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Mailing Address

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

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Editor-in-Chief

Geological hazards have resulted in significant loss of life and destruction to the built environment as well as the natural ecosystem. Earthquakes alone killed about a million people globally. The losses as a result of geo-hazards are worth billions of dollars. Recent catastrophic disasters have revealed gaps in geo-hazard knowledge available to planners, developers, financiers, policymakers, and decision-makers. As a requirement for disaster risk management and greater resilience to these occurrences, it is critical to comprehend the complete range of geo-hazards, including severe events. Any endeavor to decrease the occurrences and consequences of future disasters would necessitate a thorough scientific understanding of the hazards and the elements at risk. As well as improved skills to avoid or avert hazards, mitigate or resist them, and recover from them within socially and economically acceptable boundaries.

National Institute of Disaster Management (NIDM) under the aegis of the Ministry of Home Affairs, Government of India is mandated to endeavor for disaster resilient India through its training, research, documentation and publications. Taking the Suo Moto cognizance of the vulnerabilities and risks of geo-hazards, NIDM decided to publish a special issue on Geohazards in its bi-annual Journal "Disaster & Development". This special issue of the journal collates the original and innovative research work on various aspects of "Geohazard" and their management.

The scholars, academics, and others who have submitted their innovative and original work for this issue are greatly appreciated. The papers were examined by experts in the field of disaster management who have years of experience and knowledge. We are hopeful that this issue will be valuable for the readers in understanding the geo-hazard, associated risks and also the prevention and mitigation measures and further will aid in enhancing the resilience of the nation.

MKBindal

Major General Manoj Kumar Bindal, VSM

Editorial Note

NIDM with immense pleasure, introduce Volume 10, Issue 02, July to December 2021 of the journal "Disaster and Development". This issue covers the diversified spectrum from theoretical considerations to case studies of disaster risk reduction and resilience focusing on Geo-hazards.

India on account of its diverse geological attributes and geodynamic processes is vulnerable to a number of geohazards that lead to fatalities and widespread damage. Earthquakes affect around 59 percent of the land surface of India. The entire Himalayan belt is estimated to be vulnerable to large earthquakes. Landslides jeopardize 12.6 percent of the country's landmass. Landslides with cosmopolitan distribution, frequent and sudden occurrences have the potential to cause catastrophic disasters and wreak havoc on communities, human settlements, livestock, livelihoods, and the environment. The tsunami that hit the Indian Ocean in 2004 caused massive devastation and loss of lives. The event spurred to development of Tsunami Risk Management Guidelines, which specify inter-agency duties and responsibilities, as well as tsunami risk planning, mitigation, and response. Chamoli disaster 2021 engulfed more the 200 lives besides huge devastation to the infrastructure and structure downstream. Bhuj earthquake (2001) and the Indian Ocean tsunami (2004) were the major geohazards that comprehended the need for robust disaster management set up in the country and in resultant the Disaster Management Act 2005 was enacted.

Disasters are inescapable; some are man-made, while others we have no alternative but to confront. When dealing with calamities, the most daunting challenge for all of us is preventing the loss of lives and property damage. It is feasible to minimize the losses if we prepare properly. And for preparedness, understanding the phenomenon is crucial. Therefore, to develop a better understanding of the Geo-hazards, their vulnerabilities, and risks in addition to strategies for their proper management, NIDM comes up with this special issue of the journal.

NIDM with its every endeavor is relentlessly pursuing its mandate for a disaster-free India by developing and promoting a culture of prevention and preparedness. This bi-annual journal is one of the steps in this direction which provides a platform to the researchers, academicians, and others for publication of their unique and innovative research work on all aspects of disaster management. The journal is also available on the website of NIDM so that each individual can assess it and be benefitted.

This issue would not have been possible without the invaluable support of the Editorial Board members, to whom we extend our heartfelt gratitude. We'd also want to thank the reviewers and NIDM's publication team for their help throughout the journal's development. We hope that this excellent collection of publications will prove to be a great resource for DRR&R practitioners and readers and will encourage further research on different facets of disaster risk reduction and resilience.

Surya Parkash, Ph.D.

Disaster Vulnerability Assessment & Action Plan to Strengthen Disaster Resilience of Gangtok, Sikkim

Rohit Magotra[1], Moumita Shaw*[1] and Ajit Tyagi[1]

Abstract

The Indian Himalayan Region (IHR) is highly vulnerable to natural disasters like earthquakes, floods, and landslides due to its geo-environmental settings. Along with the increasing urbanization, IHR is also expected to experience severe impacts of climate change in the near future. Urbanisation exerts additional environmental stress and amplifies the impact of natural disasters. Physical and socio-economic vulnerabilities of cities posed by disasters are often accompanied by a lack of necessary resources – financial, human, and institutional – as well as access to relevant scientific information to cope with them. Inefficient governance along with inadequate infrastructural services also increase the vulnerability of socially and economically marginalized populations living in urban areas.

A Vulnerability Assessment Framework (VAF), based on parameters of Hazard exposure, climate scenarios and projections, basic and critical infrastructure and services, governance structure and socioeconomic status of urban areas has been used to assess the disaster vulnerability of Gangtok city, Sikkim. The analysis indicated that the city remains vulnerable to disasters like earthquakes, landslides, flash floods and enlists the gaps in the existing infrastructure and services along with the Governance. In lieu of the existing vulnerability, it becomes necessary to devise strategies and plans to develop disaster resilience plans. The paper has done the vulnerability mapping and sector specific recommendations for building disaster resilience of Gangtok city.

Keywords: *Indian Himalayan Region, Natural Disasters, Urbanization, Vulnerability Assessment, Disaster Resilience, Adaptation Strategies*

[1] **Rohit Magotra, Moumita Shaw and Ajit Tyagi,** Integrated Research & Action for Development (IRADe), New Delhi, India

* Corresponding Author Email : mshaw@irade.org

1. Introduction

The Global Climate Risk Index report 2020 (David Eckstein et. al., 2020) ranks India 5th in 2018 in global vulnerability citing the highest recorded number of fatalities due to climate change and the second-highest monetary losses from its impact in 2018. India lost around 2,736 lives in 2017 due to disasters, with an economic loss of around USD 13,789 million, the 4th highest in the world (Eckstein D. et. al., 2019).

India is exposed to multiple natural disasters, like earthquakes, floods, cyclones, landslides, tsunami, and heat wave. Out of 36 states and union territories (28 States and 8 Union Territories) in the country, 27 of them are disaster-prone (NIDM).

The DM Act 2005 uses the following definition for disaster: "Disaster" means a catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or manmade causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of, property, or damage to, or degradation of, environment, and is of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area.

Source: National Disaster Management Plan, NDMA GoI, 2016

During 1980-2010, India has experienced nearly 431 natural disasters killing around 1.4 lakh people and affecting around 15 crores people, with an economic loss of USD 48.06 billion (EM-DAT, 2019). With growing urbanization and increasing occurrences of small and large-scale disasters in urban areas, years of development effort and infrastructure are continually being destroyed and eroded (Sanderson, 2000).

Indian Himalayan Region (IHR) covers around 16% of India's total geographical area, spread over 12 states (ENVIS, 2018). The Himalayan region is one of the four most vulnerable areas to disaster, including earthquakes, floods, landslides, and forest fires (MoEFCC, 2016). On average, IHR is hit by 76 disasters, killing 36,000 people and affecting 178 million people every year (United Nations-affiliated organization, 2013). Landslides frequently affect the IH and nearly 127 landslides events were reported between 2009-2018 (Khadka, 2021).

Indian Northeast (NE) region in India part of IHR is particularly vulnerable to natural disasters, due to its fragile geo-environmental settings and economic underdevelopment. Rapid growth is currently taking place in the environmentally sensitive region/non-urbanized region of the Himalayas. From a completely economic standpoint, this may seem ideal, at least in the short run, however, the unplanned accommodations made to adapt to such rapid changes have resulted in environmental degradation (Anbalagan, 1993). The increasing levels of urbanization, if not handled with caution, will be extremely detrimental to the climate and people of the Himalayas (Walker, 2011). A high degree of vulnerability to these disasters will increasingly make the region environmentally insecure in the future unless pragmatic interventions are made immediately.

A natural hazard turns into disasters due to structural and managerial flaws as well as the violation of natural and man-made laws before the hazard strikes. A Disaster Resilient city has the capacity to deal with such disasters- it can cope with or withstand perturbation up to a moderate degree (Parikh. J.2014) (https://irade.org/Disaster%20Resilient%20Cities.pdf

Climate change adds yet another layer of stress to those of environmental degradation and rapid unplanned urban growth, further reducing communities' abilities to cope with even the existing levels of weather hazards (UNISDR , WHO, 2008). Climate change affects disaster risks in two ways - increase in weather and climatic hazards, and through an increase in the vulnerability of communities to natural hazards, particularly through ecosystem degradation, reduction in water and food availability, and livelihood changes.

The paper presents the results of the vulnerability assessment of Gangtok city, Sikkim to develop a disaster resilience plan by highlighting their exposure to potential hazards and developing city-level resilience to build strong infrastructure, able governance, and good socio-economic conditions.

The paper is a part of a study carried out through the support of the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India (GoI), under the National Mission on Himalayan Studies (NMHS) to design and develop Disaster Resilience Action Plan for Indian Himalayan cities.

2. Study Area

2.1 Gangtok Sikkim

Gangtok the capital and the largest city in the Indian state of Sikkim and the headquarters of the East Sikkim district is located in the eastern Himalayan range, at an elevation of 5,410 ft above mean sea level and located at 27°20 N & 88°37 E. (Refer to figure 1 Gangtok city location and municipal boundary with wards). The city is flanked on east and west by two rivers, namely Roro Chu and Ranikhola, respectively. These two rivers divide the natural drainage into two parts, the eastern and western parts. Both the streams meet the Ranipool and flow south as the main Ranikhola before it joins the Teesta at Singtam. The climate in the city is monsoon-influenced subtropical highland climate or the Himalayan type of climate. The average maximum during summer season is around 22˚C, with maximum temperatures rarely crossing 25°C and minimum temperatures during the winters being recorded at 3˚C. Rainfall starts from the pre-monsoon in May, and peaks during the monsoon, with July recording the highest monthly average of 649.6 mm. The region receives an annual rainfall of 3494 mm over 164 rainy days.

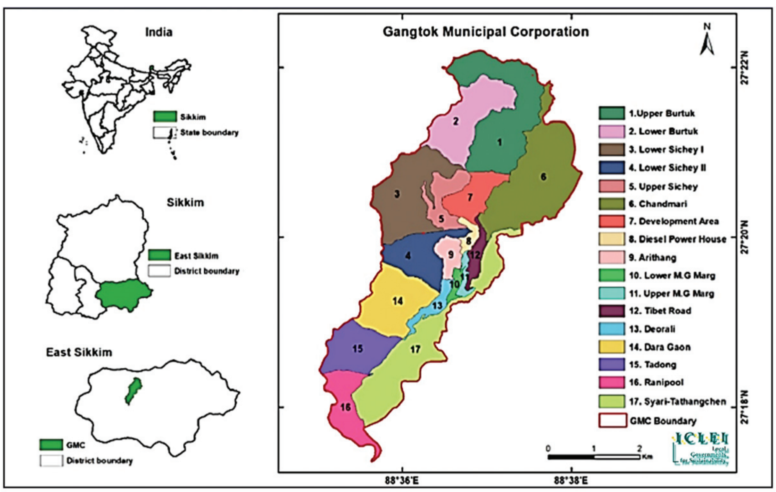

Figure 1: Location Map of Gangtok showing the Municipal Boundary and the Wards of the City

(Source: Gangtok Disaster Resilience Action Plan, IRADe, 2020-21)

The Gangtok municipal area was notified in the year 2010, comprising of 15 municipal wards and areas covering around 19.016 sq. km. The total wards have increased to 19 wards since 2020 (UDD, 2020). The total population of the city is 100,286 (Census 2011), hence the population density of the city is 5223 persons per sq. km.

The city of Gangtok is most vulnerable to earthquakes as it falls under the high-risk Seismic Zone IV and V. Apart from the earthquake, torrential rainfall triggers flash floods and landslide incidences, blocking roadways and connectivity to the city. Along with these, the city is vulnerable to hailstorms/thunderstorms and forest fires.

3. Data & Methodology

To understand and analyze the vulnerability and climate-resilient measures in Indian Cities, a Vulnerability Assessment Framework (VAF) was designed by IRADe in Asian Cities Climate Resilience, Working Paper Series 8, IIED (Jyoti Parikh et al., 2014). The Framework was developed based on four themes "Hazards-Infrastructure-Governance-Socio-Economic characteristics (HIGS)". The framework was developed to systematically understand urban issues that shape climate-resilient urban development and help shape policies and projects developed by cities to address these risks. City-level disaster risks can be analyzed using the HIGS framework that integrates information on physical and meteorological Hazards, analysis of urban infrastructure and services, Governance variables, Socioeconomic and demographic indicators This Vulnerability Assessment Framework (refer to Fig 2) provides a customizable approach for cities to analyze their vulnerabilities to understand the potential areas of corrective actions as well as enable comparison across cities. It further identifies impacts which are of concern across multiple cities, and are city-specific. Such a nuanced analysis is needed to better inform national, state, and local policymaking on urban development and management. What is particularly valuable is that the vulnerability assessment methodology can spur autonomous action by enabling cities to assess their vulnerabilities using the HIGS framework and prioritize response strategies.

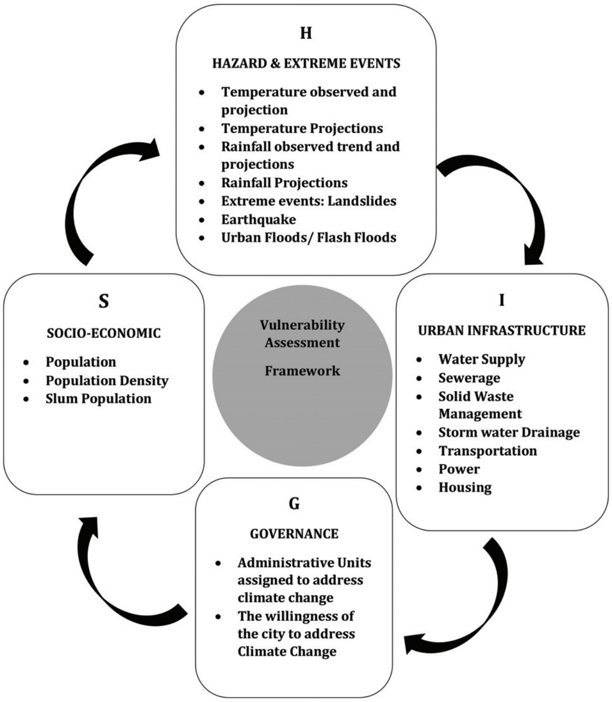

Figure 2: Vulnerability Assessment Framework and detailed list of variables

This Vulnerability Assessment (HIGS) framework was further improvised and first applied by IRADe on twenty Indian Cities for assessing their vulnerability to natural hazards. Later in 2012-14 IRADe further evolved the HIGS framework and conducted a study on disaster resilience across 10 cities in India viz. Pune, Ahmedabad, Bhopal, Vishakhapatnam, Hyderabad, Bhubaneswar, Shillong, Guwahati, Dehradun, and Srinagar (J. Parikh, et al., 2015). The holistic framework HIGS (J. Parikh, et. al., 2015) was further improved and extended for assessing disaster resilience in 10 cities (R. Magotra, et. al., 2019) by incorporating parameters that give local/regional diversification, flexibility, and interdependency (flow of information) to be customized for the use in other regions/cities. The HIGS (RVA) framework is further made more dynamic by adding more climatic parameters (temperature, precipitation, climatic scenarios, and projections, etc.) and evaluating their status. Methodology in this study revolves around collecting secondary information from the city and analyzing them concerning:

a) Exposure and vulnerability,

b) Evaluation of existing critical infrastructure and basic urban services,

c) Resilience (response and recovery systems) and evaluation of city management and governance.

The data for Gangtok has been collected through primary and secondary sources, including stakeholder consultations with ULBs (Urban Local Bodies) and related agencies. Also, historic weather data, hazard timelines, and exposure to various hazards were compiled and collated with abnormal natural events to evaluate the vulnerable profile of the region. Various parameters have been analyzed to assess each of the four aspects (Hazard, Infrastructure, Governance, and Socio-Economic Conditions) of the framework are:

Hazard and extreme events: Exposure to geophysical variables; history of hazards, their frequency of occurrence, and magnitude of impact. Climate variables observed and projected.

Infrastructure Status: Water supply, waste management, stormwater drainage system status, power, and transport infrastructure, the status of the infrastructure, maintenance, coverage, and access to the basic infrastructure.

Governance: The institutional framework of the city management, urban administration, public health, response, recovery system, and evaluation of city management in the context of disaster proneness, financial status/independence of the Urban Local Bodies, and efficiency in delivering the basic services. Smart initiatives like E-Governance, ICT (Information and Communication Technology)

Socio-Economic: Population and urbanization trends, urban population density, and slum population.

Interconnection of different variables is important to bring forth the priorities of disaster resilience towards which the cities must act fast and integrate them into their developmental activities.

Urban Vulnerability Assessment framework was used to assess the disaster resilience of Gangtok. The Vulnerability Assessment Framework was used to assess the urban vulnerability of the Gangtok and to bring forth the areas of adaptation which the cities should prioritize for improving its resilience and integrate it with their developmental initiatives.

4. Analysis and Discussion

4.1 Disaster Vulnerability of Gangtok City

Sikkim is among India's most vulnerable regions to both natural and human induced disasters due to its location in the very high zone in terms of an earthquake and high zone in terms of landslides (SSDMA, 2012). A large portion of the Sikkim territory including Gangtok is covered by the Precambrian rock comprising of phyllites and schists and therefore the slopes are highly susceptible to weathering and prone to erosion. As a result, landslides are frequent, isolating the numerous small towns and villages from the main city (UDHD, Govt. of Sikkim). Surface runoff from water by natural streams (locally called jhora) and man-made drains, has contributed to the risk of landslides. Table 1 highlights the hazard exposure month of Gangtok during a year.

Table 1: Hazard Exposure and Timeline, Gangtok

Index	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Landslides												
Flash Flood												
Hailstorm/ thunderstorms												
Forest Fire												
Earthquake												

High-intensity torrential rains may bring flash floods and trigger more landslide incidents, which may block Gangtok's land connection with the rest of the country. In 2012, 22 people were reportedly killed due to flash floods, which also washed away nearly 30 km of highway in North Sikkim (Kundu, A, 2012). Flash floods might also trigger a series of landslide incidences, which in turn compound the vulnerability of the people. During 1957 – 2005, the East Sikkim district had experienced over 153 landslide incidences. Nearly 7.51% area of Gangtok city falls in a very high-risk zone with respect to landslides potentially affecting 1.84% of the total settlements while 24.64% of the area falls under the medium high-risk zone with 18.18% of the total settlements being affected (SSDMA, 2012).

In addition to flash floods and landslides, Gangtok is also prone to earthquakes. The entire state falls in highly Seismic Zone IV/V of the earthquake zonation map of India. Around 29% of the city's area falls in the very high-risk zone affecting 18.84% of the total settlement, 13.45% of the area fall in the medium high-risk zone affecting 14.80% of the total settlement, and 31.48% of the area categorized to be in medium risk zone with 42.14% of the total settlement being affected (SSDMA, 2012). The loss of lives in past earthquakes have occurred due to the collapse of buildings, constructed with stones, bricks, adobes, and wood, which were not particularly engineered to be earthquake resistant. Table 2 provides a summary of the vulnerability assessment of Gangtok city.

Table 2: Vulnerability profile of Gangtok city

Socio-economic Characteristics	
Population	• 100,286 (2011 Census)
Population Density	• 5,223 persons per sq.km
Slum Population	• 20,504 (6,085 HHs) Notified & Non-notified slums (SFCPoA, Gangtok, 2013)
Hazard and Extreme Events	
Temperature Observed	• Gangtok has a mild, temperate climate all year round (Gangtok Municipal Corporation, 2020) • Maximum & Minimum Temperature (2016) – 27°C & 19°C respectively (Gangtok Municipal Corporation, 2020)

Temperature Projections	• By the 2030s, the average annual temperatures for Sikkim is projected to rise by 1.8 to 2.1°C with respect to the 1970s (SSDMA & GMC, 2015)
Rainfall Observed Trend	• Pre-monsoon rainfall in May • Most of the rainfall in July-September, with July recording the highest monthly average of 649.6 mm (25.6 in) (SSDMA & GMC, 2015) • Snowfall in the months of December and January were recorded in the year 1990, 2004, 2005, & 2011 (SSDMA & GMC, 2015)
Rainfall Projections	• Sikkim is expected to experience a decrease in precipitation of about 3% in 2030 with respect to 1970 (SSDMA & GMC, 2015)
Extreme Events: Landslides	• Almost 71 landslide events being registered in the city (1990-2017, sharp rise recorded between 2001-2017) • In 2016 landslide hit the Sikkim-Bengal border, resulting in the death of an unspecified number of people • In 2015, Landslides near Rambhi, in the outskirts of Siliguri, on the way to the hills have disrupted the road traffic between Gangtok and the North Bengal hub.

Earthquake	• Sikkim is placed in Zone IV/V of the earthquake • Major earthquake affected area are in and around below Arithang, below Paljor stadium and area around Amdogolai and Burtuk. • 6.9-magnitude earthquake hit Sikkim in September 2011 that killed 70 people and destroying several villages.
Urban Floods/Flash Floods	• Flash flood killed 22 people in 2012, triggered a series of landslides and washed away nearly 30km of highway in north Sikkim amid torrential rain Friday evening.

Urban Infrastructure	
Water Supply	• At present, the per capita water supply in the city is 129 lpcd (Gangtok Smart City Mission, 2018-19) • Nearly 19,811 (82.7%) households have water tap connection, with 75% of the Households having treated water supply. After connections Total length of the water supply distribution pipeline laid in the City is 203.64 Km (Gangtok Municipal Corporation, 2020) • River Rateychu is the existing source of water, and there is one WTP at Selep (capacity 41 MLD), demand being 45 MLD and check leakage (around 79%) (Gangtok Municipal Corporation, 2020)

Sewerage	• The city has 42% coverage of sewerage network services, with 96% coverage of individual & community toilets (SPCB, Sikkim, 2020-21) • The sewer system and stormwater drainage systems are separate in Gangtok. There is no treatment facility for the drains which are presently being discharged directly into the natural streams
Solid Waste Management	• The city generates about 50 Metric Tons per day (TPD) of solid waste daily (SPCB, Sikkim, 2020-21) • Almost 100% of MSW is collected , but only 15 (TPD) is treated and rest 35 TPD is disposed at the dumping site (SPCB, Sikkim, 2020-21) • No provision for the collection & disposal of hazardous toxic wastes generated from industries. • Declared the best among the top 10 cleanest cities in India, 2015. Gangtok Municipal Corporation (GMC), along with a local NGO named "24 hours Inspired", has developed a programme called "Engage 14 programme" to engage school children in the process of understanding SWM. • The Corporation has already initiated works to improve the situation at the Martam landfill site (Gangtok Municipal Corporation, 2020).

Stormwater Drainage	• There is a gap of 75.99% in the coverage of the stormwater drainage network (24%). (SPCB, Sikkim, 2020-21) • Roadside drains cover 37740m, out of which 28.09% are still earthen or below the required capacity (SPCB, Sikkim, 2020-21). • 25-30% incidence rate of sewerage mixing in the drains. • The incidence of waterlogging prevalent status is 4.72% (SPCB, Sikkim, 2020-21).
Transportation	• The share of personal vehicles and taxis combined is 98% of Gangtok's total vehicles, a high percentage when compared to other Indian cities. (NIUA, 2016) • The 1 km (0.6 mi) long cable car with three stops connects lower Gangtok suburbs with Sikkim Legislative assembly in central Gangtok and the upper suburbs. • Under AMRUT Transportation sector has been given preference by stressing on public transport or constructing facilities for non-motorized transport (e.g. walking and cycling). 11 projects have been initiated by the city (AMRUT, 2017-18)
Power	• Electricity is supplied by the power department of the Government of Sikkim. Gangtok has a nearly uninterrupted electricity supply due to Sikkim's numerous hydroelectric power stations.

Housing	• Urban Development and Housing Department is the nodal agency for providing individual urban housing in the state. • As per UD&HD, Govt. of Sikkim, the city has around 30,328 houses occupied by 23773 households with an average household size of 4 persons (2011) • 66.18 % of the houses are permanent in structure (Census 2011)

Governance	
Administrative Units assigned to address climate change & Disaster Management	• Sikkim State Disaster Management Authority – state-level institution for planning, coordinating and monitoring disaster prevention, mitigation, preparedness and management • Department of Land Revenue and Disaster Management - nodal agency for looking after disaster response, mitigation, preparedness and prevention
Administrative Units assigned to address climate change & Disaster Management	• District Disaster Management Authority, East District - includes District Core Committee for Crises Management, District Crisis Management Sub-Committee for Search & Rescue Operation and Relief & Rehabilitation • Gangtok Municipal Corporation- responsible for Sanitation and Solid Waste Management

Administrative Units assigned to address climate change & Disaster Management	• IMD & GSI - weather forecasting and disseminating weather information and hazard early warning • Municipal Disaster Management Committee, Ward Disaster Management Committee etc.
The willingness of the city to address Climate Change & Disaster Management	• The city has taken proactive initiatives and has developed very good practices for disaster resilience which includes: • Disaster Management Plan 2020-21 & 2018-19, East Sikkim, SSDMA • Report on Human Vulnerability Due to Natural Disasters, Sikkim, SSDMA, 2018 • Gangtok City Disaster Management Plan (Evacuation and Response), 2015 • Multi-hazard Vulnerability Assessment, East Sikkim Gangtok, 2012 & 2018, SSDMA • Comprehensive Mobility Plan, 2010 • CDP Gangtok

The Vulnerability Assessment of Gangtok provides a comprehensive understanding of the existing urban basic infrastructure and socio-economic condition of the city and their vulnerability to various hazards and the existing administrative and governance structure to mitigate and adapt to the same.

