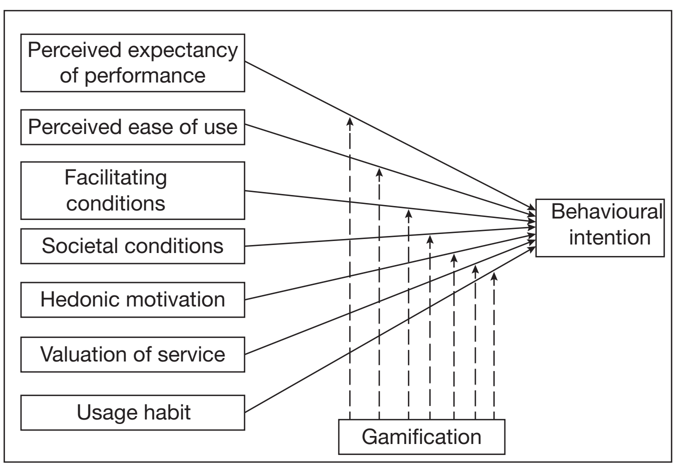

Figure 1: Theoretical framework for study [adapted from Venkatesh et al. (2002)]

The study was conducted in the state of Kerala which do not experience heavy rainfall every year but was struck by floods in 2018 thereby causing loss to lives and property. Kerala being the highly populated state ranks highest in terms of their literacy and development. Data were collected in the month of July–August 2018 which was just after the floods were declared by Indian meteorological department. Studies have also confirmed that Kerala is one of the states in the country where e-democracy has been widely used. The data were collected from respondents who contributed to "Kerala Chief Minister disaster relief fund". The respondents were chosen from a snowball sampling approach as there is no existing publicly available database for people who contributed towards KCMDRF. The authenticity of their payment was checked with their digital receipts of their payments. Each and every construct was briefly explained to the respondents using an audio message in their local language as well as in English and the writeup in English.

To check the reliability of the instrument, the instrument was first shared with professors from the area of information systems and psychology. The questionnaire was then sent for language editing to professor from the communications department to ensure that the translation was done correctly from English to local language. A pilot study was conducted with post graduate students of the state who could understand the vernacular language as well as English and possible ambiguity was removed. The final questionnaire was then administered using online portal for a diverse group of citizens above 18 years of age irrespective of their socio-demographic profile. As financial donors could be people from any community and region, the study was not restricted to a particular community and geography except Indian sub-continent. The respondents were checked in terms of their professional affiliation by collecting their email id and sending them a confirmation email to validate their credentials. The data were collected from July to September 2018 in multiple waves. The study received 439 responses out of which only 205 were found to be valid and met all the criteria. They were further tested for reliability and validity and were used for final analysis.

Results and Discussion

The demographic details of the data indicate that approximately 41 per cent males took the survey. The distribution of age comprised of 22 per cent people less than 20 years while remaining users between the age of 20 and 25 years. The usage pattern of devices indicate that approximately 85 per cent owned a smartphone while the remaining either had a basic handset or similar low-end device. A quick glance at the usage patterns indicate that 37.03 per cent respondents experienced and made such payments less than 10 times in the last year, approximately 10 per cent of the users experienced it more than 10 but less than 20 times in the last year and the number dipped as the usage experience increased further. It was also seen that 37.8 per cent of the respondents had not experienced and made similar payments in the last year.

The data retrieved from Section 2 of the questionnaire was analysed via Smart PLS 3.0 (Chan et al., 2010; Lee et al., 2013) which used a partial least square structured equation modelling. The approach is apt for analysis of data where relatively small sample sizes are dealt (Chin et al., 2003).

The data were collected from single respondents which might have resulted in common method bias (CMB). The data were therefore treated with Harman's single factor test of CMB which resulted in less than 50 per cent single factors for the study. The issue of CMB was thus found insignificant for the study (Delerue & Lejeune, 2010).

In accordance with this the values of average variance extracted (AVE) should be more than 0.5 (Fornell & Larcker, 1981) and same applies for all factor loading as well (Kline, 1998). The values of AVE for this study were found to be more than 0.5 as visible from Table I and the same is visible from Table I for factor loadings also. Molina et al. (2007) suggested that composite reliability values should be greater than 0.7. It is also seen that the model is reliable as the valuation of Cronbach alpha is also greater than 0.7 (Nunnally & Bernstein, 1994). The simultaneous validation of both the factors leads to good convergent validity.

The other counterpart of the model, that is discriminant validity referred to as the level to which items can be differentiated between variables (Thong, 2001). The results in Table I indicate that "the square roots of the AVEs of each construct were larger than their corresponding correlation coefficients with other factors" (Deng et al., 2014). On a parallel note, the result illustrates that pattern of loading and cross loading supports discriminant validity (Venkatesh et al., 2012). The output from SEM analysis confirms that about 65 per cent of the variance of behavioural intention was explained by identified constructs from the literature. It supports the idea of application of UTAUT2 model to study the behaviour of citizens for financial donorship in an Indian scenario for disaster relief operations. The results derived from PLS-SEM shown in Table II depict that adoption of mobile apps which induce gamified elements is dependent on the aforesaid factor. It is visible from the results that PEP, SI, FC, HM and UH support the existence of modified UTAUT2 model for this study. Therefore, hypothesis H2, H3, H4 and H7 are well supported with the model and are considered true for adoption of mobile apps which induce gamified elements while hypotheses H1 and H6 are rejected because of a lower significance level.

Table I: Discriminant Validity Test Results

	BI	PEP	PEoU	SI	FC	HM	VoS	UH
BI	0.845							
PEP	0.439	0.785						
PEoU	0.578	0.356	0.787					
SI	0.290	0.025	0.145	0.899				
FC	0.734	0.302	0.556	0.098	0.943			
HM	0.297	-0.012	-0.273	0.025	0.267	0.912		
VoS	0.169	-0.012	-0.0315	0.066	0.167	0.612	0.845	
UH	0.587	0.199	0.674	-0.012	0.403	0.134	0.156	0.856

Table II: Hypotheses Testing Results Using Partial Least Square

	Dependent Variable	
	Intention	**Supported**
R2	0.756	
Perceived Expectancy of Performance	0.041	No
Perceived Ease of Use	0.214**	Yes
Societal Influence	0.119*	Yes
Facilitating Conditions	0.254**	Yes
Hedonic Motivation	0.189**	Yes
Valuation of Service	0.089	No
Usage of Habit	0.456**	Yes

Notes: **p-value<0.01; *p-value<0.05

The study also aimed at examining the moderating role of gamified elements on the constructs using the PLS-SEM model. The results from Table II divulge that PEoU, PEP, HM, SI, VoS and UH were insignificantly moderated by the external factor – gamification. On the contrary only FC and BI were found to be significantly affected by gamification (β = 0.1478, p<0.05). In other words mobile apps with gamification ensure higher degree of association of FC as a factor influencing the adoption rate of mobile apps which induce gamified elements while women did not. The results clearly indicate the acceptance of only H11 as a valid tested and accepted hypothesis while the others were rejected.

Table III: Results of Partial Least Square Results with Gender as Moderators

	Dependent Variable	
	Intention	**Hypothesis Test**
R^2	66.56	
Perceived Expectancy of Performance	0.024	No
Perceived Ease of Use	0.245**	Yes
Societal Influence	0.113*	Yes
Facilitating Conditions	0.257**	Yes
Hedonic Motivation	0.153**	Yes
Valuation of Services	0.116	No
Usage Habits	0.415**	Yes
Gamification	0.034	No
Perceived Expectancy of Performance X Gamification	-0.097	No
Perceived Ease of Use X Gamification	0.043	No
Societal Influence X Gamification	-0.024	No
Facilitating Conditions X Gamification	0.156*	Yes
Hedonic Motivation X Gamification	-0.034	No
Valuation of Services X Gamification	0.087	No
Usage Habit X Gamification	-0.035	No

Notes: **p-value<0.01; *p-value<0.05

The results derived from testing of the hypothesis indicate the various relationships among the dependent and independent variables. Hypothesis H1 depicts an insignificant result between PEP and BI which means customer experience of mobile apps that induce gamified elements on mobile devices was not at par. The results were not in sync with the results of model conceptualised by Venkatesh et al. (2003). Therefore, it is the onus of the service providers of mobile apps which induce gamified elements to include more features which may not only keep the customer more engaged but also keep them informative and up to date. The results for hypothesis revealed that PEoU significantly influences BI which also supports the results and theory by Sim et al. (2011). This indicates that the options of mobile apps which induce gamified elements are user-friendly and do not require extra efforts to learn them. The third hypothesis was also in line with the early research by Yu (2012) and indicated that effect of societal influence, such as peer pressure, family, friends, relatives and social group, impacts the rate of adoption in a positive manner of gamified mobile apps among users. A similar pattern of result was also witnessed for H4 which in turn supported the previous results found by Wang & Yang (2005). The study found that HM had a causal relationship and proved to be an important antecedent of BI which was also validated by earlier study by Kim et al. (2007). The users of gamified mobile apps enjoyed their experience and the adoption of gamified mobile apps on mobile phone enhances their level of entertainment and pleasure. Venkatesh et al. (2012) in his research confirmed that VoS significantly contributed towards BI but the present study negated the results for the adoption of gamified mobile apps. One of the last conclusions derived from H7 found that UH was significant with BI which was an extension to the theory laid by Polites and Karahanna (2013).

Conclusion

This study is an attempt to comprehend the explanatory factors of behavioural intention under gamified environment for engaging customers to financially contribute towards disaster relief operations. The study intends to explore some important constructs that have a bearing on customers' behavioural intention to adopt and use technology, and to assess the effect of these identified constructs on the user's behavioural intention for sustained and engaged citizens towards achieving financial resilience for affected victims. The results will also be useful for mobile application developers to enhance the citizen experience and make the application more user friendly. One other strategy of promotion and enhancing customer base of such apps could be shooting up its publicity on web portals like Facebook, Twitter, etc. or through government policies/schemes which will enhance its coverage across all regions uniformly and across all age groups. A parallel role of telecommunication agencies is important in enhancing the quality of transmission of channels using web-based subscription. The effect of PEP on BI is not significant towards adoption rates of such apps; mobile programme developers should consider introducing programmes that educate in such a way so as in to uphold the degree of positive user-performance specifically for the targeted group of users.

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Escalating the Effect of Search Rescue and Evacuation in Disaster by Information Provisioning

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ABSTRACT: In this paper we present a proposal to enhance the effectiveness of the Search Rescue and Evacuation operations by making provision for collaboration amongst the first responders. Typically the responder teams are geographically dispersed. Information exchange between them leads to shared understanding of the situation on the ground. Subsequently it is possible for the responder teams to collaborate and achieve greater success in the operations. Focus of the paper is on the information needs of the first responders which enables the collaboration amongst them. We analyse the disaster environment from the system perspective and articulate the information needs of the first responders. We propose a solution for meeting the information needs by composing the modern-day tools which are expected to enhance the effectiveness of the operation.

KEYWORDS: search rescue and evacuation operation, information needs, collaboration, net-centric operations, asymmetric operations, ICT solutions

Introduction

The success of Search Rescue and Evacuation operations predicates on the timely actionable information. The effectiveness of the operation enhances if the information is shared among the responders who are typically geographically dispersed. The information which needs to be shared is termed as *information needs* of the responders. The shared information enables the responders to have shared understanding of the situation on hand and thereby enables them to plan together in a better way. Meeting the information needs of the responders enables them to plan together, form a bigger team and address bigger challenge. The act of team forming and working towards a common goal is termed as *collaboration*. It is documented that actionable information sharing among the responders enables emergence of collaboration. The level of success of an operation gets decided by the presence of collaboration among the geographically dispersed responders. The collaboration has been identified as a key enabler for enhanced effectiveness of an operation. The collaboration has been well-researched in the net-centric military operations. The disaster is categorised as Operations Other Than War (OOTW) or Asymmetric Operation. We take cue from the military operation and extend the concept of Observe Orient Decide and Act (OODA) to the Search Rescue and Evacuation portion of the disaster management.

The collaboration is achievable by deploying a composition of modern-day information technologies. A considerate composition of these information technologies lead to desired emergent properties which meet the information needs of the rescue team members. In order to be able to compose correctly it is imperative to understand the disaster environment from the perspective of information needs.

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In this paper we analyse a disaster environment from the system perspective and identify information needs of the responders which can potentially establish collaboration amongst the rescue team members. In the next section we present the analysis of disaster environment as a system highlighting the importance of the information content.

Disaster from System Perspective

In this section we visualise a disaster environment from system perspective where we treat the disaster as adversary. In our analysis we restrict ourselves to the natural disasters like floods and landslides within country. Considering the system theory, a system which determines an outcome based on a-priori advantages linked with a positional state is considered as 0^{th} order dynamical system. A system with position and ability to change its position is considered as 1^{st} order dynamical system (can also be stated as feed forward system). Such a system would be capable of leveraging first order dynamics to gain eventual positional advantages. If a system is able to sense the opponent and the environment, model the two, and predict their future course of actions/evolution (based on either priors or learning) and then change its position to achieve positional advantages based on sensory inputs (feedback comes in) to meet an objective, then it is called second order system. Higher order systems would also be able to model a second or higher order dynamics of the opponent. It can be shown that all higher systems would be reducible to second order dynamics for the purpose of analysis. Considering the fact that the OODA can potentially be used against equally competent opponent, it can lead to a state where the opponent would have succeeded in making the system non-synchronised. In this situation the number of accessible states of the system tends to be many, including unpredictable. This is considered as the increased entropy (measure of available states) of the system. A feedback loop can be leveraged effectively to synchronise. Taking the transfer function of a second order feedback system as $t^2 s^2 + z t s + 1$, the 't' is the natural frequency of the OODA and '*z*' is the damping factor. 't' defines the interval between two observations and '*z*' defines the swiftness of the response. The '*z*' is defined as the functional of operational information and situational information and expressed $Z_t = D[O,S]_t$ for an instance '*t*'. Here *O* is defined as is operational entropy, the initial condition for the operation. *S* is Situational entropy; the dynamically evolving condition for which the feedback is given. *D* acts as operator decided by the Doctrine or rules being followed for particular operation. The presence of 't' in expression of '*z*' indicates the instantaneous update of *O* and *S* making the analysis as piece-wise. During the operation the value of '*z*' is influenced by situational entropy *S*. *D* encompasses the knowledge base and the set of priors which acts as an operator on the instantaneous update and decide the instantaneous 'z_t'.

The entropy of the system can be reduced by increasing/pooling of information. Therefore in order to reduce the entropy of the system, the information needs to be pooled leveraging various sources. It is a possibility that the pooling can lead to deviation of system from critically damped state. To make it critical there has to be continuous evaluation and filtering of information '*I*' being pooled in and passed through theory of belief propagation. To this effect $S = fuse[filt[I_{[n,t]}]]$. Where *n* is the number of sensors/ sources and *t* is the indication of the respective time stamp. Therefore, z_t can be expressed as $z\_t = D\ [O, fuse\ [filt[I_{[n,t]}]]$. In an operation, apart from observing the situation, it may also be required to estimate the opponent's move. This brings in another processing term to z_t as $z_t = D[O, fuse[filt[I_{[n,t]}]], E_o[fuse[filt[I_{[n,t]}]]]$ or $z_t = D[O, S, E_o]_t$; where E_o is the estimation of the opponent's entropy. Typically natural disaster can at most be first order opponent which can be dealt with the OODA loop realisation. Other incidences where opponent is capable of planning and execution based on the sensor inputs falls in the category of second order systems. Therefore the estimation of opponent entropy E_o is not included in the scope of the current paper as the inclusion of this diverges from disaster operation. However one can do so for the purpose of implementation, taking the benefit of game theoretic approach.

Needs Analysis View

In this section we attempt to identify the information needs of the responders. The forces (Police, Paramilitary, Special Forces, etc.) are required to respond to disaster for various roles of their specialisation. In all the incidences the success of the response depends on the information about the threats, exploitable assets (or available infrastructure), defendable assets, and whereabouts of peer incidence responders and opponents. The direct threats and assets can be given with the example like

- **Direct threats**: Adversary, natural danger, dangerous animal/object.
- **Assets**: Peer team, Communication (bandwidth, equipment, tower), Transport, Shelter, Supplies.

During the operation the challenge is to achieve the desired objective mitigating the threat with minimal affect/loss to assets. In a dynamic environment of an operation the actionable information plays a key role in mitigating the threats and leveraging/defending the assets. Specific to the operational needs from the perspective of responder, the broad level requirements can be stated as following:

- **Blue force tracking (BFT)**: Tracking of our own forces for the purpose of latest positional assessment and direction if required.
- **Surveillance input about the epsilon neighbourhood**: Requirement for planning of operation and to update the incidence to responders (blue force) about any course correction due to ongoing development.
- **Open domain information availability**: Is required for augmenting the available information.
- **Expert analysis**: An assessment of emerging situation, niche capability of decoding the move of the adversary, their encryption, etc. falls in this category.

In the next section we analyse these requirements in detail.

Analysis of Requirements

Here we analyse the information needs of incident responders in Search Rescue and Evacuation operation. We derive the elements of S from the perspective of Search Rescue and Evacuation operation and mandatory supporting infrastructure to sustain it.

- **Blue force tracking**: Awareness about the location of own teams with 'big picture' of the area of operation comes under Blue Force Tracking. It needs availability of position sensor with each peer along with a common map. The location can be *Lat-Long* or *Easting-Northing* or even $[X, Y]_{ref}$ (*X, Y* with respect to a non-standard reference point). Depending upon the type of map (terrain, satellite, isobar, isothermal, etc.) the refinement in the location information may be there. For the purpose of this paper we call this as $[I_{loc,t}]_{map}$. The choice of map is dependent on the type of operation. The location need to be communicated with peers and across the teams through command post for higher level collaboration among the incidence responder teams.
- **Surveillance input about the epsilon neighbourhood**: Understanding of the terrain and facilities like shelters $I_{terrain}$, hazardous environment I_{env}, enemy movement, I_{emov}, available infrastructure like communication facility I_{com}, transport facility I_{tran} *etc*, all in the context of the relevant map (*i.e.* $[I_{*,t}]_{map}$) is treated as the surveillance inputs about the epsilon neighbourhood. This requirement mandates availability of relevant environment sensors, EO/IR sensors, and doctrine-based preprocessing capability of information extraction from the captured data. This information also acts as input to expert analysis module for analysis of tentative/futuristic movement/action of the adversary.
- **Open domain information availability**: Typically it is not possible to plan sufficient density of sensors for a given disaster area, as it is unpredictable. The density and the position of sensors in the operational area cannot be elevated to a desired number from the perspective of spanning the area of operation. In this case the information ought to be pooled from various open domain sources. This category of information can be divided into various social media sites, mobile-based apps, international news channel, local news channel, etc. Since the affected area is within the country where media reports can reach and report the incident to their respective channels, it is deemed fit to leverage the news websites and other social media sources to harvest information. Availability of relevant information from open domain like social media $I_{soc,t}$, news channels $I_{news,t}$

and so on plays an important role in assisting the responders. While processing the information an appropriate weightage can be given to each information source and final information can be shared. For this purpose a suitable information aggregating, filtering and refinement tool along with a database is needed. This information augments the information availability with the decision makers and in turn to responders.

- **Expert analysis**: Analysis on the emerging situation at adversary side, for example, analysis of surveillance inputs, tapping and deciphering of the adversary communication, breaking the encryption used, identification and assessment of their resources and vulnerable points comes under expert analysis. This requirement needs dedicated tools which are specialised and aimed at the target. Since the paper is dealing with the disaster, the scope of the expert analysis is limited to the analysis of the evolution of the disaster, that too if it is a moving category type like flood with continuous inflow of water.

Implementation

In our solution we deployed a composition which satisfies the information needs of the first responders. An indicative deployment of our implementation consists of the Edge nodes, Forward Command Post and Command Post as given in the following diagram.

Command Post (CP)

Operation-wise the CP comprises computing elements responsible for display of the information in the area of interest and to collaborate and disseminate the operational data/information. The command post also has the capability to assist in planning, analysis of emerging situation and to provide directions and command to the teams in action. These are the nodes deployed at static location on robust network. In the context of our deployment we are using NUC (Next Unit of Computing) as the computing element at CP.

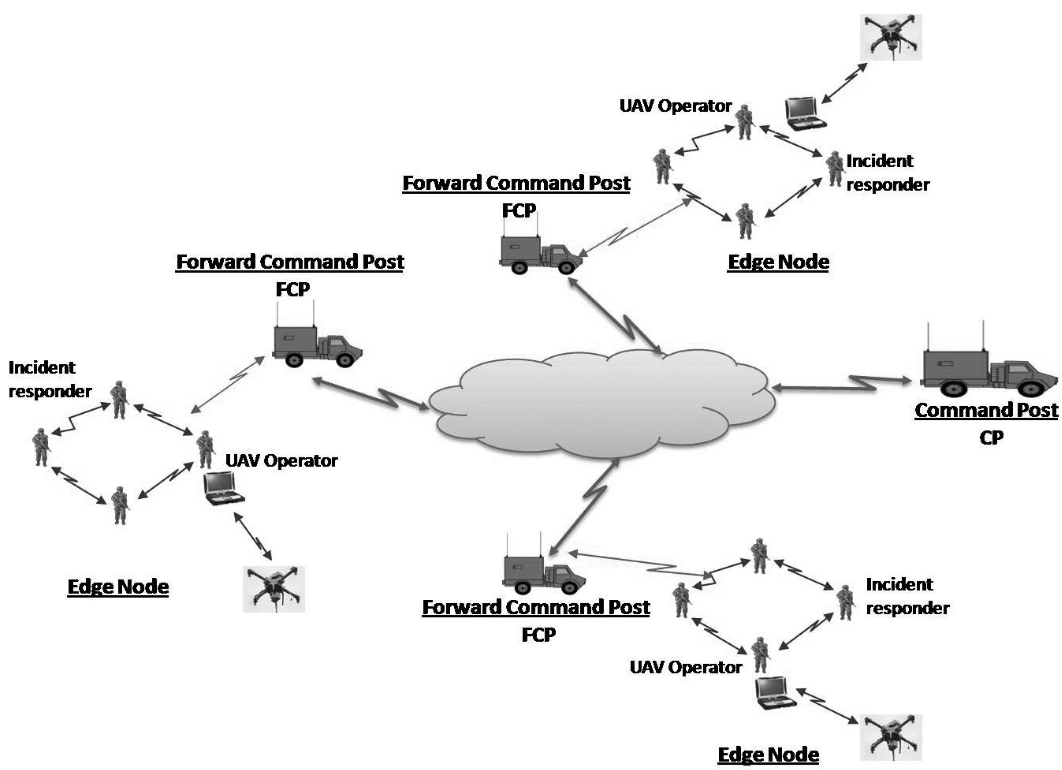

Figure 1: Indicative deployment of Command Post, Forward Command Post and Edge Node. At the edge nodes the incident responder who will be carrying a mobile device. The UAV operator will be controlling the UAV through the ground control station

Forward Command Post (FCP)

Operation-wise the FCP comprises computing elements responsible to collect and propagate the operational data/information. FCP is also responsible for planning, analysis of emerging situation to provide directions and command to the teams in action in the area of influence. These are nodes in mobility, deployed at operational locations. In the context of our deployment we are using NUC (Next Unit of Computing) as the computing element at CP.

Edge Node

These nodes largely interface with the data generating sensors used in the operations. These nodes are responsible to collect and propagate the operational data/information. Computing elements at this level consist of Size Weight and Power constrained platforms, which in our deployment are the Android mobile phones. At the edge nodes, the system can have two types of users, the incident responder who will be carrying a mobile device and the UAV operator who will be controlling the UAV through the ground control station.

Technology Realisation

Our solution consists of a composition of modern-day technologies and computing elements.

Technology Components

Geographical Information System (GIS) is used at the edge systems and the FCP/CP for visual display of overlays on maps depicting the situation pictures as well as the Common Operational Picture (COP). GIS along with positional sensors is used for Blue force tracking (BFT) of the responder team. Image and Video Processing is used for the processing of Images and propagating the same over the constrained network so as to enable reconstruction of images with even partially received data. Messaging infrastructure is implemented for collaboration between incidence responders and CP/FCP.

#	Technology Component Required	Technology Component Used in Realisation	Platform
1.	Geographical Information System - GIS component is required for visual display of overlays on maps that depicts the situation and generated Common Operational Picture	CAIR GIS Library - CAIR Developed GIS library	Linux
		OSMdroid Library - Open Source GIS library based Open Street Maps	Android
2.	Image and Video Processing - Required to transmit the captured images and reconstruct the image with partially received data with given resolution (low/high)	CAIR IVP Library - CAIR Developed library for image and video processing	Linux
		Android-based IVP Library - CAIR Developed library for image and video processing migrated to android platform	Android
3.	Database Management system - Database Management System is required for data persistence and to view the historic data	PostgreSQL - Open Source	Linux
		SQLite - Open Source	Android
4.	Instant Messaging – Messaging is required for propagation of message contents of type text, images, files and location information and collaboration between incidence responders and CP/FCP	Extensible Messaging and Presence Protocol (XMPP) - Open Source	Linux & Android

Hardware elements: The following is the hardware elements used in our deployment as the computing elements and sensor.

	Hardware Element
FCP/CP	NUC (Next Unit of Computing) from Intel
Processor	Intel Core i7–7567U Processor
RAM	16GB
Hard disk	1TB
Operating System	Fedora 28
Edge Nodes	Moto G [5S] Plus from Motorola
Processor	Qualcomm snapdragon 625 processor with 2.0GHz octa core CPU
RAM	4GB
Storage	64GB
Camera	13MP camera
Location	GPS,A-GPS
Operating System	Android 7.1.1.
Drone/Quad copter	NETRA V 2.1 UAV
Wi-Fi device	
Standard	802.11n
Max bandwidth	162.5 MB/s

Sample Workflow:

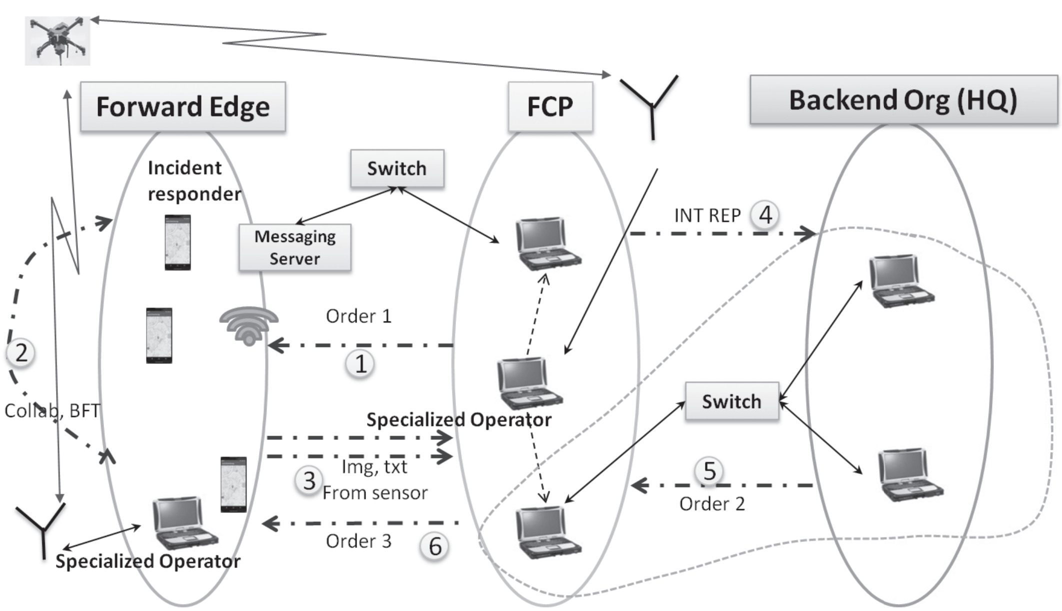

Figure 2: Sample workflow depicting flow of information across the incident responder at FCP and Edge nodes. One of the FCP node will be configured to harvest open source information from News Channel

- The workflow starts with the FCP issuing an order to the Forward Edge to start the Search Rescue and Evacuation operation. The order is issued as a text message/document format. The maximum size of the text message that can be sent in the system is approx 1MB.
- On receipt of the order, the incident responders at the Forward Edge start collaborating and co-ordinating among themselves through text/image chat and blue force tracking (BFT). The positional accuracy of the GPS receiver varies from 25 metres to 350 metres while indoors. While the incident responder is outdoors, the accuracy of the GPS receiver is as good as 4 metres.
  One of the incident responders is a specialised user, UAV operator, who operates the drone for capturing the situation picture.
- The situation picture is sent to the FCP by the incident responders as text/image messages. For an input image size of 3MB
  - Processing Delay (at Android Platform): 8850 ms approx
  - Chunk Size 100KB (Configurable)
  - Chunk Interval 500 ms (Configurable)
  - Reconstruction Time 4s (at FCP on NUC)

  Minimum number of chunks required to visualise the Image is 500KB (5 chunks). It takes approximately 3 ms to send 5 chunks over Wi-Fi network.
  i.e. 5*100*1000/(162.5*1024) = 3 ms (Approximately)

  There is also a reconstruction delay of approx 3834 ms at the FCP on receiving the image.
- The FCP also has the *Open Domain Information collection* and processing component installed on a separate system with connectivity to the internet. The information thus collected and processed will be leveraged for the generation of the intelligence report at FCP. The Intelligence report compiled at the FCP, based on the inputs received from the incident responders and drone feeds, is sent (image/text) to the Backend Organisation (HQ).
- Based on the Intelligence report, the back end organisation sends further orders (image/text) to the FCP on how to proceed with the operation.
- FCP generates further orders based on the higher HQ's directives and this order (image/text) is sent to the Forward Edge for further necessary action.

Conclusion

In our implementation it was assumed that conformal antennas, hastily formed network exist. BFT is realised using positional sensor in mobile device, GIS component and messaging component. Surveillance inputs in text/image format obtained using collaboration application. RSS feeds from News channel is relied upon to harvest open domain information. It was observed that our implementation meets the information needs of the incident responders for Search Rescue and Evacuation during disaster.

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Design and Fabrication of Mini Kinematic Legged Robot for Critical and Rescue Conditions

Danda Parthasarathy Reddy[a], Judewen Xavier S.[a], Kishore J.[a], Sundarasetty Venkatesh[a], R. Kaja Bantha Navas[b] and S. Prakash[a]

ABSTRACT: Now-a-days problems are more in rescue team and military forces for saving people in accidental situations like fire accidents, coal mines and building debris. Major problems in handling life-saving situations in unknown conditions are finding people and their location. By using Mini Kinematic Legged Robot with six legged camouflage, we can overcome the problems. A mini robot consists of six legs, Arduino board, motors, spy 360° camera, vacuum stick, rollers and battery. Robot works on the principle of camouflage which can hold the parts of body as per situations and it can move without legs using rollers placed under body. Robot structure is made up through 3D printing machine because low cost, less weight, etc. The material used for fabrication is PLA (Polylactic Acid). It is made up of renewable resource like corn starch, tapioca roots, etc., and it is degradable. Robot motion is controlled by Arduino-programmed motors for speed. The robot can walk on any surfaces with a stiff gait slowly.

KEYWORDS: mini robot, kinematic legged robot, critical and rescue robot

Introduction

According to the counterparts in nature, legged robots have the potential to negotiate rough terrain agilely. Some advanced legged robots have been designed to achieve this goal such as Big Dog, Little Dog, Spot and Rob Simian. Although the wheeled robots cannot cross the rugged topography as the legged robots, they can perform high-speed, smooth and energy-efficient locomotion on the flat ground inspired by the quadruped mammals in nature. Ever since, Defence Advanced Research Projects Agency (DARPA), an agency under the US Department of Defence, has been working to improve the quality of defence robots. It is now conducting a global competition to design robots that can perform dangerous rescue work after nuclear accidents, earthquakes and tsunamis. By using the mini kinematic robots, the desired places and locations that cannot be reached by human beings can be reached by this type of small robots for finding and helping and tackling emergency situations.

Manmade disasters occur in a smaller area for examples like terrorist bombing, serious accident, leak of dangerous substance, radioactive leak and so on occur in smaller areas. The area afflicted is the danger zone. The challenge is not here and to look at the entire external extent of the damage, but rather to see the interior of the rubble, location and condition of the survivors and state any potential danger. Visibility is difficult due to no lighting and grey dust. Recognising the victims, potential danger and accurate mapping are more important here.

The survivors in the hot zone are often in immediate need of medical treatment or evacuation within 48

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hours. Therefore, the challenge is to be able to search through all possible obstacles found in the building collapses and reach the victims as fast as possible. UGVs are recommended for these types of disasters and it is strongly recommended that the UGVs should be water proofed or highly water resistant because there is usually some water present that comes from damaged sprinkler and sewage systems. These robots should be man-packable, as small as possible for driving through the rubble. Rescuers can supposedly interact with the victims when found, so there is no need for larger-size robots in human–robot interaction.

Prior Art

Xochitl Yamile Sandoval Castro et al. (2013) explain about a three revolute (3R) chain that has been chosen for each limb in order to mimic the leg structure of an insect. The rotation matrix with unitary vectors and the Denavit-Hartenberg (D-H) conventions are used to find the pose of the thorax. The problem of inverse position is solved by geometrical analysis. The direct and inverse infinitesimal kinematics are obtained by the reciprocal screw theory. It is considering a suction cup attached to each leg and modelling it as a UP linkage. A numerical example of the thorax pose was made by solving the equations obtained from the direct position analysis. The equations of the inverse position analysis were solved to obtain the angles of the joints. Finally, the velocity values of the thorax obtained from the infinitesimal kinematics were validated by simulating the movements of Hex-Piderix using specialised software.

Lingfeng Sang et al. (2014) explain about the high carrying capacity of the human-carrying walking chair robot. In this work, 2-UPS plus UP parallel mechanism is selected with the leg mechanism. First, design of the whole mechanism is described and degrees of freedom of the leg mechanism are analysed. Second, the forward position, inverse position and velocity of leg mechanism are studied. Third, based on the kinematics analysis and the structural constraints, the reachable workspace of 2-UPS plus UP parallel mechanism is solved and then the optimal motion workspace is searched in the reachable workspace by choosing the condition number as the evaluation index. Fourth, according to the theory analysis of the parallel leg mechanism, the control system is designed as per the compound position control strategy. Finally, the optimal motion workspace is verified by using circular track with the radius 100 mm. The experiment results show that the leg mechanism moves smoothly and does not tremble obviously. These theories of analysis and experiment research of the single leg mechanism provide a theoretical foundation for the control of the quadruped human-carrying walking chair robot.

Zhong Wei et al. (2017) explain about the design and implementations of a novel leg-wheel robot called Transleg. Transleg adopts the wire as the transmission mechanism to simplify the structure and reduce the weight. The wire-driven method has never been used in the leg-wheel robots, so it distinguishes Transleg from the existing leg-wheel robots. Transleg possesses four transformable leg-wheel mechanisms, each of which has two active degrees of freedom in the legged mode and one in the wheeled mode. In this case, two actuators driving each leg-wheel mechanism are mounted on the body, so the weight of the leg-wheel mechanism is reduced as far as possible, which contributes to improve the stability of the legged locomotion. Inspired by the quadruped mammals, a compliant spine mechanism is designed for Transleg. The spine mechanism is also actuated by two actuators to bend in the yaw and pitch directions. It is beneficial to the turning motion in the legged and wheeled modes and the bounding gait in the legged mode. The experiments on the motions in the legged and wheeled modes, the switch between the two modes and the spine motions are conducted. The experimental results are demonstrated and validated by the prototype of Transleg.

Methodology

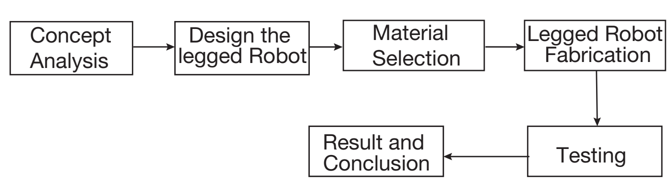


Figure 1: Methodology for the Mini Kinematic Legged Robot

Figure 1 represents the methodology for the Mini Kinematic Legged Robot.

Design and Fabrication of the Robot

The basic components of the robot are:

- Moving parts that perform an action like arms and legs
- An actuator to power moving parts and sensors to detect environment
- A control system that makes decisions and overlooks the overall operation

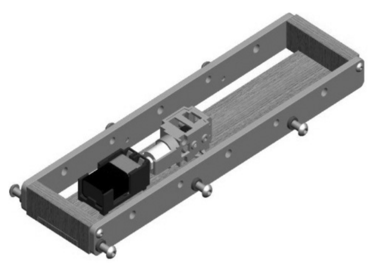
The main components for the Mini Kinematic Legged Robot are as shown in Figure 2. Assembled view for the Mini Kinematic Legged Robot is as shown in Figure 3. In leg with gear assembly has 10 gears. In this, we used five set of gears used in one side and remaining for another side. In that one gear is unique (55M1A model gear) and the rest of the four gears are of the same model.

- TG G4 36 HEX DRIVE (Front first yellow coloured gear)
- TG G2 34 12 CROWN (Beveled yellow coloured gear)
- TG G1 36 12 (blue colour gears)

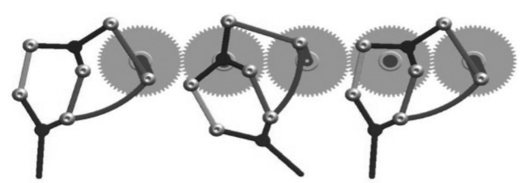
- TG G1 36 12 (blue colour gears)

The gears are made up of plastic. They have in total four gears. In this, one is bevel gear and remaining gears are spur gears. Small gear is connected to the motor shaft. The small gear is connected to the bevel gear and the whole system is interconnected. The front main shaft is connected to the legs of the robot, which is worked by the gears.

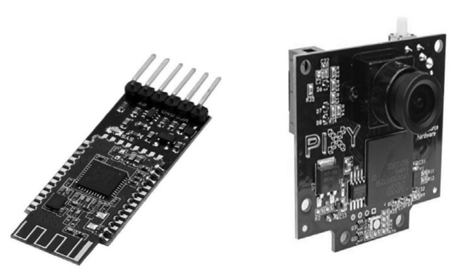
The main design steps are designed in solid works software and the part file converted into the STL file for 3D printing. In this paper the six-legged mechanisms of joints are fabricated by 3D printing. The internal gear mechanism is with beveled mechanism. The legs are interconnected with the help of small plastic gears (562A or 50102A). The frame of the robot is made up of plywood. The outer body is made up of plastic with the help of PVC material. The smart object camera is installed at the front of the robot. The motor and smart camera is connected to the 9 volt battery and Bluetooth Arduino is also connected to the battery. Robot works on the principle of camouflage which can hold the parts of body as per situations and it can move without legs using rollers placed under body.



Frame with Motor, Gearbox and Battery

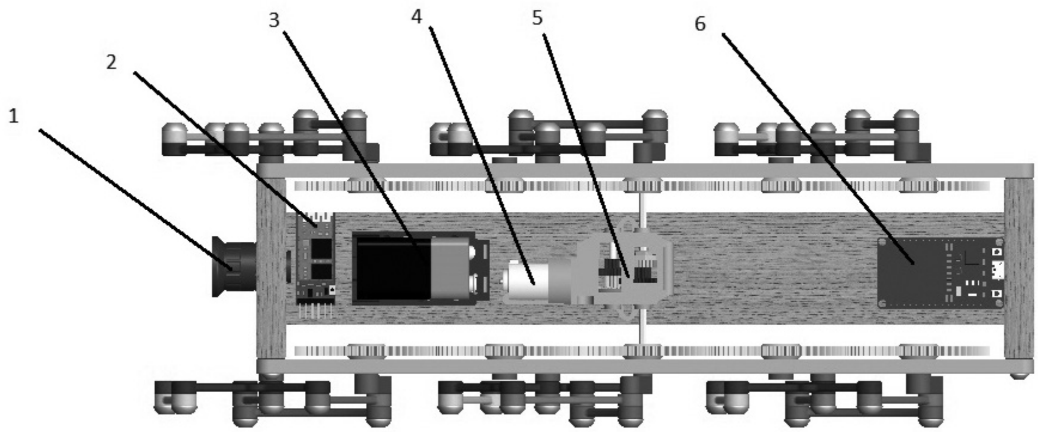


Leg with Gear Assembly



Bluetooth and Smart Camera Objective Tracker

Figure 2: Components for the Mini Kinematic Legged Robot



1 – Camera; 2 – Camera Controller; 3 – Battery; 4 – Motor; 5 – Gear Box; 6 – Bluetooth Controller

Figure 3: Assembled view of the Mini Kinematic Legged Robot

Robot structure is made up through 3D printing machine because of low cost and less weight. Robot motion is controlled by Arduino-programmed motors for speed, and a camera which is held on top is used for surveillance. Isometric and front view of Mini Kinematic Legged Robot is shown in Figure 4 and Figure 5. This robot consists of 360 camera with 150 mm x 130 mm x 80 mm dimension. Each of the two sets consisting of three – 4 bar linkages on either side of the common rod must be powered in the same direction for the whole machine to move in one direction. Links are connected by the gears and the gears are powered by D.C motor. When power is given, it drives the gears connected to the shaft, as gears are connected to the small link of the linkages. The linkages can move in front and back direction. After 3D printing the core process finishing is to be done. The bottom body is made up of wooden plywood and side is made up of aluminium (3mm thickness). So the frame is in light weight mode, side walls are strong enough to hold because of aluminium material (7075).