Hazard and Extreme Events: The city is most vulnerable to earthquakes followed by landslides and urban floods. Owing to the climatological changes projected with rising temperatures and changing patterns in annual rainfall, the city is expected to experience adverse effects of climate change and an increase in hazard events.

Infrastructure Status: In terms of the basic infrastructure and services, the availability of potable water is an important issue, with outdated and dilapidated water supply pipelines, regular leakage, and shortage of water is experienced in many parts of the city. A system for the collection and disposal of hazardous waste needs to be developed along with the up-gradation of the existing landfill site at Martam, East Sikkim (SBCP Sikkim, 2019-20).

Along with the increasing urban population, the city experiences a heavy flow of floating population (working migrants & tourists) hence, provisions are required in the sectors of public transportation and housing sector in the city.

Governance: The administrative and governance structure of the city to manage disaster has been well laid, however, there is a need to define the role and responsibilities of each department and organization to mitigate disasters not only during or post-disaster occurrences but also in the pre-disaster management process and initiating disaster early warning and developing and updating disaster database.

Socio-Economic: the city is one of the fastest-growing urban areas in the NE region with an increasing population growth rate, hence, increasing the population exposed to disasters. With over 58 slum pockets scattered across the city, the vulnerability risk on the people exposed to disaster is also high for Gangtok city

5. Recommendations

Effective disaster management systems are essential to mitigating the impact of disasters (Garschagen, 2016). The management system needs to involve government, civil society, communities, and the private sector (Wilkinson, 2012), who are some of the major stakeholders in Disaster Management.

Based on the study, some of the sector-specific recommendations for improving the disaster resilience of Gangtok city has been related to:

- Infrastructure - Construction and building bye-laws, Critical Infrastructure, Drainage, and sanitation systems.
- Hazard Management – Hazard disaster mapping, Hazard Early Warning Systems, Administrative and Governance, and Socio-economic development.

5.1 Infrastructure

5.1.1 Building bye-laws & Construction

- Gangtok follows the Sikkim Building Construction Regulations, 1991 (As amended by the Sikkim Building Construction (Amendment) Regulations, 2000), and the National Building code and Delhi Master Plan(s), which needs to be amended from the prescriptive to form-based/performance-based/site-specific, and formulation of a new enforcement mechanism .
- Nature-based construction technology adaptation and Bio-engineering measures should be given top priority.
- The northern wards, Burtuk and Chandmari are highly susceptible to landslides, owing to the higher elevation and slope among other aspects, hence new construction projects in these areas should have a clear plan on how multi-hazard disaster mitigation design and features shall be integrated into the construction.
- There is a need to develop a standard soil map in line with the stability zonation map to avoid need-based risk computation in the city.
- It should be made mandatory for buildings to obtain a certificate of structural safety before approval by a local body. Hollow concrete blocks, precast stone blocks, concrete blocks, and stabilized soil blocks can be used for construction purposes.

5.1.2 Critical Infrastructure

- Critical infrastructures like hospitals, schools, power generation and distribution centers, evacuation structures (e.g. multipurpose shelters), fire stations likewise need to be highlighted with their locations on ward level maps.

- Action Plan needs to include the location of rescue and relief infrastructure to make them functional at times of disaster emergencies.
- Systematic investigations and remedial action need to adapt to restore and conserve heritage and critical Infrastructure.
- Inspection of all structural measures twice a year, once before the commencement of the monsoon and again after the monsoon has withdrawn and ensured that restoration/strengthening measures of vulnerable spots are carried out (NDMA guidelines).
- With the increasing urbanization and tourism, Gangtok will experience vertical growth in the future, hence it becomes necessary for geo-coding buildings, basic and critical infrastructure at ward level. Basic infrastructure like potable water supply and other basic infrastructure will become a significant issue with growing urbanization, and ULBs need to consider management plans for the same.

5.1.3 Drainage and Sanitation

- Need to map the drainage pattern of the city and its neighboring areas, including streams and jhoras, as most of the landslide incidences are located near such streamlines.
- Need to develop Sewerage treatment plant, as the untreated sewer system and stormwater is discharged into the natural streams.
- The solid waste is usually dumped in the johras with no compliance. The dumping of solid waste in johras often leads to the disruption of the natural flow of the water. This results in the increased vulnerability to waterlogging and flooding, causing landslide and soil erosion in the city.
- Need to develop provision for collection & disposal of hazardous toxic wastes generated from industries.
- Clearing of culverts and jhoras and stabilization of roadside drain along all important roads.
- Catchment-wide interventions (agriculture and forestry actions and water control work). Constructing new channels or improving the discharge capacity of the present drainage system. Diversion of floodwaters into natural or artificial constructed channels or basin.

5.2 Hazard Management

5.2.1 Hazard/disaster Mapping

- A statistical overview of their frequency of occurrence and intensity is needed, along with ward-level disaster susceptibility records required. Records related to the history of hazards and infrastructure details of health centers, which are easily available needs to be maintained and updated regularly.
- Need to develop a Hazard /Risk-specific Disaster Action Plan, with a comprehensive view of all-natural and manmade disasters. (IRADe, Analytical Report for CDMP Review of Six Cities, 2013). Develop maps at the scale of 1:4000 and map hazard/risk-wise vulnerable zones.
- Preparation of large-scale maps (1:10,000/1: 15,000) of areas vulnerable to floods with contours at an interval of 0.3 m or 0.5 m. (NDMA)
- Hazard inventory needs to be developed to analyze its impact and develop the required mitigation measures. Hazard susceptibility needs to be mapped based on slope profile, city land-use pattern, land elevation, slope aspect, drainage pattern, rainfall pattern, and likewise.
- Regular updation of disaster database for future reference. Disaster communication systems need to be strengthened so that at the onset of disasters the early warning about the disaster can reach all the citizens of the city well in advance.
- Drainage mapping along the Landslide zone to record the change in the course over the period along with the catchment areas of streams and jhoras.
- Controlling water on roads and hill slopes – Water harvesting, roadside drainage, and cross drainage check dams.
- As mapping the hazard/disaster vulnerability and hazard susceptible zones across the city of Gangtok is being carried out at state and city level by various organizations and authorities like Sikkim State Disaster Management Authority, Land and Revenue Department, Geological Survey of India, Gangtok, SCA Himalayas, and DST CC, it becomes necessary to integrate such data and develop a common database and present the same at the common platform for the use of related departments and community at large. Along with a common database, updation of the same (metrological data), meteorological and hazard inventory, is required.

5.2.2 Slope Landscaping

- Installation of sustainable structural measures such as retaining wall. Adaption for the most durable type of retaining walls- Banded Dry-stone masonry or Cement masonry, Gabion, or retaining earth (NIDM Guidelines). Temporary slope retaining measures - Sandbag retaining wall, Precast concrete wall, sheet piles made of steel or timber, empty bitumen drum can also be used.
- Promoting afforestation activities and indigenous soil conservation techniques and growing of native plants with strong, deep root systems plantations along jhoras and nalahs.
- Landscape treatments such as vertical greening, screen planting, and toe planters. The use of Soil Improvement techniques is necessary to abate erosion along the slopes.

5.2.3 Early Warning System

- Need to install all-in-one early warning systems in the highly disaster vulnerable area for early evacuation.
- Early Warning systems for floods and landslides should be set up to coordinate and facilitate pre and post-disaster operations. Early Warning Systems should be the functional component of the City Disaster Management Plan.
- Installing instrumentation and slope monitoring for real-time early warning. For instance, Landslide Early-Warning System (LEWS) (NIDM Guidelines) needs to be installed.
- Developing regional Flood Information system – based on HKH Hydrological Cycle Observing System (HYCOS) as per the guidelines of WMO and monitoring, warning, and response systems (MWRS).
- Generating Flood Outlooks (NOAA (http://www.cnrfc.NOAA.gov/flood_outlook.php), regional flood outlook provides real-time flood information about the threat of potential large-scale flooding, forecasting, and warning services.
- Rainfall being the major cause of Gangtok Landslides - rainy seasons need to be monitored closely, with concerned localities need to be informed through the early warning system.

- Rehabilitation and stabilization of landslides affected sites along with the development of local expertise for early monitoring of ground instability.

5.3 Administration and Governance

- Defining role and responsibility of the Government and local bodies, public sector, NGOs, communities, and people at large before, during, and after a disaster.
- Training of first responders in search, rescue, and medicare. Training for visual and print media in the science and art of landslide management.
- Integrated land-use planning needs to be initiated at the city level. Disaster Resilience Action Plans should be developed and plans should be made dynamic with lessons from each city hazard/disaster to be integrated for better land use planning, governance, and response mechanisms.
- On the state and city governance front, the functioning of the agencies needs to be streamlined and made accountable to improve service delivery. Single point central offices are also needed in some cases, in both the cities are needed for consolidated Database Management System (DBMS) for effective and efficient planning.
- The current role of city ULB is limited in disaster management activities within the city. Strengthening of interdepartmental coordination and sharing of responsibilities to ensure easy recovery at the time of crisis.
- For better functioning of EWS at the city level, there is a need to strengthen the network among city institutions, encourage partnerships, and build the capacities of all key stakeholders.
- The Emergency Operation Centres (EOCs) should be equipped with the necessary types of equipment and the latest technology. Well trained staff in EOCs, which should be located in safe zones to avoid a halt in its functioning during floods
- Developing and enhancing awareness among the community, mobilizing Local recourses expertise along with Public information and education system development. Sharing of virtual mapping and similar techniques can be considered for the dissemination of data and disaster management strategies at the community level.
- Along with the community, it's essential to work towards capacity building of the Urban Local Body officials and on-ground implementation of the Action Plan,

with the provisions of ward level community and basic infrastructure to mitigate disasters.

5.4 Socio-Economic

- A Slum rehabilitation plan should be developed to protect the most vulnerable, which usually encroach low lying disaster-prone areas of the city. Rehabilitation and provision of Shelters for poor people living in the landslide-prone and flood-prone areas is needed.
- Increasing public awareness and education is the key to cultural practices of safety. Awareness regarding proper land use as well as sustainable land management needs to be provided.
- Gender wise segregation of the data on migrant population which is the floating population of the city should be captured too.

Table 4: Roles and Responsibilities of Implementing Agencies

Agency	Roles and Responsibilities
Indian Meteorological Department & Geographical Survey of India	• Weather forecasting and disseminating weather information • Geomorphology and Soil mapping, • Provision of Information to Urban Local Bodies on extreme weather events • Warning and early warning system set-up and updation of information
Department of Land Revenue and Disaster Management - Sikkim State Disaster Management Authority (SSDMA)	• Planning, coordinating and monitoring disaster prevention, mitigation, preparedness and management • Developing Multi-hazard / disaster Management Plan – city level • Mapping multi-hazard risk and vulnerability profile of Gangtok

- Installation, gathering, managing and disseminating the early warning/ relevant information
- Capacity building and mock drills/training
- Amendment of Building Bye-Laws
- Installation of Landslide Early Warning Systems (LEWS) and Flood Information System - Hydrological Cycle Observing System (HYCOS)
- Installation of sustainable structural measures or slope landscaping such as retaining wall for landslide mitigation
- Nallah and streams channel improvement, catchment-wide interventions and related structural measures for flood mitigation

Urban Development & Housing Department, Govt. of Sikkim

- Construction and maintenance of buildings (residential & non- residential)
- Amendment of building bye-laws
- Work in close collaboration with state govt. and Urban Local Bodies (ULBs) in terms of urban development and implementing housing schemes
- Assisting and guiding ULBs in terms of its functioning and execution of duties

Public Health Engineering Department, Sikkim

- Provision of adequate safe water and sanitation
- Water supply connection and sewer line connection – plan and execution of plans
- Functioning of city sewerage treatment plants for safe disposal of effluent and the water treatment plants

District Disaster Management Authority

- Search & rescue operation
- Relief & rehabilitation
- Traffic management during hazards
- Provides required guidance and corporates with the urban local bodies during disaster and disaster mitigation

Ward Level Disaster Management Committees

- Review and Analysis of ward level hazard vulnerabilities
- Work in coordination with District Disaster Management Authority (DDMA)

Urban Local Bodies: Gangtok Municipal Corporation

- Sanitation and Solid Waste Management
- Drainage mapping and planning of stormwater drainage system and sewerage network
- Relief & Rehabilitation of City slums/Urban poor
- Clearing of Jhoras/streams/nallahs
- Perform other duties relating to Disaster Management as assigned by the Disaster Management Authority

Though the NE region as a whole is expected to see an increase in average annual rainfall in 2030 with respect to 1970; Sikkim is expected to experience a decrease in precipitation of about 3% in 2030 with respect to 1970 (INCCA, 2010; State Action Plan on Climate Change for Sikkim, 2011). In the 2030s, the average annual temperatures are projected to rise by 1.8 to 2.1°C with respect to the 1970s (State Action Plan on Climate Change for Sikkim, 2011). For the 2050s, the average maximum temperature in Sikkim is expected to increase by 1.8-2.6°C These predicted climatic changes will exacerbate the impacts of natural disasters like flash floods and landslides that the city is already vulnerable to, along with the risk of earthquakes, thunderstorms/ lightning, forest fires, and water scarcity.

Along with the climate changes, increased urban population, from 17% (2001) to over 271% (2011), and urban space development has increased population exposure to disasters and their direct and indirect impact. In addition to the urban population, the floating population has increased over the period, with increased tourists' inflows and slum population (31%). These vulnerable populations are at high risk and require indiscriminate basic services and its proper management.

The study indicates a need for strengthening the institutional framework and the mechanism for effective data management and coordination amongst the various Government departments and institutions. The existing gaps in the urban infrastructure and the hazard management system need to be looked into. The urban vulnerability assessment indicated a huge risk incurred due to current building practices, with the building bye-laws (Sikkim Building Construction (Amendment) Regulations, 2000) not updated and lacking in need-based development. There is a need to adopt indigenous material/nature-based solutions and bio-engineering techniques for construction purposes. The existing critical infrastructure needs to be mapped at the ward level and heritage buildings need to be restored and conserved, which proper structural inspection at regular intervals. The existing physical and socio-economic infrastructure is unable to cater to basic urban requirements. The city immediately needs a sewerage treatment plant and control the dumping of solid waste in johras.

For Hazard Management, hazard zonation mapping is essential with updated hazard inventories and impact assessment. There is a need to update the existing Landslide Early warning system and procure a Flood Early warning system. An all-in-one early warning system in the highly disaster vulnerable area for early evacuation programs are recommended. Rehabilitation and stabilization of landslides affected sites by slope landscaping, installation of sustainable structural measures, and promoting afforestation activities and indigenous soil conservation techniques. A consolidated Database Management System (DBMS), needs to be established along with defining the roles and responsibilities of the urban local bodies. Slums pockets and population distribution needs to be mapped and a rehabilitation plan should be made to protect the most vulnerable.

Over the decades the Sikkim State Disaster Management Authority (SSDMA) has developed and updated the Disaster Management Plans, East Sikkim (2020-21, 2018-19), describing specifically various aspects of disaster management at the state and city level while mapping the vulnerability of the people to hazard. Multi-Hazard Rapid Vulnerability Assessment (MHRVA), 2012 and 2018 (by SSDMA and land Revenue & Disaster Management Dept. Govt. Sikkim) has also been prepared to enhance the disaster preparedness for effective response and to 'Build Back Better' in investment in DRR and Recovery, Rehabilitation and Reconstruction. Susceptibility/vulnerability maps are developed for hazards like Drought, Earthquake, Fire, Flash flood, Landslides, Hailstones & Snow/Avalanches at the scale of 1: 25,000 and 1: 10,000. SSDMA and Gangtok Municipal Corporation (GMC), has also prepared Gangtok City Disaster Management Plan (CDMP) (Evacuation and Response), 2015, focusing on the disaster response and evacuation activities.

A Disaster Resilience Action Plan is required for the city, with ward-wise mitigation and adaption plans with local ward level committee being set up to ensure adequate community participation. Detailed maps at ward level scale should be developed mapping the hazard susceptibility (landslides, flash floods, and earthquakes) zones, and existing critical infrastructure. Hazard Vulnerability mapping is an integral part of drafting a disaster resilience action plan for any city, which can be replicated and used for developing short-medium-long term structural and non-structural resilience action strategies/measures for other Himalayan cities along the Himalayan regions.

Some of the existing programs and schemes at the city and state level wherein the Disaster Resilience palling can be incorporated in the Urban Development:

- **AMRUT –** hazard vulnerability assessment can be used to map existing status and gaps in the urban basic and critical infrastructure and develop strategies to strengthen the disaster resilient infrastructure, like wastewater treatment plans, covered drains, restricted dumping of solid waste into natural streams, increasing stormwater drainage networks likewise.

- **Housing for All –** Socio-economic vulnerability assessment, can help in mapping the urban vulnerable sections while delineating hazard-prone areas for proper rehabilitation. This will also help in adopting and encouraging traditional knowledge in the construction of hazard resilient houses.
- **Smart City Mission –** the vulnerability assessment can aid in amending building bye-laws to ensure structural safety and include bio-engineering and nature-based solutions for slope –landscaping, and construction disaster-resilient infrastructures. This will also include Training and Capacity Building of the ULB officials and the first responders (community) to mitigate disasters.

Thus the vulnerability assessment will not only help in mapping the existing physical and socio-economic vulnerability needs of the city but also help in framing a detailed implementation framework to strengthen the governance and administrative structure of the city while procuring and strengthening the early warning systems and preparedness methodology for improved risk management.

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Risk Factors Associated with Earthquake in Sikkim

Depesh Subba*[1]

Abstract

Disaster is a sudden catastrophic event caused by natural hazards or human-induced or sometimes from a combination of both which results in substantial loss of lives, damage and destruction of property and environment. With the advancement of science and technology, there has been some progress in prediction, preparedness and management of natural hazards. However, such progress has been negligible in case of earthquake which is a sudden and unpredictable geophysical events.

Disasters are prevalent worldwide and India is no exception to disasters. India is one of the most vulnerable countries in the world and 59% of its land area is vulnerable to seismic hazards. The entire Himalayan region is considered as vulnerable to high-intensity earthquakes. This article is based on Sikkim- an Eastern Himalayan State which falls under the seismic Zone IV. The earthquake of 18 September 2011 of 6.8 RS is the most devastating in Sikkim history which caused huge loss. The paper tries to comprehend the risk factor associated with earthquake due to recent surge in urban growth and industrial units/development projects.

Keywords: *Eastern Himalaya, Sikkim, Urbanization, Industrial Units, Development Projects.*

1. Introduction

The United Nations International Strategy for Disaster Reduction (UNISDR 2009) defines disaster as "A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources." Likewise, the Disaster Management Act of 2005 of India defines disaster as

[1] **Depesh Subba,** Assistant Professor (Environmental Studies) at Sikkim Institute of Higher Nyingma Studies(SIHNS/Sheda), Government of Sikkim.

* Corresponding Author Email: depeshsubba11@gmail.com

"a catastrophe, mishap, calamity or grave occurrence in any area, arising from natural and man-made causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of, property, or damage to, or degradation of, environment, and in of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area". In simple, disaster is caused by natural hazards or human-induced or sometimes from a combination of both which damages lives and properties.

Generally, the natural hazards are classified into five major categories viz., meteorological, geophysical, climatological, hydrological, and biological (National Disaster Management Plan 2016). In last decade (2010-2019), there have been 2,850 disasters triggered by natural hazards where 83% were caused by climate and weather-related extreme events. These disasters affected 1.8 billion people approximately. In 2019, 308 disasters were triggered by natural hazards affecting 97.6 million people where floods (127), storms (59), disease outbreaks (36), earthquakes (32) and hydrological-related landslides (25) were the most frequent (World Disaster Report 2020).

Over the years, some progress has been made in prediction, preparedness, evacuation, recovery, management of hazards with the advancement in science and technology. However, there are some hazards like earthquake where progress has been negligible. The earthquake is a geophysical event which is sudden and unpredictable in nature and can trigger a huge disaster.

Table 1: Earthquakes from 1960 to 2019

Geophysical	Since 1960		2010-2019		2019
	Total	Annual Average	Total	Annual average	Total
Earthquake	1021	17	131	13	32

(Source: World Disaster Report 2020: Come Heat or High Water, IFRC.)

From 2010 to 2019, our world had experienced total of 131 earthquakes. In the year 2019 alone, world had experienced 13 incidents of earthquakes. It shows that earthquake is an inevitable event and has been great threat to human civilization considering its unpredictable nature and intensity. Therefore, preparedness by limiting vulnerabilities is the best option we have to mitigate the effect of earthquakes.

2. Earthquake in India

India with diverse physiographic and climatic settings is exposed to various natural and anthropogenic hazards. Factors like climate change and population growth further make India one of the most vulnerable countries in the world (Nambiar 2015). India's 59% of land area is vulnerable to seismic hazard (National Disaster Management Plan 2016) and the Indian subcontinent has experienced high number of devastating earthquakes in last decade (Mohapatra and Mohanty 2010). The entire Himalayan region is considered as vulnerable to high intensity earthquakes with magnitude exceeding 8 Richter Scale (RS) (National Disaster Management Guidelines: Management of Earthquakes 2007).

Given the regional threat of earthquake, the small Eastern Himalayan State of Sikkim falls under the seismic Zone IV; i.e. high damage risk zone or destructive in nature. As per National Centre for Seismology (NCS), twenty nine cities and towns in India are categorized highly vulnerable to earthquakes which also include Gangtok - capital city of Sikkim[2]. So, considering the location and risks factors, the article tries to put light on vulnerability aspects of earthquakes in Sikkim.

3. A Brief Seismic Background of Sikkim

Sikkim is situated in the Eastern Himalaya. It is known for its pristine environment and rich biodiversity. There is wide rural-urban population composition where 74.85% lives in rural area while 25.15% in urban area. The East district is the most urbanized district among four districts where urban population constitutes 43.19% which is above state figure of 25.15% (Census of India, 2011).

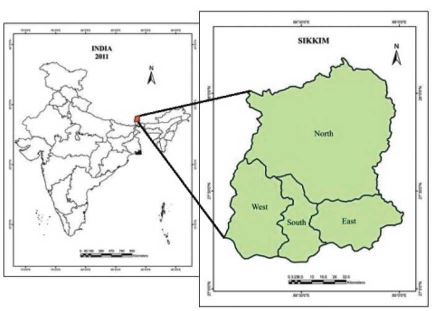

Figure 1: Location Map of Sikkim

Sikkim is located in the Alpine-Himalayan mountain system- a major earthquake belt and falls under zone IV which is high damage risk zone or destructive in nature (Bureau of Indian Standard). The Bureau of Indian Standard (BIS) has categorized the country into four seismic zones viz. Zone II, Zone III, Zone IV and Zone V. The seismic Zone V represents seismically the most prone region with higher incidence of activities of earthquakes which includes majority of northeastern states, parts of Jammu and Kashmir, Himachal Pradesh, Uttaranchal, Rann of Kutch in Gujarat, part of North Bihar and Andaman & Nicobar Islands. Zone II is the least prone region with lower incidents of activities of earthquakes. Sikkim is categorized in Zone IV along with Jammu & Kashmir and Himachal Pradesh, Union Territory of Delhi, northern parts of Uttar Pradesh, Bihar and West Bengal. Sikkim's location at the centre of Eastern Himalaya makes it sensitive to tremors even the epicenter is in other surrounding regions like North-East region or Nepal or Tibetan-China region. The occurrence of earthquake in Sikkim can trigger multiple effects like landslide, GLOF or earthquake induced flood in its river system which can devastate the region. Further, this region receives considerable amount of rainfall which make the region even more vulnerable.

Table 2: Earthquake History in Sikkim

Date	Magnitude	Region	Date	Magnitude	Region
18-09-11	6.8	Sikkim-Nepal Border Region	02-01-13	3	Gangtok, Sikkim
18-09-11	5	India (Sikkim)-Nepal Border Region	03-10-13	5	Sikkim
18-09-11	4.5	India (Sikkim)-Nepal Border Region	04-07-14	3.9	Nepal-Sikkim (India) Border Region
18-09-11	4.2	India (Sikkim)-Nepal Border Region	17-09-14	3.9	Nepal - India (Sikkim) Border Region
22-09-11	3.9	Sikkim	23-04-15	4	West Sikkim
17-10-11	3.5	Sikkim	25-04-15	7.9	Nepal
29-10-11	3.5	Sikkim, India	26-04-15	6.9	Nepal

09-12-11	3.7	India (Sikkim)-Nepal Border Region	27-04-15	5.1	Nepal-India (West Bengal) Border Region
13-12-11	2.9	Gangtok, Sikkim	15-08-15	4	Sikkim
14-12-11	4.5	India (Sikkim)-Nepal Border Region	10-10-15	4.5	Sikkim
18-12-11	3.7	India (Sikkim)-Nepal Border Region	12-03-16	3.8	Jalpaiguri-Sikkim
18-01-12	3.4	Sikkim, India	28-08-16	4.2	India (Sikkim)-China Border Region
14-02-12	3.6	Sikkim-Nepal Border Region	18-09-16	3.2	Darjeeling-Sikkim
27-03-12	4.9	Sikkim-Nepal Border Region	01-12-16	3.5	Bhutan-India(Sikkim) Border Region
30-05-12	4	Sikkim-Nepal Border Region	17-01-17	3.6	North Sikkim
11-06-12	3.8	Sikkim-Nepal Border Region	23-02-17	3.5	Sikkim
18-09-12	4.1	Sikkim	26-03-17	4.6	East Sikkim
11-10-12	3.3	India (Sikkim) – Tibet border region	16-05-17	4	Sikkim
22-10-12	3.9	Nepal-India (Sikkim) Border Region	08-07-17	3	East Sikkim
30-11-12	4.1	West Sikkim			

Source : (a) Sikkim State Disaster Management Authority, Government of Sikkim.
(b) India Meteorological Department, Ministry of Earth Sciences, Government of India.
(c) National Disaster Management Authority, Government of India.

Over the years, earthquakes has been frequent and constant threat in Sikkim. The earthquake of 18 September 2011 in Sikkim of 6.8 magnitude is the most devastating in its history where 97 people died (75 in Sikkim) and caused huge socio-economic loss (National Disaster Management Plan 2016). The psychological trauma is beyond calculation. In 2011 alone, Sikkim had experienced the maximum number of tremors (11 times) including the high intensity of 6.8 magnitude of 18 September and experienced nine tremors in 2012. After the earthquake of 18 September 2011, Sikkim has felt more than 38 tremors of varying intensity. Although the maximum number of earthquake intensity was below 5 RS, the possibility of high intensity earthquake is always there due to geological history of the Himalaya.

Table 3: Houses Damaged in Sikkim (in Numbers)
(Due to Sikkim Earthquake of September 18, 2011)

Districts	Fully Damaged	Severe Damaged	Partially Damaged	Minor Damaged
North	6000	-	-	-
South	820	-	446	1582
East	6000	-	9000	-
West	1679	5327	8342	-
Total	**14499**	**5327**	**17788**	**1582**

(Source: Khawas and Rai (2017))

The table 3 shows the house damage done by Sikkim earthquake of September 18, 2011 in four districts. Here, the house damaged is categorized into 'fully damaged', 'severe damaged', 'partially damaged' and 'minor damaged'. Among these four categories, the 'fully damaged' houses have been recorded from all districts where North and East districts observed high number of 6000 houses each. However, in total, the 'partially damaged' houses have recorded the most – 17788 houses followed by 'fully damage'- 14499 houses. The number of 'minor damaged' houses have recorded the lowest among these categories. This data shows the kind of intensity and destructive nature of earthquake.

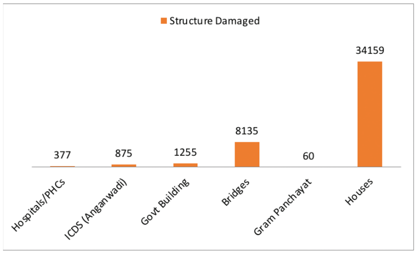

Figure 2: Structural Damages within Sikkim (in Numbers)
(Due to Sikkim earthquake of September 18, 2011)

(Source: Khawas and Rai (2017))

Figure 2 again depicts the structural damage done by the Sikkim earthquake of September 18, 2011. The figure shows that the maximum damages were observed in 'houses' (34159) followed by 'bridges' (8135) and 'Govt. building' (1255). The figure reveals the structural issue of houses/buildings.

3.1 Earthquakes Vulnerabilities in Sikkim

i. **Urbanization:** Urbanization alters the demographic and socio-economic structure. It generally leads to population and settlement growth. The population growth is one of the primary factors of exposure to various hazards. This is also in the case of earthquake. The increasing population growth increases the exposure to earthquake vulnerability. The situation is even critical in Himalayan region due to its geological setting and unplanned growth. Further, the unplanned urbanization makes Himalayan region a 'concrete' hub of settlement which enhances the degree of earthquake vulnerability. Similarly, Sikkim- a small Himalayan state is no exception to earthquake vulnerability. Over the years in Sikkim, the vulnerability of various disasters has increased due to increasing concentration of population and environmental degradation (Acharya, Bandyopadhyay and Praharaj 2012).

   For instance, the Sikkim earthquake of 18 September 2011 is most devastating experience in history of the state. The maximum effects were reported from urban centers/compact settlements where the commonly reported incidents were infrastructural damages like collapse/cracks of government and private building. Referring to Sikkim earthquake of 18 September 2011, Khawas and Rai (2017) have also mentioned that "unchecked and unplanned urbanization was the chief reason for the damage of building structures in Sikkim. They mentioned that shaking of the ground was not what killed most of the people but the falling buildings in Sikkim was the reason of vast causalities and death".

   Over the years in Sikkim, the urban centers have observed considerable in population growth over finite geographical area due to factors like employment opportunities, education, business, tourism. The industrialization especially of Pharmaceutical companies in surrounding urban centers have further contributed in the spurt urban growth.

Table 4: Decadal Change in Population of Sub-Division by Residence, 2001-2011

Districts, Sub-division	Percentage Decadal Variation 2001-2011			Percentage Urban Population	
	Total	Rural	Urban	2001	2011
Sikkim	**12.89**	**-4.99**	**156.52**	**11.07**	**25.15**
North District	**6.53**	**-1.80**	**272.12**	**3.04**	**10.62**
Chungthnag	-4.42	-4.42	0.00	0.00	0.00
Mangan	10.30	-0.86	272.12	4.09	13.79
West District	**10.69**	**8.03**	**187.72**	**1.48**	**3.85**
Gyalshing	11.26	6.40	384.66	1.29	5.60
Soreng	10.07	9.83	24	1.69	1.91
South District	**11.65**	**-1.51**	**437.23**	**3.00**	**14.44**
Namchi	13.22	-6.84	437.23	4.52	21.44
Ravong	8.56	8.56	0.00	0.00	0.00
East District	**15.73**	**-16.18**	**131.75**	**21.57**	**43.19**
Gangtok	16.41	-24.19	120.62	28.04	53.13
Pakyong	12.97	12.97	0.00	0.00	0.00
Rongli	14.11	-10.09	0.00	0.00	12.21

(Source: Census of India, 2011)

During 2001-2011, the rural and urban decadal growth of -4.99% and 156.52% respectively has observed in Sikkim. Sikkim has total urban populations of 153,578 persons. Gangtok tops the list of high urban population with population of 100,286 which recorded growth rate of 241.6% in 2001-2011. In 2001, Gangtok had 28.04% of urban population which has increased to 53.13% in 2011. In 2001-2011, Gangtok observed the striking percentage decadal variation of urban and rural population of 120.62% and (-24.19%) respectively. Overall, there has been substantial increase in urban population in 2001-2011 (Census of India, 2011). All the districts have observed the substantial growth in urban population in 2001-2011. Such rapid and unplanned urban growth has raised issues like land use pattern, building structure/spacing, drainage system, environmental degradation, traffic etc. These urban centers are hubs of huge concrete buildings with varied heights - maximum five slabs or above. Such unregulated urban growth along with increasing concentration of urban population adds fuel to already fragile topography. In addition, the location of convergent boundary of Indian and

Eurasian tectonic plates where Main Dun Thrust (MDT) & Main Boundary thrust (MBT) lie nearby Gangtok, which makes the area further vulnerable to earthquake (City Disaster Management Plan, Government of Sikkim 2015). The damage and casualties would be large in these urban centers if the high magnitude earthquake strikes the region.

Therefore, physical aspects like fragile topography, high rainfall coupled with socio-economic and demographic factors like high urban population, unplanned urban growth has enhanced the exposure and the vulnerability aspects of earthquake in Sikkim. Unfortunately, it has not been realized yet by large section of population in general and concerned stakeholders in particular; which is a matter of great concern.

ii. Industrial Units and Development projects

In India, the industrialization process/development projects had started to spread rapidly after the advent of India's liberalization policy in 1991. From then onwards, the industrialization process/development projects even started to be established in far flung regions of the country with the primary objective of 'development' of those regions. In this process, the Northeastern States also saw establishment of various industrial units/development projects. Likewise, Sikkim also welcomed such industrial units/development projects and lately Hydroelectric Plants and Pharmaceutical Companies especially.

Now, Sikkim with geographical area of 7096 sq.kms and population of 610,577(smallest State in terms of area and population) is home to 14 major Pharmaceutical Companies. Mostly, these companies started to venture in Sikkim from the year 2000 onwards mainly due to the New Economic Policy of the North Eastern Region and Indian Government's North-East Industrial and Investment Promotion Policy (NEIIPP 2007) that promised to offer tax incentives/exemption to the Northeast States for more than 10 years (Sikkim Development Report 2008). Therefore, despite its late entry the sheer number of pharmaceutical companies are astounding in Sikkim. Surprisingly, all these pharmaceutical companies are concentrated in around or near river side of Teesta, Rangpo and Ranikhola (Subba 2015).

These companies offer both opportunities and challenges. Local employment generation (mostly unskilled labor) is the direct benefit of these companies.

However, location of such huge multi-storey companies around or near river side is a major concern considering fragile Himalayan topography as this region falls under seismically active Zone IV. Therefore, their location around or near river beds poses risk in earthquakes. Further, the location of more than 30 Hydroelectric power dams upstream makes the situation critical. This will affect not only the surrounding areas but also the people living in downstream areas of Sikkim and West Bengal. There is possibility of high number of casualties because these Pharmaceuticals Companies operate day and night. Hence, the establishment of industrial units/development projects like Pharmaceutical Companies and Hydropower dams in river system has enhanced the risk factor associated with earthquakes in Sikkim.

There is no denying the fact that these developmental projects are important for the economic growth. However, there are certain aspects which need to be taken consideration before establishment of any big industrial/development projects. Like the concept of 'one size does not fit all'; the concerned government should consider the critical aspects like 'carrying capacity', geology, topography and environment of the region before implementation of any big industrial unit/development project.

3.2 Policy Suggestions

Timely preparedness is the viable option to deal with earthquakes as not much can be done to stop them. The preparedness in terms of minimizing risk/vulnerability aspects is crucial to avert the disaster-losses. It requires both infrastructural and human resource planning. The infrastructural planning needs to include broadly industrial, urban and developmental planning. In human resource planning, the State Disaster Response Force (SDRF), policy/decision makers, medical personnel need to actively engage in preparedness, management and post-disaster recovery process. In this aspect, the Government of Sikkim (GoS) recently has come up with volumes of disaster management plans under Sikkim State Disaster Management Authority (SSDMA). However, in terms of infrastructural planning Sikkim need to do lots of work. The GoS needs to prepare its short and long term planning to mitigate disasters. The feasibility of sites to industrial units/development projects needs to be studied; and sites should be allocated far away from river side and urban centers. There should be strict building code and regulation for private, government and industrial constructions. The structural and non-structural aspects of building are crucial to minimize earthquake casualties. Therefore, a regular awareness programme from the government about the non-structural management of household objects in building especially of hazardous materials like LPG, electricity is highly recommended.

Some Sikkim specific earthquake resilience suggestions are: First, focus should be to limit urban migration and unscientific urban growth which can be done through channelizing administrative services and development establishments outside urban centers. Second, it is essential to equip human resources including medics, SDRF with scientific training about disaster preparedness and management; they have to be in 'ready-to-go' position as part of quick response team. Third, reform in building structure needs immediate attention to curb the unscientific and sky-rocketing constructions. In a phased manner, efforts should be made to make earthquake resilient buildings and settlements. With government's intervention it is possible to limit the building height to a standard level as the building resilience is the key to minimize the effect of earthquake. The scientific feasibility of construction of buildings and infrastructure units should be carried out incorporating micro-level environmental, geological setting or 'carrying capacity' of the area. The mapping or zoning of geologically weak areas and land use planning is advisable. Fourth, consultations with technical/experts, urban planners/researchers and police personnel are highly recommendable in making and implementing industrial unit/development projects. Fifth, there should be public awareness about the preventive disaster measures and adaptation of disaster friendly housing. Sixth, comprehensive insurance of property and life is highly recommended which would be a smart move in dealing post disaster tragedy.

4. Conclusion

In a nut shell, it is impossible to stop natural hazards like earthquake but its adversities can minimize with timely preventive measures. The timely prevention approach will be more efficacious than post-disaster curative approach. Therefore, Sikkim needs to come up with its own area specific and disaster specific management plans and policies.

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Restoration of Coastal Barriers and Descriptive Analysis of Cyclones: Tauktae and Yass

Bevelio Philip Goes*[1]

Abstract

The Indian Ocean is a region of high energy thus, fuelling the Geohazard; Cyclone. Cyclones that drift past the coastal regions or cross the coastline (landfall), cause major destruction and losses. During the bleak situation of the pandemic, the recent formation of two pre-monsoonal cyclones – Tauktae along the west coast and Yaas along the east coast within two weeks – inflicted further misery in India. Such abnormal frequency of pre-monsoon cyclones have raised many questions regarding the changes observed in climatological patterns. The Cyclone Tauktae is categorised as an 'Extremely Severe Cyclonic Storm' whereas the Cyclone Yaas is a lower intensity 'Very Severe Cyclonic Storm' making landfall at Saurashtra and Odisha respectively. Least flooding was experienced due to the higher water holding capacity of the ground before monsoons. The storm surges by both the cyclones were categorised as Very High-Risk Zones causing inundation and severely eroded seashores. Although cyclone Yaas had a lower intensity it was accompanied by greater surge heights, as it coincided with the occurrence of a supermoon. The development of a cyclone in proximity to the west coast has raised many eyebrows. An effort is made to understand the coastal dynamics and the future consequences of ignorance. The natural barriers have been destroyed in most regions for economic gain. The rising temperatures and sea level, deduce the increase in frequencies of intense weather patterns like cyclones.

Keywords: *Tropical Cyclone, Tauktae, Yaas, Intensity, Storm Surge, Inundation, Hazard, Mitigation, Restoration, Sandunes, Mangrove*

[1] **Bevelio Philip Goes,** M.Sc. Geography and Geoinformatics, Central University of Karnataka
* Corresponding Author Email: goesbevelio@gmail.com

1. Introduction

The Earth is a dynamic planet with various climatic phenomena occurring within the blanket of its atmosphere. The atmosphere is structured as layers of gaseous mixture with the lowest layer i.e., the Troposphere having the highest frequency of turbulences. These turbulences create various weather phenomena on the Earth's surface. The unequal heating of the atmosphere causes a difference in atmospheric pressure geographically, causing a large-scale flow of gases known as wind. Winds can be pervasive or local and occur with a temporal pattern.

The variable winds result in phenomena like cyclones and anticyclones. They are formed due to the combination of atmospheric pressure gradient, convection of air and moisture and the Coriolis effect causing the wind to spiral and ultimately form vortexes (intense circular storms) (Husain, 2011). The cyclones are low-pressure systems, with wind rotating in an anticlockwise and clockwise direction in the northern and southern hemisphere respectively with a minimum endured wind speed of 62 kmph (34 knots) spiralling upwards. Unlike anticyclones that diverge downwards with high-pressure centres, cyclones are a result of the convergence of winds into low-pressure areas. Cyclone; as it is known in India is derived from the Greek word 'CYCLOS' which means Coil of a Snake. It is also known as Typhoon in Western Pacific, Willy-Willies in Australia, Cordonazo in Mexico, Bagious in the Philippines and Hurricane in the United States of America (Devi, 2021). Cyclones can be classified into two types namely;

Temperate Cyclones: Also known as Extra-Tropical or Mid-Latitudinal cyclones; they occur in the mid latitudinal regions of both the hemispheres. The temperate cyclones extract their energy from horizontal gradients of temperature in the atmosphere and are a result of unstable conditions formed at polar regions due to clashing and convergence between the fronts (cold and warm air masses). The temperate cyclones have cold cores.

Tropical Cyclones: According to the World Meteorological Organization a tropical cyclone is a synoptic scale (3100 km), non-frontal disturbance, over tropical or subtropical waters, with organized convection and definite cyclonic surface wind circulation. As defined the Tropical cyclone occurs in low-pressure tropical regions i.e., between from equator and the Tropic of Cancer in the Northern hemisphere and Tropic of Capricorn in the Southern Hemisphere with temperatures between 25˚C to 27˚C. Approximately 80 tropical cyclones occur annually (Husain, 2011).

Tropical cyclones typically have an eye which is a central region of warm temperatures; shaped in a circular or elliptical eye. It is formed by the sinking of air from the upper levels to lower levels and thus characterized by calm winds, clear sky and lowest pressure with diameters ranging from 10 to 100 Km. Hence there is an abrupt hiatus in precipitation when the eye passes over an area. The region surrounding the eye have the maximum pressure and temperature gradient with the heaviest precipitation and strongest wind. This region is a ring of convective clouds spiralling inwards having a width of about 20-100 Km. Torrential rains, storms surges and wind gusts are the associated threats of cyclones. The strongest winds of cyclones occur near the surface. The Life cycle of a cyclone can be generalised into 4 stages namely;

1. Formative stage: This stage is the pre developmental stage of a cyclone that can last 3 to 10 days. Also known as Cyclogenesis it is believed to begin with the formation of depression.
2. Immature stage (1st day to 3rd day): The Immature stage is subsequent to the formation of depression and is the further progress of the low-pressure system. The central pressure falls gradually along with the increase in size and surface wind speed during the formative and immature stages.
3. Mature stage (2nd day to 3rd day): During the mature stage, intensity i.e., central pressure and wind, remains the same but the size of the system may increase.
4. Decaying stage (2-3 days): The last stage i.e., the Decaying stage occurs due to landfall, colder Sea or unfavourable atmospheric condition or the interaction with other Tropical Cyclones thus decreasing the wind intensity and increasing the central pressure.

The Indian ocean being located within the tropics; is a hotbed for cyclonic storms. The North Indian Ocean is inflicted by two tropical cyclone seasons; one being the pre-monsoon cyclone in May and the other being post monsoon during October-November. Interference from the monsoon circulation hinders the development of cyclones from June to September. From the 80 annual cyclones occurring over the globe, 5 cyclones originate in the North Indian Ocean. The ratio of tropical cyclones between the Bay of Bengal and the Arabian Sea is 4:1 (Mohapatra, 2015). These storms mostly persist within the oceans but some come in contact with the land. On approaching the land vast damages are caused by such a phenomenon. A total of 96 districts lying within 100 km from the coast and are directly prone to the effects of cyclones. In the Journal Article titled *Cyclone hazard proneness of districts of India* by M Mohapatra; 12 are classified as 'Very highly Prone', 41 districts are 'Highly Prone', 30 districts are 'Moderately Prone' and the remaining are 'Less Prone' districts based on the frequency of tropical cyclones. A cyclone over the north Indian Ocean typically has a life period of 5 days.

Based on intensity, the evolution of the tropical cyclone can be categorised as;

1. Low (L)/Well marked Low-pressure area: The initial and latter stages of the cyclone is formed as a low-pressure area with surface wind speeds below 31 kmph. This stage is categorised with the T number of; LLC/T 1.0
2. Depression (D): Categorised as T 1.5; the surface wind speeds range between 31 to 49 kmph.
3. Deep depression (DD): Following the depression is the Deep depression which is characterised by sustained surface wind speeds of 50 to 61 kmph. The T number is T 2.0.
4. Cyclonic storm (CS): This form of the low-pressure system is the initial storm and the T number range from T 2.5-3.0 with a surface wind speed of 62 to 88 kmph.
5. Severe cyclonic storm (SCS): Post the Cyclonic Storm is the Severe Cyclonic Storm as T 3.5 and the surface wind speed ranging between 89 to 117 kmph.
6. Very Severe cyclonic storm (VSCS): The Surface wind speed of the Very Severe Cyclonic Storm is between 118 to 166 kmph. The T number classification range from T 4.0-4.5.
7. Extremely Severe Cyclonic Storm (ESCS): The Extremely Severe Cyclonic Storm has a T number ranging from T 5.0-6.0 with surface wind Speed sustaining between 167 to 221 kmph.
8. Super Cyclonic Storm (SuCS): The Super Cyclonic Storm is the ultimate evolutionary form of the cyclone with the surface wind speeds being above 222 kmph and the T number ranging between T 6.5 to 8.0. (Mohapatra & Sharma, 2019).

All cyclones do not achieve the complete evolutionary forms. They can attain maximum intensities of any form within the 8 stages.

In May 2021, a unique and event struck the coastal belts of India. Still reeling under the influence of the 2nd wave of the COVID-19 pandemic, two mighty cyclones namely Tauktae and Yaas attained landfall within two weeks creating further setbacks in India. The pre-monsoon tropical cyclones Tauktae and Yaas formed on either flank of the Indian peninsula. This unique phenomenon resulted in vast devastation and also provided an insight into the understanding of climatology and its future impacts. Therefore, the cyclogenesis, its physical characteristics, associated damages and the climatic impact of the two cyclones is analysed through this article.

1.1. Etymology and Description of Tauktae and Yaas

A panel comprising of thirteen countries, that include India, Pakistan, Bangladesh, the Maldives, Myanmar, Oman, Thailand, Sri Lanka, Iran, Saudi Arabia, Qatar, Yemen and the United Arab Emirates is led by the UN Economic and Social Commission for Asia and Pacific (UN ESCAP) and the World Meteorological Organisation for naming the cyclones within the tropical region. A new list comprising of 169 names of cyclones was released in 2020, with each country suggesting 13 names each. Such a panel is created for easy identification of the storms thus enabling easy warning notifications globally. The names are kept simple to avoid technical names thus facilitating effortless spreading of awareness and remembering to the common people. The Indian Meteorological Department (IMD) is among the six Regional Specialised Meteorological Centres (RSMC) authorised to issue advisories and propose names for the tropical cyclones in the region of the north Indian Ocean (Yeung & Mitra, 2021).

The word ‘Tauktae’ (pronounced Tau’Te) is derived from the Burmese dialect which means ‘gecko’; a lizard. The Cyclone Tauktae is categorised as T 5.5 Category 3 storm with 125 mph wind speed according to the Joint Typhoon Warning Center (JTWC). This is equivalent to Extremely Severe Cyclonic Storm; the categorisation by Indian Meteorological Department (IMD). According to IMD, the central pressure (eye) of Tauktae is 950 mb. In the 2021 North Indian Ocean cyclone season; Tauktae is the second depression, first cyclonic storm, first severe cyclonic storm, first very severe cyclonic storm, and first extremely severe cyclonic storm (Korosec, 2021).

‘Yaas’ literally means ‘a tree that has a good fragrance’ and is derived from the English word Jasmine. This cyclone is the second cyclone of the 2021 North Indian Ocean cyclone season categorised as T 4.0 i.e., a Very Severe Cyclonic Storm with the broken low to medium cloud mass arranged as a shear pattern. The minimum cloud top temperature was -93^{o}C. The system of Yaas is embedded with intense to very intense convection layers.

The next Cyclone to occur will be named 'Gulab', recommended by Pakistan which basically means a rose.

2. Data

For mapping, the inundation area caused by storm surges from both the cyclones, the pre-cyclone and post-landfall SAR data of Sentinel 1 from the Sentinel Hub were acquired. The advantage of SAR remote sensing is its capability to penetrate cloud cover, thus producing rasters devoid of cloud hindrance. Data to represent the development of the cyclone and the parameters (intensity and surge height) of Tauktae and Yass were obtained from the Meteorological and Oceanographic Satellite Data Archival Centre (MOSDAC) portal which is a repository for the INSAT-3D satellite archives from Regional Specialized Meteorological Centre (RSMC), New Delhi and the periodic surge height guidance from Indian National Centre for Ocean Services (INCOIS). Remotely sensed rainfall data was acquired from the PERSIANN imagery through the Centre for Hydrometeorology and Remote Sensing (CHRS) data portal. The ALOS PALSAR DEM raster of Goa was acquired from the ASF Vertex portal to create a topographical profile of the Coastal region. Apart from the geospatial data; bulletins from IMD, editorials from news resources, research articles on cyclones and a webinar – 'Cyclones & Storm Surges', by NIDM-IMD were referred for the study.

3. Methodology

3.1. Analysis

Time-series comparison of the data is tabulated for understanding the pattern of the cyclone intensity, squalls and surge heights. The cyclone intensity recorded from the data sources were at regular intervals of 6 hours during the six days and five days of cyclones Tauktae and Yaas respectively. The per-day maximum rainfall level as well as the surge height- above the astronomical tide – were considered for each coastal state during the period of the cyclonic development. The inundated area along the coast at the location of landfalls is mapped by calculating the difference between both the pre-cyclone and post-landfall SAR images using the raster calculator. The pixels with the maximum index (difference) signify the flooded region. The DEM raster of Goa is taken as an example to display the coastal profile.

3.2. Data Illustration

The Cyclone intensities, storm surges and rainfall data are represented as bar, area and line graphs respectively. The INSAT-3D raster represents the cloud cover and its temperature at the landfalls of the respective cyclones. The tracks of both the cyclone along with periodic date and intensities are depicted in a layout (Fig. 1.). The topographical profile of the coast is represented using the elevation from the DEM. The inundated area of both the landfall locations is mapped as a layout.

4. Tracking the Development of the Cyclones

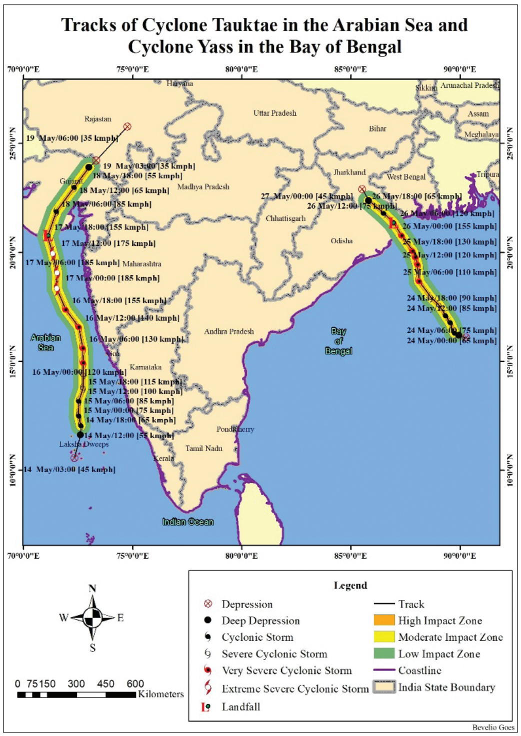
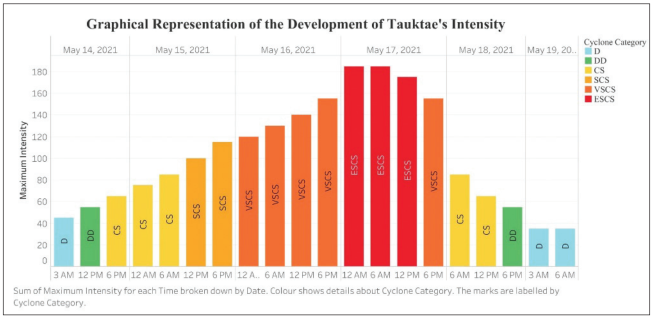


Figure 1: Tracks of Cyclone Yaas and Tauktae with the respective category evolution, intensities and classified impact zones. Each impact zone is a buffer of 10, 15 and 25 kms for the High, Moderate and Low Impact Zones respectively; as classified by ISRO in the BHUVAN portal.