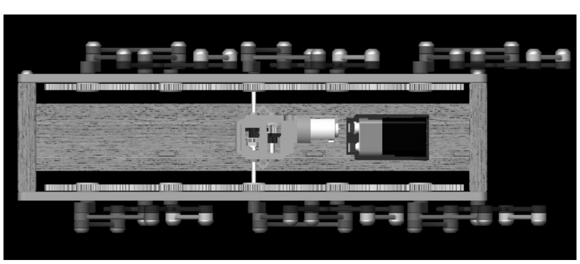


Figure 4: Top view of Mini Kinematic Legged Robot for critical and rescue conditions

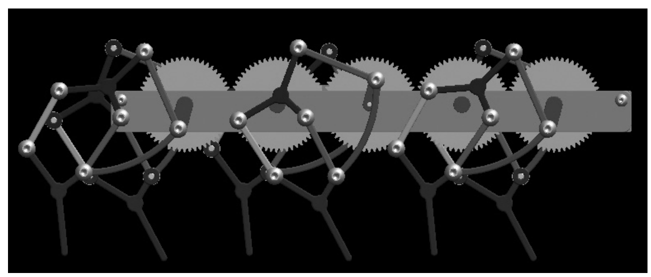


Figure 5: Side view of Mini Kinematic Legged Robot for critical and rescue conditions

Conclusion

In this paper, the robot is designed in such a way to survive in any condition. It is controlled manually within Bluetooth signal area. The robot has a smart camera and Bluetooth device. This robot can move in water also. This is controlled by the remote conditionally in a particular distance for 10 m. The robot looks like a solid tube but when it is working the robot looks like a moving object. This robot can move in hard pit holes and places that humans cannot go to.

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Search, Rescue and Evacuation: Psychology, Criminology and Victimology Perspectives

Rikza Imtiyaz[a]

ABSTRACT: A natural disaster takes place because of any natural hazard. The world has seen some great natural disasters over time and the damage has been a lot. There had been many major disasters in the world that have shattered many cities and countries. To cope up with disasters we need efficient response mechanism. Response includes preparedness, pre-disaster planning, resource identification and resource mapping; GPRS is used in resource mapping, DM Act 2005 envisages pre-disaster and post-disaster planning. Search, rescue and evacuation are inextricably interrelated and are subsets of disaster response and emergency management. First responders such as police, community, civic agencies and armed forces based on typology of disaster too undertake search, rescue and evacuation process. Air lifting evacuees from difficult/stranded and trapped localities are shifted to pre-designated shelters guarded by security; special care should be taken in these shelters as several cases of molestation, rapes, assaults as well as robbery are reported. Disaster-induced migration causes children and young girls to be uprooted from parents and thus more susceptible to such heinous crimes. Other easy prey are single women who suffer secondary and tertiary victimisation.

KEYWORDS: disaster, early warning systems, mitigation, migration, secondary victimisation

Introduction

Human vulnerability to disasters is an age-old phenomenon. Every human civilisation has suffered through the consequences of disasters. Human vulnerability to disasters has increased with rapid industrialisation and urbanisation and overall changes in various dimensions of society. Every society has been coping with this problem through internal as well as external resources. Theoretically speaking, a close look at the typology of disasters shows that every particular disaster has a particular context in terms of its origin and the probable target community which is likely to be affected. To be precise, the typology reflects the vulnerability of a particular group or community to the disaster. For example, a coastal area is more prone to cyclonic disasters than a non-coastal region. It logically leads to the assumption that every single disaster is a unique experience in itself and requires separate preparedness and mitigation plans. A close look at the literature on disasters reflects that the maximum focus has been on the natural disasters, mainly because the effects of a natural disaster are horrifying, traumatic and shatter the critical infrastructure adversely.

While talking about natural disasters, it is important to note that the prevention of a natural disaster like cyclone, earthquake, forest fire, etc. is not possible. A prior signal of such natural disasters can only minimise the extent of damage to lives and property and livelihood. Prior signalling will help the various agencies in reducing the risks and damages with better preparedness and also in mobilising action

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for resources. Keeping in view the intensity, gravity and damage, the focus is on natural disasters by researchers, practitioners and activists. The preparedness and mitigation plan for a human-made disaster has greater chances of reducing the casualties and devastations as compared to natural disasters. Certain human-made disasters can be effectively prevented with the help of healthy ethos, values and better planning. While the world as a whole is occasionally exposed to natural disasters, the occurrences of human-made disasters are very frequent. Certain human-made disasters continuously haunt us today. For example, today we are under the constant fear of a nuclear war. Indian citizens, particularly on the border, are under the fear of attack by a neighbouring country all the time. Any disaster arising out of war can be devastating for any nation. The fear of such disasters can be reduced and eliminated with a healthy bilateral and diplomatic relationship. Unplanned, unstructured growth of cities, the increasing rate of migration from rural to urban areas, gross inequalities, uneven economic development, pressure on existing resources for survival have on and off led to disasters which do fall under the category of human-made disasters.

Although we can greatly minimise the number of casualties by taking several actions before the disaster hits a particular area. Most of the lives can be saved by proper search, rescue and evacuation of the disaster hit area. Thus utmost care needs to be taken of these three parameters in order to save human lives.

Hazard

A hazard is a potentially damaging physical element or phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation (UNISDR, 2002). It, however, no more remains linked to the geophysical conditions but extends to the potentials created by manmade activities, which pose and create future events leading to the disaster (UNISDR, 2002, b). If a fidgeting boat in ocean is able to ride out to the shore, it is a potential hazard, not a disaster. If earth shakes, people are able to cope with, no one gets injured no fatalities result, then it is a hazard, not a disaster.

Disaster

Disaster has no definite definition, it is the impact of potential hazard. The disaster is a general event or series of events which give rise to casualties and/or damage or loss of property, infrastructure, essential services or means of livelihood, human, material, economic or environmental losses on a scale that is beyond the normal coping capacity of the affected communities. A disaster is an entity without the ability to think, without intent, and without morals. It's a kind of relationship with the victim that exists only by virtue of its proximity to the victim. With disaster victims the psychosocial dynamics involves considering the force that damages, injures, and kills as a manifestation of nature (Dussich 2012).

The ecological setting for disasters can be outdoor or indoor, in a forest or in a city, in sea or on a mountain, in the air or on the ground, and with people, or without people. Thus, disasters can cause extensive damage, injury or death to human beings and their property, or can cause damage to nature, but not to humans (Dussich 2012). Of course, when humans are present in vulnerable areas, there is opportunity for protective measures to be taken to reduce human exposure to disaster and enhance their resilience (definition of Disaster as defined in DM Act 2005). Police as a discipled and as a legal institution since ages is trained and tasked to deal with emergencies and disasters in broader framework of their duty to ensure public safety. Disaster law needs to recognise the role of police in tackling disaster. Traditionally, police have always been part of disaster response but Disaster Management Act 2005 does not specifically define the role of police as one of first responders so as to give their role a legal sanctity. Likewise, state police manual also needs to incorporate the role of police in disaster management to give statutory recognition. Certain states like Gujarat, Odisha, Kerala, Delhi and few others have recognised the role of police as mandated duty of the police under their state laws. The Ministry of Home Affairs may issue guidelines to other states so as to give the legal sanctity of the duty of the police. Besides, Bureau of Police Research and Development (BPR&D) has also integrated the role of police in disaster management in model police act of 2006 (updated in 2015) and is also under active consideration of the Ministry of Home Affairs.

Response

Response processes begin as soon as it becomes apparent that a hazardous event has come up and lasts until the emergency is declared over. It is a package of activities by first responders (like EMS) executed after the impact of a disaster so as to review the needs which include food, water and shelters, minimise the casualties and agony, lessen the extent of damage to infrastructure and environment caused by the disaster, ingress the path to recovery and rehabilitation. The actions are taken during and after the disaster. Response is the most complex function of emergency management as it is mostly conducted at the time of high stress, time-constrained environment and with limited resources. Delay in response activity can directly lead to damage and tragedy, thus response is a sensitive stage.

Response consists of various stages that ensure minimisation of loss and tragedy. It not only includes activities that are immediate such as first-aid, search and rescue and provision of shelter but also includes system and procedures that are developed to coordinate and support such activities. Response also includes revival of several critical infrastructures such as transportation routes, restoring communication and electricity and ensuring clean food and water supply. Response speeds up the return of a normally functioning society. The quality of response depends upon good information and coordination between first responders, victims and participants, the timing and order of events, action and processes involved. The measures are taken with a view to mitigate or reduce the effect of disaster that has taken place or is happening currently in order to avert further agony, financial loss or both. The primary focus of response, relief or emergency encompasses forewarning, action for evacuation and shifting the affected people at protected shelters, administering first-aid, establishing protected rehabilitation centres, control room, etc.

Response can be divided into two stages:

Pre-disaster Response

The response begins as soon as an emergency situation is recognised by the officials and order the authority to commence the response effort. Each disaster has specific indicators and prior to the disaster the authorities must have established means of detecting those indicators. While hazards such as wildfires, droughts and cyclones may provide significant lead time, other hazards such as earthquakes can strike with almost no advanced notice, that is, recognition does not occur until the actual event begins. Advancement in technology continuously increases the chance of early warning and help in mitigating disasters. Along with technology, a nation must know how to act to the warnings provided by technology. For instance, during the Tsunamis of 2004 and 2009, the US Government provided early warning to vulnerable countries of Asia and Africa which were in the way of Tsunami but most of the countries lacked the procedure to quickly and effectively warn their population and initiate evacuation to higher grounds.

If recognition occurs in advance about the disaster then the response depends on the disaster characteristics, the systems available to emergency managers, and the ability to communicate with a ready profile.

Post-disaster Response

Once a hazard begins and is recognised by officials, response efforts may commence in earnest.

The affected are the first responders and the first to know that a hazard has struck and a disaster is in progress, especially with rapid onset disasters such as flash floods and landslides. Agencies at regional, national and international level become aware of the disaster by firsthand responders. Social media too plays an important role in making the agencies aware of disaster.

Once disaster response begins, the first priority is saving lives. This includes search and rescue, first-aid and evacuation. The search and rescue can continue for days or weeks, depending on the disaster's severity. Along with these functions, certain additional functions include:

- Water and shelter
- Disaster assessment
- Shelter
- Sanitation
- Security
- Social services
- Resumption of critical infrastructure
- Volunteer management

Search and Rescue

Search and Rescue (SAR) is an essential component of response during the occurrence of a potential hazard or catastrophe resulting into disaster response. It is also a subset of mitigation; first priority in case of disasters like floods, cyclones, tsunami, etc. is to save life. Disasters result in victims being trapped under collapsed buildings in case of earthquakes or likely to be sunken or washed away in flash floods, storms, dam failures or technological accidents which require organised search by trained professionals called Emergency Management Services (EMS), like police, fire-fighters, and paramedics besides specialised agencies like armed forces and National Disaster Response Force (NDRF) based on nature, severity and typology of disasters and engineers who are well equipped. SAR involves three distinct but interrelated actions like locating victims, extracting (rescuing) victims from whatever conditions or situations and providing medical first-aid to stabilise them till they are transported to the nearest paramedics. It has been universally found that three-fourth rescued are those who have been rescued in six hours after disaster happens. Survival rate is lesser after that golden period. The equipment of rescuer agencies must possess advanced equipment and should be trained since untrained rescue agencies with inadequate equipment often put themselves in peril. In India NDRF, armed forces if requisitioned, are well-trained and equipped. In successful SAR, inter-agency coordination with robust interoperable communication network is very important, 9/11 in the USA and even hurricanes in New Orleans in 2005, Bhuj earth quake in 2001 in Gujarat, Kosi floods in Bihar 2008, SAR was affected due to lack of effective inter-agency coordination and communication. Presently NDRF and armed forces and a few states have raised and trained State Disaster Response Force (SDRF) after DM Act 2005. Odisha has raised Odisha Emergency Response Force (ODERF), are too well-trained except Chemical, Biological, Radiological, Nuclear (CBRN) and well equipped with multilevel communication equipment, broadband radio, satellite phones, V-SAT, special clothing which increase the ability to locate and save victims. First-aid treatment in golden hours saves lives. Availability of well-equipped hospitals and rapid transportation too matter to quickly shift seriously injured rescued victims.

Evacuation

Evacuation may be necessitated before, during and after a disaster occurs. After early warning notification which is now much advanced in India, Indian Meteorology Department (IMD), ISRO, weather satellites, mobiles, wireless, broadband radio, besides traditional media, social media like Twitter, Facebook and Instagram facilitate early warning about potential hazards.

At times it is necessary to move the population away from the hazard as it can reduce the effect of many disasters whether natural or human-induced. It is often observed that some people despite early warning refuse to move, it happened in the recent Kashmir floods in 2014 despite evacuation order communicated by all sources some people were not ready to move and later they suffered. Local administrations facilitate transportation like rail, boats, vehicles escorted by police in evacuation. Often some people may not be willing to move due to other reasons like poverty, disability, fear of uncertainty or inability to understand the gravity of the situation. Once the situation worsens the same people start leaving on their own; legal framework too defines if evacuation is to be mandated by executive order, in case of large-scale evacuations, civic agencies assisted by local police requisition large numbers of vehicles, boats, buses and shift people to a pre-designated shelter.

In disaster-induced evacuation poor and socially disadvantaged people often get ignored by civic administration and influential people get better support in terms of evacuation and relief distribution. Globally people suffer on the basis of ethnicity, caste and often religion.

In modern days social media also plays a big role. Even in villages quite a few members in a family remain active on Facebook, Instagram, Twitter and get to know the gravity of situation and inform their neighbourhood too to move away to safe places; few move away on their own to friends, relatives; some rich people can even rent out a place to live in but poor can't afford and have no option but move to shelters provided by the local administration. In disaster-induced migration, children, aged, women, girls and disabled are more vulnerable and suffer the most. Disaster-induced migrations often lead to family members being separated. Elderly and single people are at risk if they have no one to check on them. The police can set up search teams and put together systems where loved ones can check on one another. They can set up command centres where the victims and family may be reunited. They work with other EMS to list the various medical facilities used for treating sick or injured people.

There are instances of secondary and even tertiary victimisation once evacuated; people mostly young girls and women often suffer physical assault. If new shelters are not properly guarded thefts can't be ruled out; elderly parents if separated or on losing their child in floods suffer severe depression, need treatment by psychiatrists, psychologists are required for counselling; food, water, medicines and behaviour of unknown people at new places may lead to secondary victimisation of victims already traumatised emotionally by disasters.

Once the people are evacuated, they need shelters to be put into. Thus shelter is provided to the displaced population where they are given safety, clean food and water. Shelter is further discussed below.

Shelter

After the basic need of first-aid, food and water is fulfilled, the first responders affected by the disaster need to be shifted to emergency shelters. Without shelters, the survivors, victims, injured, traumatised old people are likely to suffer from secondary victimisation and also the stress of being homeless. In catastrophic events such as earthquakes, floods and hurricanes, the number of displaced population may be in hundreds and thousands. Thus it is the task of disaster managers to accommodate every single affected victim. The most appropriate places of shelter during such conditions are the public and private facilities within the community which are not affected by the disaster such as schools, auditoriums, stadiums, warehouses, airport hangers, etc. For short-term stay camps and village tents are set up for people which still need to be moved later due to their longer stay. The duration of stay is assessed by proper investigation of the post-disaster phase.

Various shelter options and the periods for which they are appropriate include:

- Hosting by family and friends and others within community
- Placement in a rental house or hotel or motel
- Placement in public or private structures such as schools, halls, stadiums, etc.
- Placement in organised camps and tents or trails, or other light housing options

Disaster managers while putting up and choosing appropriate shelters for the disaster-induced migrated individuals should keep certain mandatory parameters in mind so that the shelter does not breed secondary and tertiary victimisation of people. These parameters are discussed briefly below:

- **Access to Water:** The water supply should be available all year round for both drinking and usage purposes.
- **Space per Person:** The place should accommodate only that number of people which can be accommodated in it. Every person should have a safe and comfortable place.
- **Accessibility of the Camp:** The logistics need to be provided to the camp site every now and then, thus the camp site should be accessible by buses, trucks and helicopters as well.
- **Environmental Consideration:** The environment should be resistant to environmental crisis such as outbreak of diseases due to flies and rodents.

- **Land-Cover:** Certain soil conditions are unsuitable for human beings to survive. For example during floods, soil that absorb maximum moisture are important than those that don't.
- **Land Rights:** Land for setting up the shelters is important thus it should be free from any sort of legal problems and also shouldn't be near any sort of environment degrading area such as mining.

Thus all these parameters make any shelter an appropriate residing area for traumatised victims.

Command, Control and Co-ordination

Command and Control (C2) is a network to generate an effective response necessary to meet the constraint of the hour. Disaster is always accompanied with a lot of confusion and stress with gives rise to a chaotic situation all over the struck area making it difficult for the people to cope up with the situation. Thus command is then taken in hand, either by a group of locals or by the authorities in order to stabilise the situation. The so-called authority of the spot that reaches first to the responders (usually the local police) controls the chaos which lessens the vulnerability of further losses. The command and control further results in the co-ordinated working of various agencies which speeds up the rescue and rehabilitation of the victims and brings back normalcy. Also, command and control of police in temporary shelters of people proves to be an asset as discipline and safety is strictly maintained.

Secondary and Tertiary Victimisation

In disaster-induced evacuation and/or migration evacuation is notified and at the same time many move out having heard about impending catastrophe to their friends, near and dear ones at relatively safer places and quite a lot are shifted by civil authorities to pre-designated shelters. Often these victims of disaster-induced evacuees are lodged in school buildings, panchayat ghars and other shelters, often due to insanitation diseases are born and due to lack of resources, fewer toilets and a big queue and at times in times of floods and cyclones.

Sewage tanks and pipelines splash out in town and sub-urban areas leading to widespread infections. Besides family disintegration such as wife losing husband and husband losing wife, children losing parents and so on affects mental status of the survivor that leads to second victimisation. And there are instances of young women and girls being subject to molestation, physical assaults are instances of tertiary victimisation. In Syrian crises ISIS hit population migrated to neighbouring countries with great hardships, if local administration and local people receive them well, assuage their injured feelings, traumatised disaster victims gradually come back to their normal behaviour if not they become mental patients and require the help of psychiatrists and psychological counselling. Likewise, Rohingyas forced due to persecution by the Buddhist regime in Burma travelled thousands of miles to countries like Bangladesh, India, etc. and if the local government, civic society, civic agencies and local people are not receptive they suffer secondary and tertiary victimisation.

Conclusion

Response is the most important and visible function of disaster management. The response precedes preparedness, pre-disaster resource mapping in both government and non-government resources, and during and after till recovery/restoration and reconstruction phases. Recovery phase lasts longer, needs generated by disasters are very complex and are highly dependent on preparedness, resources, type of disaster occurred, etc. However, for the poor nations of the world, response is not carried out properly and is often merged with taking care of causative measures. These nations do not have the resources as well as communication networks to quickly respond to warnings issued earlier. Response thus is the ability of the responding agencies to carry out this function, which most often determines how severely the affected areas are impacted and how quickly they can recover. In India besides armed forces, local police, community and civil defence NGOs, as per Disaster Management Act 2005 specialised forces such as National Disaster Response Force (NDRF) and National Security Guard (NSG) have been created (EMS). Therefore, despite community and local police, emergency management forces, fire- fighters, paramedics who reach at site of disaster and quickly undertake rescue and search and evacuation, armed forces and specialised forces such as NDRF, and NSG in case of man made disasters such as terrorist attacks do swing into action to protect people, livelihood, aquatic life; even coast guard, coastal police and naval forces play important roles with precision.

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Optimisation of First Response Time in Fire Rescue Operations

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ABSTRACT: For fire rescue operations, response time is widely regarded as the most crucial element in minimising the scale of the catastrophe. It is defined as the time taken by the first vehicle to arrive at site of incident after being informed about the accident. Reducing the response time can translate into reduction in number of deaths and casualty and thus could be used as an indicator for quality of the rescue service. Since response time depends on traffic conditions, it is necessary to include real-time traffic situation in the positioning of fire engines. But so far, studies have incorporated real-time traffic situations only in dispatching and routing decisions and thereby ignoring the initial position of the fire engines in optimisation.

In this paper, a strategy of positioning the fire engines is introduced such that the first response time is minimal. Real-time traffic information is also used in the positioning of the fire engines. Application of the strategy is discussed through a case study (Manchester City, UK). Response time per incident is reduced by 30.54 per cent with the existing number of fire engines. On the other hand, number of fire engines can be reduced from seven to four to achieve the same value of first response time. Optimal configuration of four engines could yield response time standard of the existing setup of seven stations. Sensitivity of the optimisation with respect to traffic situation is discussed. Further, sensitivity of the response time with respect to an additional fire engine is investigated.

KEYWORDS: first response time, fire engines, facility location, p-median optimisation, real-time traffic

Introduction and State-of-the-Art Literature Review

From Great Fire of Rome to Makati Fire of Manila, fire accidents continue to haunt urban settlements throughout the world. Metropolitan areas of developing countries are even more vulnerable because of higher organic settlements, illiteracy and prevalent poverty. Such immense losses to property and lives can be minimised if the fire engines reach early at the accident scene. The first response time can be improved by placing the fire engines at strategic locations. Location of fire engines and other emergency vehicles such as ambulances have been formulated as: (i) covering problems to maximise population covered/served by the vehicles; (ii) p-median/p-centre problems to minimise the travel time or distance travelled by vehicle to reach the incident location; (iii) probabilistic problems to consider busyness of vehicles; and (iv) simulation problems to deal with the working of the entire system including delays incurred, workload of staff and availability of vehicles. All these studies optimise the location of the base station of the emergency vehicles assuming that the vehicle would return to the base location after responding to an emergency call.

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But, setting up a permanent base station involves land acquisition, construction and periodic maintenance thereby making it highly expensive. Moreover, a few years after establishing the optimal permanent stations, the system will cease to be the most efficient configuration due to incremental changes such as urban development, change in population and ageing of equipment. This implies the optimal location of the permanent stations for the emergency vehicles is temporally dynamic. Thus, there is a need to change the location of fire engines (i.e. where they are stationed) but without constructing new stations. Kolesar and Walker proposed dynamic relocation of fire engines but only when some of the fire engines are dispatched to incident location. Moreover, fire engines could move only between already established permanent fire stations, which may not be a strategic location to achieve better response time.

Response time is widely regarded as the most crucial element in minimising the scale of the catastrophe. It is defined as the time taken by the vehicle to arrive at site of incident after being dispatched. Reducing the response time can translate into reduction in number of deaths and casualty and thus could be used as an indicator for quality of the rescue service. Since response time changes with traffic conditions, it is necessary to include real-time traffic situation in siting of fire engines. But so far, studies have incorporated real-time traffic situations only in dispatching and routing decisions and not to decide the initial position of the vehicle itself.

Methodology for Optimisation

For applying the optimisation on position of fire engines in a city, the entire area could be divided into smaller zones and allocated a point each. Any past incident in the zone could be assigned to that point. Such zones could also cover all the areas where a fire engine could be placed. So the same points could be assigned fire engines as well. Therefore, every point in the area will have two attributes – number of fire incidents in the past and the binary value indicating the presence (value = 1) or the absence (value = 0) of an engine.

This paper proposes the methodology to apply this concept of optimal positioning of fire engines to an urban area with multiple demand points (areas vulnerable to fire hazard) and quickly changing traveltime values due to highly dynamic traffic conditions so as to minimise first response time in fire rescue operations. The framework of this methodology is as shown in Figure 1.

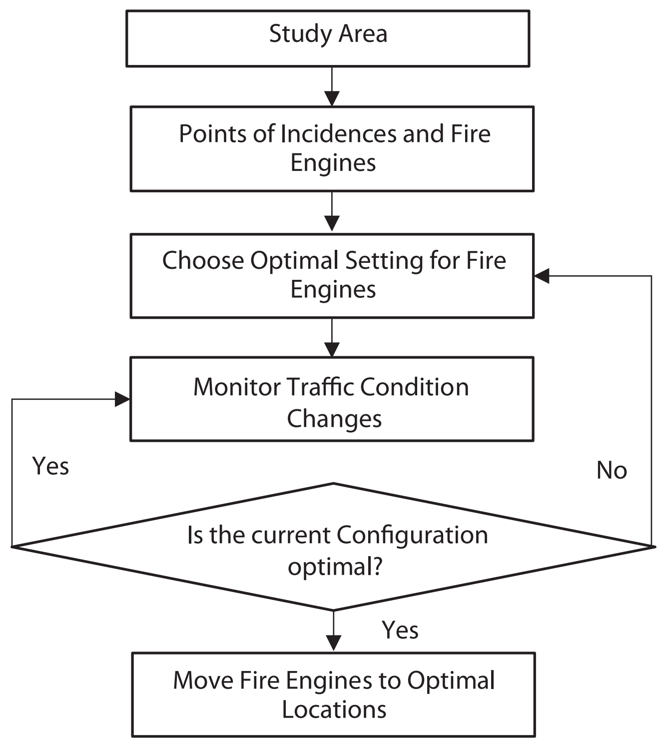

Figure 1: Methodology for optimal positioning of fire engines

Mathematical Formulation

In this paper, problem is formulated as a p-median problem to locate the fire engines such that the *weighted time* (which is directly proportional to response time) to reach the incident location is minimised.

The mathematical description is as follows:

Parameters: incidents (i) = Total number of fire incidents at point i

travel time (j, i) = Time taken to travel from j to i

x (i, j) = 1 if fire engine at point j is sent to incident at i
0 otherwise

y (j) = 1 if fire engine is located at point j
= 0 otherwise

$\text{engines}_{\text{total}}$ = total number of fire engines available

Objective:

$$\min \sum_{i}^{n} \sum_{j}^{n} \text{incidents}(i) * \text{travel time}(j,i) * \times (i,j) \qquad [1]$$

Subject to:

$$\sum_{j}^{n} x(i,j) = 1 \text{ for all } i = 1, 2 \ldots.. n \qquad [2]$$

$$\sum_{j}^{n} y(j) = \text{engines}_{\text{total}} \qquad [3]$$

$$x(i,j) <= y(j) \text{ for all } i, j = 1, 2 \ldots. n \qquad [4]$$

Equation [1] minimises the total weighted travel time by all the fire engines while tackling incidents. Constraint [2] ensures that number of fire engines used shall not exceed the number of available fire engines. Equation [3] constrains the travel time to be positive. Equation [4] ensures the binary constraint.

Case Study

There are three steps to optimise the position of fire engines. The first step is to find the number and location of fire incidents in the past and assign it to corresponding points of the entire study area. These points form O-D pairs (origin destination) for which travel time is extracted in the second step through Google Maps API using ArcGIS based Python script. The final step of our methodology is to programme the optimisation logic for given O-D pairs and solve it using CPLEX solver available online on NEOS server. Methodology is explained in Figure 2 and the detailed description of each step is as follows.

Step 1: Finding Number of Past Incidents for all the Points in the Study Area

The study area is chosen as Manchester City, UK. All the fire incidents in the past with their exact time and location are available at the Greater Manchester Data website – DataGM. Fire incidents' data is extracted for three consecutive years; 2010–11, 2011–12 and 2012–13. It is tabulated in Table 1. The total number of incidents comes out to be 25,044.

Details about fire stations such as their position and their appliances were readily available on the official website of Greater Manchester Fire and Rescue Service. In the city of Manchester, there are seven fire stations – Moss Side, Withington, Wythenshawe, Gorton, Philips Park, Blackley and Manchester Central each with at least one water ladder. For this case study, water ladders are used synonymously as fire engines.

The city of Manchester is divided into 31 wards. For simplicity, centroid of each ward is taken as a point of incident. If a fire station falls in a ward, a fire engine is allocated to the centroid of that ward. Existing positions of all the fire stations are depicted in Figure 3. All the points are candidate origins and candidate destinations for the fire engines. Thus, these points form an O-D matrix for which travel time is extracted in second step.

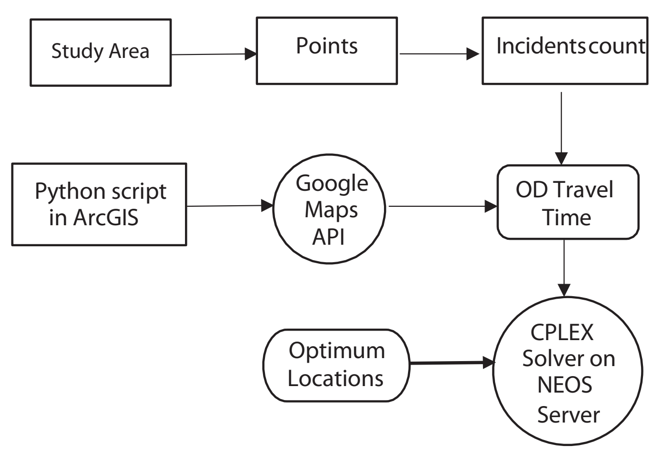

Figure 2: Methodology adopted in optimal positioning of fire engines in Manchester City

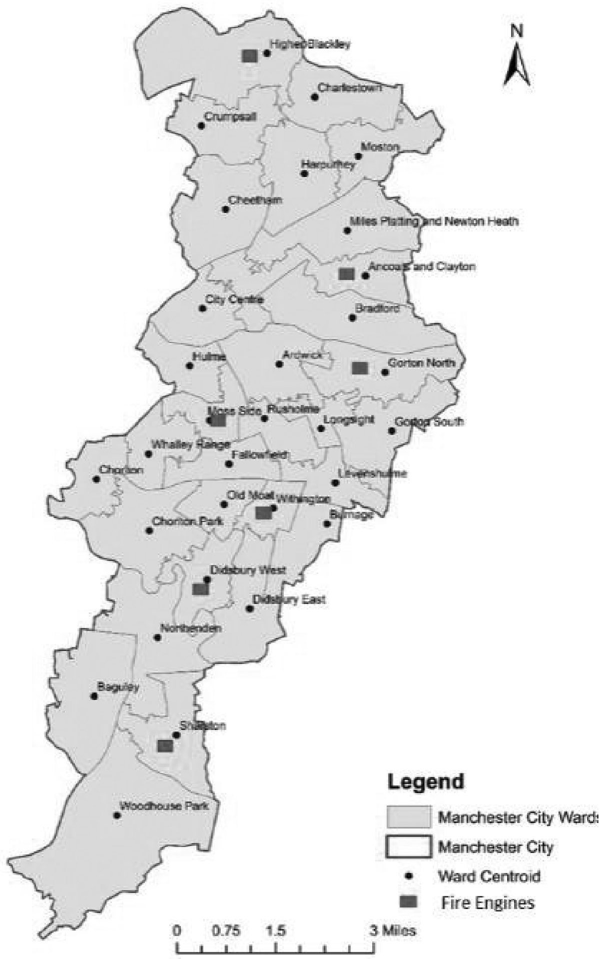

Figure 3: Wards of the Manchester City with existing setup of fire engines

Step 2: Computing Travel Time for the given O-D Matrix

Wang and Xu suggested an automated method to extract travel time between O-D pairs as described in Figure 4. A python script based Arc toolbox is created in ArcGIS 10.2.2 which requires polygon *shapefile* of the study area as an input. The tool box assigns point to the centroid of every ward and prepares the O-D matrix. For every O-D combination, a Google Maps API request is generated to calculate the shortest possible travel time.

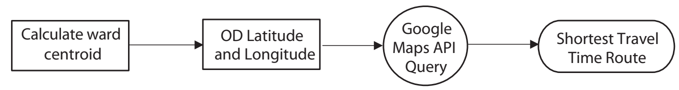

Figure 4: Methodology to extract shortest travel time information for the given OD matrix

Step 3: Solving Optimisation Model

The problem is formulated as a linear programming model which can be solved using CPLEX solvers available online in an open source domain on NEOS servers for Optimisation. Travel time matrix is taken as input and number of available fire engines is taken as constraint. Every point is assigned a binary variable to indicate the presence of engine (flagged by 1) or the absence of it (flagged by 0). It is value of this binary variable which forms the output of the model.

Table 1: Number of Fire Incidents in Wards of Manchester City

Points	Ward Name	Number of Incidents (Year-wise)			Total Incidents
		2010–11	2011–12	2012–13	
1	Northenden	181	173	149	503
2	Fallowfield	110	129	121	360
3	Ardwick	594	551	506	1651
4	Crumpsall	381	366	437	1184
5	Ancoats and Clayton	486	437	398	1321
6	Hulme	231	168	199	598
7	Whalley Range	164	133	133	430
8	Baguley	382	384	368	1134
9	Gorton North	273	294	214	781

(*Continued*)

TABLE 1: (Continued)

Points	Ward Name	Number of Incidents (Year-wise)			Total Incidents
		2010–11	2011–12	2012–13	
10	Charlestown	257	188	164	609
11	Withington	118	123	149	390
12	Rusholme	132	146	121	399
13	Higher Blackley	255	215	177	647
14	Didsbury East	149	134	124	407
15	City Centre	1184	1083	1109	3376
16	Cheetham	468	421	453	1342
17	Woodhouse Park	244	216	203	663
18	Longsight	198	173	185	556
19	Levenshulme	130	151	132	413
20	Sharston	249	248	213	710
21	Chorlton Park	166	162	146	474
22	Gorton South	323	317	211	851
23	Old Moat	149	118	101	368
24	Harpurhey	454	472	403	1329
25	Burnage	104	93	87	284
26	Moston	173	141	100	414
27	Bradford	382	358	310	1050
28	Moss Side	236	233	248	717
29	Chorlton	173	148	153	474
30	Didsbury West	185	141	192	518
31	Miles Platting and Newton Heath	406	345	340	1091
					25044

Result

As discussed in Section 4, all wards in the city of Manchester are assigned number of fire incidents in the past three years and the travel times between all the wards at the time of the incident were extracted. Based on these values, the formulation proposed in this paper, is solved and position of fire engines which gives the minimum total weighted travel time is calculated. Minimum total weighted travel time also results in the minimum response time per incident which can be calculated by dividing the total weighted travel time by total number of incidents. This response time per incident is proportional to travel time per incident. The output of the model indicates whether a fire engine should be placed inside a given ward or not. Since there is an upper limit on the number of fire engines to be used in the model, not all the wards will have engines. Those wards which are both farther away from remaining wards and have higher number of fire incidents reported in the past will have higher chances of getting an engine in this model. Once the engines are placed inside a ward, it is assumed that all the incidents of that ward are covered immediately and their response time is considered as zero.

If the positions of fire engines are their current stations, response time per incident comes out to be 5.59 minutes. Instead, if positions of fire engines are optimised based on the proposed model as shown in Figure 5, response time per incident reduces to 3.8 minutes. Moreover, if only four engines are used to optimise response time with the setup as shown in Figure 6, travel time per incident comes out to be 5.51 minutes which is similar to the existing setup in the city of Manchester with seven stations. Thus, using this algorithm, same response time standards can be achieved using fewer engines.

Sensitivity Analysis with Respect to Travel Time

When the traffic conditions change, response times of fire engines are bound to change since the travel time will change. If the information about this changing travel times is incorporated in deciding optimal locations of fire engines, response time standards of non-peak hours could be maintained in peak hours as well.

In order to understand the sensitivity of optimal positioning of fire engines with respect to travel time from one ward to the other, it is required to increase travelling time to any one of the available wards and check for change in configuration. Let's say ward called "Cheetham" is chosen. Travel time from all the wards to "Cheetham" is increased by 10 minutes. Optimised configuration of fire engines changes as shown in Figure 7. The model places an engine directly in the "Cheetham" ward thus cancelling the need of calling an engine from nearby ward which would have consumed a lot of travel time.

Table 2: Results from the Case Study of Manchester City

Case	Total Weighted Travel Time (sec)	Response Time per Incident (min)	% Change
Existing setup	8,405,917	5.59	0
Optimising response time with seven engines	5,838,791	3.89	– 30.54
Optimising response time with four engines	8,278,780	5.51	–1.5

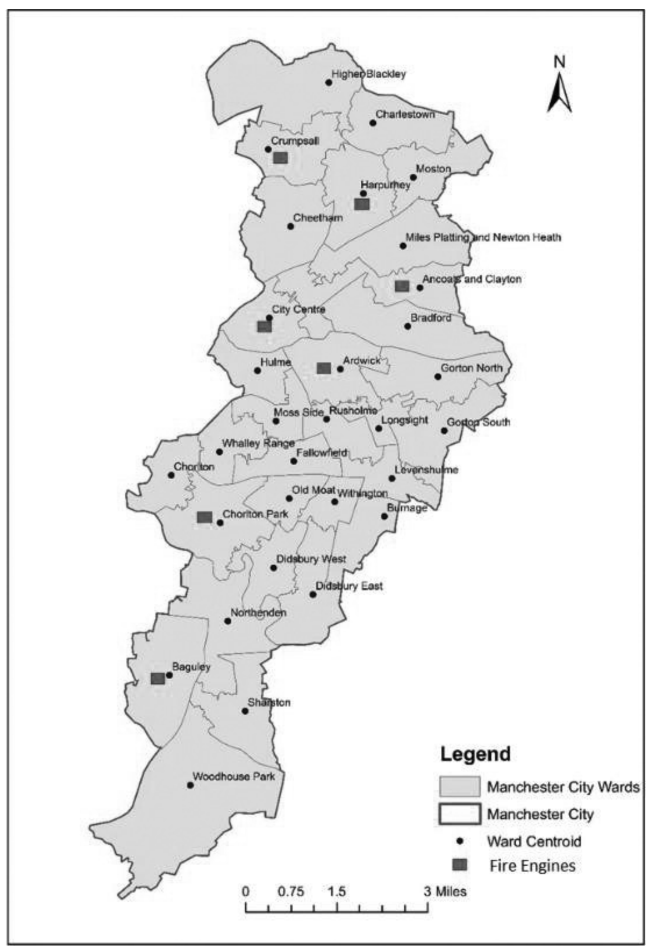

Figure 5: Optimal setup with seven engines

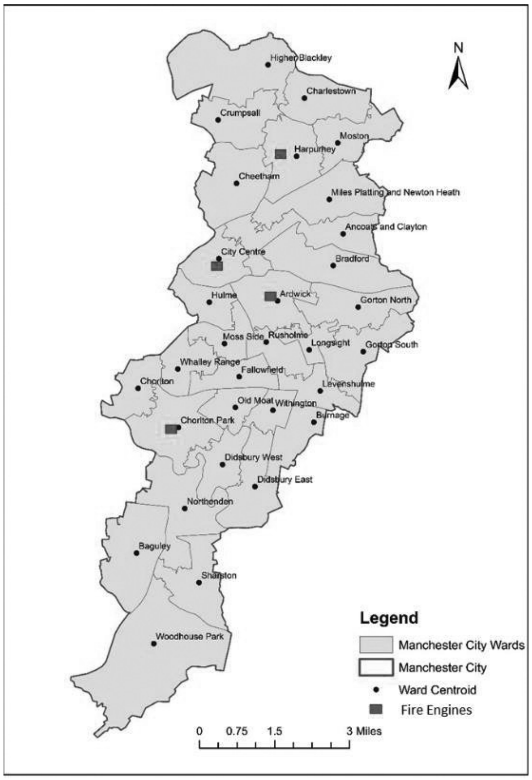

Figure 6: Optimal setup with four engines

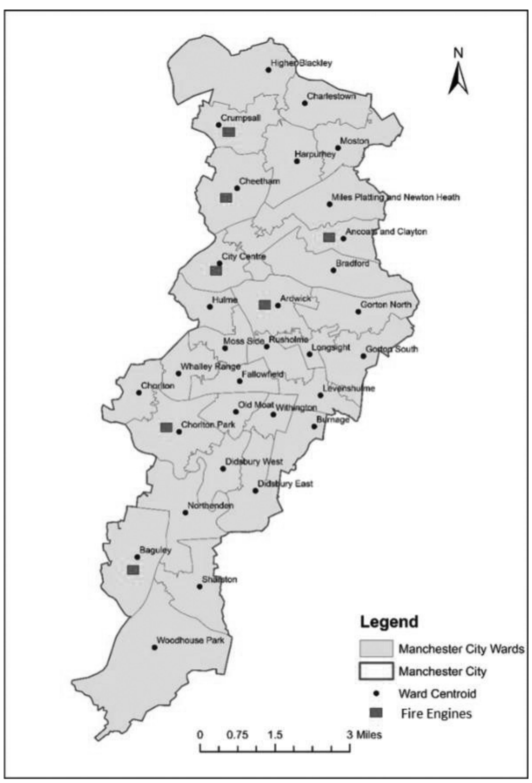

Figure 7: When the travel time to Cheetham is increased, an engine is placed in the ward

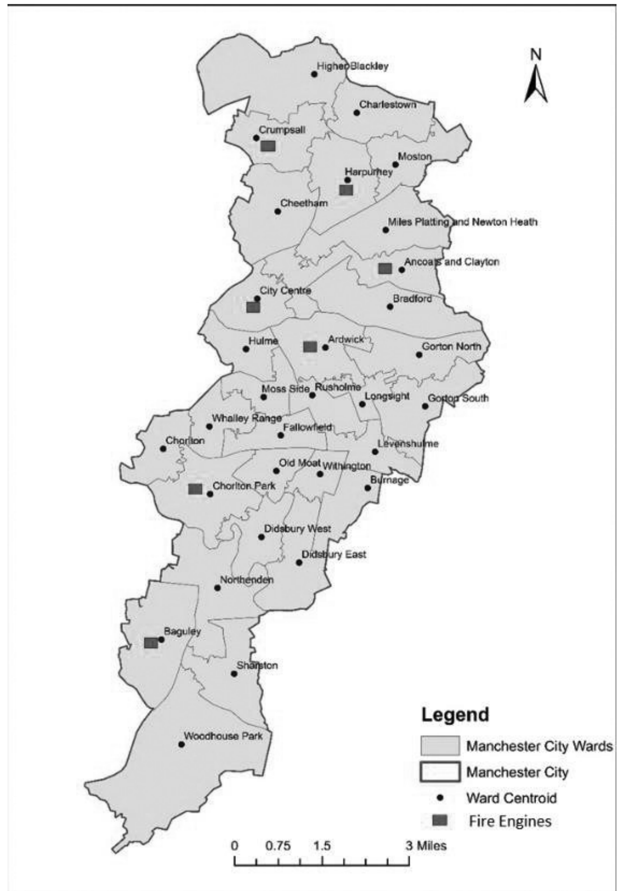

Figure 8: When travel time to Burnage is increased, no change occurs

To do further analysis, let's choose ward called "Burnage" and let's increase travel time from all the wards to "Burnage" by 10 minutes. This time there is no change in the optimised configuration of fire engines as shown in Figure 8. Despite increasing the travelling time, this model doesn't find it necessary to place an engine in the ward "Burnage". This could be explained from the fact that the number of fire incidents reported from the ward "Burnage" is the least among all the wards. Thus, frequency of an engine travelling all the way to Burnage from nearby stations is anyways very low thereby diminishing value of the weighted travel time (= total number of incidents x travel time) which is used in the optimisation model. Hence, increasing value of travel time to Burnage has little impact in the total sum of weighted travel times for all the wards, which results in absence of any change in the configuration.