4.1 Cyclogenesis and Subsequent Development

4.1.1 Track of Cyclone Tauktae (13th May 2021 - 19th May 2021)

Tauktae originated from a tropical disturbance, which was first monitored by the Indian Meteorological Department on May 13, 2021.



Graph 1: Intensity Bar Graph of Cyclone Tauktae. As observed is the steady increase in intensity of Tauktae and the rapid decrease after landfall.

i) A Well-Marked Low Pressure (WML) Area originated over the southeast Arabian Sea and the adjacent Lakshadweep area on 13th May 2021 at 08:30 am IST.

ii) The Probability of cyclogenesis i.e., the formation of depression (D) was observed at the east-central region of the Arabian Sea. This depression moved with a speed of 19 kmph in the North-Northeast wards' direction.

iii) This depression then intensified into a Deep depression (DD) at 08:30 am IST on 14th May 2021. The convection of clouds led to the formation of a curved band pattern with a cloud top temperature of -93˚C. The surface wind speed of this system ranged from 50-75 kmph.

iv) Later the system enhanced into a Cyclonic storm (CS) at 06:00 am IST on 15th May 2021 over the east-central region of the Arabian Sea moving northwards with a speed of 12 kmph. The magnitude of the surface wind speed ranged from 80 to 90 kmph. Through the INSAT imagery in Fig. 2., Tauktae is described with a ragged eye pattern.

v) At 05:30 pm IST on 15th May 2021, the storm intensified to Severe Cyclonic Storm (SCS) with a surface wind speed ranging from 95-115 kmph over east-central Arabian Sea.

vi) A Very Severe Cyclonic Storm (VSCS) over the east-central Arabian Sea with a speed of 19 kmph was formed at 08:30 pm on 16th May 2021 moving North-Northwest wards. The wind speed magnitude was from 115-185 kmph.

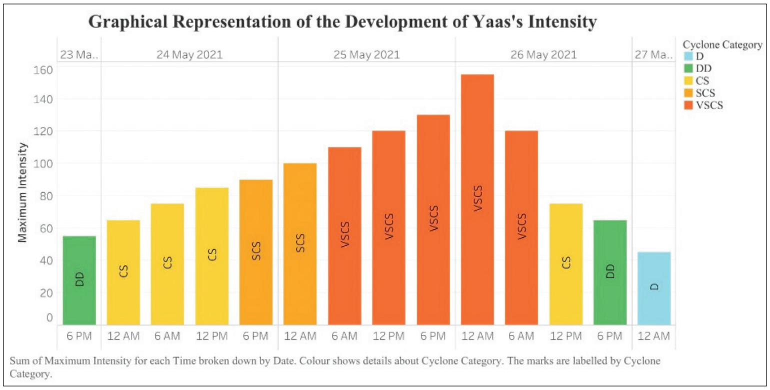
vii) At its peak the cyclonic system of Tauktae formed as an Extremely Severe Cyclonic Storm (ESCS) over east-central region of the Arabian Sea at 05:30 am IST on 17th May 2021 moving North-Northwest wards with a speed of 20kmph and surface wind speed reaching a magnitude of 210 kmph.

viii) On 17th May 2021, upon landfall at Saurashtra, the intensity of the system decreased from ESCS to VSCS with surface wind speed decreasing to 150-175 kmph.

ix) On 18th May 2021 the system further weakened to a CS and then to a depression over south Rajasthan and adjacent Gujarat.

x) The remnant of the Tauktae system moved north-eastward from Rajasthan to Uttar Pradesh as a low-pressure area with scattered low to medium cloud cover.

4.1.2 Track of Cyclone Yaas (23rd May 2021 – 27th May 2021)



Graph 2: Intensity Bar Graph of Cyclone Yaas. As observed is the steady increase in intensity of Yaas and the rapid decrease after landfall.

i) A Low-Pressure Area over the North Andaman Sea and the adjoining east-central Bay of Bengal originated on 22nd May 2021.

ii) Later a Depression was formed moving with a speed of 4 kmph towards West-Northwest direction.

iii) This system intensified into a deep depression located 600 km North-Northwest wards of Port Blair on 23th May 2021 at 11:30 am IST. The magnitude of the wind speed lied between 50-70 kmph.

iv) 24th May 2021 at 05:30 am IST the deep depression converted to a Cyclonic Storm moving in the direction of North-Northwest. The surface wind speed magnitude ranged from 50 to 70 kmph.

v) Later at 11:30 pm the cyclone Yass intensified into a Severe cyclonic storm over north-western region of the Bay of Bengal with surface wind speed from 100 to 120 kmph.

vi) The next day i.e., the 25th at 05:30 am IST the storm enhanced into a very severe cyclonic storm moving with a speed of 15 kmph north-westwards. The surface wind speed of the system ranged from 115 to 185 kmph. On 26th May 2021 the system made landfall over Odisha.

vii) This system then weakened to a Cyclonic storm on 26th May 2021 at 05:30 pm IST with surface wind speed from 75-95 kmph, leading into a depression on 27th May 2021 at 11:30 am IST and ultimately led into a well-marked low pressure over Bihar and east Uttar Pradesh.

viii) Similar to cyclone Tauktae the remnant of Yaas broke into low to medium clouds in central and North-eastern states of India and the Bay of Bengal.

4.2 Landfall

The phenomenon of the cyclone moving over the land after intensifying in the ocean is known as landfall. In a landfall, the eye of the cyclone moves across the coast towards the land thus intersecting the coastline. The peculiarity of the cyclone is that the fiercest winds do not occur within the eye but in the immediate surroundings of the eye. This explains the higher intensity of the cyclone effects before the landfall. The landfall generally is accompanied by strong wind gusts, severe storm surge and torrential downpour thus causing massive damage to the region. As observed in the tracks of Cyclones Tauktae and Yaas, after the landfall the storm generally weakens rapidly. This is due to the interaction with the rugged terrain and the absence of the required source i.e.; ocean heat and moisture are not available on land.

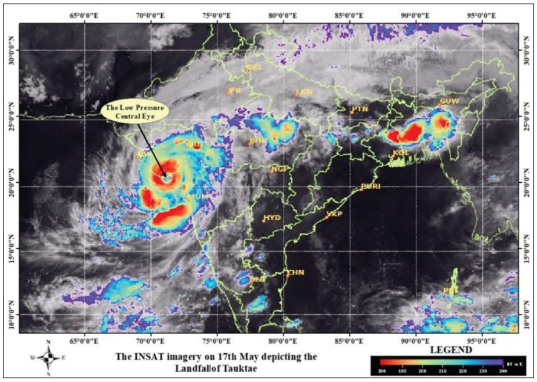


Figure 2: Layout of INSAT-3D image depicting the landfall for cyclone Tauktae along with the Cloud top temperatures. Minimum Cloud top temperature is -93°C and presence of a warmer ragged eye is observed. (Image Courtesy: MOSDAC)

The eye of the storm will cross the Gujarat coast between Una and Diu in the Saurashtra region with a slightly lower wind speed (155-165 kmph) than the attained peak speed of 210 km (TWC India Edit Team, 2021). According to PK Jena; Odisha's Special Relief Commissioner (SRC) the cyclone Yaas landfall occurred near Dhamra port in Odisha at 9.15 am IST on 26th May 2021. The landfall process took 3-4 hours to complete.

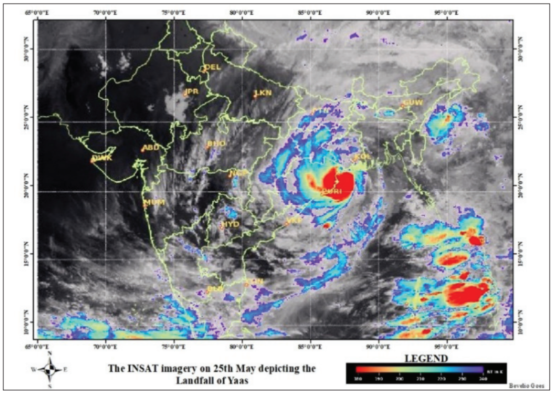
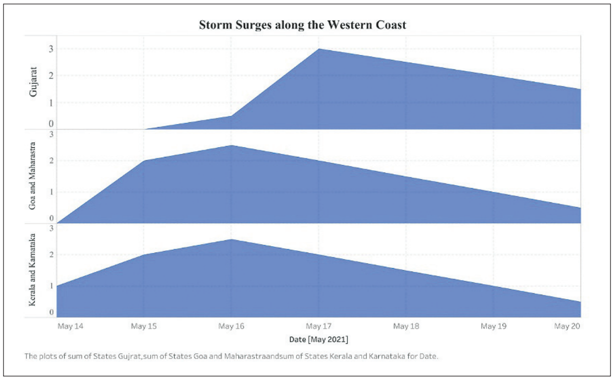


Figure 3: Layout of INSAT-3D image depicting the landfall for cyclone Yaas along with the Cloud top temperatures. As observed, the minimum Cloud top temperature is -93°C and there is absence of an eye pattern. (Image Courtesy: MOSDAC)

5. Impact of the Tauktae and Yaas

5.1 Impact of Cyclone Tauktae along the West Coast

Cyclone Tauktae is one of the strongest cyclones along the west coast. The depression over the Lakshadweep resulted in inundation of the low-lying areas by tidal waves about 1 meter above the astronomical tide.

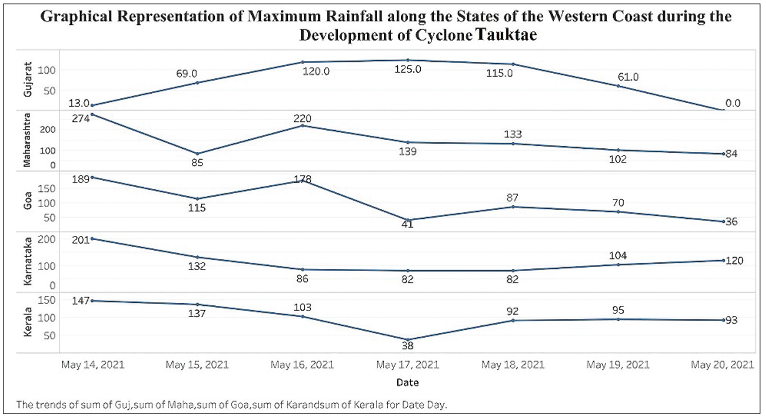


Graph 3: Daily Storm Surge heights above the astronomical tide for each coastal region during Tauktae's development. The landfall state; Gujarat experienced a later commencement of the surged but had the highest average surge of 3 meters.

The states of Kerala, Karnataka, Goa, Maharashtra experienced massive squalls which led to the destruction of thatched houses as well as 'pucca' houses, threat to flying objects, destruction of power and communication poles, metalled and unmetalled roads, railways, uprooting of trees and decrease in visibility. Being in the range of 100 to 200 km from the western coasts of Kerala, Karnataka, Goa and Maharashtra, the states endured wind gusts of more than 100 kmph. The city of Mumbai suffered wind speed up to 114 kmph as recorded by the weather station at Afghan Church in Colaba, which is the highest recorded wind gust in Mumbai in the past 70 years. Due to the landfall and the cyclone reaching its peak near the coast of Saurashtra, the State of Gujarat experienced the highest squalls with magnitudes of 170-185 kmph.

Apart from gusts, torrential precipitation is also one of the accompanied calamities. On 17th May parts of Mumbai like the Juhu Airport experienced rainfall of more than 300 mm within 24 hrs. This is the highest recorded rainfall amount in the month of May.

The coastal state of Goa and Kerala experienced rainfall of 145 mm from 14th to 16th May. The Saurashtra and Kutch were impacted with rainfall in excess of 200 mm. Apart from the coast, the inland states like Rajasthan, Haryana, Uttar Pradesh, Delhi and the Northeastern states experienced low intensity but heavy rainfalls from the remnant of the cyclone. Delhi received 60 mm of rainfall which is the highest in May in 35 years. The capital state also experienced the lowest temperature during this month at 23°C since 1951.



Graph 4: Daily maximum rainfall for each western state.

The entire western coast experienced large tidal waves leading to flooding of the low-lying areas. With wave heights between 4-5 meters, the coasts experienced massive erosions. The coastal region of Kerala and Karnataka experienced storm surges of 1 meter whereas the coasts of Goa and Maharashtra experienced tidal surges reaching 2.5 - 3 metres. The Kutch and Saurashtra region was most affected by the storm surges as the intensity of the Tauktae was highest before the landfall. The Gulf of Khambhat being a funnel-shaped bay concentrated the surges thus facilitating the tidal waves to be reaching 5 meters.

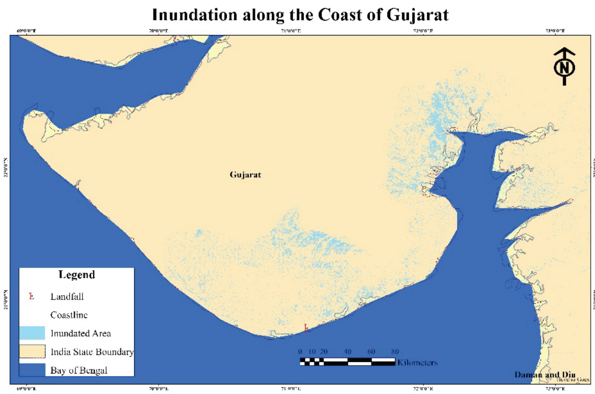


Figure 4: Map depicting the inundation caused by storm surge along the coast of Gujarat with a total inundation area of approximately 3482.6 km^2. As observed high inundation occurred near the Gulf of Khambhat due to the funnel shaped coastal configuration.

All these combined forces led to huge destruction. Strong wind gusts destroyed houses, huts, and state infrastructures. It also led to the uprooting of trees, communication and electricity poles creating blackouts, blockage of transport routes and also afflicting mobile connectivity. 70% of the state of Goa was in darkness for more than 48 hrs with more than 500 trees being uprooted. The intense rainfall-induced flooding and landslides in high terrain areas of Gujarat. The cyclone occurring during the pre-monsoon period ensured high seepage of rainwater into the ground thus reducing the risk of higher flooding in the affected areas. Indian Meteorological Department (IMD) stated that the low-pressure area in the North Indian region attracted high moisture content from the Arabian Sea thus ensuring rainfall for two more days till May 20th after the diminishing of the cyclone.

Figure 5: Waves hitting the Gateway of India in Mumbai on May 17, 2021 (AFP/Sujit Jaiswal).

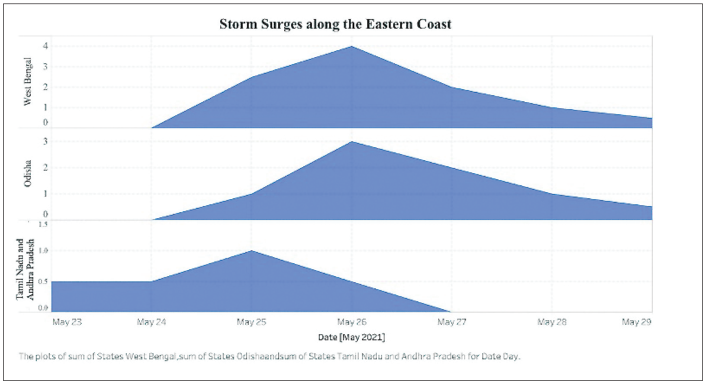
The greatest threat from cyclone Tauktae is the storm surge, especially near the region of landfall. The entire western coastline faced erosion thus destroying beaches, embankments and shacks. Apart from erosion, surges also inundated low lying areas and caused saltwater destruction in Lakshadweep, Kerala, Goa, Maharashtra and Gujarat. Such huge storm surges hindered and fishing activity which is a major occupation of the coastal regions. Many houses, structures and boats along the coast were destroyed. In Trivandrum, the roads along the coast were damaged by storm surges. As the highest storm surges were along the coast of Gujarat, vast areas of Saurashtra were inundated.

Figure 6: File photo on 19th May 2021 in Utorda, Goa. It depicts the seawater intrusion to the right of the picture due to the diminished sandune. (Regan Fernandes)

Not only do these disasters cause economic losses but also result in a high number of casualties. 16 fishermen were missing off the Kanyakumari coast. The sinking of barge P305 belonging to the Oil and Natural Gas Company (ONGC) resulted in 66 deaths off the Mumbai coast. The reported deaths due to the cyclone in Kerala were 10, 3 in Goa, 8 deaths in Karnataka, Maharashtra accounted for 18 deaths and Gujarat being the most affected accounted for 64 deaths. This total amounts to 169 deaths due to cyclone Tauktae. Around 80 people were injured as a result of the cyclone. The deaths reported were due to house collapses, drowning at sea, lightning strikes and other accidents linked to the cyclone. This cyclone also affected parts of Pakistan.

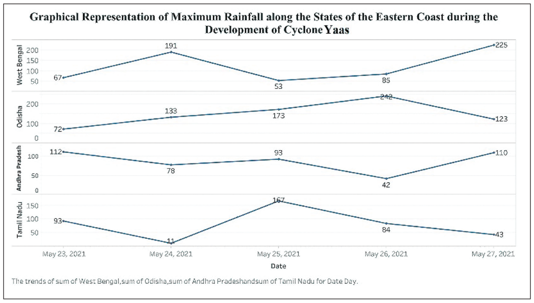
5.2 Impact of Cyclone Yaas along the East Coast

Unlike Tauktae, the cyclone Yaas is a VSCS thus being of lesser intensity. The worst affected states were West Bengal and Odisha with gale winds reaching 85 kmph. Sightings of tornados were also reported in Hooghly and North 24 Parganas districts on 25th May. Approximately 80 houses were destroyed in West Bengal. Torrential rainfall in West Bengal and Odisha were approximately at 90 mm on 24th May. This rainfall was not only restricted within the Coastal states of West Bengal and Odisha but also in the adjacent inland states of Bihar, Jharkhand and North-East India.



Graph 5: Daily Storm Surge heights above the astronomical tide for each coastal region during Yaas' development. Although not being a landfall state, West Bengal experienced the highest average surge at 4 meters.

Though the intensity of Yaas was lower, the storm surged during the cyclonic system of Yaas was greater than that caused by Tauktae. This greater storm surge was due to the lunar position during the cyclonic period. The full moon was closely aligned with the perigee thus being a supermoon and resulting in huge spring tides. The surges reported in Odisha ranged between 5 to 6 meters. In West Bengal, the reported wave heights in East Midnapore ranged between 3-5 meters.



Graph 6: Daily maximum rainfall for each eastern state.

Similar to Tauktae the gusts caused by this cyclone also destroyed houses, uprooted trees and communication and electricity poles leading to power outages near the coastal areas. Storm surges affected the coastal regions of West Bengal and Odisha ahead of the landfall leading to massive inundation, as most of the region is a low-lying plain. Compared to Tauktae the number of deaths due to Cyclone Yaas in India is lower-resulting in 6 deaths.

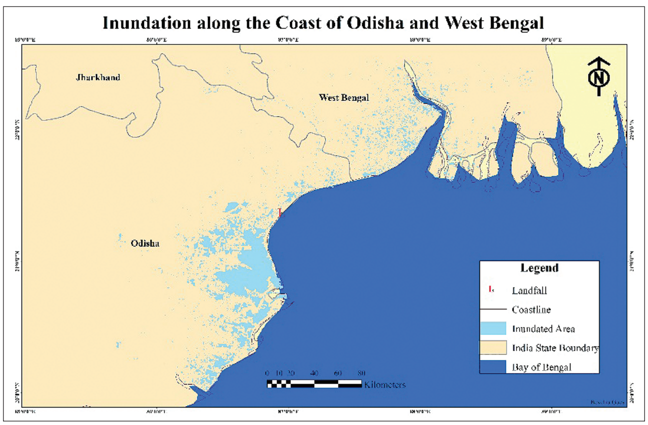


Figure 7: Map depicting the inundation caused by storm surges along the coasts of Odisha and West Bengal with a total inundation area of approximately 4275.82 km^2.

6. Mitigation Measures Engaged during the Cyclones

The disaster impact caused by cyclones can be reduced by; hazard and vulnerability analysis, preparedness and planning and most importantly the early warning and mitigation. The Early warning system (forecasting) involves the prediction of interrelated cyclonic attributes like track, areas threatened by winds, rainfall and storm surge. The Indian Meteorological Department (IMD) which also acts as the RMSC, is the warning and forecast centre for cyclones occurring in the North Indian Ocean. With the forecast of cyclone Tauktae on 13th May and of cyclone Yaas on 19th May, the national forecaster issued warnings, possible damages and advisories to people living within the red alert zones under the threat of the two cyclones. The national warnings by IMD are conducted in five stages i.e.;

1. *Pre-cyclone Watch:* Such a warning is issued when a formation of a cyclonic disturbance that has the potential to intensify into a Tropical Cyclone is identified. The color code for this warning is Yellow.
2. *Cyclone Alert:* This bulletin is issued at least 48 hrs prior to the expected cyclone. The color code is Orange.
3. *Cyclone Warning:* This warning indicates the latest position of the Tropical Cyclone along with its characteristics like intensity, landfall time and position, the height of storm surge, damages expected and the actions suggested and is issued at 24 hrs before the cyclone. The color code is Red.
4. *Post-Landfall Outlook:* During the cyclonic system a warning at about 12 hrs before landfall and till the end of the cyclone is issued.
5. *De-Warning:* Post the cyclonic effects, when the tropical cyclone weakens into depression a De-Warning is issued.

Many techniques that are used to forecast the location and intensity of cyclones include; Radar, Statistical and Synoptic analysis, NMP models and most importantly through Satellite imagery. The INSAT-3D is one of the major satellite sensors for tracking cyclones. The rainfall is monitored by rain gauges and by the advanced use of remotely sensed images of PERSIANN, STAR, IMERG and other such sensors. One of the major approaches for storm surge guidance is by tide gauges and by surveying high watermarks. Such techniques are limited in number, perishable and lack accuracy. To compensate for this deficit, analytical nomograms and dynamic models are created for storm guidance using characteristics like intensity, pressure drop, landfall and storm motion.

IMD had urged the concerned authorities to take action by keeping the 5 districts of Kerala on red alert for 15th May, Gujarat under a red alert for 17th and 18th May and warning about damages over Porbandar, Gir Somnath Botad and Bhavnagar, Amreli Junagarh and the Coast of Ahmedabad. The fishermen were advised not to conduct fishing along and off the Karnataka coast till May 17 and along and off Maharashtra, Goa and Gujarat coast till May 18. More than 2 lakh people along the coast of Gujarat were evacuated. Camps were set up for 87 people in Kerala. Apart from warnings and evacuations, many response teams were arranged during the cyclonic system to restore the trail of destruction rescue people. Initially, the National Disaster Response Force (NDRF) Director General SN Pradhan had assigned 53 NDRF teams; each having a strength of 47 personnel to tackle the after-effects of Tauktae for the western coast. Of these, 24 teams were pre-deployed to maintain the well-being during the cyclone whereas the rest were kept as backup. Due to the high impact and intensification of cyclone Tauktae the NDRF had increased the number of teams to 100. Apart from NDRF in Goa and Kerala the Indian Navy and Army helped in clearing debris and assist in the restoration of connectivity. The Indian Air Force arranged 16 transport aircraft and 18 helicopters on operational readiness in peninsular India necessitated due to Cyclone Tauktae.

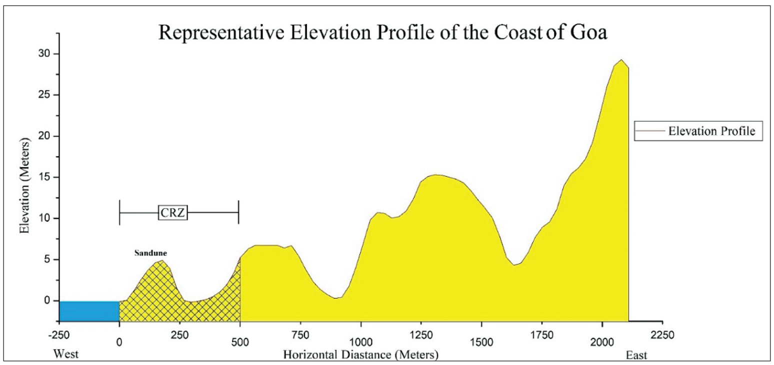
The IMD marked the coastal region of Odisha and Bengal as a red alert. Around 15 to 20 lakh people were evacuated from the zones marked as a red alert. To restore the damages and rescue people about 106 teams of NDRF were deployed. West Bengal and Odisha each were provided with 46 teams. More than 2500 trees and poles that obstructed properties and roads were removed and more than 1000 persons were rescued by the Indian Defence Forces along with the coast guards. According to the Press Trust of India (PTI) a total of 404 rescue teams that include the NDRF, 205 Fire service teams, 60 from the Odisha Disaster Rapid Action Force (ODRAF) and 86 groups of tree-cutters were deployed in Odisha. In West Bengal and Andhra Pradesh huge number of fire brigades, police and disaster relief personnel were deployed for rescue operations. The Eastern Command of the Indian Army deployed 17 cyclone relief columns, comprising of specialised army personnel with their associated equipment and inflatable boats in West Bengal. Also, 22 teams of NDRF and State Disaster Response Force (SDRF) were deployed in Bihar. The landfall also resulted in massive damages in Bangladesh.