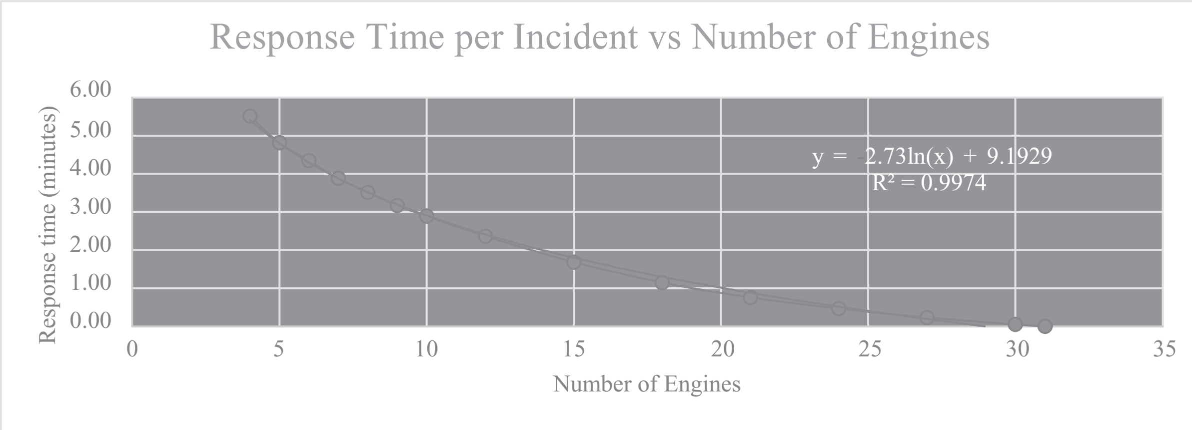

Figure 9: Relationship between number of fire engines and the response time per incident

Sensitivity Analysis with Respect to Number of Fire Engines

If number of fire engines is increased, it is obvious to think that response time per incident will decrease. But it is necessary to understand the marginal utility of adding a fire engine in a system which already has "n" engines in place. It is very important to check if the response time reduction achieved by adding an extra fire engine is sufficient enough to justify the cost incurred in operating that engine. To do so, value of the total number of fire engines (= enginestotal) in the model is varied, and their corresponding response times per incident are plotted as shown in Figure 9. The functional relationship for the given travel time information could be best described as logarithmic equation:

$$\text{Response Time}\left(\text{per incident}\right) = -2.73\ln\begin{pmatrix}\text{Number}\\ \text{of Fire}\\ \text{Engines}\end{pmatrix} + 9.19 \quad [5]$$

It should be noted that equation [5] depends on traveltime information. Once traffic conditions change, values of coefficient and the intercept will change. However, the functional relationship remains logarithmic. Thus, such equations could be generated for different times of the day and accordingly marginal utility of fire engines could be calculated every time. This will drastically optimise the operational fleet size and reduce the operational costs.

Conclusion and Future Work

- To mitigate urban fires, most of the studies have proposed permanent fire station at optimal locations. However, it is expensive and no longer remains most efficient due to incremental changes such as change in population, urban development, innovation in technology, etc.
- In this paper it is shown that permanent stations do not necessarily adapt with dynamic traffic conditions thereby increasing travel time for the first response. If the dispatching policy is adapted according to real-time traffic conditions in order to maintain response time standards, this paper shows that permanent fire stations will require a greater number of fire engines.
- The concept of floating fire engines is explained in this paper. It requires fire engines to be placed at optimal locations calculated using real-time traffic information such that response time for point of incident which is also equal to travel time for fire engine is minimum.
- Application of the floating fire engine model is discussed through a case study on Manchester City. Response time per incident is reduced by 30.54 per cent if the current fleet size is kept as it is. The existing response time standards maintained in

the city through seven stations are achieved by optimally locating only four fire engines.

- To maintain response time standards of non-peak hours during peak hours, it is important to investigate the sensitivity of the optimal configuration with respect to change in travel time. It is found that if the travel time to a ward increases, fire engine is kept in the ward itself provided there is enough number of fire incidents in the ward.
- To understand the marginal utility of an additional fire engine in a system already having "n" engines, it is important to analyse the sensitivity of response time per incident with the total number of fire engines. It is found that the response time per incident is a negative logarithmic function of number of fire engines. Parameters of this relationship change with travel time. Thus the most optimal fleet size could be identified using this relationship for any given travel time.
- The proposed model is deterministic in nature. It considers that an engine will always be available when called. However, in reality, multiple fires can happen simultaneously thus attributing a busyness fraction for every facility. It will be included in our future work.
- Application of this model in real life requires solution to operational problems such as staff assignment and equipment location-allocation which will become part of future work.

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X Role of the Armed Forces

Intervention of Indian Armed Forces in an Operational and Non-operational Scenario during a Disaster in India

Rhythm Mathur[a]

ABSTRACT: India is a nation of a large population, built on a strong past, vying to make its place in the world while fighting all the obstacles of poverty, inequality, natural phenomena, etc. In such a scenario, disasters whether man made or natural are truly mayhem and is a challenge in its own to bring the order and normalcy back in existence. With the complex divisive political and functional hierarchy in the nation, the derring do of quick, effective, laudable and committed response is often seen coming from the Indian Army and its wing forces.

The study that is about to be conducted is on the lines of the management of disasters that the India's Armed Forces manage to undergo and create in situations of helplessness and chaos during disaster. The major tasks of relief, recovery and response in a disaster need immense co-ordination, planning and controlling of activities that need to happen during the times of crisis as well as well before the mishaps occur in order to be prepared. The research reviews existing literature in depth of the role of other institutions established categorically for disaster management and the periphery tasks involved.

In earlier times, when a disaster struck, the Department of Relief and Rehabilitation under the Union Ministry was the designated authority. The responsibilities were primarily hence post-disaster and more or less no focus on preparedness and preventive measures. However, with the enactment of the Disaster Management Act 2005, a paradigm shift is seen in preparedness, response, rescue and mitigation. Today, at times of crisis be it the Taj Hotel terrorist attack, Assam floods, destruction caused by earthquake in J&K, fire emergencies, delivering supplies and necessities to the victims of a disaster, Indian Army is the first directive responders before any action pursued by the civil bodies. The study hence studies the role of Armed Forces in detail as of how the relief, rescue and rehabilitation of the affected ones have always been ensured and taken care of. The perception of people when it comes to management and rescue during a disaster by the Indian Army is of the highest order of trust feeling of safety and assurance of extraction from the mire of a disaster.

KEYWORDS: armed forces, civil–military, disaster relief, disaster response, intervention, disaster management

Introduction

Armed Forces form an important source of effort and problem-solving organisations under the call and directions of the government in order to respond and provide relief within their capacity. India has been a victim to many big disasters in terms of loss of life, property, affected area, etc. Ever since independence,

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with the independent functioning Armed Forces forming a significant portion of job which paid you well as well as fulfilled your hunger for patriotism to make you and your country progressive and move towards development, we somewhere lost the very basic cause of why the Armed Forces were formed. The country with its diminishing resources has been figuring a way out to come out triumphant, fair and optimistic of all the pools of problems it has been in this 21st century era of development. Unlike the bigger, developed and potentially progressive countries like the USA, France, Russia and the United Kingdom, the phase of development of our country in its early years of development has been very different from them. Being a country with a large amount of population, seventh in terms of size of landmass, having with a great amount of resources, development for us came in a time when most of our competitors were in the top of their games. This changed the game for us, and by the end of 20th century we were fighting our way in the acing the race of development amongst the world's best. Armed Forces from then till now have been an important member of the organisations, institutions along with the government which has brought the country to what it is today. From fighting thee wars for independence to wars for freedom, civil riots, national emergencies and most importantly the disasters. This research is about the role the Armed Forces have played, which most often goes unsaid, unmentioned and unrewarded and obvious enough to intervene in almost all disaster emergencies and crisis.

Methods

The research is conducted by means of the following methods:

- Secondary data research of existing documents cited and referenced in the references.
- Questionnaires: in order to garner the general perspective of the theme of the research.
- Studying case studies in each of the many disasters in which Indian Armed Forces played a major role.
- Experience and observational skills by my own field work.

Current Structure of National Disaster Response

Disaster management is a comprehensive term for all the activities that take place in finding a solution to the problems that arise after a disaster. The theory of the management hence is a multi-disciplinary aspect of study, and hence the structure involves participation of more number of sectors. This mainly includes national organisations, state, district, village-level groups, communities, civil societies as well as non-governmental organisations. Along with the above, Armed Forces have an immensely important role to play called for deliberately when a situation is out of control. The following can be identified as few of the most important doctrines, military policies, legalities and frameworks: Military Aid to Civil Authority, Civil Defense Act and Amendment, National Disaster Management Policy, National Disaster Management Act 2005 (The Gazette of India).

Perspective of Disaster and Disaster Management (Government/Armed Forces/Civilians/Humanitarian)

As much as the role of the Indian Armed Forces seems smooth and inspirational, it is a complicated and well spun web of responsibilities amongst the officials and responsibility holders. These forces are ready at the spur of the moment of any disaster and react with their best of capabilities. Government is the ultimate decision maker in the times of crisis, so for them it's a trade of finding the best solution during the hour of crisis. To which Armed Forces' role is a consequence, and their perspective is just to follow and provide relief. Civilians are the responders despite being the victims; after all disaster's first responders are a community. Humanitarians find disaster management as a field of fulfilling the humanity and action in response to a crisis.

Studying the Role of Armed Forces in an Operational and Non-operational Scenario during a Disaster: Discussion

Principles of Engagement

Contrary to the role of Armed Forces for the nation, the principles of engagement is a hot topic of concern. In layman's terms of concern the principles of engagement entails the management and establishment of order and security, protection of the citizens of the country and helping resolve any conflict, emergency or chaos amongst the citizens with the help of physical, strategical and armed approach. The section talks about the kind of engagements the Armed Forces should get into.

Brief Understanding of the Role of Armed Forces: Expanding the Concept

The intervention of Armed Forces is a complex mechanism which looks very simple and sorted from outside. The intervention of Armed Forces differs before, during and after a disaster, which indeed is not the primary role as repeatedly described above. Understanding the role of Armed Forces as a concept briefly talks about the concept in operational and non-operational scenario. *Understanding operational and non-operational scenario,* the paper, talks about two important scenarios emphasised as "operational" and "non-operational". By operational scenario, it is meant the times when the Indian Armed Forces as an organisation is in operation and action to manage the disaster and there is a need of their presence. Operational Scenarios are mostly post-disaster, which include the Crisis Management section of the cycle entailing of Impact Assessment, Response, Recovery and Reconstruction. On the other hand Non-operational Scenarios are the Risk Management phase of the Disaster Management enclosing Mitigation, Prevention, Preparedness, Preparation, Early Warning System and the moments before the occurrence of the disaster. Therefore, the role of organisations especially Armed Forces varies in each of the scenarios.

Collectively Organising Forces in Disaster Management

Briefly, the following forces play majority of role in managing disasters along with the Armed Forces in the lead. To name the most important ones, Central Paramilitary Forces, State Police Forces and Fire Services, Civil Defense and Home guards, State Disaster Response Forces, National Disaster Response Forces, National Cadet Corps, National Service Scheme, Nehru Yuva Kendra Sangathan, ITBP, NGOs, iNGOs, etc.

Nature of Intervention

Armed Forces capabilities mostly are for war, to combat and to conduct operations. Together in sea, land and air through assessment, reconnaissance and patrolling they primarily provide ascertain levels of casualties and damage. It is a weapon as well to tackle the unrest and state emergencies simultaneously assisting the civil authorises (Walker December, 2006). The Armed Forces is a word used together to symbolise the actions for the Army, the Air Force and the Navy on grounds bringing a response to a situation through their various capacities and capabilities. The section nature of response describes the kind of task that is performed by the Armed Forces in the purview of Disaster Management. Understanding from the detailed literature review being done here, it can be inferred that they are mainly response related which can be a combination of rescue and relief. According to a post-graduate research by Juliana M Walker titled *The Military and Domestic Disaster Response: Lead Role Revealed through the Eye of Katrina* the nature of response can be categorised into a very vague distinction described briefly in this section:

- Assistance and guidance for various processes on request.
- Response based on manpower and human capabilities to perform tasks like rescue and evacuation.

- Command and control of a large-scale affected population and subsequently giving them a safe haven for a temporary time period until a help from the centre is announced.
- Co-ordination of instructions in order to be smooth like butter knife in times of mire for the nation. In this every ounce of discipline, efficiency and unity counts to respond in a well-strategised manner.
- The engagement of the forces depicts that the nature of response is purely based on their capacity, training and skills which are being developed for war and combats.
- Continuing the fifth point it means that it is in mass and excellent group performance that the forces respond. The Air Force provides the assistance by air mostly transporting, emergency landing; the Navy helps in rescue and evacuation through waterways and the Army on the other hand plays a key role by actually doing the work man by man at the site of disaster.
- Together these forces make strong response teams even though ill equipped and ill trained for the task.

In a nutshell according to an article published in Yojana March 2012 edition by Vinod K Sharma and D Kaushik Ashutosh titled *Natural Disaster Management in India,* nature of response can be duly categorised on the basis of various levels of government offices National, State and District and subsequently till village panchayat level. However, the degree of nature of response can be on the lines of the administrative response, much trending and the emerging non-governmental organisations, the community and local bodies for first kind of response. A sum of all of these is what the Armed Forces does in emergency within first 24 hours of mishap.

Rationale of Intervention of Armed Forces

Disasters are a combination of psychological trouble, financial blow off and physical fatigue which to bring control is an overwhelming task in itself. In India not only up the game of other institutions in the country is an urgent need but there is a need to take up certain steps in order to make Armed Forces personnel in disaster management more efficient and promising considering the wide range of disasters and mishaps to tackle which no proportionate increase in organisations is ready to take up. Indian Armed Forces respond out of discipline, enthusiasm, patriotism and love for the brothers and sisters in the country.

Legitimacy of Intervention of Armed Forces

The legitimacy can only be defined on whether or not the papers and the dossiers appreciate the intervention of the Armed Forces. The influx of forces is purely on the basis on need, will and failure of a good response by the organisations designated by the government. It can be however noted that the constitutional mandate of 73rd and 74th Amendments ingrained the role of local bodies to react first in an emergency situation. Apart from the institutional framework and policies responsible for fabricating the response, relief and rehabilitation mechanism, NDMA is the one bringing the paradigm shift in the approach of disaster management (Vinod k Sharma 2012).

Politics of Intervention of Armed Forces

Armed Forces fall in the vicious circle of diplomacy and politics in our country when it comes to response and management during disasters. Despite minimal mentions in the role of Armed Forces in DM Act 2005, without special reference in the role it performs in reality. The men in the uniform repeatedly get in stuck in this kind of politics because of the inability in participating in functions involving staff, finances, diplomacy and hence end up only executing tasks rather than formulating them too.

Linking Role of Armed Forces with Humanitarian Response and Logistics

Another angle of understanding the current scenario of disasters in correspondence with the efforts made by the Indian Armed Forces is of providing aid to our neighbours. According to Ganpathy Vanchinathan in his article *Need for Institutionalized Humanitarian and Disaster Relief Operations across Borders* published at CLAWS explains that there are treaties and agreements for instance SAARC Agreement on Rapid Response to Natural Disasters (SAARND) for providing assistance and aid to our neighbouring countries in the hour of need in any form possible. Armed Forces of donor nations every time cannot cross the border to extend aid and hence are addressed differently bringing in the role of HADR, i.e. Humanitarian Assistance and Disaster Relief, in operations. The activities inadvertently fall in the humanitarian aid and response ensuring the logistics.

India's Current Scenario

India with its historical evidence, climatic conditions, geographical location and the tremendous amount of population load on a landmass not meant to sustain it has proven to be a highly disaster-prone country for obvious reasons. As a matter of fact, 55 per cent of India's landmass is prone to earthquakes, 68 per cent is vulnerable to drought, 12 per cent to floods and 8 per cent to cyclones apart from heat waves and several other disasters (Gautam 2012). Disaster risks are further accentuated by the increasing threats of the ever-growing population, disparities in income, non-uniform urbanisation and industrialisation, environmental degradation, climate change, etc. (Moirangmayum Sanjeev Singh 2015). Among the 35 total states (UT+ states) 25 is disaster prone thereby inferring that about 50 million people in the country are susceptible to any disaster each year (Vinod K Sharma 2012).

Understanding the trends of the disasters, in the recent decade there has been a shift in major causes of disasters in the country. Therefore India's vulnerability is measured and known to the officials working for and amongst the disaster preparedness and preventive sects of the country. The threats are perceived differently amongst different population on the basis of their awareness and responsiveness to a particular mishap. In our country the National and State Disaster Force remain calm even after having designated equipments and specialisation vis-à-vis the defence forces whose organisational discipline, logistic capabilities, resilience and national presence making them quicker and more useful to react despite sans a formal mandate to deal with such kinds of crisis (Former GOC Central Command, 2014). In usual scenarios the Army assists primarily in rescue and then eventually relief while synchronising and listing the course of action in the best possible ways keeping in mind the standard operating procedures (A. Gupta 2015). Re-establishing communication, heavy duty rescues, supporting equipment like establishing relief camps, tents, blankets and food for immediate relief are common SOPs in the efforts by the Armed Forces.

The "Josh" within the Armed Forces

The Armed Forces have been the most reactive as being repeatedly proven in more and more varied researches done. The "Josh" is the term used by the platoons and the men in the forces to describe the enthusiasm, will to accomplish the task with the best ways and means. The team commanders often ask "How is the Josh?" to which is replied as "High". The cry is known to generate the highest of the wills to work, with best of the intentions to go and achieve the aim of the exercise bringing in integrity and poise.

In the context of Disaster Management, the aspect of Josh brings us to the facts and beliefs of the thought process with in the Armed Forces. The Armed Forces are believed to be always enthusiastic to come forward and perform in the worst of the crisis. The involvement of military as learnt in the hierarchy is often not a planned inclusion but more of an emergency call. The Armed men are always on the go of the orders irrespective of the kind of task being allotted. This gives rise to the meaning of humanitarian action within the forces.

Challenges

It should be understood that the Indian Armed Forces aren't doing a favour for the country by assisting in the hour of crisis of disasters, but the highlight being they are the first responders because we don't have any other legitimate organisations to respond. It infers that a country which depends on forces during a disaster is doing so because of the lack of capacity elsewhere and that Military assets would be the last and most appropriate resort (Gautam January 2012). Making it obvious, there are innumerable challenges faced them in many forms and despite hindrance; they have never let us down. With reference to Sanjeev Singh and Kaveri Tandon in their article on Armed Forces in Disaster

Management: Challenges in Indian Perspective, following are some common challenges faced:

- Response time-Conducting Operations-Lack of Training-Unprecedented record of Disasters: Gautam (January 2012).
- Resource crunch -Equipment: Gautam (January 2012).
- Humanitarian Aspect - Policy level: Hudson (2009) - Sync with other organisations
- Sharing of assets - Infrastructure deficiency: Walker (December 2006).

International Scenario

As much as the involvement of Armed Forces is in the internal matters of the country, for the past several decades we have been aid to our neighbours, friends and foes. Humanitarian work doesn't need to see gains but are instead done for the cause of humanity. The role of Armed Forces is prominently active in South Asia, where in India China play huge roles being few of the largest democracies (Raj Summer 2008). Hurricane Katrina (Sept 2005), Philippines Mudslide (Feb 2006), Indonesian Earthquake (May 2006), Lebanon (Aug 2006), Kashmir earthquake (2005), Tsunami in Indian Ocean (2004), etc. are a few to names to highlight in which the Armed Forces played a major role. Thus Armed Forces in a lot of countries are ready for OOAC, which stands for Out Of Area Contingencies mostly of which are unplanned and to be given a reaction within a few minutes.

Country like Australia does have Disaster Planning groups, emergency committees and strong armed base. Existence of National Security Council, National Relief Committees and Defense Operation rooms in Malaysia, similarly National Disaster Coordinating Council and Red Cross in Philippines play an important role in disaster response besides a major role played by the Armed Forces.