7. Conclusion

Occurrence of cyclones in the Indian ocean is common during May on the eastern coast of India over the Bay of Bengal. The occurrence of two pre-monsoonal cyclones – one on the western coast and the other on the eastern coast of India is an uncharacteristic phenomenon to transpire.

Being one of the fiercest cyclones to hit the west coast in decades, Tauktae was categorised as an Extremely Severe Cyclonic Storm on 16th May at night. According to JTCW the tropical cyclone Tauktae is the fifth-strongest cyclone on record in the Arabian Sea. Previously, most cyclones in the Arabian Sea tracked either directly towards Gujarat or migrated west of the Arabian Peninsula. But on 17th May, the centre of Tauktae tracked only 140 km west-southwest of Mumbai, India. During both the cyclone seasons, storm strikes around Mumbai seldom occur due to the prevailing meteorological conditions. According to National Oceanic and Atmospheric Administration (NOAA), since 1903 only five cyclones have been tracked within 100 km of Mumbai. With the recent Tauktae hitting the entire west coast – Kerala, Karnataka, Goa, Maharashtra, Gujarat – forecasters believe climate patterns are changing. The cyclone Yaas is among the many preceding cyclones to hit the eastern coast of India with Odisha and West Bengal being landfall prone zones during a cyclonic system. The presence of 1250 early warning systems in coastal villages and 450 cyclone shelters in Odisha, has drastically reduced the casualty rate since 2000 (Mahapatra, 2021).

The impact of both the pre-monsoon cyclones was more confined than regional. Due to the high seepage capacity of the ground, the flooding by precipitation was minimal. Apart from gales the storm surges caused seawater ingression in both the western as well as the eastern coast. The impact of a storm surge is associated with cyclone intensity, bathymetry of the coastline, angle at which the cyclone strikes the coast, coastal configuration and also the time of landfall (Mohapatra, 2015). The funnel shape coastal configuration of the gulf of Khambhat concentrated the storm surges thus causing the extreme inundation. The occurrence of the supermoon during the landfall of Yaas further intensified the storm surges. Perpendicular motion of the cyclone towards the coastline lead to surges of higher intensity as compared to parallel motion. Hence the coastal areas that did not experience the landfall, had significantly lower surge heights. The saltwater inundation caused by the surges damage vegetation and reducing soil fertility in the long run. The flooding caused by storm surges also pollutes freshwater water sources like rivers, lakes and groundwater thus reducing the availability of potable water. The storm surges during the landfall of both the cyclones were categorised as Very High-Risk Zone. The coast is a geomorphologically dynamic region. Due to sand mining, unscientifically built seawalls, breakwater and infrastructure across certain coastal regions, the scenario of coastal erosion has worsened thus destroying the protective coastal relief features. Natural barriers such as sandunes (Figure 6.) and coastal vegetation protect the inland from such surges and thus minimizing the inundation. The coastal vegetation not only acts as a barrier but also hold the soil beneath thus reducing the erosive effects of surges and winds. Water is a hazard when it is excessive, deficient or contaminated. Comparing the sandune height in Graph 7 and the surge heights in Graph 3 and 5, one can conclude that such natural reliefs can be 'lifesavers against the wrath of the sea', during storms. A Cyclone, result in excessive water content, and its contamination thus damaging the surrounding as well as creating a shortage of potable water.



Graph 7: Topographical profile of the coast in Sernabatim, Goa. The sandune height observed is approximately at 5 meters.

The Arabian Sea and the North Indian Ocean were observed with warmer sea waters with temperatures ranging from 30°C to 32°C. These temperatures are above the average climatological temperatures from 1981 to 2010. The source of cyclones to fuel its deep convective storms is partly due to the result of increased temperatures. Until 2010 there were no observations of category 4 or stronger cyclones since 1998 over the Indian

Ocean. Since then, six category 4 or stronger cyclones (including Tauktae) have formed. According to (Dam, 2021) 'India's monsoon rainfalls will likely increase by 5% for every degree Celsius of global warming. This suggests that with increasing temperatures in the Arabian Sea and the North Indian Ocean more energy will be available to develop cyclones of higher intensities and the rainfall pattern will be more chaotic with shorter timespans and increased intensities. A Red alert was issued by IMD on July 19 in the coastal region of Goa and Maharashtra. Intense spells were experienced on the west coast in July. Wind gusts of 65km/hr during this period caused extreme damages in various parts of the coast. In Goa due to heavy rainfall, the northern villages were flooded, damages were caused to the archaeological site; Safa Masjid, caving of roads due to heavy flow of water, the collapse of Pailul-Sattari bridge, houses, landslides at the Ghats disrupted rail and interstate bus traffic, destruction of mobile connectivity are some of the damages caused. IMD stated that the rainfall during August and September is likely to be on the higher side of normal in Madhya Pradesh, West Bengal, Odisha, Jharkhand, Bihar and the North Eastern States. Such devastation is an uncommon spectacle in Goa and is the worst monsoon flood since 1982, providing an insight into the changing climatic pattern. Though the intensity was lower than the cyclone, the lack of seepage capacity of the ground was the major reason for the flooding.

The trend in the rising temperature of the Arabian Sea in the past 3-4 years has increased the probability of powerful tropical cyclones over the Arabian Sea (Murakami, et. al, 2017). Although some experts believe that rising temperature is not the only reason for the increased cyclonic events. As tropical cyclones become frequent on the western as well as the eastern coast of India, emphasis should be laid on restoring and protecting the natural barriers. Therefore, with this predicted future of a combination of factors like rising sea levels, warming oceans, climate change, rapid intensification, shorter timespans and changing meteorological conditions; there will be an increase in quantitative as well as the qualitative risk of cyclones. A disaster of such monstrous level cannot be prevented but its impact can be reduced by preservation and restoration of natural shields like coastal vegetation and sandunes, improved preparedness, immediate relief, providing accurate early warning, building resilient structures and using the ingenuity of science to create technological solutions.

8. Acknowledgment

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Natural Disasters and Children Well-Being: A Review Study

Amandeep Kaur[1] and Tejpreet K Kang[1]

Abstract

Several studies have shown a large number of negative symptoms of psychological well-being after natural disasters. Natural disasters present a critical and developing threat to the prosperity of children. Consistently, 175 million children get affected by natural events, including earthquakes, typhoons, droughts, heat waves, extreme tempests, and floods. Children are especially vulnerable during these types of disasters and experience expanded issues concerning to their mental health, physical health, and learning after all the exposure. The quantity of children influenced by these disasters every year is alarmingly high and can be expected to ascend as climatic change proceeds. Children and youth are sincerely helpless against their encounters during a calamity.

This paper aims to study the overall well-being of children after their encounters with natural disasters.

A systematic literature review was undertaken by searching and choosing peer-reviewed papers from PubMed, SCOPUS, ResearchGate and Google Scholar four major worldwide electronic databases.

The current paper provides the impact of natural disasters on children's well-being. Further research is vital to design interventions to improve the well-being of survivors of natural disasters. Anticipation and mitigation programs and policies can decrease children's fear and risk by assisting communities to prepare themselves and react in a better manner to these catastrophes. Expanding school security, expanding the accessibility of evidence-based recovery programs, and focusing on administrations to children at most elevated risk for problems and are expected to mitigate the effect of catastrophic disasters on children. Lastly, recognition of severe and troublesome reactions should be trailed by

[1] **Amandeep Kaur and Tejpreet K Kang,** Human Development & Family Studies Punjab Agricultural University, Ludhiana, India

* Corresponding Author Email: amanv15995@gmail.com

satisfactory help and treatment, as per the developmental stage and emotional needs of every child and taking the supportive organizations into consideration.

Keywords: *Natural Disaster, Vulnerability, Children, Child Health, Disaster-related Health*

1. Introduction

Children younger than 18 years are an especially weak populace when presented with natural disasters (Peek 2008). Contrasted with adults, children go through severe ill effects of calamities since they inhale more air per pound of their weight, have more slender skin and are at more danger in instances of loss of fluid and are bound to lose body heat (CDC 2020). Calamities can also hurt children indirectly. At the point when a natural disaster influences guardians and different grown-ups (like educators), children's care, security, and emotionally supportive systems are dissolved (Kousky 2016). Beyond the quick trauma and damage brought about by disasters exposure, children likewise may experience longer-term physical, mental, and educational deficiencies. Disasters are generally acknowledged to be an aftereffect of complex collaborations between perils like earthquakes, typhoons, floods and vulnerability – a result of complex associations between the physical, monetary, social and political circle, experienced in various ways by an assorted scope of people and groups (Gaillard 2010). Vulnerability can be identified with the actual exposure of communities to perilous events, for example, those living in flood fields or alongwith faulty points; yet it is additionally associated with the social and monetary setting inside which these populaces exist (Comfort et. al., 1999). While there stay a few vulnerabilities of the specific relationship between outrageous climatic events (tornadoes, floods and dry season) and worldwide environmental change, the generally recognized proof shows that there will be an expansion in the kinds, recurrence and seriousness of hydro-meteorological (or environment) hazards. The Intergovernmental Panel on Climate Change (IPCC) perceives that changing climatic hazards is probably going to affect the individuals who are already vulnerable, even though they have exposure to outrageous occasions, their capacity to adapt to such shocks is low (IPCC 2007). This is particularly intense in developing nations where the administration is feeble, training frameworks are poor, adapting limits are lower and where climate-sensitive wellbeing components like hunger, diarrhea and intestinal sickness are higher (Anderson, 2010). India is one of the world's most calamity inclined nations with twenty-seven of its twenty-nine states and seven association regions presented to intermittent natural dangers like earthquakes, cyclones, avalanches, dry seasons and floods. Ecological degradation and environmental change and have additionally intensified the recurrence and severity of calamities alongside expanding the vulnerability of key resources including individuals. Furthermore, very nearly 33% of the nation is likewise influenced by civil conflict. In realism, there is regular ignorance in strategy and problem making for children who are the most at-risk from the effect of catastrophic events.

In 5 significant disastrous hazards from 2000-2016 somewhere in the range of 17,671 children die. The 2015-2016 droughts in 10 states influenced an expected 330 million individuals, including 37 million children under age five (UNICEF 2019). Numerous factors of children's lives are influenced unfavorably, like leaving school unwantedly because of schools being utilized for different purposes like safe houses during catastrophic events, missing inoculation because of interruption of health administrations and the non-accessibility of clean water, nutritious food, and sanitization facilities prompting sicknesses and malnourishment. Furthermore, while the calamities are going on, there are likewise expanded rates of savagery, maltreatment and exploitation just as trafficking, child marriage and labor. Thinking about the recurrence of repetitive droughts, floods, serious climate or struggle in various areas across India, development results of children and women, especially from small and marginalized communities are unfavorably affected (UNICEF 2019).

In any calamity, children are bound to be harmed, and unable to get help or medical services. They are likewise more helpless against contaminations and lack of healthy sustenance and are additionally exposed to more serious risk through separation from their parental figures. In the majority of the hazards, between 33% and half of the deaths happen in children (Kamath 2015). The drawn-out outcome of catastrophes additionally affects children more as compared to grown-ups, particularly those who reside in ruined conditions. Ensuring mental issues, for example, post-traumatic stress disorder and depression sway their physical and psychological well-being, just as education and nourishment (Kamath 2015). India and the entire of South Asia, on account of interesting geo-climatic conditions, are inclined to catastrophic events. About 60% of the Indian landmass falls in the seismic zones III-V and consequently is defenseless against earthquakes. The Coastal States, especially in the East Coast (like Andhra Pradesh, Orissa and West Bengal) are inclined to cyclones. As per a report curated by the International Displacement Monitoring Center, which tracks internal relocations around the world, a bigger number of individuals in India than in some other nations were uprooted by catastrophic events in 2012 (Global Estimates 2013). In the last decade, our nation confronted gigantic calamities like the Indian Ocean tidal wave, the Kashmir earthquake, the Uttarakhand flash flood and the Kosi floods. Security of the children should be a need previously, during and after a catastrophe. Children-centered catastrophe hazard reduction ought to be remembered for the calamity mitigation strategy with sound interests in creating safe frameworks, especially well-located schools and wellbeing offices with great road access. A productive early warning signal framework, a decent pre-disaster readiness and plan from central to village level, inter-area coordination, fast reconstruction and restoration are required. Suitable frameworks ought to be set up to give instant and effective assistance to individuals influenced by disasters, particularly till outside help can reach in conditions when a local organization is likewise influenced by the disaster (Kamath 2015).

2. Methods

2.1 Strategy of Systematic Review

This study was a systematic literature review, which has started with these necessary questions: "What are the pathways of impact on children in the context of a natural disaster?" "What would be the effect of natural disasters on children's overall well-being?" The definition of children was based on that of the UNICEF: "a child means every human being under 18-years-old."

2.2 Data Sources

A systematic search took place during one month period from July 12, 2021 to August 10, 2021. The sources consisted of PubMed, SCOPUS, Research Gate, and Google Scholar. In total, 21 papers out of 68 were selected and evaluated using thematic analysis.

2.3 Database Searching

The initial search process was conducted to find an answer to the designed questions. Furthermore, experts were consulted and the related articles were examined. The Search terms like Child*, adolescent*, teen*, disaster* were used.

3. Pathways of Impact

Children might get at risk after a disaster. They depend on guardians, who might be ill-equipped. Extremely young children will most likely be unable to impart essential information if they get isolated from their guardians. A few children require exceptional consideration, good nourishment, and extraordinary supplies. Children's physical build makes them more unsafe than grown-ups to some health impacts. For instance, children inhale more air per pound of bodyweight than grown-ups do, and their bodies contain less liquid, making them more vulnerable to drying out. They can likewise be at a stage in their development process where medical conditions can have life-long consequences. They might experience more prominent difficulty handling severe injury. For that load of reasons, a disastrous event might affect a child in various ways in comparison to how it affects an adult. Undoubtedly, it might influence children distinctively depending upon their age group (Kousky 2016).

Natural disasters can affect children through numerous pathways. To begin with, they cause immediate bodily damage. A disastrous event can harm schools and medical services offices, intruding on education and diminishing the accessibility of medical care. Hazardous events can demolish a family's resources. Relatives or children can be harmed or killed, or they can contract diseases from post-catastrophe circumstances. Families might lose pay either because employed individuals from the family lose their jobs because of injury or macroeconomic conditions or because the functioning individuals from the family are killed. In most of the developing nations, loss of income joined with loss of resources and higher uses for disaster fixes could make families send children into the labor work. Families may have less monetary resources to spend on medical care, food, or school supplies all with adverse consequences on children. At last, a disaster can cause children stress and injury, which can be exacerbated by seeing their parents under stress. For children, such a circumstance can prompt psychological wellness issues that can affect physical wellbeing and schooling. Stress can likewise have an impact on pregnant ladies (Kousky 2016).

Children who get separated from their parents or essential guardians during or after a disaster address another reason for concern, particularly concerning to non-governmental organizations. Such children might be manhandled, taken advantage of, and disregarded. A calamity's effects are intervened by the characteristics of families, children, communities, nations, and the actual disastrous events. Various children in different circumstances won't respond the same way to a particular catastrophe. Effects on children likewise change across nations because of financial conditions, nearby organizations, and political realities that impact disaster reaction and recovery. However, studies have analyzed whether living in a space vulnerable to a disaster has any impact on children and a few investigations have investigated what living with hazard can mean for family income and utilization decisions. For instance, families in dangerous regions might be bound to grow crops low in risk yet in addition low in returns, for example, a variety that endures droughts yet produces lower yields. Then again, families may decide to live in more dangerous regions that give different advantages to children, like nearness to occupations or education (Kousky 2016).

Turoff et. al., (2021) outlined five pathways between natural disasters and violence, including: (i) environmentally induced changes in supervision, accompaniment, and child separation (ii) transgression of social norms in post-disaster behavior (iii) economic stress (iv) negative coping with stress and (v) insecure shelter and living conditions.

3.1 Effects on Physical Health

Following serious disasters, children frequently experience the ill effects of medical conditions. Disastrous events can impact children's well-being through a few channels. Initially, a hazard can lessen the intake of fundamental nutrients, calories and of supplements because a family loses food yields or monetary resources to buy food. Secondly, a disaster can demolish the well-being foundation. This can imply that diseases or wounds brought about by the disaster are hard to heal and turn out to be more terrible, yet it additionally implies that non-disaster-related medical issues might go untreated. Contaminated surfaces and the absence of clean drinking water can make irresistible infections spread. During and after floods in Bangladesh, for instance, cases of diarrhea, cholera, and other intestinal illnesses expanded because of the absence of safe drinking water (Brouwer 2007). The diarrheal ailment can prompt dehydration and malnourishment. Because of their little size, infants and exceptionally small kids are particularly defenseless, and lack of hydration can become perilous. Also, those pathways can connect, all in all, impoverished nutrition can worsen sickness.

Children's well-being might be more at risk in a disaster for various biophysical reasons. Their immune systems are less experienced, their respiratory rates are higher and numbers of their systems are as yet going through fast development and growth. It has been reported that fetuses in the belly and extremely small children are especially vulnerable to intense or life-long impacts from negative health shocks. Different researches have clarified the physical and mental health impacts of the flood (Tapsell et. al., 2002). For example, during and after flood circumstances individuals experience physiological health impacts like cold, hack, influenza, sore throat, or throat contaminations and cerebral pains, skin rashes, gastrointestinal sickness, chest disease, hypertension, asthma which brings about mental pressure (Tunstall et. al., 2006).

3.2 Effects on Mental Health

Disastrous events can cause multiple emotionally destructive conditions for children. Not exclusively is the occasion distressing and alarming, however after it goes away, stress can be brought about from the harm to children's houses and assets, from relocation, and breakdowns in society and nearby economies. At the point when friends and family are absent or harmed the sorrow can be significant and children might make some harsh memories handling and adapting to these misfortunes. Children might get stressed when their guardians' capability to secure their decays or when they watch parental figures experiencing dread and stress. A number of studies have discovered that when guardians have undeniable degrees of post-disaster symptoms, their children have significant levels also. Children (like grown-ups) can be pretty much vulnerable to psychological issues like tension or sadness, also, a few groups respond more intensely to a hazard than others do. A disaster's effect on children fluctuates dependent on their earlier encounters to awful mishaps, financial elements, age, sexual orientation, character qualities, intellectual abilities, and associations with their folks and families. Mental health symptoms typically decrease as a catastrophe subsides into the past. Yet, when disaster produces an extreme threat to life or emotional disturbances, the effects can persevere for quite a long time. Notwithstanding, a few components, like accessible and strong guardians, have been found to buffer the effects.

Jenkins & Meltzer (2012) clarify the psychological health effect of the Indian Ocean tsunami, 2004. The survivors showed a wide scope of symptoms identified with nervousness, depression and PTSD. The displaced victims of the disaster showed a higher rate of symptoms when contrasted with the non-displaced victims. Superfluous fear and adjustment issues were normal. The sensation of hopelessness and a steady condition of despair was likewise found in the people who were victims. There were a lot of psychological issues in the survivors from the Nordic nations. The most usually announced issues were relentless grief, a condition of shock and dread, maladjustment and dysfunctionality. Few victims were determined to have mental issues containing the side effects, for example, staying away from a particular circumstance with a fear of being dismissed or embarrassed, a condition of consistent bitterness and vulnerabilities, neglecting to comprehend the causes and explanations for the anguish; dread of socializing and steadily staying away from social circumstances.

3.3 Effect on Social Health

Children often relapse after a disaster, losing abilities they obtained before the disaster or getting back to practices they had grown out of. They stick more with the guardians or other essential parental figures. They begin mentioning guardians for taking care of or dressing. They attempt to compete with younger siblings for attention from guardians or other essential parental figures. Children begin confronting the inability to perform chores and fulfill typical obligations. Indeed, even the report about disaster influences children in a few different ways like they might confuse reality and realities with their dreams. They might get worried about separation from guardians. They might compare a scene from an alarming film with a news film. Children might experience issues perceiving that the disaster isn't up close and personal. Indirect exposure to calamities can happen via exposure to the media (like radio, TV or web-based media) or guardians' gossips. Children, who watch media coverage might show symptoms of being stressed, depressed or restless, they may also get exposed to sleep disturbances due to these responses or their failure to quit thinking about what they have seen or heard. A part of these reactions could be incited by the dread that they, or their families, will experience what they are finding in the media. These symptoms are relative to the amount of time these children are exposed to inclusion (Houston et. al., 2011). Children presented to media inclusion of catastrophes could be in danger of re-traumatization (Koplewicz and Cloitre 2006). Another source of exposure to calamity is prenatal exposure to the disaster. In a study researching school performance following prenatal exposure to calamities, the prenatally exposed children accomplished lower scores on 3rd-grade standardized tests in math and reading (Fuller 2014).

3.3.1 Inequalities in Child Health

A variety of ideas have emerged surrounding the mechanisms by which Socio-economic circumstances (SECs) influence health, most of which were established with adult health in mind and distinguish between material, psychological and behavioral aspects (Whitehead et. al., 2016).

Material: This pathway focuses on living conditions and the reality that persons in higher social positions have more access to resources that promote health, such as a warm, safe house and nutritious foods (Cooper and Stewart 2013). The physical home environment has a significant impact on the health of young children. Less well-off families have less influence over the physical components of their living environment; they are more likely to live in homes of inadequate size and quality, and they are less likely to have direct access to the garden. The relationship between SECs and child health, notably respiratory difficulties in children, has been found to be mediated by material hardship and poor home condition (Spencer 2005).

Psychosocial: Infants and early children have minimal understanding of social structures and limited control over their health and health behaviors, the influence of this pathway must almost materialize through the feelings and subsequent behaviors of their caregivers. Psychosocial factors on health may become more relevant when children enter adolescence and begin to develop a sense of social standing and independence from their families. After controlling for other components of SECs such as household income, perceptions of social status or family wealth relative to peers have been linked to physical and socio-emotional well-being (Sweeting and Hunt 2014). The stressors associated with living in social disadvantage and their impact on health and health behaviors are referred to as the psychosocial pathway. Parents who are suffering more financial difficulty, for example, are less likely to quit smoking and are more likely to relapse. Poverty has a negative impact on maternal mental health, which in turn has an impact on child health (Wickham et. al., 2017).

Behavioral: Health Inequalities, according to this pathway, are caused by disparities in health behaviors such as smoking, alcohol intake, nutrition, and physical activity. Unhealthy behaviors are more common in less advantaged groups, and they surely have an impact on health. Children have little control over what they consume or how active they are during pregnancy, infancy, and early childhood (Dahlgren and Whitehead 2007). As a result, this pathway comprises socially distributed parental and caregiver health-related behaviors (such as smoking during pregnancy, newborn feeding, and immunizations), which have direct effects for child health. This pathway could contain some parts of parenting, such as parental activities. Mealtime interactions and limits around screen time, for example, have been linked to inequities in childhood obesity. As children grow older, they begin to develop their own health-seeking and risk-taking behaviors, which are impacted by SECs as well as the health behaviors of others in their immediate environment (including siblings and peers) (Chambers et. al., 2017).

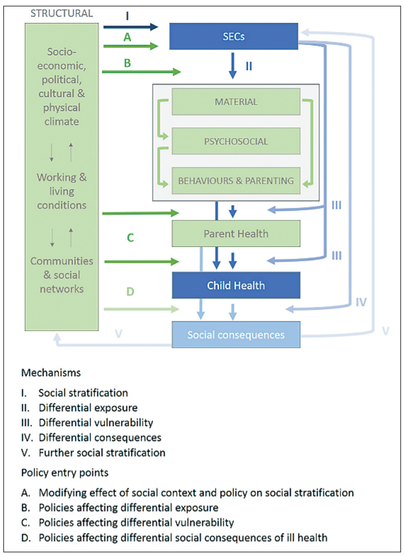

Figure 1: Conceptual Model Demonstrating the Pathway to Child Health Inequalities (adapted from Diderchsen et al. SECs, socioeconomic circumstances)

3.4 Future Challenges and Possible Actions for Health Inequalities

Immediate action is also essential in the face of widening health inequality. The value of the early years for population health, Health Inequalities, and society as a whole cannot be overstated, and efforts to address inequities must begin before conception and continue throughout life. Reduced child poverty and continuing investment in high-quality, accessible early childhood education and day-care, parental programmes, key workers, and children's centres should all be part of this (while ensuring that the least advantaged benefit most). Despite the fact that child health professionals may feel powerless to impact Social Determinants of Health and compelled to focus on immediate clinical issues, there are a number of crucial activities that they might undertake:

1. Take an equity-focused approach to practise and training: be conscious of the unequal distribution of health and make others aware of it. Consider the material, mental, or behavioral challenges that patients may be facing, as well as potential solutions (for example, referrals to welfare benefit advice, food banks, parenting programs, children's centres, and psychiatric assistance).
2. Generate evidence: Consider the representativeness of participants and the possibility of uneven uptake and effectiveness when designing, implementing, and evaluating programs and services. Create best-practice examples.
3. Advocate: for more equal and child-centered resource allocation and distribution, both within and between government sectors.

3.5 Effects on Schooling

Disaster can damage education and schooling in three essential manners. To start with, it can obliterate schools themselves, intruding on children's schooling. Secondly, in case of children are harmed or debilitated or undernourished, then they may not go to class as often and additionally may function all the more ineffectively in school. Thirdly, in developing nations specifically, a disastrous event that lessens family abundance or pay might force guardians to move kids out of the school and into the labor market to assist with improving family pay. In case these effects on schooling continue and regardless of whether they do, it is as yet an inquiry among researchers that they could lessen monetary resources further in their life. Serious disasters can harm or destroy schools. At the point when schools can't open after a hazard, not exclusively is a child's schooling disturbed; however, the child might need to stay in possibly dangerous conditions. In case there is no other child care, the child's parents might be kept from getting back to work, accordingly making monetary pressure (NCCD 2010).