The Debate

Works by many researchers in this field of studying Armed Forces and Disaster Management have a definite mention of the bi view of role of Armed forces in Disaster Management. According to PK Gautam and Shivananda H, one of the views is that the forces need to be competent enough for war-like conditions. Changing the shift from the main profession to the one in Disaster Management thins the effect and potential is the real condition. The other view is that of status quo. The dependence and making it an obvious fact that the Armed Forces will take care has led to mellow down of the initiative of other institutions involved. Meaning, capabilities are not inborn, they have to be created within the available resources and conditions.

It can also be understood that Militarisation of disasters is a concept in its own. It infers that the view on Armed Forces as respondents can be bi viewed encoring the idea of Military cultures across the globe (David Etkin n.d.). The Armed Forces show heterogeneity in their nature across the world due to various reasons like working conditions, kind of dealings in the profession, differences within the forces in terms of roles and ways of operations. This diverges the way of role of Armed Forces into one to support its participation second to not. The first will come at a compromise with the primary task of the Armed Forces and fighting against the mandate and constraints of the legislations and policy of the country which are seamlessly in favour of only and only in national defence. The second perspective coming largely on the basis of the perspective and pragmatism of tackling disasters and the havoc caused. Theoretically, there is an urgent need for an independent organisation which takes the roles and responsibilities on its shoulder as primary responders.

Clearing the Air

The debate is clearly not a big issue and certainly not new to the platform. Involving the Armed Forces is not the thing to be interrogated in the subject of this research paper. The question is to where to demarcate the role of the Armed Forces when called for help. There is a need to define the nature, interference degrees and perhaps the situations and scenario where the role is unavoidable. Clearing air is the heading defining the role of the forces in a clear, defined and explicit manner. This is in no way means inculcating the role of disaster management as a primary role but to instead ensure a dedicated branch which develops in terms of physical strength, finances and development.

The Paradox

Despite being an officially granted source of help and management for disasters, the government refuses to recognise the Armed Forces as an organisation formally, legally and legitimately in the DM Act 2005.

Strategies for a Safer Future: Discussion

Further, there is a general perception among the force commanders that the present organisational structure has been dealing with disasters quite well. Nevertheless, for effective rapid response at short notice, the response teams need strengthening in sub-areas and areas where they are generally located. In this regard, the raising of Territorial Army (TA) battalions for disaster management should be undertaken. Following can be major strategies labelled and described briefly for a safer future:

- Collective Training: Lack of organised training, information supply, background awareness and skill management for the forces is a cry for help for more attention in this arena. Either taking up ideal institutions like NDMA and NIDM to train more and more personnel or strengthen Armed Forces with an arm definite just for Disaster Management (A. Gupta, Managing DIsasters: integrating Armed Forces in NDMA structure 2014).
- Resource Integration: Our country lacks in integrating what she already has in her cradle.
  There has been time when Armed Forces have single handedly taken care of post-disaster management which is not a good sign for a developing nation like ours. We need to make our organisations come together, delegate responsibilities in order of role in emergencies. Integration is the key to a long-term future planning.
- Structural Changes: The apex body NDMA although a hub for forecasting, EWS, systematic planning, assistance and management needs to buckle up its horses. The institution from what it is now should be three times at least more efficient surpass what the Armed Forces are now. To change the structure would mean to bring changes and alternatives in the existing hierarchy and responsibility and the degree to which it goes to (A. Gupta, Managing DIsasters: integrating Armed Forces in NDMA structure 2014). Further an establishment of a standard disaster management grid can be the new tricks of the trade. Meaning, a standard operating procedure should be pre- established like regional response (community, local bodies, local government hierarchy, etc.), response from state to name a few. From integrated response centre to manpower generation in the hour of need should be top class at the apex body.
- Continuance of Traditional Role: The current tradition is to call the Armed Forces without realising the degree of danger and urgency of the situation. Digression from the current behaviour is a must, and we have to find different ways and means to build up stronger organisations and not just depend on one solely.

Recommendation: Results

Armed Forces are readily asked to follow frontline directions for defence of any nation playing a huge role in the sector of disaster management (Moirangmayum Sanjeev Singh 2015). However, there always remains room for improvement and development for better results. Following can be the highlights of what can become better when Armed Forces are involved in tasks of disaster crisis, emergencies and their management.

- Lessons have to be learnt from the ways Armed Forces have reacted and given response and relief to those vulnerable and victims of the disasters.
- Similarly, Armed Forces should make it a point that they should keep the community and affected and other authorities on the same plane so as to have better co-ordination and more effective response.
- Lessons for Armed Forces have to be to have better relations with civil authorities such as police, fire services and other first aid providers.
- Even though Armed Forces have mostly played a role of first responders in many situations, they are not certified members of quite a lot of executive committees in the closure of Disaster Management circle, even the national, state and district levels.
- A responsibility fulfilled in good faith shouldn't be turned into an obligation, the discretion should be in practice and procedures and processes must be

ensured for proper response, therefore should be considered as last resort on paper and on grounds as well.

- Formulation of fresh SOPs and eradication of older ways of working (Essays 2015).
- For such a scenario, a proper post-disaster analysis, on the basis of facts or a SWOT analysis, should be ascertained as quickly as possible to judge, in case of requirement of Armed Forces (Raj Summer 2008).
- Exercising, training and planning for the worst possible situations. This may mean preparing the first responders the best while keeping alternative organisations on standby yet forming a best case of training, planning and implementation (Walker December 2006).
- The above point covers the aspect of rapid deployment in tandem with Warning and Preparedness system being effective and useful (Essays 2015).
- Re-structuring policy and institutionalisation frameworks in such a way that deployment of the Armed Forces are not the first options by default and not any necessary reasons are left to deploy Armed Forces. This would mean making our wing institutions strong as ever.
- Upgrading equipment and trainings standards with modern-day technology and mechanisms for a better performance in the hour of need.
- Decreasing over-reliance and credibility on Armed Forces so as to bring responsibilities on other organisations and making them first respondents.
- According to a research it is said that the population supports the community-based approach more than the command and control systems of the Armed Forces during complex disasters. This can be because locals and community are always better responders than any organisation foreign in any sense (David Etkin n.d.). Hence an urgent need to strengthen the community and local bodies for management and control.
- Better information and data sharing amongst the authorities working for a similar cause like multi hazard maps, vulnerability indices, existing disaster management dossiers and necessary equipments with which Armed Forces might be away from. Thus not only decreasing the labour-oriented load on the forces but also increasing precision and results.
- Building new ways and means of better forecasting and pre-determining disasters and mishaps by undertaking new researches in geology, climate change and course of disasters in India will not only be a recommendation for intervention of Armed Forces in operational and non-operational scenario but for many other organisations in the country.
- Mock exercises under the code of Armed Forces involving locals, stakeholders keeping in mind the worst-possible situations, should be carried out for better rapport and response.

Conclusion

Keeping in mind the study structured above, it becomes evident that a lot more is stuck in the depths of this topic and to fathom it we need to get answers. Going by the quote "A man is judged by his questions not his answer" we should throw some light on the following key questions that arise in our minds forming the core of this research and come to a certain conclusion.

- Does our nation have a Disaster Response Policy that can be implemented practically or does it exists just theoretically?
- Do the existing institutions give a fair chance to the Armed Forces to completely indulge themselves in the field of Disaster Management or are they still the apparent second responders?
- Can it be said that in the days to come, state disaster authorities will be in a need to call the Armed Forces in order to execute quick response and relief?
- Is the involvement of Indian Armed Forces really the only legitimate solution left for Disaster Management despite the upbringing of other wing field specific unit?

It can be concluded that the Armed Forces are always up for the deed that has to be performed and yet are not facilitated enough to continue doing the job without any recognition and legitimacy. There needs to be a dedicated sector responsible solely for disaster management and cannot be left anymore on the ever-ready shoulder of the Indian Armed Forces.

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Role of Armed Forces in Disaster Management in India: What Does This Mean in the Context of Specialised Institutions and Response Forces (NDRF and SDRFs) Created by the DM Act of 2005

A. Shajahan[a]

ABSTRACT: Rapid urbanisation, climate change-induced increase in hydro-meteorological disasters have resulted in loss of life and property in India since 1990s. Indian Armed Forces have been traditionally part of the government response mechanism for disaster relief during natural disasters. Armed forces are called upon to assist the state/local governments when their handling capacity is overwhelmed. Their participation was on the basis of *'Last to enter – First to exit'* principle. However, in practice there is over-reliance on Armed Forces. Towards reducing this dependence on Armed Forces and developing civil capacities in line with UN IDSR (1990), Govt. of India enacted the Disaster Management Act 2005 (DM Act 2005). This Act created institutions like the National Disaster Management Authority – NDMA, National Disaster Response Force – NDRF, etc. for a holistic approach to Disaster Management. In the post-2005 (DM Act Enactment) framework, with the specialised response forces such as NDRF and its equivalent SDRFs, there is a need to evaluate the role of Armed Forces. This paper attempts to find answers to the questions on the role of Armed Forces in view of new stakeholders like NDRF/SDRF and NDMA/NEC (National Executive Committee) by analysis of the legal and institutional framework and its adequacy. The paper adopts a mixed methodology of qualitative and quantitative data collection methods by an inductive approach. The framework for Armed Forces participation in disasters and the framework as a result of the DM Act 2005 is analysed in this paper. Post-2005, there has been an increase in the stakeholders in the disaster response space. However, there has been no appreciable change in the frequency or extent of participation of Armed Forces raising questions on the adequacy of the current legal and institutional framework.

KEYWORDS: DM Act 2005, disaster response, role definition for Armed Forces, NDRF

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Introduction

India's Disaster Profile and Armed Forces in Disaster Response

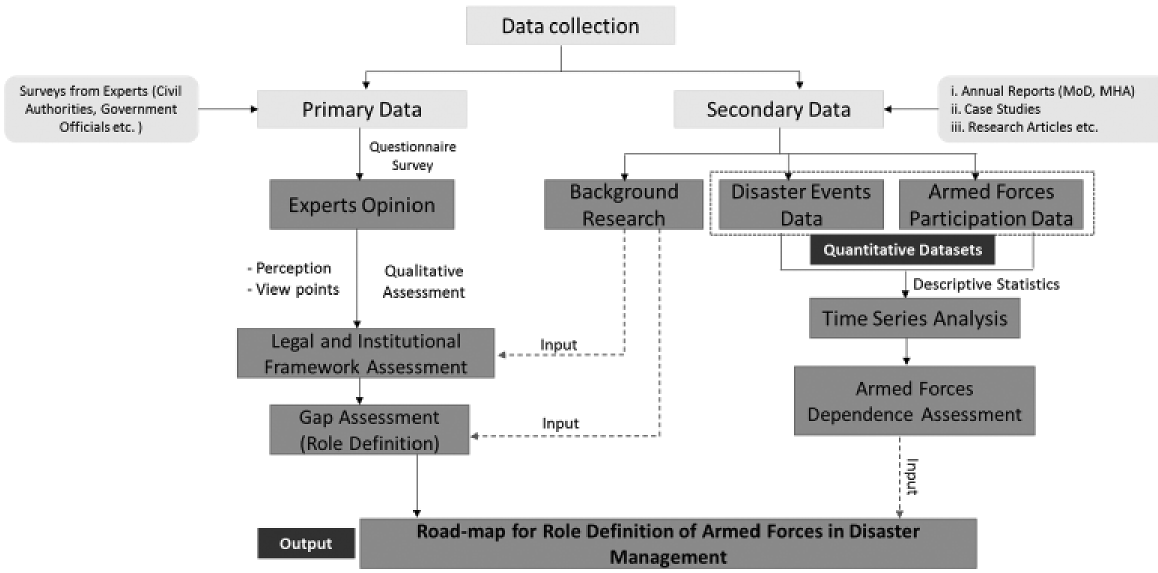
India is one of the ten[1] most disaster-prone countries in the world (NIDM, 2015). In recent times, floods during peak monsoons in 2013 ravaged Uttarakhand and J&K in 2014. These calamities have had a debilitating effect on the economy, social structure and people of the affected regions. The national annual figures for the average affected people is 49,087,940, and the economic damage is USD 1,550,446,000 (SAARC DISASTER REPORT 2011)[2]. India is vulnerable in varying degrees to a large number of natural as well as man-made disasters. Over 40 million hectares (12 per cent) is prone to floods and river erosion. About 58.6 per cent of the landmass is prone to earthquakes of moderate to very high intensity. Of the 7516 km long coastline, close to 5700 km is prone to cyclones and tsunamis. About 68 per cent of the cultivable area is vulnerable to drought, and hilly areas are at risk from landslides and avalanches (Satyendra 2014). One of the most important functions to be performed in times of disaster/after-disaster is identification, mobilisation and deployment of relief in the impacted area and evacuation of stranded population. As per Oslo guidelines, the category of asset that contributing countries reported most frequently deploying, and in the greatest volume, was air transport. The second and third most frequently deployed categories of assets were medical support and expert personnel (SIPRI 1994)[3]. Armed Forces globally are repositories of these three most critical capacities and capabilities. Disaster response/relief is extremely complex and demands smart strategies and innovative employment of the Air Power for seamless resource mobilisation and evacuation of affected people, as often it remains the only means of doing so. In the Indian context especially, Armed Forces have always been among the first responders to any calamitous event triggered by natural disasters. The IAF – Indian Air Force, which is the fourth largest in the world, has been a vital component of country's Humanitarian Assistance and Disaster Relief – HA/DR, operations during all calamities. Owing to their training and field experience, the Armed Forces become an inalienable part of any disaster team (Satish Kumar 2008). The primary role of Armed Forces is to preserve national interest by safeguarding the territorial integrity of the nation against external threats. Their secondary role is to assist the civil authorities in handling internal threats, maintaining of essential services and also assisting central or state governments during calamities (Mammen 2004).

Objective

The present paper aims to analyse the current legal and institutional framework for DM in the country and examine if there is a need to re-evaluate and institutionalise the role of Armed Forces in disaster response/relief within the DM Act Framework.

Methodology

Mixed methodology of qualitative and quantitative data collection methods by an inductive approach has been adopted for this paper. Desk Research of international and national reports, MoD Annual reports, MHA Annual Reports, Case studies on the intervention of Armed Forces and Air power in various disasters sourced from newspapers, archives of armed forces and by field visits to participating squadrons/ military formations. Key informant interviews and semi-structured interviews of senior functionaries of IAF and other services were undertaken. Similarly key civil authorities that oversee DM activities were also interviewed. Views/opinions of government officials from Dept of Revenue/DM of the Govts of Telangana, Andhra Pradesh, Karnataka and Uttarakhand were collated during informal interactions during annual pre-Monsoon coordination meetings during 2016–17. Similar outcomes from Mid-Career Interaction Programme held at College of Air Warfare on the topic, "Civil-Military Relations in context of HADR" held in Feb 2018 have also been included.



DM Frameworks in India

Historical Evolution at National Level

The early legal framework introduced during late 1870s was the Famine Codes by the Famine Commission. This was followed by preparation of "Relief Manuals" by the states before and after independence. In 1970s, a comprehensive programme on Drought Mitigation was taken up through DPAP – Drought Prone Areas Programme. Independent India faced the problem of food scarcity, and a formal first attempt at ministerial framework emerged with the establishment of a Scarcity Relief Division in the Ministry of Agriculture. This division subsequently was assigned work related to various other natural calamities. The nomenclature of Scarcity Relief Division was later changed to Natural Disaster Division, and the Ministry of Agriculture became the nodal agency for DM at the national level. DM was, at this stage, still focussed on relief and rehabilitation, and there hardly was any focus on prevention and mitigation. However, global initiatives like IDNDR, HFA, etc pushed the GOI – Government of India to focus on prevention and mitigation aspects to evolve a holistic approach to DM. This was further accelerated by India's experience of major natural disasters like the Latur earthquake in 1993. GOI constituted the HPC – High Powered Committee under JC Pant in 1999 to review "existing arrangements for preparedness and mitigation of natural disasters and recommend measures for strengthening the organisational structure". The HPC submitted its final report in 2001. The report recommended "Constitutional & Legal framework, Organisational structures & Institutional mechanisms" towards a vision of "Disaster-free India by adhering to a culture of preparedness, quick response, strategic thinking and prevention". The Gujarat earthquake of 2001 led to the constitution of an 'All-party national Committee' headed by the Prime Minister. The HPC of 1999 was further converted into a Working Group of the National Committee and submitted its report to the PM in 2003. The main recommendation of the Working Group was for the adoption by GOI, a National DM Policy. Further, GOI set up the Second ARC – Administrative Reforms Commission under Shri Veerappa Moily in 2005 to prepare a blueprint for revamp of the "Public Administrative System". The ARC submitted its third report titled "Crisis Management: from Despair to Hope" in 2006 by which time the GOI enacted the DM Act 2005. The 2001 Gujarat earthquake jolted the central government to convert the HPC into a Working Group. While the HPC/Working Group recommended "enactment of a central legislation on DM". The GOI at this stage took the view[4] that "disasters being a state concern, the states be advised to enact their own respective legislations". However, the Tsunami of 2004 jolted the GOI, and the DM Act 2005 followed (PK Mishra 2013). Even as the DM Act of 2005 as a central legislation was underway, some Indian states passed their own DM laws, namely, the Gujarat DM Act 2003, the Bihar DM Act 2004, the Uttar Pradesh DM Act 2005 and the Uttaranchal Disaster Mitigation, Management & Prevention Act 2005. The Gujarat DM Act was the country's first DM Act and was very comprehensive and inspired many states especially the UP DM Act.

Current Legal and Institutional Framework for DM in India

Legal Framework for DM (Pre-2005)

The Union Ministry of Home Affairs[5] is the nodal ministry for disaster management. The National Crisis Management Committee (NCMC), headed by the Cabinet Secretary and constituted under the Ministry of Home, oversees the various disaster-related activities in the country. It functions as a decision-making body and gives directions to the Crisis Management Group (CMG). Further, for execution of polices formulated in the ministry, the Central Relief Commissioner (CRC) is designated as the nodal officer for coordination of relief operation.

DM Act, 2005

The act was a watershed in disaster management in our country; it established NDMA – National Disaster Management Authority – as the nodal body for policy formulation and for coordinating all capacity building and capability accretion programmes in the field of DM. It also established NDRF – National Disaster Relief Force, the largest single standalone specialised disaster force in the world. It also created NEC – National Executive Committee, envisioned as the main executing arm of the NDMA for evolving a multi-sectoral holistic mechanism for DM in India. The act also lays down the framework and structure of DM framework at state and district levels in the form of SDMAs and DDMAs – State Disaster Management Authority and District Disaster Management Authority.

Legal Framework for DM (Post-2005)

Enactment of DM Act, 2005, was a landmark event as it established for the first time a comprehensive law on DM at the national level. Prior to 2005, there existed sectoral laws on environment, forests, mines, etc. Post enactment of the DM Act 2005, both the old and new institutions continue to be part of the DM institutional framework. The National Crisis Management Committee (NCMC) in MHA, a pre-2005 institutional arrangement, is still functional and takes over the functions of NEC (a post-2005 body) during major disasters.

Legal Framework for Armed Forces in Disaster Management

Armed Forces Pre- and Post-2005

Prior to enactment of DM Act 2005, Armed Forces formed core of the response mechanism of the government. It was to address this dependence and build and strengthen government capacities at national, state and local levels that the GOI enacted the DM Act. Post-2005, the number of stakeholders has substantially increased, namely NDRF, SDRF, Civil Defence, NGOs, Volunteers. The Armed Forces continue to be called for assistance during calamities. Presently, the response scenario thus represents a complex maze of stakeholders who bring overlapping capacities and diverging command and control structures and differing philosophies of operation and information sharing. The Armed Forces under the Ministry of Defence (MoD) are called out to assist civil authorities. The Armed Forces respond to disasters as a part of their mandate to aid civil authorities[6] or ACA as specified in the Instructions on Aid to the Civil Authorities by the Armed Forces, 1970. The Armed Forces render disaster relief under the duty listed as 'ACA' – Aid to Civil Authority[7]. The term "aid to civil authorities" (ACA)[8] is a British imperial usage (Brigadier PK Mallick, 2007) referring to the process by which local authorities can request the central government to lend assistance in times of emergency. The key provisions that govern Armed Forces participation in DM are Instructions on aid to civil authorities by the Armed Forces 1970, Manual of Indian Military law, chapter VII, Defence Services Regulations – Regulations for the Army, chapter VII, paragraph 301 to 327.

The ambit of ACA and the nature of tasks defined for the Armed Forces are listed below:

- Maintenance of law and order,
- Maintenance of essential services,
- Assistance during natural calamities such as earthquakes and floods and
- Any other type of assistance, which may be needed by the civil authorities.