3.6 Long-term Consequences

Proof from outside the field of catastrophe looks at long-term mischief to prosperity from malnourishment in the womb and adolescence. Malnourishment while in delicate stages have been connected to the major danger of disease and passing among babies and grown-ups to a more limited height, less work limit, less strength, hypertension, and elevated cholesterol. Numerous studies have connected well-being disturbances early in life to education and labor market results. For instance, health disturbances in early life are related to fewer years of schooling, diminished monetary action, postponed development, more behavioral issues, lower IQ, and lower test scores (Currie 2009). Proof also depicts that the impacts of early-life health disturbances can endure for ages. Women who were malnourished as youngsters have lower-birth-weight kids themselves. Not exclusively did women in Tanzania encounter an extreme flood before they were 18 years old experience durable adverse consequences, yet their children had lower tallness for-age z-scores. (This wasn't the situation among offspring of men presented to the flood) (Caruso 2015). Not all effects might be so diligent. For instance, stunting in extremely small children can probably be turned around to some extent if a child's current circumstance significantly improves for instance, in case the child's degree of nourishment increments drastically (Martorell et. al., 1994).

4. Interventions

These are some post-disaster intervention strategies to deal with children and help them with coping:

1. **Settings:** Recovering after a disastrous event can get started in a non-clinical atmosphere. Schools perform a significant part in calamity recuperation and are usually the foundation of relief activities. Through the execution of constructive school-based and instructor-based interventions following calamities, children can recapture a feeling of regularity in their lives and get mental help at the same time. Also, these facilities can be conveyed in schools without the stigma that is usually connected with psychological interventions, and guardians and families know and by and large trust school staff and the whole process.
2. **Group Interventions:** Group interventions can help more disaster-impacted children at a lower cost than individual interventions and as such, they might be a decent decision after a disaster when assets might be more restricted than expected. Also, numerous children presented to disaster will encounter just low or moderate degrees of stress and won't need individual interventions.
3. **Social Help:** Social help is gigantically significant in assisting with adapting after a

disastrous event, acting to further develop prosperity and mental well-being, and setting the direction after a hazard for recuperation. In children explicitly, social help from guardians, schoolmates or companions filled in as a defensive factor against negative symptoms. It is hence imperative to pick interventions that cultivate an encouraging groups of people and access social help to children to help them in adapting after a disaster.

4. **Key Partnerships:** Awareness and cooperation between and among clinicians and psychological wellness support staff, including school and local area faculty, is important to encompass the kid with protective and supportive advisers.

5. Limitations

Articles in English only were incorporated in this systematic literature review. Secondly, Time frame was a limitation as there was only one month to prepare the review.

6. Conclusions

In conclusion, the present review paper demonstrated several impacts of natural disasters on children's well-being. Despite the methodological limitations of the studies, these findings are valuable for understanding how well-being of children is impacted following a natural disaster. Natural Disasters can damage children's physical and psychological wellness just as their schooling. More youthful children appear to be generally vulnerable. The impacts of the intense calamities or shocks to health and schooling at crucial times in children's growth can keep going for quite a long time, even into adulthood. Children's reactions to hazards generally depend upon the sort of disasters, the nations, networks, and families in which children reside and the attributes of individual children. As climatic change adjusts outrageous events, some places might start to see more recurring catastrophic events, from floods to heat waves. Families could make some bad memories recuperating from frequent disasters and the consequences for children could be ordinarily more serious than those from one-time shock. Contemplating regions that as of now face frequent disasters could assist with distinguishing strategies for different regions as the climate warms. Further research will be needed to find appropriate strategies for enhancing the mental health of survivors in natural disaster-affected communities. The high-risk population of natural disaster survivors, in particular, need post-disaster mental health recovery programmes that involve early detection, on-going monitoring, prevention and intervention programmes, and long-term psychosocial support.

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High Resolution Remote Sensing, GPS and GIS Based Geospatial Database Creation for Disaster Risk Reduction in Lucknow City

Aniruddha Uniyal[1], Shamiuddin[2], P.N. Shah[3], Priyanka[4], Laxman Singh[5], Shobhit Pipil[6], S. Rao[1], Rajiva Mohan[7] and A.L. Haldar[8]

Abstract

This paper aims at creation of comprehensive geospatial database for emergency and disaster risk management in multi hazards prone Lucknow city which is one of the major habitations of Ganga Plain and has a population of about three million and is also the state capital of U.P., (the most populous state of India). The city is prone to man-made disasters including fire, road, rail and air accidents and collapse of buildings. Apart from these man-made disasters, the city is also prone to, floods, earthquakes, hydrological droughts and wind hazards. The tremors of 2015 Nepal earthquake were conspicuously felt in Lucknow. This study outlines the requirements to prototype a geospatial database in such a way that it can be used for preparedness, response as well as in recovery phases of any disaster or emergency in the future. During this study the critical facility database of Lucknow city was created for disaster risk reduction through conjunctive use of high resolution satellite data, Global Navigation Satellite System (GNSS) receivers and finally through integration of the data in Geographical Information System (GIS). Further, the linking of available resource data (nonspatial) of various line departments with the spatial data and maps of critical facilities was also performed in GIS environment. This database can certainly prove to be vital input for City Disaster Management Action Plan as well as District Disaster Management Action Plan. Since the geospatial database

[1] **Aniruddha Uniyal, S. Rao,** Remote Sensing Applications Centre, U.P, Sector "G", Jankipuram, Lucknow.
* Corresponding Author Email: aniruddhauniyal@yahoo.com
[2] **Shamiuddin,** Geological Survey of India.
[3] **P.N. Shah,** 15 Sonal Park, VIP Road, Vadodara.
[4] **Priyanka,** SWaRA, Lucknow.
[5] **Laxman Singh,** Ram Laxman Bhavan, BKT, Lucknow.
[6] **Shobhit Pipil,** IIT, Kanpur.
[7] **Rajiva Mohan,** Gomti Nagar, Lucknow.
[8] **A.L. Haldar,** NIDM, New Delhi.

of health facilities and veterinary facilities of the city can be utilized for knowing the location of hospitals, available paramedical staff, number of ambulances and medicare facilities available in each of the hospitals and available resources of veterinary hospitals respectively. Location of critical facilities such as fire brigade stations, hospitals and veterinary hospitals shown on the critical facility maps of Lucknow city can help the disaster managers to know about road connectivity of these facilities to various localities of the city. This information can be used to rapidly mobilize the manpower and available resources of line departments in an emergency situation or even during disaster situation within the district or in the nearby district at the request of the local authorities. The information on these critical facilities when analyzed in conjunction with the urban density map of the city can be used to create decision support modules required for setting up new critical facilities and upgrading existing ones as per the population density. The communication also reflects major constraints in creation of comprehensive geospatial database and its effectiveness in disaster management.

Keywords: *Remote Sensing, GIS, GPS, Geospatial Database, Emergency, Disaster Risk Reduction*

1. Introduction

Disaster risk reduction aims at drastically reducing the risks of loss of human lives, injuries and economic and ecological losses. Recent advances in geospatial techniques such as availability of high resolution satellite remote sensing, GNSS and GIS etc have revolutionized the disaster risk management efforts during various phases of disaster management cycle viz. preparedness, response, recovery and rehabilitation. Global Navigation Satellite System (GNSS) technology has made it possible to precisely record the coordinates of point locations including those of critical facilities whose operations are vital for disaster risk management. Geospatial database of available resources of critical facilities, infrastructure and urban density etc can be of immense use in mitigation planning.

An effective, economical and task oriented disaster management system requires comprehensive, accurate, timely and accessible collection of baseline data (Laefe et. al., 2006). The development of data collection methods for pre and post-disaster related activities using a multi-hazard approach is critical to GIS database creation (Uddin et.

al., 2002 & 2003). Good Child (1996), recognized the need for developing a layered, integrated, GIS system for disaster management and further stressed that all the relevant data must be affiliated with a single GIS-based disaster management system. Yet, the extensiveness, inter-relatedness and distributed ownership of infrastructure directly tax the limited resources of most communities to adequately maintain up-to-date and easily accessible knowledge of the infrastructure and utilities. To better track these substantial infrastructure needs, there is an ever increasing reliance on computer tools and databases (Laefe et. al., 2006). Specifically, Infrastructure Management Information Systems (IMISs) have been created at all levels of the public and private sectors (Uddin and Engi 2002 & 2003). The data sets owned by various governmental and non-governmental organizations have to be collected prior to initiating any computer-based search and rescue operations. The enormity, complexity and temporal criticality of this task highlighted the acute and immediate deficits of currently available spatial information for disaster management. An effective system must integrate data for all facets of disaster planning and management, including photographs, architectural and structural drawings, current Geographic Information System (GIS) maps and text descriptions of major building features e.g. building location and structural system condition (Huyck and Adams 2003). To fully benefit from such a system requires the regular contribution of data from a wide variety of sources (Laefe et. al., 2006).

Examples of data standardization in India include the Technology Information, Forecasting and Assessment Council of India, where disaster information is being linked to improve disaster preparedness (Singh and Shukla 2003). The Ministry of Home Affairs, Government of India has initiated the development of a GIS-based National Database for Emergency Management (NDEM) in collaboration with various Govt. Ministries/agencies such as Department of Space, Department of Science & Technology and Ministry of Communications & IT (www.ndmindia.nic.in). Ministry of Home Affairs (MHA), Govt. of India in collaboration with United Nations Development Program has initiated IDRN (India Disaster Resource Network). IDRN is a nation-wide electronic inventory of essential and specialist resources for disaster response, covering specialist equipment, specialist manpower resources and critical supplies (www.idrn.gov.in).

Information on Disaster Management Support (DMSP) is available on the website of National Remote Sensing Applications Centre, ISRO, GoI (https://www.nrsc.gov.in/Disaster%20Management%20Support). Further, the Disaster Management Support

Services are also available on the India Geo-Platform 'Bhuvan' of ISRO (https://bhuvan-app1.nrsc. gov.in /bhuvandisaster/). Updated information on floods in U.P. is also being provided by Disaster Management Cell of Remote Sensing Applications Centre, U.P., Lucknow on http://rsacup.org.in/en/page/flood-2021. Information on hazards in U.P., and disaster management action plans is also available on the website of Uttar Pradesh Disaster Management Authority (http://upsdma.up.nic.in/).

Despite the fact that disasters are multi-factorial in their incarnations and destructive abilities, it is postulated that there is a common subset of data related to the physical infrastructure that is needed for effective disaster management both temporally (before, during and after) and irrespective of the specific disaster. Much of the required information for one disaster can be considered as common to all disasters, both because of general requirements of access and evacuation but also because a named disaster such as an earthquake may generate multiple hazards e.g. collapsed buildings, fires, road blockage, and utility interruption (RSAC-UP 2011). Geospatial databases are critical inputs for disaster management centric geoportals and mobile applications too.

Disaster managers can retrieve the information available on geoportals and the mobile applications, for swift mobilization and optimal utilization of available resources of critical facilities from the vicinity of disaster affected area. Such facilities will include fire stations, health facilities, veterinary hospitals, temporary shelters (school and community centre buildings) and warehouses (for stockpiling food grains).

2. Study Area and Hazard Scenario

Present study covers entire Lucknow city and its peripheral areas bounded between latitudes 25˚40'N to 27˚0'N and longitudes 80˚49' E to 81˚05' E (Figure 1). Gomti river is the main river flowing through the city. Small seasonal stream Kukrail also flows through the city and merges into Gomti River. Lucknow city is one of the major habitations of Ganga Plain and is also the state capital of Uttar Pradesh the most populous state of India. Today infrastructure development is main focus in Lucknow and the city with a population of about 28 lacs (according to Census of India 2011) is expanding in every respect to don the mantle of a metro. However, this city is prone to multi hazards i.e. flood, earthquake, hydrological droughts and wind hazard. Risk is viewed as the probability that a hazard will occur during a particular time period. A disaster is a hazard occurrence resulting in significant injury or damage. In Lucknow city significant part of populace is residing in old multistoried buildings in the old city and this increases the vulnerability to earthquake hazard although the city falls in the Earthquake Damage Risk Zone III (BMTPC 2005). Some of the multistoried buildings have been constructed over the areas which are actually dried up water bodies, such constructions are also vulnerable to shocks of earthquakes (RSAC-UP 2012). Lucknow city has also felt the main shock and aftershocks of April and May, 2015 earthquakes of Nepal. The city went into the panic with people hurriedly coming out of their houses during tremors, most of the schools remained closed for a couple of days and some houses even witnessed minor cracks. Many localities of Lucknow city adjacent to Gomti river are prone to floods e.g. parts of Gomti Nagar witness floods during heavy rains of monsoon season. The city of Lucknow and surrounding area of Lucknow district (named after this city) had witnessed floods in the year 2008 and there were 25 villages affected by floods in the city during this year (RSAC-UP 2011). Furthermore, many parts of the city witness water logging during rainy season. According to wind hazard map of BMTPC (2005) Lucknow city lies in the High Damage Risk Zone.

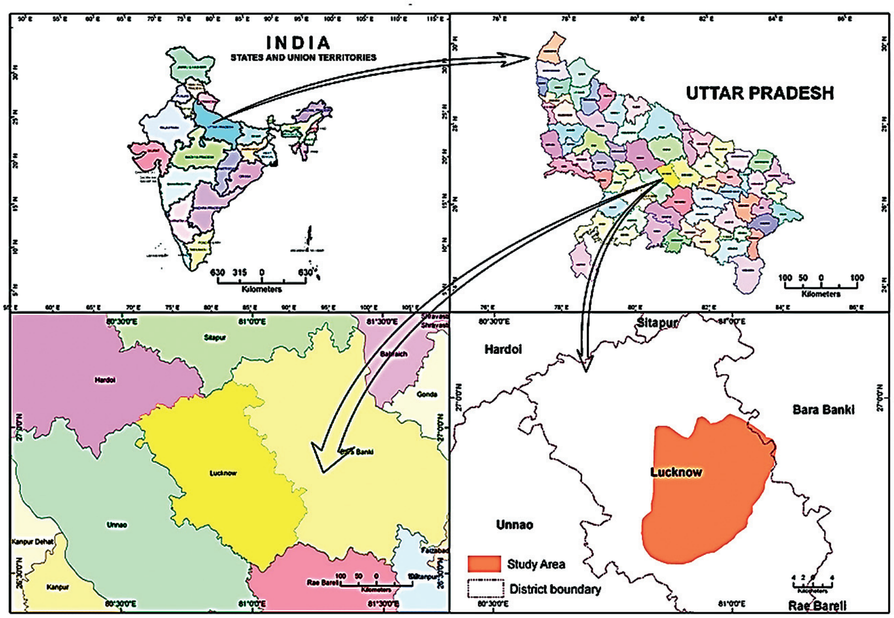


Figure 1: Location Map of Study Area

Apart from these natural disasters, the city is also prone to man-made disasters including fire and collapse of multistoried buildings. Since, the intricate road network with traffic congestion in many areas, railway lines passing through the congested areas, often crowded railway stations and bus stands, two major airports (in the northern and southern part) and pockets of industrial areas in the outskirts enhance the vulnerability of this city to accidents and manmade disasters.

The electrical wirings in many commercial and residential complexes of Lucknow city are hanging a top the roof or on the walls as bunches of cables and pose a potential risk of fire. Further, the city also witnessed few stray incidents of collapse of houses during the rainy season of 2018. According to Times of India of 4th August 2018, four lives were lost in the incidents of wall and building collapse in Lucknow due to incessant rains on 3rd of August. Some of the commercial and residential buildings in many localities of the city are more than 100 year old.

Construction of many new multistoried buildings on dried up ponds and peripheral parts of lakes doesn't rule out the possibility of subsidence of such buildings in the future.

Recently many townships in the vicinity of Lucknow have witnessed industrial disasters. Thirty two lives were lost on November 1, 2017 due to an explosion inside the boiler of National Thermal Power Corporation Power Plant Unchahar near Raebareli (Hindustan Times 09 Nov, 2017). Unchahar is about 115 km from Lucknow City. Some other recent manmade disasters/accidents in the vicinity of Lucknow city include explosions in fire cracker units in near Mohan and in Mohanlalganj in 2013 and 2014 respectively. Seven casualties were reported in a house cum firework unit at Pakra village near Mohan in Unnao district (about 35 kms from Lucknow city) on 19th Sept. 2013 (Times of India 20 Sept., 2013). Four person were killed and 10 injured in an explosion in a cracker factory in Mohanlalganj area of Lucknow on 20 Sept., 2014 (The Hindu). Most recently in 2020 and 2021 due to outbreak of COVID-19 pandemic the Lucknow district has so far witnessed more than 2.38 lacs cases of COVID-19 and about 2651deaths (en.wikipedia.org), with many of them accounting for Lucknow city. The city has also recorded 700 dengue cases since January 2021 till 20th October, 2021 (Time of India, 21st October 2021).

One of the major problems faced by Lucknow City is the lack of readily available integrated information system on rapid response infrastructure and manpower of rescuers. This study outlines the requirements to prototype a geospatial database in such a way so that it can be used for preparedness, response as well as in recovery phases of any natural or manmade disaster in the future.

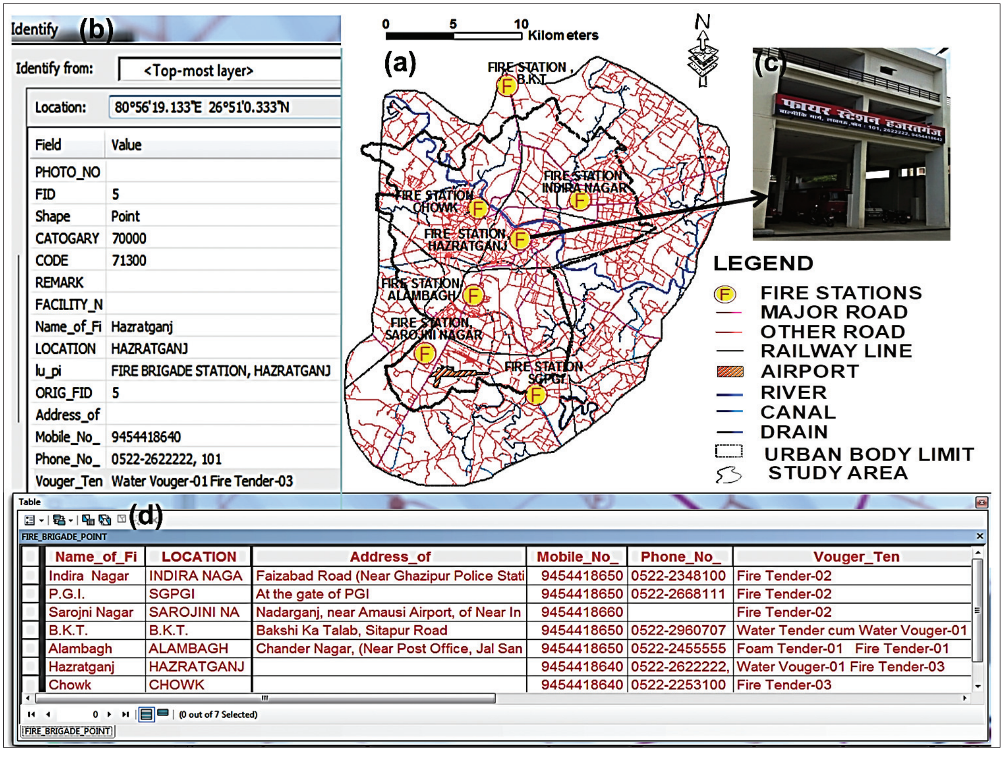
3. Objectives

The present study aims to create geospatial database of critical facilities viz. fire brigade stations, hospitals, veterinary hospitals, schools and also that of the infrastructure and urban density through conjunctive use of high resolution satellite images, Global Navigation Satellite System (GNSS) and GIS techniques. The collection of data pertaining to available resources and manpower of different line departments and linking of this non-spatial data with the spatial data are important objectives of this study.

4. Material & Methods

Quickbird satellite images with spatial resolution of 61 cm in Panchromatic mode and 2.44 meters in multispectral mode have been merged using ERDAS Imagine software in order to generate the PAN sharpened False Colour Composites (FCCs) of very high spatial as well as spectral resolution. Some enhancements have been applied to the merged images to improve their quality. Furthermore, the mosaic of Cartosat-1 as well those of Cartosat-2 PAN (satellite images) were generated. Owing to better spatial and spectral resolution Quickbird PAN & multispectral merged satellite image was used for major interpretation work. Cartosat-1 as well the Cartosat-2 PAN, IKONOS and Indian Remote Sensing Satellite (LISS IV multispectral) images were also used for mapping some areas including those for which Quickbird image had cloud cover.

Base maps showing major roads, other roads, lanes, railway lines, railway stations, bus stands, and urban density maps were created using high resolution satellite images and through on screen digitization in ArcGIS software. Geocoordinates of all the critical facilities viz. fire brigade stations, hospitals, veterinary hospitals and educational facilities etc were collected in the field using GNSS receivers and were subsequently transferred on to the base maps (in GIS environment) in order to generate critical facility maps showing location of fire brigade stations, hospitals, veterinary hospitals and schools etc (Figure 2a, 3a & 4a). Further, the available data pertaining to human resources, equipments and other resources etc of each of the critical facility such as health, veterinary and fire brigade etc of Lucknow city was collected in a standard format from the departments concerned. This non spatial data and field photographs of most of the critical facilities (taken in the field) were joined with the respective map (or spatial data), e.g. the manpower and available resource data received from the Medical and Health Department and also the photograph of the health facilities have been linked with the health facility map using ArcGIS software (Figure 3a, b, c & d). This is how the resources of each of the critical facilities are also shown in tabular form and linked with the spatial data (critical facility maps) in geospatial database.



Name_of_Fi	LOCATION	Address_of	Mobile_No_	Phone_No_	Vouger_Ten
Indira Nagar	INDIRA NAGA	Faizabad Road (Near Ghazipur Police Stati	9454418650	0522-2348100	Fire Tender-02
P.G.I.	SGPGI	At the gate of PGI	9454418650	0522-2668111	Fire Tender-02
Sarojni Nagar	SAROJINI NA	Nadarganj, near Amausi Airport, of Near In	9454418660		Fire Tender-02
B.K.T.	B.K.T.	Bakshi Ka Talab, Sitapur Road	9454418650	0522-2960707	Water Tender cum Water Vouger-01
Alambagh	ALAMBAGH	Chander Nagar, (Near Post Office, Jal San	9454418650	0522-2455555	Foam Tender-01 Fire Tender-01
Hazratganj	HAZRATGANJ		9454418640	0522-2622222,	Water Vouger-01 Fire Tender-03
Chowk	CHOWK		9454418640	0522-2253100	Fire Tender-03

Figure 2: a) Location of Fire Brigade Stations in Lucknow City, b) Information on Hazratganj Fire Station extracted from the GIS database using the tool identifier, c) Photograph of Hazratganj Fire Station included in the GIS database, and d) Attribute Table of GIS layer of Fire Stations showing location, address, mobile Number, basic phone number and number of Fire Tenders in each of the Fire Station in Lucknow City

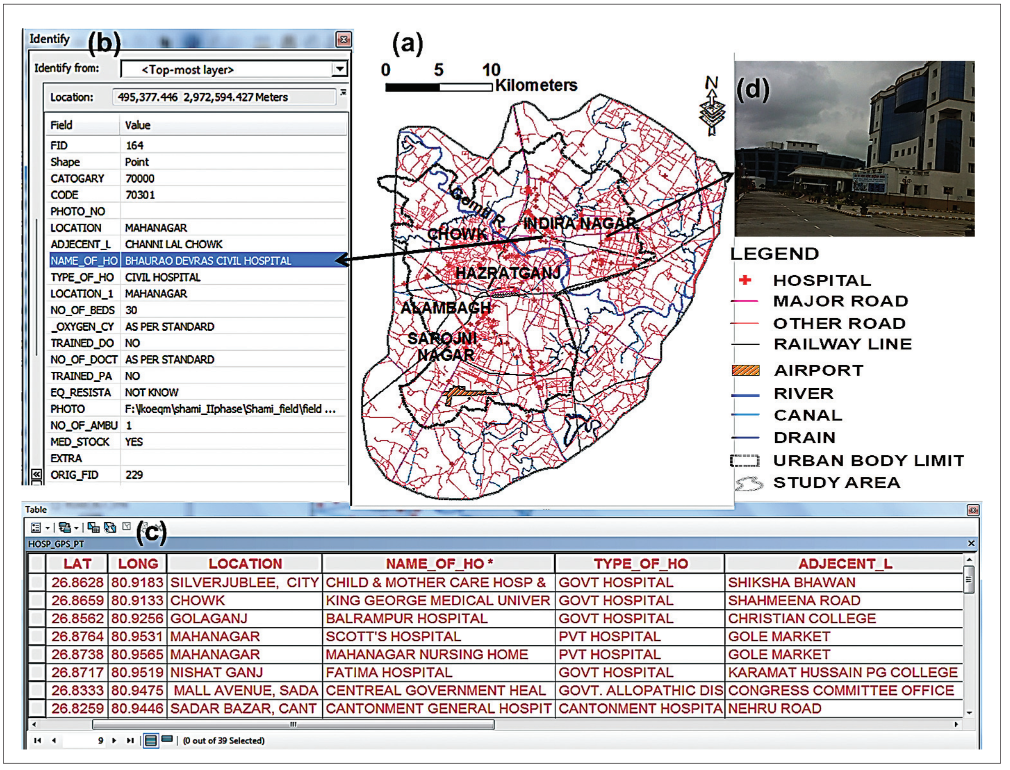


Figure 3: a) Location of important Health Facilities of Lucknow City, b) Information on Civil Hospital Mahanagar, Lucknow extracted from the GIS database using the tool Identifier, c) Attribute Table of GIS layer of Health Facilities of Lucknow City showing Latitude, Longitude, location, address, landmark and type of the facility and d) Photographs of Ram Manohar Lohia Institute of Medical Sciences included in the GIS database

5. Results and Discussion

Fire brigade stations are among the first responders in the event of any disaster situation. Fire fighters are called in almost all the man made disasters such as fire, industrial disaster, collapse of multistoried building, road, rail and air accidents as well as during chemical disasters. Furthermore, if a natural disaster such as flood and or earthquake strikes in any inhabited area the fire fighters are among the first to take up the search and rescue operations in the affected area. Hence, the information about this critical facility is very crucial for the immediate deployment and optimal utilization of available resources in order to minimize the impact of the disaster. Comprehensive information about this critical facility not only helps in proactive disaster response but also in the identification of the gap areas. The geospatial database pertaining to the location and available resources of various fire stations of Lucknow city such as Hazratganj, Chowk, Alambagh, Indira Nagar, PGI, BKT, Sarojini Nagar and Gomti Nagar opens new avenues for drastically improving the preparedness by raising new resources including the equipments and manpower and this in turn can help in rapid deployment of their resources in an emergency situation (Figure 2a to d).