Institutional Framework for Armed Forces in Disaster Management

Framework Provided by ACA,1970

The Defence Crisis Management Group (Alhuwalia PS, 2014) functions from Integrated Defence Staff (IDS) Operations Room (Ops Room), which is also known as Interim National Command Post. The IDS Ops Room is always in direct communication with the Army, Navy, Air and Coast Guard Ops rooms. This is the place from where all disasters whether it was the Tsunami, floods or the recent earthquake were tackled. The basic document governing the assistance rendered by the Armed Forces to civil bodies is a publication issued by the Ministry of Defence called, "Instructions on Aid to Civil Authorities by the Armed Forces" 1970. Further amplification on this as to how the three services should respond is contained in the "Tri Services Emergency Response Plan" of June 2002.

Framework Provided by the DM Act 2005

CISC – Chief of Integrated Defence Staff to the Chairman Chiefs of Staff Committee – is a member of National Executive Committee[9] (NEC) of the NDMA. NEC is the only institutional arrangement in the DM Act framework that has a formal role/representation of armed forces.

Analysing the Relevance of ACA in the Context of Current DM Framework

ACA has been a British raj legacy, modified in 1970 at a time when Ministry of Agriculture was the nodal agency for DM in the country. DM at that time was primarily oriented towards handling of recurrent famines and droughts. Since 1990s the frequency and ferocity of hydro-metrological disasters have risen. The capability in the civilian space was restricted to volunteers of Civil Defence, and there was almost inevitable dependence on the Armed Forces for all major and minor disasters. The DM Act of 2005 created a new structure of statutory bodies to implement a holistic approach as against the hitherto response-centric approach to accommodate multi-agency participation in DM in the country. NDRF, the largest stand-alone response force in the world, NDMA, NIDM, etc. were established. However, the role of Armed Forces was neither defined nor articulated by the Act, and the Armed Forces continue to operate under the framework of ACA (1970) while all other stakeholders operate under the framework of DM Act (2005). This places one of the key stakeholders (Armed Forces) outside the framework (DM Act) as it exists today. Doctrinally too, the Armed Forces are in the 1970s' mode and continue to function organically and organisationally that they are only "an On-Call" agency which will participate when called for. The lack of role definition in the DM Act 2005 has in a way ensured the 1970s' continuum in the Armed Forces though practically they are part of almost every major DM crisis. The large ambit of ACA and how it's adequacy or otherwise to cater for the complexities that define DM especially the response segment is highlighted in the following table:

Table 1: Ambit of ACA: An Analysis

	Provisions of ACA	Roles/Missions	Legal Provisions
1	Maintenance of law and order	Flag marches, Curfew maintenance, Shoot at sight orders, etc.	Area is declared as 'Disturbed' by the Civil authority
2	Maintenance of essential services	Whenever essential services are jeopardised due to strikes or unrest, Armed Forces are tasked by the Govt to provide the same	Army Postal Service (APS) stepped into providing P & T services when the Postal Dept. went on a long protest strike during the late 1980s Essential Services Maintenance Act (ESMA) is invoked by the govt
3	Assistance during natural calamities such as earthquakes and floods	Rescue, Evacuation, Medical services, Relief camps, Airlift of supplies and personnel, etc	Post 2005, the no. of response forces and participants has substantially increased
4	Any other type of assistance, which may be needed by the civil authorities	Election duties, Shifting of new currency during Demonetisation (2016), Airlift heavy material for Rail and road construction, etc.	Some of these tasks may fall in ambit of mitigation efforts within the DM cycle. E.g., airlift of heavy machinery for Kedarnath helipad construction (2016)

Table 2: ACA: Capabilities and Objectives

Provisions of ACA	Desired Capabilities	Objective
Maintenance of law and order	Show of Strength-More Troops and Armoured Vehicles and Fire Arms	Ensuring Law Enforcement even if it entails casualties among protesters/ civilians/rioters
Maintenance of essential services	Differing Capabilities depending upon the contingency like Medical services, postal services, personnel for running/manning govt offices, etc.	Ensuring uninterrupted services so that government functioning or citizens are not subjected to any inconvenience
Assistance during natural calamities such as earthquakes and floods	Specialised manpower and equipment that can be made effective by the fastest means and ensure saving of as many lives as is possible by evacuation or by supply of relief material	Saving lives
Any other type of assistance, which may be needed by the civil authorities	As required depending upon the task allotted by the Govt	

It is evident from the above tables that ACA combines tasks and roles that are diverse and need different approaches to each one of them. Participation in DM response especially entails swift and effective response that is aimed at saving as many lives as is possible. The capabilities, command and control structure, equipment required to execute are variedly different for say maintenance of Law and Order from those needed for disaster response. Hence, placing disaster response alongside law and order and maintenance of essential services does not reflect conceptual realisation of the complexities of the current disaster response space. Therefore, the need to separate "Assistance during natural calamities such as earthquakes and floods" from the ambit of ACA and a redefinition within or outside the provisions of DM Act 2005 clearly emerges. The Tri-Services plan (2002) that guides the Armed Forces at the ground level is also a pre-2005 document. It is evident that the Armed Forces have remained immune to the post-2005 legal and institutional changes and developments in the DM biosphere, inspite of being key stakeholders with critical capacities and capabilities. Armed Forces formulate their plans and procedures derived from the envisaged role as given in the ACA. They simply bring upon their combat equipment, training and command and control structure into the disaster zone when called upon to do so by the "Civil-Authority". This invariably leads to duplicity of effort due to multiple stakeholders present.

Role of Armed Forces as per DM Act, 2005

As per the letter and spirit of the DM Act 2005, the Armed Forces are to be called upon to assist the civil administration only when the situation is beyond the coping capability of the state governments. In practice, however, the Armed Forces form an important part of the government's response capacity and are immediate responders in all serious disaster situations. On account of their vast potential to meet any adverse challenge, speed of operational response and the resources and capabilities at their disposal, the Armed Forces have historically played a major role in emergency support functions (National Disaster Management Policy 2009). The Disaster Management Act 2005 is surprisingly silent on the aspect of assigning a well-defined role and responsibilities to the Armed Foces. There may have not been an explicit articulation in the Act but the military will continue to form part of the "Core Group" for immediate response (Col. OS Dagur 2008). The Raksha Mantri in his inaugural address (Manekshaw papers 2008) delivered during a seminar on the subject in December 2005, in the backdrop of many disasters to include the tsunami, avalanche and snow storm, followed by the earthquake in Jammu and Kashmir (J&K) had stated, "*The world over, without exception, all governments have involved the armed forces whenever a disaster strikes. They are invariably the first to respond and quickest to reach the affected area. As has been increasingly observed in recent cases across the world, the men in uniform have played a stellar role in mitigating and alleviating the suffering caused by disasters. We need to, therefore, strengthen their hands in executing this onerous task by giving them all the support needed in this direction".* The role recognition and role definition of Armed Forces did not emerge in the post 2005 DM framework. However, in practice, neither the employment philosophy nor the engagement mechanism has been qualitatively altered and the Armed Forces continue to be involved in Disaster Response operations as before.

Role of Armed Forces as per Other Non-statutory Provisions

As per National Disaster Management Policy (approved by the Union cabinet in October 2009)**,** the Armed Forces are called upon to assist the civil administration only when the situation is beyond their coping capability. In practice, however, the Armed Forces form an important part of the government's response capacity and are immediate responders for all serious disaster situations. On account of their vast potential to meet any adverse challenge, speed of operational response and the resources and capabilities at their disposal, the Armed Forces have historically played a major role in Emergency Support Functions. At the National level, the Chief of the Integrated Defence Staff to the Chairman Chiefs of Staff Committee has already been included in the NEC. Similarly, at the State and District levels, the local representatives of the Armed Forces may be included in their executive committees to ensure closer coordination and cohesion.

The National Disaster Management Plan (NDMP) 2016 was released by GOI as per the mandate of Section 11 of the DM Act 2005 that mandates the NDMP for whole of India. Section 37 of the Act further specifies "every ministry and department of the

Government of India, including the hazard-specific nodal ministries, shall prepare comprehensive DM plans detailing how each of them will contribute to the national efforts in the domains of disaster prevention, preparedness, response, and recovery" (NDMA, 2016). Many ministries including the Ministry of Defence under which the Armed Forces operate have not yet completed this task of comprehensive disaster plans. The plan defines "Response" as measures those are taken immediately after receiving early warning, anticipating an impending disaster, or post-disaster in cases where an event occurs without warning. It further amplifies that the primary goal of response to a disaster is saving lives, protecting property, environment, and meeting basic needs of human and other living beings after the disaster. The immediate focus will be on search and rescue of those affected and to evacuate those likely to be affected by the disaster or secondary disaster that is likely to happen. In the section on response, roles and function and responsibilities of ministries and agencies that have a key role to play are described. The NDMP provides a well-defined framework for disaster management covering scope of work and roles of relevant agencies along with their responsibilities and accountability necessary to ensure effective mitigation, develop preparedness, and mobilise adequate response. However, in keeping with the underlying spirit of the DM Act Viz, not entrenching the role of armed forces in the DM matrix so civil capacities develop, the plan too contains no explicit enunciation for armed forces even as the plan elucidates role of all government agencies in the response role.

DM Act Institutions

NDRF

NDRF with a current strength of 12 battalions is the "specialist response" provider under the new DM framework. However, the enormity of the disasters in recent times especially the Uttarakhand Floods (2013) and the J&K floods (2014) has exposed the constraints of NDRF as a responder (Vivek Chadha, 2014) current strength of 12 battalions, NDRF cannot match up the 'boots on ground' that the Armed Forces are capable of putting up in the affected area. Hence, for the foreseeable future, armed forces will remain a part of rescue and response operations.

NDMA/NEC

The National Crisis Management Committee (NCMC) in MHA, a pre-2005 institutional arrangement, is still functional and takes over the functions of NEC (a post-2005 body) during major disasters. However, the Task Force for Review of DM Act constituted under Dr PK Mishra opined that NEC has been ineffective[10] and recommended the rescinding of NEC and incorporation of NCMC (a pre-2005 institutional arrangement in the MHA) as the premier agency for DM. There is no institutionalised representation of the Armed Forces in the NCMC.

Discussions and Findings

As can be seen, prior to the enactment of DM Act of 2005, the Armed Forces undertook HA/DR missions under the ACA. They continue to do so, even after 2005. The DM Act which established the legal framework for DM at the national, state and local level defined the role of various stakeholders. However, it failed to articulate the role or procedure for engagement of Armed Forces or in simple words, the role recognition and role definition of Armed Forces did not emerge in the post-2005 DM framework. The Armed Forces are important constituents of the government's capacity to respond to disasters. However, when it comes to Armed Forces, the Act merely includes the mention of "deployment of naval, military and air forces, other armed forces of the Union or any other civilian personnel as may be required for the purposes of this Act" under the heading "Measures by the Government for Disaster Management" (Sec-11 & 37). There is no amplification or mention of the role of the Armed Forces with a view to offer legal support and back-up. The Act is surprisingly silent on the aspect of assigning defined role and responsibilities to the Armed Forces. (Manekshaw papers 2008). The Indian Armed forces need to be given a charter, an institutionalised role for managing disasters in the country (CLAWS, 2014).

The lack of role definition of the Armed Forces has impacted the capacity building, training and effective utilisation of the unique capabilities of the Armed Forces for optimal disaster response. The lack of role definition continues to place the Armed Forces outside the ecosystem that has been created by the enactment of DM Act 2005. The resultant gaps that emerge on ground are summarised below.

Lack of Civil–Military Jointness in DM Training and Capacity Building

NDRF created by the act has been in the forefront of acquiring these specialist skills and has acquitted itself well[11]. However, the Armed Forces have remained divested of these training initiatives. There has been no qualitative change in the training or preparation of Armed Forces for disaster relief post 2005.

Lack of Civil–Military Liaison

During non-disaster period, there is hardly any meaningful liaison between the civil government machinery and the military. At the state level, the liaison apparatus is rudimentary and restricted to meetings on land encroachment, exchange or top dignitary visits, security issues, etc.

Specialist Equipment

Armed Forces despite being first responders in most cases do not have specialist equipment (unlike NDRF) and make do with their military hardware available in the affected area or that flown in. Post-disaster operations are complex and demand smart and specialist equipment like thermal imagers, radiation metres, etc.

Local Capacity Development

When government-sponsored or NGO-driven capacity building programmes are undertaken targeted at the local community to build resilience, the Armed Forces even if deployed in the area are not a part of such exercises.

Conclusion

Hence, for full realisation of the potential of Armed Forces and their efficient contribution in DM, it is imperative that the role recognition and definition and procedure of engagement be incorporated in the national disaster framework, as it will add a new paradigm to the nation's capabilities in DM.

Notes

1 'Do's & Don'ts for common Disasters'. NIDM. Accessed at http://nidm.gov.in/PDF/IEC/leaflet-dos.pdf on 01 May 2015.

2 Figures for three decades 1980–2010 from SAARC Disaster report-2011.

3 Oslo Guidelines/Guidelines on the Use of Military and Civil Defence Assets in Disaster Relief (1994)/'Assets Provided'/Pg-15/52.

4 As per GOI communication by Deputy PM to all CMs dated 23 July 2003.

5 The nodal agency for DM was Min of Agriculture till 2002,post which MHA was designated as the nodal agency. However, for drought, Min of Agriculture continues to be a nodal agency.

6 This is a Ministry of Defence pamphlet issued in 1970 for 'Assistance by Armed forces to Civil Authority' and serves as the guiding document for Army, Navy and the Air Force for their engagement in disaster relief and response.

7 As mandated by the Union War Book.

8 'Role of Armed Forces in Internal Security: Time for Review'. Brigadier PK Mallick. CLAWS Journal. Winter 2007. Pg-68.

9 A post 2005 institutional arrangement created by the DM Act of 2005 with Home Secretary as its ex-officio chairperson.

10 4.5.2.1 of the Task force Report March 2013. Pg-52.

11 46 member team of the National Disaster Response Force (NDRF) reached Japan on March 28, 2011, to provide disaster relief and rescue assistance in the tsunami-struck town of Onagawa. The team was equipped with the latest state-of-the-art gear for radiation monitoring, detection and personal

safety equipments and were self contained in terms of nuclear, biological and chemical (NBC) suits, emergency rations and essential medicines. The NDRF team also carried Collapsed Structure Search and Rescue (CSSR) equipment and relief material like portable shelters, tents, blankets, medicines, water bottles, etc.

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Role of Armed and Other Forces during Disasters

Parvez Hayat[a]

ABSTRACT: Disasters have been an indispensable concern to be addressed throughout human history. Disasters, whether natural or human induced, are common phenomena around the globe necessitating emergency measures. Disasters continue to occur and the same is constantly increasing in its magnitude and frequency impacting economy globally for multivariate reasons. Losses in terms of economy, livelihood, human and culture are many times higher in developing and under-developed countries which are more vulnerable and technologically and resource-wise at disadvantageous position. As per Centre for Research on Epidemiology of Disasters (CRED) data base and world disaster report 2002, over 200 natural disasters have taken place in various parts of the globe and it has killed over 1.5 million people.[1] Although number of disasters are increasing due to globalisation, increased urbanisation and flawed development, economic losses are at the same time on decline due to effective and sustainable disaster risk reduction (DRR) measures adopted by both developed and developing countries. Technological advancement too plays an important role in risk mitigation and effective disaster response. Role of emergency management services (EMS) such as Armed Forces based on typology of disasters and extent of severity and intensity as well as extent of disasters, local police, fire-fighters, paramedics and community as first responders hold valuable lessons for the future. Specialised forces such as armed forces, National Disaster Response Force (NDRF) also play important roles in disaster emergency handling for saving lives, livelihood, search, rescue, relief distribution and rehabilitation.

KEYWORDS: Armed Forces, coordination, public safety, security, inter-agency communication, second victimisation

Introduction

"No community or city can be certain that it will not be the victim of the next disaster. The unexpected is a fact of life; it can come anytime, anywhere" (Leonard 1973).

India is vulnerable to natural hazards on account of its unique geo-climatic and social conditions. Floods, tsunami, cyclones, earthquakes and landslides have been recurrent phenomenon affecting almost 85 per cent of the geographical area. Disaster vulnerabilities are on the rise due to increasing urbanisation, rapid industrialisation, environmental degradation and climate change, and flawed development within high-risk zones. Disasters such as technological, biological, nuclear accidents, fires, transport accidents, aviation accidents, industrial accidents and pollution due to human actions are called man-made. Armed forces, EMS and other specialised forces play crucial roles in mitigating disaster losses, saving lives and livelihood.

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Disaster Response

Response includes pre-disaster preparedness, based on vulnerabilities and typology of disasters. Response functions focussed at limiting injuries, loss of life and damage to property, livelihood and the environment and are taken before, during and immediately after a catastrophic event occurs.

Types of pre-disaster response actions: Preparedness includes early warning which may be technology driven or community driven through social media, evacuation, prepositioning of resources, last-minute mitigation. The first priority is saving lives by search and rescue (SAR), which may continue for days or weeks.

Search and Rescue

Search and rescue based on criticality and typology of disasters is undertaken first by local police, community and other paramedics for treatment, fire-fighters in cases of fire, evacuation, public safety and security and provision of water, food before other specialist forces such as armed forces and NDRF arrive. It is civic agencies, local police along with the community which undertake SAR, relief distribution, transporting evacuees to pre-designated shelters, provide health sanitation, opening of transportation routes, rapid resumption of critical infrastructure, restoring communications and electricity to facilitate early recovery to take place.

Inter-agency coordination and communication with interoperable radio communication network is too vital for effective response. Ultimately scale of the disaster dictates the response. Such developments brought about a paradigm shift in the approach of the government from mere relief and response-centric approach to a holistic approach covering preparedness, mitigation, response, relief, recovery, rehabilitation and reconstruction (what we build and where we build).

Role of Armed Forces and Other Specialist Forces

Emergency response for a catastrophic event is an enormous responsibility involving the full coordination of nearly all of government agencies. The community based on topography of disasters as explained by Quarantelli (2003) is mostly the first responders besides local police, to a disaster situation due to proximity to disaster site. Indian Armed Forces perform a crucial job when called upon as “Aid to Civil Authorities” since Indian constitutional framework provides for the armed forces to render assistance during disasters/calamities when situation is beyond the coping capacity of the civil administration to adequately and effectively respond. They have disciplined manpower.

However, armed forces have formed the core of the disaster response capacity and are crucial first responders in almost all high-intensity disasters. Air Force, Navy and Coast Guard have been supplementing the efforts of army. They have specialised workforce such as engineering corpse, medical corps, veterinary corps and bomb disposal corps. They have ability to work in adverse climate conditions as well. The armed forces have capability to meet nuclear, biological, radiological and chemical (CBRN) threats.

Their services though should be utilised as a last resort and can be called upon to intervene and take on specific tasks with precision in critical situations. The armed forces possess larger resources, represent very advanced technological and logistical capabilities that mobilise and deploy at short notice in order to support life-saving rescue and relief efforts.

The armed forces are trained and well equipped to react in emergencies such as disasters where situation is beyond the coping capacity of civil administration, capable of moving to any part of country in shortest span of time. The manpower at their disposal makes them valuable in providing prompt reliefs such as dropping foods, water and medicines to affected areas, restoring critical infrastructure damaged by catastrophe, erecting temporary military bridges, clearing debris in case of earthquakes causing collapse of buildings. Humanitarian Assistance and Disaster Relief (HADR) operations play a significant benign role that armed forces perform including dropping relief material, food, water and medicines. They are well equipped with tremendous resources and possess advance communication systems that get quickly deployed at the site of calamity and assist in search, rescue and relief actions with precision.

Navy is made “Designated Authority” for coastal security, and it is laced with latest equipment. Besides Navy in case of operations in coastal belts in cyclones, tsunami which causes flash floods triggered by earthquake in Ocean where early warning system (EWS) gives very little time, the role of naval forces become very crucial; while local coastal police can undertake operation only up to 12 nautical miles in ocean, coast guards of Navy and Naval forces can operate rescue operations up to 200 nautical miles. Here inter-agency coordination becomes crucial, agencies such as Indian Meteorological Department (IMD) which sends Early Warning Systems (EWS), state meteorological department which sends signals to civil authorities particularly local coastal police, coastguard, Navy, etc.

Navy uses satellite communications and, therefore, in cases of coastal disasters – cyclone, hurricanes, tsunami, it is first to alert other responders such as fishermen in deep waters, coast guards under Naval command, coastal police who also patrol in deep waters to check espionage, inspect identity of boats in Indian side of ocean waters in coastal areas. It is also a mistake to utilise individual soldiers from the military, except in special situations. Armies are not individual soldiers; they are designed to be viable units, and they are taught to function as units. These units must be mobilised, equipped and positioned to do what they are trained to do. If artillery units are taken to rescue people from the wreckage of a crashed aircraft or from damaged buildings, they will be performing a highly technical task without training.

In Kashmir floods in 2015 and recent Kerala floods, they recued thousands of people injured minimising the social cost. The experience from Asian Tsunami, cyclone “Nargis” in Mayamar, cyclone “Sidr” in Bangladesh and “Hud–Hud” Visakhapatnam, Andhra Pradesh, 2013, in coastal areas of AP attest proficiency of armed forces for disaster SAR and relief operations and their capacity to reduce human suffering by rendering effective relief actions and Medicare.