Geospatial database of health facilities can be used to optimally utilize the available medical resources e.g. number of ambulances, doctors, paramedical staff etc in each of the hospital in the vicinity of disaster affected area. This information may help in quick and coordinated mobilization of the available medical and health resources and hence in a disaster situation, higher number of human lives may be saved during the golden hour by providing the first aid at a short span of time and by quick transportation of victims to the hospitals. Geospatial database can be used for health preparedness as well as in medical and health response (Figure 3a to d).

Disaster management planning includes remote area planning, logistics planning, education & training, epidemiological study and networking and timely information to media. Geospatial database can be used by planners in the pre hospital stage of medical plan to quickly carry out site assessment in order to select suitable sites for setting up temporary emergency control centres in case if, the disaster affected area has no hospital in the vicinity. However, in case if, disaster affected area has many hospitals in its vicinity the quick comparative examination of the required and available resources of each of the hospital can be done using the geospatial database (Figure 3a,b&c). This can help the Chief Medical Officer to immediately identify the hospital to be used as emergency control centre for setting up command post (in the disaster affected area) based on its available resources, specialization and also the road connectivity and alternate routes to the hospital. Further, in the hospitals stage of the medical plan the geospatial database can be retrieved for quickly assessing the available resources in terms of oxygen cylinders, live saving drugs, other life saving equipments and facilities along with the number of doctors, specialists and paramedical staff. The execution of medical plan in the farther and or congested areas of the city requires immediate mobilization of local resources to the disaster site. This mobilization of local health resources can be done by using a set of information. Geospatial database is like a ring of large tree with n-number of branches accessible to each of the health manger and planner at different levels of hierarchy. This ensures two way communication among rescuers such as doctors of government and private hospitals and health managers mainly Deputy Chief Medical Officers or Chief Medical Superintendent and Chief Medical Officer. Further the maps of the health facility, urban density and road can be used by health managers to carry out site assessment of the disaster affected congested area and to identify shorter and safe routes for ambulances for taking the victims to the nearby hospitals for further treatment and also for logistic planning including quick identification of available local health resources. Indenting of additional medical resources at a faster pace can be done by checking from the geospatial database the availability of resources such as the number of ambulances in the hospitals or sites identified as emergency control centres (Figure 3a to d). Furthermore, the temporary morgue facility can also be identified using this database.

Veterinary hospitals also fall in the category of critical facilities from the point of view of disaster management and or emergency management. Any natural disaster such as earthquake, flood, or thunder storm and man made or technological disaster such as fire, chemical disaster, leakage of poisonous gas or explosion in a factory or vehicle with hazardous material not only claims human lives but cattle heads, domestic animals and even wild life in the nearby forest or zoo. Hence veterinary hospitals are considered a critical facility for disaster response. Apart from a number of milk dairies in various parts (particularly in the outskirts) of the city, the Lucknow Zoo and Kukrail Forest are the two well known animal habitats in Lucknow city, further there is significant number of pet, stray and other farm animals in the city. Geospatial database of veterinary hospitals showing their available resources can make it easier for the decision makers to quickly list the medicines required to overcome the disaster situation. Further, it could be an additional aid in planning and mobilizing the resources of the nearby veterinary hospitals to the site of the disaster in order to minimize the loss of cattle heads and consequent spread of epidemic among the human and animal population (Figure 4a to d).

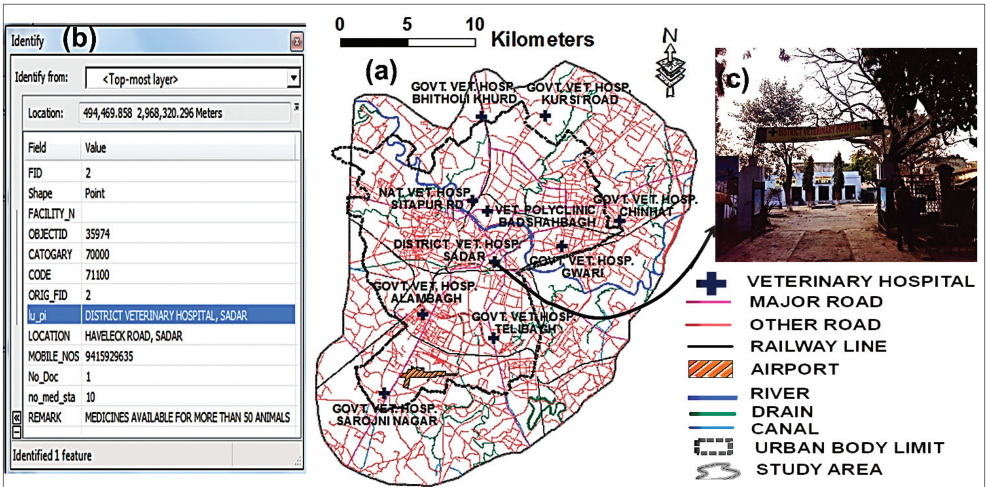


Table (d)
VETERINARY_HOSPITAL_POINT

lu_pi	LOCATION	MOBILE	No_Doc	no_med_s	REMARK
DISTRICT VETERINARY HOSPIT	HAVELECK ROAD, SA	9415929	1	10	MEDICINES AVAILABLE FOR MORE THAN 50
GOVERNMENT VETERINARY HO	ALAMBAGH	9335904	1	4	MEDICINES AVAILABLE FOR 50 ANIMALS
GOVERNMENT VETERINARY HO	BHITOLI KHURD, SITA	9415175	1	4	MEDICINES AVAILABLE FOR 50 ANIMALS
GOVERNMENT VETERINARY HO	SAROJINI NAGAR	9450024	1	7	MEDICINES AVAILABLE FOR 50 ANIMALS
GOVT VETERINARY HOSP, GW	GOMTI NAGAR	9450000	1	3	MEDICINES AVAILABLE FOR 50 ANIMALS
GOVT VETETRINARY HOSPITAL	CHINHAT	9415516	1	7	MEDICINES AVAILABLE FOR 50 ANIMALS
GOVT. VETERINARY HOSP, KUR	KURSI ROAD	9415855	1	6	MEDICINES AVAILABLE FOR 50 ANIMALS
NATIONAL VETERINARY HOSPI	NEAR SHIA PG COLL,	NA	NA	NA	MEDICINES AVAILABLE FOR 50 ANIMALS
POLYCLINIC BADSHAHBAGH	NEAR IT COLLEGE	9935335	1	5	MEDICINES AVAILABLE FOR 50 ANIMALS
VETERINARY HOSPITAL, TELIB	TELIBAGH	NA	NA	NA	MEDICINES AVAILABLE FOR 50 ANIMALS

Figure 4: a) Location of Veterinary Hospitals in Lucknow City, b) Information on District Veterinary Hospital extracted from the GIS database using identifier, c) Photograph of District Veterinary Hospital Havlock Road, Sadar, Lucknow included in the GIS database and d) Attribute Table of GIS layer of Govt. Veterinary Hospitals of Lucknow city showing Location, Mobile Number, Number of Doctors, Staff and Availability of Medicines.

Educational facilities are considered critical facilities and can be used as temporary shelters in the event of a major natural disaster e.g., high flood or earthquake or even during man-made disaster such as major fire etc in a part of the city or in the surrounding area wherein, a large populace may have been rendered homeless and or may have to vacate their homes. GIS based maps of educational facilities showing their location and connecting roads make it possible for the city disaster managers to easily identify the shelters in the vicinity of disaster or emergency site (Figure 5a to c). Furthermore, the attribute data of the educational facilities such as number of rooms, area of rooms, year of construction etc makes it possible for the city or district disaster managers to identify the number of buildings of educational facilities (based on their capacity) to temporarily accommodate the disaster victims. Based on the attribute data in the geospatial database the decision makers or disaster managers can avoid very old and earthquake unsafe building of schools or colleges as shelter houses in the event of an emergency. Further, the geospatial database can also be used to select the sites for new school and college buildings away from the flood and water logging prone area and or dried ponds or lakes.

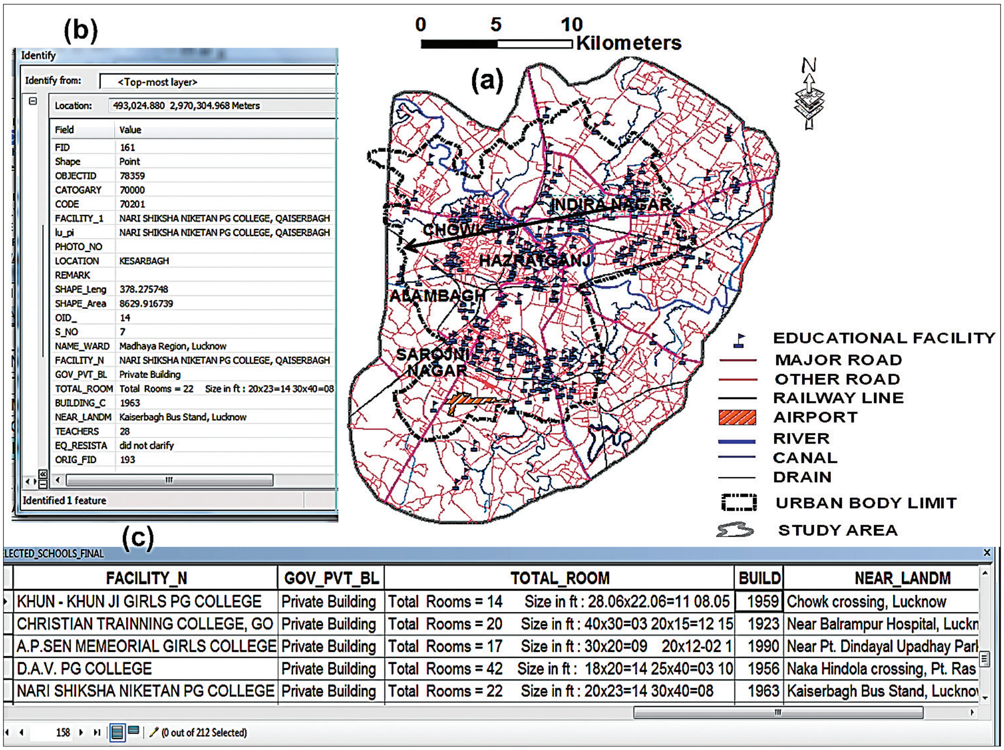


Figure 5: a) Location of important Educational Facilities in Lucknow City, b) Information on one of the P G College of Lucknow as extracted from the GIS database using the tool Identifier and c) Attribute Table of GIS layer of Educational Facilities showing name of the facility, type (Govt./Private) total number of rooms, size of rooms, year of construction and near by landmark

Urban density plays an important role in defining the vulnerability and elements at risk in a particular area when studied in conjunction with and available resources viz. critical facilities and infrastructure (particularly connectivity and critical facilities) and the probable hazards. Lucknow city is one of the fast expending cities in India and among the fastest expending cities in Uttar Pradesh with new urban agglomerations are appearing along the highways. Satellite data based urban density map indicates very high urban density in Chowk and Hazratganj areas of Lucknow city. Further the examination of high resolution satellite images has revealed that in Hazratganj area of the city in spite of very high urban density, the congestion is less (as compared to Chowk area) due to wider roads. High urban density is noticed in the peripheral areas of Hazartganj and Chowk localities. In the western part of Lucknow city Rajajipuram and Thakurganj areas also have high urban density. In the southern part of the city major part of Alambagh, some areas of Bangla Bazar and western part of Telibagh areas have high urban density. In the eastern and northern part of the city particularly the Trans Gomti areas of Vikas Nagar, Aliganj, Indira Nagar and some pockets of Gomti Nagar localities have high urban density. Pockets of Moderate urban density are noticed in large parts of Gomti Nagar, Indira Nagar and western part of Rajajipuram. Low to very low urban density is noticed in the peripheral parts of the city (Figure 6). However, in the years to come these areas of very low and low urban density may transform into areas of moderate urban density and new urban agglomerations along Kanpur Road, Hardoi Road, Faizabad Road and Sitapur Road areas of Lucknow city may witness high to very high urban density.

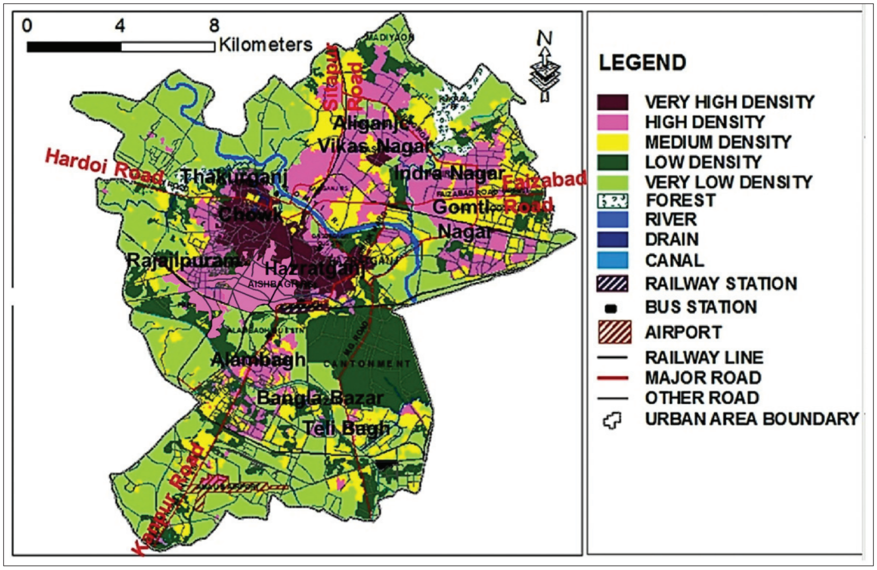


Figure 6: Urban Density Map of Lucknow City (based on satellite images)

6. Constraints

Major constraints in creation of comprehensive geospatial database and its effectiveness in disaster management are elaborated below:

(i) Lack of data about resources of private sector including facilities and resources with most of the private hospitals and nursing homes and veterinary hospitals.

(ii) Lack of available information about equipments such as electrical and hydraulic shovels, gas cutters and drillers available with "A" grade contractors of line departments such as Public Works Department and Irrigation Department and National Highway Authority. Since these equipments are essentially required for rescue operations in the event of an emergency or in a disaster situation.

(iii) Lack of well defined mechanism for regular updation of geospatial database of available resources of various line departments due to absence of GIS cells in District Control Rooms.

(iv) Mechanism for providing the geospatial database to end users/disaster managers in real time at any place through mobile applications is only partially developed.

7. Conclusion and Future Scenario

Remote sensing, GPS and GIS based geospatial database can be used to create elaborate and effective City Disaster Management Information System (CDMIS) as a part of an integrated approach for using scientific and technological advances in order to mitigate and manage natural as well as man-made disasters. By using these techniques even minor details pertaining to infrastructure, critical facilities (along with available resources of each of these facilities) can be depicted. Furthermore, this database can certainly provide vital inputs for City as well as District Disaster Management Action Plan. In the event of an emergency and or disaster situation in Lucknow city this kind of database can certainly help the local administration/disaster managers in rapid mobilization of rescuers and medical teams within a relatively short span of time. This can be done through visualization of the fire station, health facility and veterinary hospital location maps and GIS database of their available resources. Roads demarcated on Fire Brigade Station, Health Facility and Veterinary Hospital maps can help the decision makers and disaster managers (of the city) to know the road connectivity of these critical facilities to the disaster affected area. The health facility database and maps can be utilized for knowing the location, approach road, phone number, available paramedical staff, number of ambulances and critical care facilities in each of the nearby hospitals (Figure 3a to d). Similarly, the maps and database pertaining to veterinary hospitals in Lucknow city and surrounding area can provide a detailed information about the location and available resources of each of the veterinary hospital (Figure 4a to d). Immediate indenting of additional resources can also be done by each of the line department after quick checking of available resources using geospatial database. Educational facility database can provide critical inputs for identification of the temporary shelters for affected populace in a disaster situation.

This geospatial database (geodatabase) comprising datasets (maps) of different critical facilities, road network and urban density can be used by planners as important inputs for disaster management planning including upgradation of existing critical facilities and setting up of new ones such as new fire stations, hospitals, veterinary hospitals as per the population density. Further the database can also be updated for incorporating elements of disaster resilience into development by including safe sites of new critical facilities and identification of their old buildings which need to be renovated, retrofitted or even shifted, if unsafe.

As the scientific community and disaster management fraternity continues to pursue innovative solutions to the numerous spatial problems in disaster management and its related fields, the future role of these technologies in disaster management is expected to expand significantly. High resolution remote sensing and GIS techniques are being used for identification of the sites for waste disposal away from the populated areas in order to prevent epidemic. In the days to come these techniques will be used more and more for health situation analysis including epidemiological surveys and real time updation of available resources of line departments at ward level in almost all the urban and semi urban areas of the country. In some of the vulnerable localities of Lucknow city such as along the Haider canal, Gomti river and Kukrail nala etc, the geospatial techniques will prove to be useful for critical input generation for health situation analysis including extent of stagnant water bodies and water logging prone areas (which serve as breeding sites for mosquitoes). Further, these techniques in conjunction with structural engineering techniques shall be used for identification of earthquake unsafe buildings (of critical facilities) and also the clusters of very old multistoried buildings which are still habited and are vulnerable to collapse. This can certainly help the prioritization process for retrofitting. However, more comprehensive geospatial databases should be available with District Disaster Management Authority and disaster managers across the country. Geodatabases are now a becoming available on geoportals and mobile application.

High resolution remote sensing, UAV, Mobile LiDAR, Terrestrial LiDAR, GNSS and GIS techniques based more comprehensive and site specific databases will be created in the days to come and would be available on geoportals and mobile applications. This in turn will enhance the level of preparedness and efficacy of response in a disaster situation in order to mitigate its impact.

Acknowledgement

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Convergence of Strategies to Reduce the Risk: A Case Study of Geohazards in Vijayapura District of Karnataka

Lenin Babu[1*]

Abstract

As per the 2019 Vulnerability Atlas of India, the country is divided into four Seismic Zones. About 57 percent of the land area of the country lies in these four Seismic Zones and about 79% of the population resides in this area. On the other hand, most houses do not have all the necessary earthquake-resistant features built-in them. With existing scientific understanding, neither we can predict nor can prevent the occurrence of earthquakes. Therefore, adherence to the NDMA guidelines for earthquake-resistant constructions can minimise the damage. However, their adoption at ground level is very limited in scale. One of the causative factors is inadequately skilled workforce. The initiative of the National Urban Livelihood Mission of the Ministry of Housing & Urban Poverty Alleviation, Government of India along with Deen Dayal Skill Development Centres can help to resolve this problem of inadequate skilled manpower for the construction of earthquake-resistant dwellings in earthquake-prone regions of the country. This paper presents such a micro level effort in the Vijayapura district in Northern Karnataka, wherein different stakeholders such as district administration, masons and technical academic institutions were brought together as awareness building measure. Such efforts in earthquake-prone regions of the country can help to usher the Earthquake-Resistant India.

Keywords: *Earthquake; Vulnerability of India; NDMA Guidelines; Deen Dayal Skill Development Centres, Earthquake Resistant India.*

[1] **Lenin Babu,** Institute for Social and Economic Change, Bengaluru.
* Corresponding Author Email: klenin2011@gmail.com

1. Introduction

Disasters such as Earthquakes disrupt lives, livelihoods and infrastructure. Earthquakes, per se, do not cause any loss of life but the physical structures damaged by earthquakes. Removal of debris also results in loss of life due to a lack of required expertise and equipment. Depending on the possibility of incidence of Earthquakes, the Indian landmass is divided into five categories. The first such map was published by the Geological Survey of India (GSI) in the year 1935 and is constantly being upgraded. As per the Indian Standard IS 1893 (Part 1): 2016, which deals with earthquake resistant design of buildings and other structures, India's land area is divided into four Seismic Zones, namely Seismic Zones II, III, IV and V. Intensities of the earthquake ground shaking likely to be experienced in the land areas under each of these zones are:

1. Seismic Zone II: Low intensity of up to VI (and lower) on MSK Scale,
2. Seismic Zone III: Medium intensity of about VII on MSK Scale,
3. Seismic Zone IV: Strong intensity of about VIII on MSK Scale, and
4. Seismic Zone V: Severe intensity of about IX (or above).

As the 2019 Vulnerability Atlas of India indicates, about 57 percent of the land area of the country lies in Seismic Zones III, IV and V, in which about 79 percent of the population resides. Thus, the threat of potential damage to property, public infrastructure and subsequent loss of life is high. OAs there is a chance that a hazard may become a disaster sooner or later, it is in the best interest of all stakeholders to ensure that the hazard is removed altogether, if not, reduced to the extent possible. Following are some of the strategies to manage the hazards (Fig. 1)

- Elimination and Substitution are the most effective strategies for reducing the hazard but are very difficult to achieve from ongoing processes. If the hazard identification was done at the planning stages, then Elimination and Substitution can be very economical and also very effective. For instance, urban flooding during monsoons. As urban development in Mumbai city is already saturated, it is very difficult to eliminate the hazard of flooding of rail tracks. On the other hand, identification of potential flooding during the planning stages of a new capital city like Amaravathi in Andhra Pradesh, eliminating the risk of flooding is easy as the city is still in the planning stage.

- Engineering Controls aim to protect the community by removing exposure to hazardous conditions, for instance, by the construction of a barrier between the community and the hazard (like the construction of a dam to prevent flooding). Though the capital costs of engineering controls could be high, their long lifetime, and low operating costs etc make them more economical. A simple example could be the construction of a Road-over-Railway line at an unmanned level crossing. It would simply remove the hazard of accidents on a railway track.
- Administrative Controls and Personal Protective Equipment (PPE) are more useful in the circumstances where the hazards are not well controlled, for instance, COVID-19 virus infection. Administrative Controls are aimed to alter the behaviour of the community to minimize its exposure to the hazard, for instance, to contain COVID-19 virus, authorities across the world have ordered the places like markets, malls etc. to close down, thus altering the behaviour of community to minimize its exposure to the virus. PPE aims to provide maximum protection to the individual member against exposure to hazard, for instance, wearing a respiratory mask against potential infection of COVID-19. These measures, Administrative controls and PPE are relatively easy to enforce and also inexpensive to establish but, in the long run, they may be difficult to sustain and also may prove to be expensive.

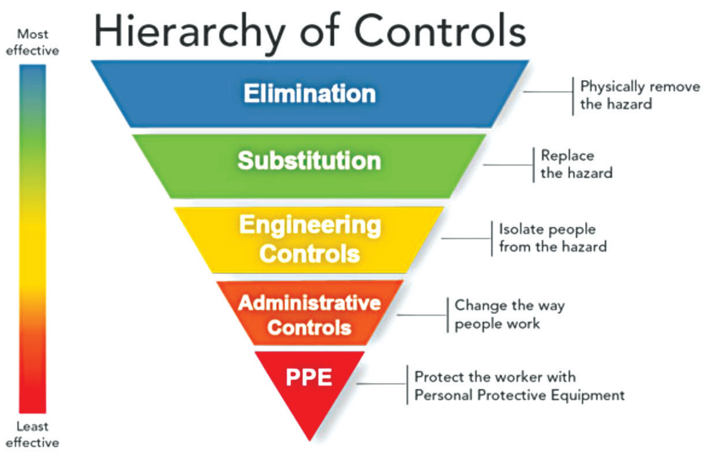

Figure 1: Different Strategies of Hazard Management

(Source: https://www.cdc.gov/niosh/topics/hierarchy/)

Our inability to predict the incidence of earthquakes stresses the significance of one option i.e., adopting a precautionary approach to minimize the damage due to the earthquakes. For instance, by adopting appropriate structural mitigation measures, countries on the 'Pacific Rim of Fire' could prevent earthquake damages to a large extent. In the Indian context, preventing earthquakes from affecting dwelling units is a small yet significant step toward building disaster resilience. In this direction, to reduce the impact of the earthquake, NDMA (2007), has recommended six sets of crucial interventions in high seismic risk areas, viz.,

1. Ensure the incorporation of earthquake-resistant design features for the construction of new structures.
2. Facilitate selective strengthening and seismic retrofitting of existing priority and lifeline structures in earthquake-prone areas.
3. Improve the compliance regime through appropriate regulation and enforcement.
4. Improve the awareness and preparedness of all stakeholders.
5. Introduce appropriate capacity development interventions for effective earthquake management (including education, training, R&D and documentation).
6. Strengthen the emergency response capability in earthquake-prone areas.