In many natural disasters, armed forces have been requisitioned by state governments since they are well trained, command larger resources, well equipped with advanced gadgets to be used in clearing debris in case of earthquake or crash of buildings, collapse of mines. Recent disasters like Kashmir floods in which the armed forces used choppers to rescue people stuck up at different marooned locations, dropped food packets, medicines, took injured and ill by air to designated hospitals.

Recently in Jaintia Hill District of Meghalaya, where 15 men were reportedly trapped and supposed to be no more alive since illegal 370 feet “Rat Hole Mine” was dug last month in December 2018, about 160 NDRF and Naval divers were pressed into rescue, a diver of the navy was able to reach bottom of the 370-feet rat hole mine. However, none of the miners were saved due to excessive Sulphur in the water which gushed from adjacent river except two decomposed bodies. The Navy officers narrated that search will only be possible once water is taken out of the rat hole mines. Finally, Navy divers using Remote Operating Vehicle (ROV) and Halogen Lamps succeeded to take out two bloated bodies through ROV. The rescue operations by NDRF and Navy were still at work in Jan 2019 on the directives of Supreme Court of India.

In December 2018, the Indian Army had rescued over 3000 tourists who were stuck near the India–China border in Sikkim’s Nathula Pass due to heavy snowfall. The *Jawans* have vacated their barracks to accommodate the stranded tourists.

The stranded tourists including women and children and have been provided food, shelter and warm clothes by the Army. It is an exemplary humanitarian work armed forces have performed. The Indian Army immediately swung into action to provide rescue and relief to the stranded tourists including food, shelter, warm clothing and medicines. The Army has also provided heavy machines and dozers of the Border Roads Organisation for snow clearance and restoration of road connectivity. Around 1500 given shelter in Armed Forces barracks, while the remaining tourists were shifted to 13 Miles in another army barracks as shown in Figure 1.

Figure 1: Armed Forces providing shelter to tourists stuck up in storm
Source: Indianexpress.com December 29, 2018

Due to heavy snow cover on roads and freezing temperature in India–China border near Nathula Pas, the army was finding it difficult to move the tourists ahead, but said that the evacuation operation shall continue till all stranded tourists are safely moved out towards Gangtok, the capital city of Sikkim; in this operations even local administration, civic agencies, local police too assisted army men, so there was good co-ordination and effective communication amongst the first responders but role of armed forces was more humanitarian and commendable. Army Jawans even vacated their own barracks till each tourists were evacuated and provided shelter, food, water and medicines.

The National Disaster Management Policy for Armed Forces approved by Union Cabinet on Oct 22, 2009, acknowledges the role of armed forces in disasters; the same policy also stresses the use of armed forces should be the last resort in severe disasters only. Armed forces have manifested their capabilities in swiftness, SAR, health and medical facilities, and transportation of injured by air, especially in chemical, biological, radiological and nuclear (CBRN) aspects, high-altitude rescue and training of paramedics, making temporary road bridges, temporary shelter by pre-fab design, air-dropping relief materials, etc.

The armed forces of the country possess superior technological and logistical capabilities, which can be mobilised at short notice to support life-saving relief efforts. Armed forces even restore communication towers to facilitate information sharing though it is not desirable to use the armed forces too frequently or too long. The legal framework depending upon the extent, gravity and typology of disasters provides for armed forces to render assistance to the civil authorities.

The central governments have always deployed the Air Force helicopters, Army boats, Army columns and medical teams from armed forces to assist affected states in rescue and relief operations. Military aircrafts are used in transportation of rescue teams and essential commodities, evacuation of stuck-up disasters-affected persons, women, children, disabled and sick from difficult locations. Government of India has also deployed on request Naval ships, military aircrafts, mobile hospitals and other resources including relief materials in neighbouring countries as well as other far off friendly countries.

Recently Nepal earthquake is an example Indian armed forces and NDRF were first to reach quickly due to proximity and swung into SAR and relief actions. Armed forces saved lives and transported injured, quickly opened their hospital for essential medicines and treatment which was commendable.

Role of NDRF, SDRF, NSG

Under the DM Act, 2005, National Disaster Response Force (NDRF) was created as a specialised response force to tackle natural and man-made disasters under the operational control of National Disaster Management Authority (NDMA). NDRF has now emerged as most visible and multi-disciplinary, multi-skilled and high-tech force, well trained in various crafts by foreign experts to effectively deal with natural and man-made disasters.

NDRF at present has 12 battalions comprising young policemen drafted from Central Reserve Police Force (CRPF), Central Industrial Security Force (CISF), Border Security Force (BSF) and Indo-Tibetan Border Post (ITBP), which comprises of trained engineers, technicians, electricians, dog squads and trained paramedics, located at 12 different locations based on vulnerability and typology of disasters to cut down the response time for their deployment. NDRF has proven its capabilities in SAR, operations in saving live, in relief and evacuation, providing food, water and medicines. NDRF remains usually engaged in training the community to build community resilience, capacity building and public awareness programmes, and it also trains State Disaster Response Force (SDRF).

NDRF is also trained to tackle biological, chemical and biological disasters, radiological, including nuclear disasters (CBRN). NDRF has been organising mock exercises with SARC countries in India for confidence building. NDRF was the first force to have landed in Nepal during earthquake in 2013 and was quickly deployed led by the then DG NDRF; they rescued a number of people, provided relief and medicines and brought appreciation for India.

NDRF has been deployed in many natural and man-made disasters including Kashmir floods, Kosi Disaster 2008, Uttrakhand flash floods, Tsunami in Odisha in 2013, Phailin, Kochi in Kerala, disaster, and recently in Kerala floods, they saved lives over 12000 persons and performed relief works at 12 strategic locations in India as shown in Figure 2.

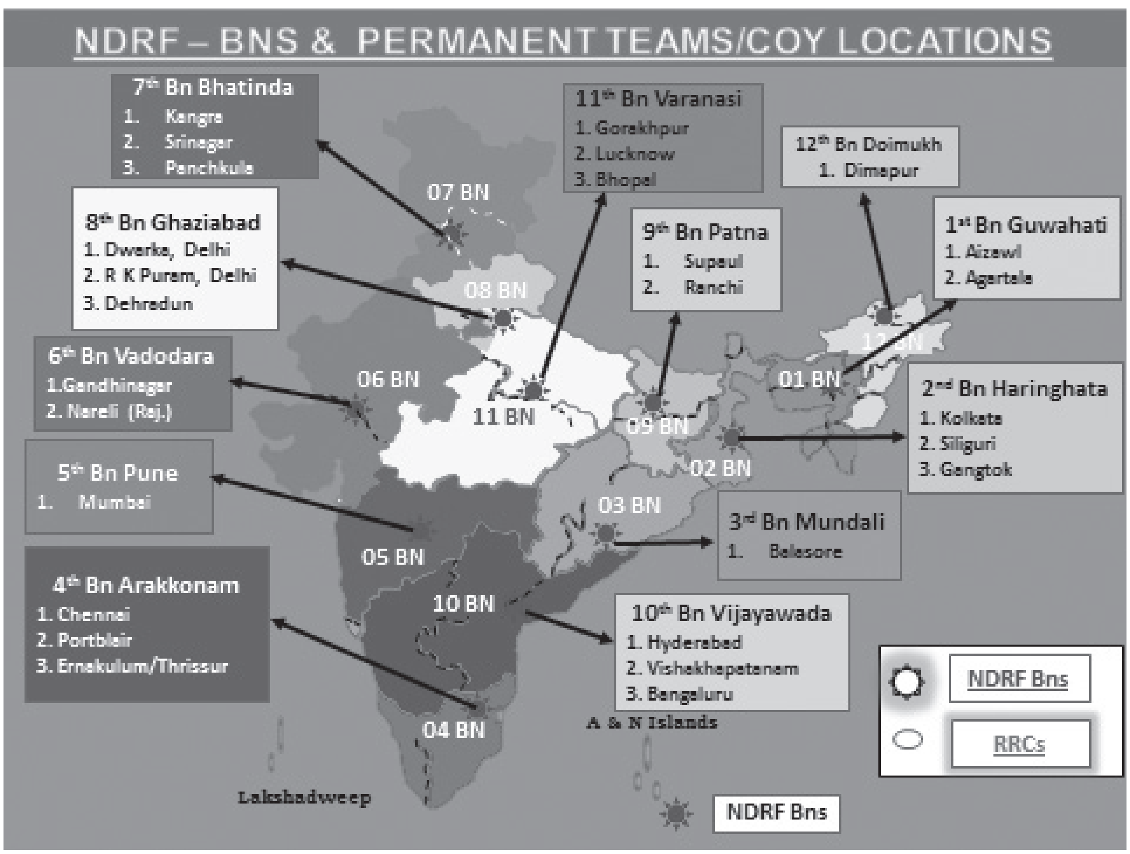


Figure 2: Deployment of NDRF in India
Source: NDRF Website

SDRF is created in approximately 22 states so far; in certain states like Jharkhand, Chhattisgarh, Kashmir, North Eastern States (NER) its creation is at infancy stage. SDRF like one in Odisha called Odisha Disaster Rapid Action Force (ODARF) is a model SDRF, which too are trained on patterns of NDRF and is well equipped with latest equipment; they have trained divers, swimmers, laced with other advanced gadgets except CBRN; they are almost equally capable as NDRF and also undertake public awareness programme in coastal belt; they are constituted by armed local police battalion on deputation; and they also train local costal community, fishermen and local police. One can say they are both first and second responders.

National Security Guard (NSG) is a very well-trained and well-equipped specialised force with its Training Hqs at Manesar in Gurgaon, Haryana state, which even uses trained dogs, drones and anti-drones in anti-terrorist and anti-hijacking operations, deployed in five strategic places in the country, and always remain in the state of readiness, which can reach to the terrorist-affected areas swiftly with air support provided by Indian Air Force in case of exigencies. They are deployed at five strategic hubs and remain in direct touch with Air Force requisitioning their crafts for rushing to affected sites.

Role of Local Police

Role of police has been largely ignored in public discourse and literature (Verano & Schaufer 2003). It was only after Katrina and New Orleans hurricanes, Odisha tsunami 1999, Bhuj earthquake 2001, 9/11 terrorist attacks in USA that police contribution in managing disasters came into public discourse, and disaster researchers and practitioners began to think that police can broaden its role in managing disasters by acquiring additional capacities.

Police along with the community are the first responder, which arrive first at the disaster site. It is the first institutional agency, familiar with local area and local people, who know the locally available resources, command respect and mandate from the state and is the face of government. In spite of a high degree of professionalism in armed forces, it is the local police who arrive first along with the local community at the disaster site in golden hours, since specialist forces and armed forces will take time to arrive. At the same time many disasters do not require requisitioning specialist forces.

Whenever, natural or man-made disasters occur, first responders will be police, fire-fighters and paramedics, commonly called by disaster experts and academia as Emergency Management Services (EMS) units. Role of police is crucial in ensuring public safety, pacifying the emotionally charged and milling crowd and calming the chaos during disaster situations. Even in the case of serious fires and fatal accidents, it is the police which arrive first due to proximity and broader presence, do the basic work, transport the injured to the nearest hospital and assist once the fire-fighters or paramedics arrive at disaster site. Police regulate the traffic and cordon off the road, assist civic agencies in Search and Rescue (SAR), evacuation, requisitioning vehicles for various duties, coordination with specialised forces such as armed forces, NDRF, etc. The police also provide protection to victims from second victimisation such as stealing from those who are dead and injured and assist civil administration in the relief distribution. Subsequently, they help ease the functioning of specialised services such as armed forces and NDRF on arrival as guides and coordinators and furnish logistic aid as it was ostensibly visible in the Bhuj Earthquake in 2001 in Gujarat and recent Kerala floods.

As per the categorisation of disasters in India, High Powered Committee on Disaster Management in its report in 2001 divides disaster management in three categories vis-à-vis role of local-, state- and national-level agencies. It categorised disaster situations into three "levels": L1, L2 and L3. The period of normalcy, L0, should be utilised for disaster risk reduction.

Level-L1: The level of disaster that can be managed within the capabilities and resources at the district level. However, the state authorities will remain in readiness to provide assistance if needed. In this situation, role of local police and special task force of district police cannot be undermined.

At the level-L1: there is limited role of external agencies either from state or from national level. These disasters are dealt by local civil administration of which local police is an integral part. Only when problem escalates at another level, then state-level State Disaster Response Force (SDRF)/NDRF may come in picture.

Level-L2: This signifies the disaster situations that require assistance and active mobilisation of resources at the state level and deployment of state-level agencies for disaster management. The central agencies must remain vigilant for immediate deployment if required by the state.

In case of level-L2: disaster management can be dealt with the state-level agencies like State Disaster Management Authority (SDMA) along with SDRF. However, seeing the limited number of personnel with SDRF at state, usually local police and STF of district police only manage the operations. The local police follow the first in and last out rule. Hence, at this level also the role of local police along with state-level specialised disaster response force cannot be ignored.

Level-L3: This corresponds to a nearly catastrophic situation or a very large-scale disaster that overwhelms the state and district authorities. The level L3 signifies a situation which must be dealt by national-level specialised agencies like NDRF and Armed Forces along the new elite force National Security Guard (NSG), which has deployment at five hubs in the country. However, often it takes time to requisition them at the place of occurrence of disaster, and golden hours is lost in due course of time.

- Crowd Management: In case of man-made disasters such as fires, accidents, terrorist attacks, deaths due to negligence in coalmines, chemical factories, etc. large crowds assemble who are at times emotionally charged, forming milling crowds. Police calm the emotionally charged crowds, control and cordons the area, maintain law and order on the disaster site till specialist agencies arrive, assist them to enter and perform their duties and also escort them to provide safe exit. In London and Barcelona terrorist attacks (2017), Police used, besides other traditional means of communication like wireless and V-SAT, even social media such as Twitter, Instagram and Facebook, to alert and warn people not to travel to affected areas, thus saving many lives.
- Ensuring Public Safety: Officers in the event of disaster situation might go from house to house searching for the injured or those who need help. They can offer transportation, basic medical care and be a bridge between citizens and rescue personnel. They can check credentials and identification to see if someone really needs to be in the area.
- Regulating Traffic and Emergency Transportation: In flash floods, fires, accidents, building collapse, etc. police regulate traffic to avoid chaos, assist and facilitate other responders to perform their task. They escort relief materials to designated places.
- Assisting Sister Agencies: Local police help external agencies in search, rescue, relief and rehabilitation, as they are familiar with local topography, language and culture. Many times, local police have a greater role in escorting relief material as well as at distribution. The proposed book identifies many situations as suggested by Quarantelli (2003), wherein local police play the crucial role in response after both natural and man-made disasters.
- Tackling Looters to Avoid Second Victimisation of Victims: Rogues and looters take advantage of a chaotic situation. When people in disaster situation are transported or shifted to safer locations or shelters, people leave homes and hardly can carry all valuables. It gives rouge elements an opportunity to commit crimes leading to second victimisation. Police presence help to deter looting. Police do day-and-night patrolling to guard the victim's houses, apprehend looters and also guard temporarily shelters where disaster victims are lodged after evacuation.
- Deployment of Resources and Provision of Multivariate Robust Interoperable Communication Network: Police can mobilise largest manpower resources and task them to SAR and public safety and law and order work at disaster site. In natural severe disasters, telephone towers get destroyed with the result that landline and mobile phones stop working. Wireless communication of the police often remains only means of information sharing; besides the police possess satellite phones V-SAT, VHF/HF and other advanced means of communication, which may be the only means

left during Bhuj (2001), Kashmir (2014), Kosi floods (2008) and Kerala floods (2018).

- Role of Police in Media Management: Police Officers are often deployed on media management since people trust a uniformed civilian who are trained to be disciplined and respected as reliable institutional source by the people, locally known and assumed that they are the ones who have first-hand correct information as they are equipped with multi-level communication network. Police officers are trained as to which information to be shared, selective sharing of sensitive information, know how to deal with emotionally traumatised people and defeat rumours.
- Distribution of Essential Relief Materials to Victims, Post mortem
- Security during Relief Distribution and Camp Management
- Inter-agency Coordination and Communication

Role of Police after Disaster in Recovery and Restoration

- Providing safe exit to other first responders, casualty information, identification and disposal of the dead.
- Ascertaining and investigating causes of disaster: In the case of cyclone Hud-Hud that struck the city and other coastal areas of Andhra Pradesh in October 2014, there was loss of life and property. As there was huge damage to many industrial set-ups by cyclone, many industrial houses were not allowing the local revenue officials to assess the damage and process compensation accordingly. It was the local police, which facilitated the ingress to the revenue officials to assess the damage and process the claims of compensation and insurance.

Kerala Floods 2018

The lives and livelihood of the people of Kerala were affected very badly in 2018; communication systems, electricity and electricity towers were affected; it resulted into a large-scale evacuation, leading to deployment of large number of police men who were deployed from different parts of the state and who rescued larger number of people, men, women, children, and even newly born kids, which may be explicitly seen in below pictures taken out by Kerala police and found mention in official report of the then DGP Kerala to Chief secretary of the state.

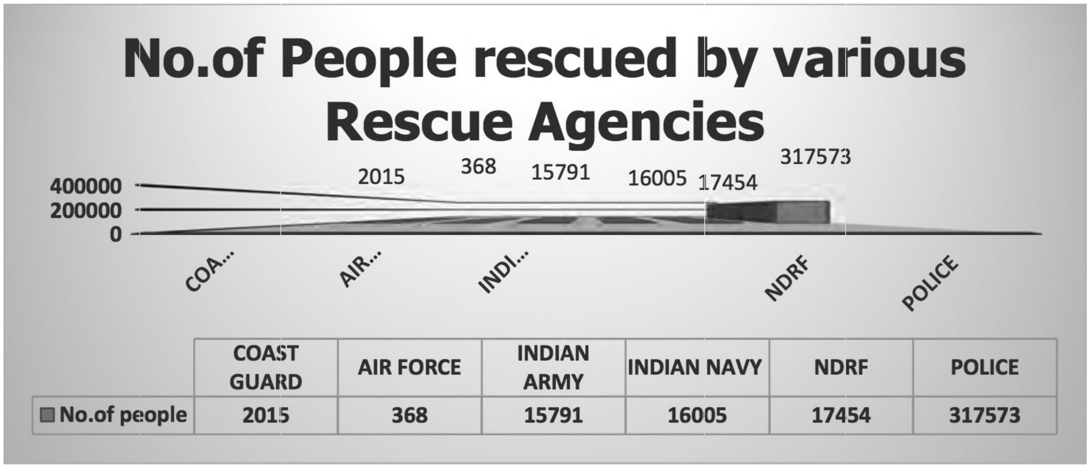
Local police with their basic training and skill assisted in evacuation and rescue work with the fact that their own family too were victims of floods as they live as civilians and saved many lives as shown in Figure 3.

Figure 3: Police involved in rescue operations during Kerala Floods 2018

Source: A Report by State Police Chief, p. 33, 2018.

The report of the Director General, Kerala refers to the deployment of police from different parts of the states in the flood-affected areas of Kerala, and it is evident that as compared to other specialised forces which arrive for a short span of time for rescue operations, local police gets involved quickly on the onset of disaster crisis and they have rescued largest number of people as shown in Table 1.

Table 1: No. of People Rescued by Various Specialised Forces as well as by the Local Police



Source: Report of Director General of Police to Government of Kerala

Of late, the flood disaster in Kerala has substantially demonstrated the role of police, and the same has been succinctly documented. Therefore, data given attest the fact that local police besides assisting the specialised forces and Armed Forces, despite limitations in realm of training, skill and equipment, do play important role in saving lives and relief distribution. To substantiate their contribution further, the recent report prepared by Kerala State Police Chief and submitted to state government with statistics and in greater detail is self-explanatory.

Conclusion

In man-made or natural disasters based on typology of disasters, first it is categorised whether it is a disaster at a desolate place where first responders can't reach in golden hours and community too cannot reach or access like transportation accidents, for instance civil aviation disaster, a plane crashing at hill top or in ocean, and a train accident at a place where community and other first responders may be located far off otherwise. In such situation only, armed forces like IAF helicopters can reach and undertake search and rescue. Otherwise in other community-type disasters local police, community and other civic services like fire-fighters, paramedics and other specialised services reach on time and undertake SAR and relief operations, transport injured to nearby hospitals, after providing first aid, transporting even injured and dead bodies to morgue and hospital to save life and provide succour and relief.

The disaster experts and some academic scholars suggest limiting use of armed forces in disaster and recommend that the command and control in managing disasters should always be in the hands of civil authorities. They argue that the very method of thinking in an army is different from a civilian situation. As Averch and Dluhy (1997) point out," a military commander knows that in war the first casualty is peace-time planning. An innovative approach is often what is required. In the civilian sector, however, pre-incident disaster plans are expected to set the parameters for response. Even if innovation is in order, the bureaucracy expects compliance and will instinctively reject deviation". Likewise, it is not correct to think that the army is required for command and control. That is a military solution with a relatively poor application to the civilian problems.

Note

1 www.disasterium.com

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