For the existing buildings, retrofitting guidelines have been developed by NDMA (2014). However, a close examination of the state of affairs or even a casual interaction with the stakeholders of construction sector indicates that there is still scope for better adoption and implementation of these guidelines and that non-adherence is higher in the case of constructions of economically stretched individuals. The dearth of trained and skilled personnel proficient in earthquake-resistant designs construction and additional costs are often mentioned as factors (KSWU 2016). But, the vulnerability assessments indicate that strict adherence to the guidelines is non-negotiable to prevent a catastrophic event (NDMA 2019). Findings of another research study under progress at the University (KSWU 2016) suggested that there could be a potential opportunity though unrelated, to overcome the inadequacy of skilled manpower, by a convergence of National Skill Development Corporation (NSDC) Reports on Skill Gap (NSDC 2013) and disaster management. NSDC reports indicated that the construction sector is projected to be a sector with significant growth in the majority of districts in the country and that there is a gap between the availability and demand of manpower requirements in the sector. If one could combine these seemingly unrelated issues, viz., shortage of skilled manpower for earthquake resistant technology, growing sectors in coming years and unemployment, it could be a win-win situation as it could pave way for reduced risk from an earthquake on one hand and better employment to the growing population in construction sectors. Expanding on these lines, the Karnataka State Women's University, Vijayapura, Karnataka has made a few micro-level efforts and this article presents the full potential of such convergence

2. Profile of Vijayapura District

Vijayapura district (formerly Bijapur) is in the northern part of Karnataka about 500 km away from the State capital, Bangalore. It has a total land area of 10,536 sq. km (5.49% of the total State area). The district has a population of 21.7 lakh persons (3.6% of the state population) (2011 Census) and a literacy rate of 67.2%, lower than the state average of 75.6% and All-India average of 74%. Agriculture remains the main occupation of the people of the district, employing 70 percent of the labour force as either cultivators or agricultural labourers. Most of the population (78%) lives in rural areas. Of the 30 districts in Karnataka, The district ranks 21st Gender Development Index (GDI), with a value of 0.573. Some key socio-economic indicators are given in Table 1.

Table 1: Key Demographic Indicators

Indicators	Year	Vijayapura	Karnataka
Population, Nos.	2011	2,175,102	61,130,704
Decadal growth rate of population, %	2001-11	20.4%	15.7%
District's share in State's population, %	2011	3.6%	100%
Urban population as a percentage of total population, %	2001	21.9%	34%
SC population, %	2001	18.5%	16.0%
ST population, %	2001	1.7%	7.0%
Sex ratio, No. of females per 1000 males	2011	954	968
Population density, per sq. km.	2011	207	319
Literacy rate, %	2011	67.2%	75.6%
Main workers, No.	2001	551,972	19,364,759
Marginal workers, No.	2001	166,241	4,170,032
Human Development Index	2001	0.59	0.65

(Source: Census 2001 and 2011, Karnataka Human Development Report 2005)

2.1 Earthquake Profile of Vijayapura District

Karnataka State Natural Disaster Monitoring Centre (KSNDMC) is designated as the Nodal Agency in Karnataka State for monitoring of Seismic activity and it has established a network of 12 Very Small Aperture Terminal (VSAT) enabled Permanent Seismic Monitoring Seismic Observatories (PSMS) during 2009-10 and later extended it to further 13 Observatories. The sites of these Observatories were chosen in the manner of geological importance and vulnerability of the regions.

Vijayapura district is prone to earthquakes and recent incidences of the same are given in Table 2. The District Disaster Management Plan (VDDMA 2020) refers to earthquakes as potential disasters and recommends measures/actions to be taken during the earthquake, provides a detailed Standard Operating Procedure (SOP) in the event of an earthquake, for instance, activating fire brigade, rehabilitation of victims, relief materials etc (DDMP 2020-21), However, it does not elaborate on risk reduction measures during the pre-disaster phase such as awareness programs, structural strengthening. Stressing on the incorporation of earthquake-resistant measures as recommended by NIDM and measures to ensure the same by respective departments could have ensured the safety of public infrastructure (Table 3 and 4).

Table 2: Recent Earthquake Profile of Vijayapura District

Magnitude	Origin Time	Lat.	Long.	Depth
2.3	2021-10-02 08:31:02	16.92	75.48	10
2.9	2021-10-01 16:09:37	16.77	75.67	10
3.1	2021-10-01 13:46:41	16.55	75.80	10
3.2	2021-09-11 08:18:47	16.82	75.72	26
4.1	2021-09-04 23:49:24	16.81	75.71	2
3.3	2021-09-04 23:48:17	16.80	75.74	2

(Source: NCS 2021)

Table 3: Structural Mitigation Measures for Earthquake

Structural Measures	Identified Locations	Implementing Departments
Retrofitting (if required) of public utility buildings like offices, schools/banks/ markets etc	EQ prone Taluka	PWD, RDPR, ZP
Retrofitting of unsafe rural houses	RDPR, ZP, LSG	Rural housing schemes and departmental programs
Identifying and safely dismantling unsafe structures	R & B department	–

(Source: VDDMA 2020)

Table 4: Non-Structural Mitigation Measures for Earthquake

Non-Structural Measures	Location	Responsible Departments	Time Frame
Capacity building of architects, engineers and masons on earthquake-resistant features	EQ Prone Talukas	RDPR, ZP	Regular Interval
Registration of trained and certified mason	Entire District	RDPR, PWD	Continuous Process
Strict enforcement of guidelines pertaining to seismic safety for government rural housing	PWD, RDPR, ZP	Rural housing Schemes	Regular Interval
Mock-drills for Schools, Hospitals and, Public Buildings and training for mason, engineers and architects	Entire district	DDPI	Regular Intervals

(Source: VDDMA 2020)

About the private constructions like individual dwelling units, incorporation of earthquake resistance measures were reported to be suboptimal (KSWU 2016) and during the interaction, the following factors were quoted, viz.,

- A dearth of skilled personnel proficient in earthquake-resistant designs and construction
- Adherence to traditional methods
- Non-adherence to stipulations of concerned departments
- Associated higher costs

3. Proposed Convergence for Better Preparedness

National Skill Development Council (NSDC), prepared detailed reports for every district about a) economic sectors/activities that are likely to grow in that particular district and b) exiting skill levels of human resources available in that district. According to NSDC estimates, between 2012 and 2022, incremental demand for 2.03 lakh persons is likely to be generated in the Vijayapura district. The report indicated that agriculture and allied activities remain as biggest employers, followed by the food processing industry. With the economy of the district growing, employment demand in supporting sectors such as construction, transportation would also increase at a faster rate (Table 5) (NSDC 2012) and the Building Construction sector requirement is 41,304 out of which half of the requirement is for semi-skilled manpower (Table 6).

Regarding educational infrastructure, the Vijaypura district has a total of 49 Industrial Training Institutes (ITIs)/Industrial Training Centres (ITCs) (as of March 2012). Of these, three were Government ITIs, six were private aided ITIs and the remaining 40 were private unaided ITIs. With an annual intake capacity of 3,492, none of the 49 ITIs incorporates the skills of earthquake-resistant construction. If suitable intervention such as knowledge of earthquake-resistant construction is made available to this semiskilled manpower through Urban Livelihood Programmes or Deen Dayal Upadhaya Skill Centres, Vijayapura district could hope to progress in the direction recommended by National Disaster Management Authority and also Sendai Framework for Risk Reduction (SFDRR).

Table 5: Incremental Demand - 2012 to 2022

Sector	Total	Minimally Skilled	Semi-Skilled	Skilled	High Skilled
Agriculture and Allied	59,998	49,971	7,469	1,359	1,200
Building, Construction Industry and Real Estate	41,304	12,391	20,652	6,196	2,065
Transportation, Logistics, Warehousing and Packaging	30,302	6,060	17,575	6,060	606
Tourism, Travel, Hospitality & Trade	26,437	5,287	17,977	2,644	529
Total (all other sectors as well)	203,663	75,169	72,539	45,810	10,145

(Source: NSDC 2013)

Table 6: Key ITI Indicators in Bijapur District

Indicator	Value
Total Number of ITIs	49
Number of Government ITIs	3
Number of Private aided ITIs	6
Number of Private unaided ITIs	40
Total Intake Capacity	3,492
Student Pass Rate	80%
Student Drop-out Rate	5%

(Source: NSDC 2013)

For effecting such a systematic change, a close interaction of different departments and stakeholders are required and a tentative framework is provided here, based on the KSWU experience.

Office of Deputy Commissioner/District Collector: District is the unit of administration in India and it is the office of the Deputy Commissioner that oversees the functioning of all other departments. Through a proactive approach, it can facilitate various national flagship programs at the district level by involving the concerned line departments, for instance,

- Deendayal Antyodaya Yojana: National Urban Livelihoods Mission (DAY-NULM): Based on a strategy that the poor are entrepreneurial and have an innate desire to come out of poverty, this Mission aims to enhance the skill sets of urban poor so that they can access self-employment and skilled wage employment opportunities, resulting in an appreciable improvement in their livelihoods. To realise the mission objectives, involvement of different stakeholders is required, *viz.*
- Knowledge Providing Agencies: NDMA has developed guidelines on earthquake-resistant construction and this knowledge has to be converted into a suitable manner – like hands-on training - to reach out to the mason. Faculty of engineering colleges or trained civil engineers can fill this role.
- Facilitating Agencies: Industrial Training Institutes/Engineering colleges/Non-Governmental Organizations can be requested to facilitate the knowledge transfer. Line Departments like Public Instruction, Municipal Directorates, Revenue can play the supporting role.

4. Conclusion and Way Forward

Inadequate awareness coupled with a lack of a skilled workforce is contributing to the sub-optimal adoption of preventive measures against the potential threat of earthquakes in the Vijayapura district and a similar situation prevails in other earthquake-prone districts as well. The pilot experiment carried out by the Karnataka State Women's University in Vijayapura district in collaboration with District administration and other line departments have indicated very good potential for convergence of national flagship programmes not only in risk reduction but also in mainstreaming disaster management. Given its potential, it is suggested that the participation of academic institutions should be actively encouraged in disaster management. In this backdrop, **India Universities and Institutions Network for Disaster Risk Reduction (IUINDRR-NIDM)** being established by NIDM is very timely and significant.

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Bioengineering with Miyawakis, Landslide Victories

Anil Kumar Bheemaiah[1*]

Abstract

Slopes are susceptible to rainfall triggered land movements, in this paper a project plan to use slopes, not traditionally cultivable, towards agroecology, as practiced in the region, based on a timeless Miyawaki afforestation technique, in combination with synthetic approaches called Bioengineering.

A new form of engineered primary growth, using Mapillary based plant groups and ecological datasets, to create Miyawaki pockets, or small plots of afforestation based bioengineering for sub surface water drainage and better soil stability is presented.

Risk assessment calculations are presented for Landslides, Factor of Safety provided, and are proven to be mitigated in planned afforestation as bioengineering on slopes.

Several case studies are presented of successful DRR or disaster risk reduction by bioengineering in the Indian Himalayan Region, other regions of India and worldwide.

Keywords: *Landslide Management, Bioengineering, Structures, FOS, Soil Stability, Sub Surface Drainage.*

1. Introduction

The successful use of Bioengineering in DRR, resilience and community involvement, agroecological practices, slopes not arable are brought under afforestation, with a dual purpose of slope stability though bioengineering practices and agroecology with proposed automated and manual harvesting and maintenance.

Several case studies and new pioneering technologies of flower shell for seed dispersal using traditional firearms, and rope rappelling on slopes are presented with greener alternatives to traditional firepower , like combustion light gas guns, with the advent of hydrogen fuel cell based automobiles, hydrogen as a fuel is dispensed in fuel

[1] **Anil Kumar Bheemaiah,** Member of Board, Mutter Gottlich, Seattle W.A 98125
* Corresponding Author Email: miyawaki@yopmail.com

stations and cost effective oxygen available, to lead a new era of biometrically safe, gas combustion firearms based on hydrogen and oxygen, used for seed propagation. Other bioengineering techniques use a combination of trees, shrubs and grasses with structural engineering ranging from slope nailing to check dams and wall structures, rendered natural with Miyawaki Pockets. Miyawaki pockets, a terminology coined by the author to a design of a minimal landscape of primary growth, based on selected plant groups, with three or more layers, with the purpose of increasing the drainage of subsurface water and mitigating the risk of a natural disaster, by increasing soil cohesion.

Engineered structures alone, in a vicious loop of increased natural disturbances further worsen the disaster risk, mostly caused by land degradation and development, farm runoff products and soil contamination issues. Bioengineering and the Miyawaki effect, restores a natural balance in a combined natural and synthetic approach, with social involvement in combined agroecology and bioengineering.

The philosophy was propounded by several leading scientists and naturalists, with Akira Miyawaki, the most prominent, with a universal adoption of the Miyawaki technique as one with the force, the very natural force that causes a disaster risk. Hence Miyawaki Pockets engineer primary forests, a return to the natural, supported by structural engineering.

1.1 Summary

Main Points:

1. Landslide models and risk assessment technologies, described, with FOS or factor of safety estimation, with soil testing, sub surface water drainage measures and land use remote sensing data mining.
2. DRR or disaster reduction measures, defined with structural engineering and bioengineering measures.
3. Case studies of successful bioengineering in DRR are presented, with Miyawaki Pockets and native species based bioengineering for DRR measures.
4. Introduction of Gas combustion fire power, using hydrogen and oxygen for rapid seed dispersal on slopes, for slope afforestation.
5. Agroecology and automated harvesting and maintenance for bioengineering measures, makes the technology cost effective and remunerative.

Afforestation decreases the risk of a landslide by precipitation, by a FOS, ranging from 120% to over 200% *(Document Card, n.d.)*
The design of a five or more layer Miyawaki with deep rooted and horizontal rooting is presented.

A mixture of deep rooted and horizontal rooted species is proven to decrease the risk of landslides.(Vasistha et al., 2011)

In a Miyawaki defined by n layers, with an average estimable, root size, r and a root ball size, s. And an oblique factor o, that defines the obliqueness of the root ball.
1 being a highly horizontal spread and 0 being deep rooted.

We develop a model for the distribution of tree line based contour afforestation on slope afforestation. Called Miyawaki Pockets, Sloping agricultural land technology guidelines suggest, deep rooted plants as a contour placed 3 to 5 meters apart,(Forbes et al., 2013; Joshi, et al.)

Detection of degradation of vegetation and reforestation is the most cited technique (Joshi, et al.)

The Miyawaki Technique is particularly effective at natural disaster mitigation, given the nature of primary growth restoration.("Tsunami Mitigation in Japan after the 2011 Tōhoku Tsunami," 2017) and afforestation for resilience.(*Document Card*, n.d.) Is a FAO report on afforestation, social agroecological approaches to disaster risk reduction, or DRR.

2. Methodology: The Flower Shell

Figure 1: Flower Shell – A New Way to Seed, 2019

Figure 1. Reproduced from *(Flower Shell – A New Way to Seed, 2019)* is an example of seeding using common household equipment, translated to slope afforestation, this would translate to the use of 'Miyawaki Shells', a technology of the reuse of unused rounds to afforestation, by the recalibration of explosive charge and the addition of the right seed mix, predigested by farm ungulates and covered in a binding agent of biomass derived from manure.

Parameters, including the seed mix, and the density of shots on a slope surface, are determined based on the slope dynamics, required afforestation and hydrology factors, including previous history of landslides and rainfall precipitation data.

3. Methodology: Combustion Light-gas Gun (CLGG), the Ulton Case Study

Hydrogen Oxygen CLGG, auttomated weaponry revives a peace movement in the addition of higher safety standards to lethality, in a pioneering innovation at biometric ignition and non lethal options in propulsion kinematic controls. Given the origins of automatic weapons in agriculture, lethality in AI is conquered , with the use of a H2-O2 weapon with flower shells demonstrating non-lethal afforestation of slopes for improved percolation and a restoration of the Qi of the Earth element in Miyawaki pockets.

Resilience is in the return of nature, by Akira Miyawaki's demonstrated work, the return of the natural forest, as an engineered forest eliminating a natural disaster.

Despite the incompleteness of the Landslide Models, a shallow model in slope hydro dynamics, indicates percolation efficiencies of Miyawaki Pockets, while further research in better risk assessment and landslide models is required for all other Landslide Dynamics.

4. Analysis: Afforestation based LandSlide Management Case Studies

(Chetan R S at al 2021) Land usage models for landslides are primarily advocated, with a primary reason for landslides cited as deforestation, development and faulty development models, with constrained percolation water movement. With a comprehensive analysis of landslide risk in the Indian subcontinent.

The landslide model uses a plasticity index in soil analysis, categorizing soil plasticity with a linear relation and measuring shear modulus of soil. This combined with water accumulation and land use metrics predicts the F.O.S or factor of safety , the pertinent quantitative criteria are.

"Plasticity index = liquid limit – plastic limit

$Ip = Wl - Wp$ (1)

Soil descriptions based on PI:
0 – Non-plastic, < 7 – Slightly plastic, 7–17 – Medium plastic, > 17 – Highly plastic"

Factor of Safety (F.O.S):
F.O.S = $C+\gamma'\cos 2(i)*\tan\phi*\gamma sat*$

$\cos(i)\sin(i)$ (2)

Where, ϕ = internal friction of soil in degree
i = Original slope angle of hill in degree
C = Cohesion in kg/cm^2
γ' = Submerged unit weight of soil in kg/cm^3
γsat = Saturated unit weight of soil in kg/cm^3

(Amashi et al., 2019) describe a soil nailing technique at Mahabaleshwar in Maharashtra, India, with the use of Slope W and Praxis software applications for an analysis of FOS factors.

(Vasistha et al., 2011) scribe a bioengineering approach as a hybrid structural and afforestation intervention methodology, studied at Varunavat Landslide, Uttarkashi. Three regions are identified and 10 common native plants, which are fast growing, deep rooted and stable are chosen. The result of a hybrid approach with intermixed stabilizing structures, afforestation and jute mesh, resulted in positive results. Table 1 and 2 reproduced from the publication lists the species used.

(Hostettler et al., 2019) initiative in Honduras for community led disaster risk reduction and resilience using bioengineering techniques is described over a 10 year period with positive results with continuous maintenance, possible through agro ecological efforts.

(Bryaane & Tewari, 2015) recommends bio engineering with Quercus leucotrichophora, Alnus napelensis, Pinus spp. and Cedrus spp for tree based slope afforestation, and shrub/grass afforestation with Eriophorum comosum, Saccharum spontanum, Pogonatherum spp. and Woodfordia fruticosa, at Mussoorie Hills, India.

(Singh, 2010) iciency and the highest cost-benefits measure for bioengineering in disaster risk reduction and curtailing erosion.

(Ghosh & Bhattacharya, 2018) on vetiver grass, lists several successful case studies of the use of vetiver grass in bioengineering and phytoremediation, based on indigenous practices of the use of the grass. The Roots have a tensile strength of 75 MPa.

5. Methodology: Miyawaki Pockets

Table 1 and 2, in the addendum, provide a list of natural species in a case study in Uttaranchal India, consisting of plants with deep roots and grasses with horizontal spread, a near zero and near 1 oblique factor.

For a n layer miyawaki consisting of at least three layers of trees, shrubs and grasses, provides sub surface drainage and soil binding increased stability, based on shear measures and a higher F.O.S.

The measure of the root ball size r over all the bioengineering flora, leads to mass of root net in the three layers.

6. Discussion

Bioengineering is proven to be a preferred approach to structural engineering, several case studies have been presented from the Indian Himalayas and other parts of the world. The approach remains a timeless science, still practiced in most parts of India, and hence free from natural disasters. The investigation into the query of why a bridge science called compensation sciences by the author does not exist for technology practiced in the post colonial era, leads to the conclusion that natural disasters are a response by the planet to the onslaught of technology and that truer druidatic sciences were eliminated in the colonial regime, with the onus on the present governments to restore the druidatic sciences and technologies and reduce disaster risks.

Future work with case studies in the HP, India area, would delineate species of plants for the creation of Miyawaki pockets for Disaster Risk Reduction, DRR.

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Conceptual Approach for Flood Risk Assessment

Zeeshan Ibrar[1]*

Abstract

Flood control infrastructural measures like levees, dikes and dams have been developed to protect socio-ecological system from the consequences of flood events. These measures aim to reduce systems' risk from exposure to flood water. The traditional measures involved in minimizing the flood risk is to keep water away from land. These flood control infrastructural measures are huge capital intensive but damages caused by flood increases manifold on failure of these structures. This led to the birth of another notion of flood protection i.e. managing flood water rather than controlling it. It involves non-structural measures with or without the combination of flood control to create a flood resilient region. The foremost step in non-structural measures for flood protection is the assessment of risk associated with flood. Flood risk assessment provides necessary information for decision making in flood risk management. The paper reviews the conceptual approach of flood risk and its application in flood protection. The paper structured into three section. The first section briefly discusses the concepts of flood risk. The second section analyses the components involved in flood risk and its empirical derivation. In last section paper discusses the conclusion and gives recommendation for flood risk management.

Keywords: *Exposure, Flood Risk, Flood Control Infrastructure, Hazard, Vulnerability.*

1. Introduction

Flood is a natural phenomenon caused due to overflow of water when the water level in the main channel reaches beyond its carrying capacity. It occurs in rivers when the flow rates exceed the capacity of the river channel, generally at bends or meanders in its

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Zeeshan Ibrar, Ph.D. Scholar, Department of Regional Planning, School of Planning and Architecture, New Delhi-110002, India,
* Corresponding Author Email: zeeshanphd219rp@spa.ac.in

course (Gangwar, 2013). Flood plains are defined as the land adjacent to river channels that are subjected to recurring inundation (Di Baldassarre, Viglione, *et al.*, 2013). The earlier civilizations throughout world have settled in floodplains of various rivers such as Chinese civilization (Huang He river), Indus civilization (Indus river), Egyptian civilization (Nile river), Mesopotamia (Tigris and Euphrates rivers) (Macklin and Lewin, 2015). These civilizations flourished in floodplains as they offer favorable conditions for trade, agriculture, and economic development (Di Baldassarre, Kooy, *et al.*, 2013). It is estimated that almost one billion people currently live in floodplains. Mazzoleni et al., (2021) analyzed that in low-income countries, there is increase in the population along floodplain after a period of high flood fatalities and in high-income countries, there is positive growth in built-up areas. The increased urbanization pressure leads to encroachment of flood plains close to river for human activities. The boundary of a floodplain cannot be defined as the magnitude of a flood is limitless. As the distance to the river decreases, the hazard increases, because areas closer to the river network are prone to flood hazard (Patrikaki et al., 2018). Areas near the river network (less than 200m) are high flood hazard zone, and the impact of flood water decrease with increasing distance more than 2000 m (Kazakis, Kougias and Patsialis, 2015; Adlyansah, Husain and Pachri, 2019). These encroachments and unchecked developments on flood plains translate the flood from a natural phenomenon to man-made disasters and put human lives and environment at risk. The risk of flooding has increased exponentially due to extreme rainfalls, sea-level rises, higher river discharge, etc. This led the change in discourse of current infrastructure measures in dealing with flood management (Molenveld and van Buuren, 2019).

The flood management system in India has evolved over the years. The 1954 flood event in Bihar coerced the government to acknowledge the flood risk and prepare an action plan to protect flood plains (Shrestha et al., 2010). This led to huge investment in construction of structural measures such as embankments, dams, reservoirs, etc. As per National Register of Large Dams (NRLD), in India, there are 5334 completed large dams and 411 under-construction large dams (PIB, 2021). Dam Rehabilitation and Improvement Project (DRIP) has envisaged comprehensive rehabilitation plan for 736 dams across 19 states. This plan has financial implication of approximately Rupees 102110 million. Despite such huge investment, these infrastructure measures do not provide protection as anticipated. The following section discussed the definition of flood risk and key components involved in flood risk management.

2. Conceptual Approaches of Flood Risk

Flood risk is the probability of harmful consequences or expected losses in terms of deaths, population affected, property damaged, livelihoods impacted, economic activity disrupted or the environmental damages (Westen and Jetten, 2015). The curtailment of flood risk leads to development of flood control approach. The flood control approach involves the infrastructural measures like constructions of dams and embankments. These infrastructural measures control the river and the flood water. The research shows that these engineered solutions are huge capital intensive and failure of these structures quadruples the flood damages (Mishra, 1997; Liao, 2014). The approach to mitigate the flood losses shifted from controlling the flood to managing the flood. This give birth to the notion of Flood Risk Management (FRM). FRM aims in minimizing the losses and damages caused by flood by preventing the exposure of people and property to flooding (Klijn et al., 2009). FRM approach is the combination of structural and non-structural measures for managing the flood waters. The structural measures aim in lowering the flood probability whereas non-structural measures aim in reducing the vulnerability of society by managing the exposure of vulnerable people and property. The structural measures include the flood defense mechanism against flooding to reduce possible impact of hazards. It involves application of engineering techniques and technologies to achieve resistance to flood. Non-structural measures uses knowledge and practice to mitigate flood risk through policies and laws, public awareness, training, and education (UNISDR, 2009). The three phase of flood i.e. pre-flood, in time of flood, and post-flood, have different non-structural measures. The measures such as public awareness, training, education, land use planning, building codes in flood prone areas, flood forecasting (early warning system), research and assessment, information resources are some of the pre-flood non-structural measures (JICA, 2016). The response-recovery plan to reduce vulnerability and strengthen the system of emergency assistance in flood prone areas are activated during flood. The post-flood measures include insurance, financial aid, capacity to compensate losses not covered by insurance, and relocation of affected population (Kundzewicz, 2002). The combination of structural and non-structural measures reduces the risk of flood. The understanding of flood and its impact helps in managing the flood risk efficiently.

Flood risk is defined in two alternative ways i.e. product of hazard, its exposure and vulnerability of exposed region, and product of flood probability and consequences

(Ernst et al., 2008; Klijn et al., 2009). The first definition uses three elements of flood risk i.e. hazard due to flood, exposure of flood and vulnerable society or area. The characteristics of floods are flood depth, flood velocity, and retaining time. The exposure to a certain depth is necessary for a society to be harmed by occurrence of a flood (Klijn et al., 2009). It is to be noted that without exposure to certain flooding characteristics (for ex. flood depth), the risk of even high vulnerable area or society is terminated (Klijn et al., 2009). In the second definition, flood risk depends upon the probability of hazard, chance or likelihood. Probability in this definition refers to the probability of flood (hazard), and probability of consequences. The inclusion of probability is a quintessential element in defining the risk and in assessing flood risk.

Flood hazard is the combination of flood probability and its level of intensity that expressed in terms of its characteristics. Flood hazard assesses the intensity of flood occurrences over an extended period of time (Wright, 2016). Probability is the likelihood of flood event i.e. return period (in years).

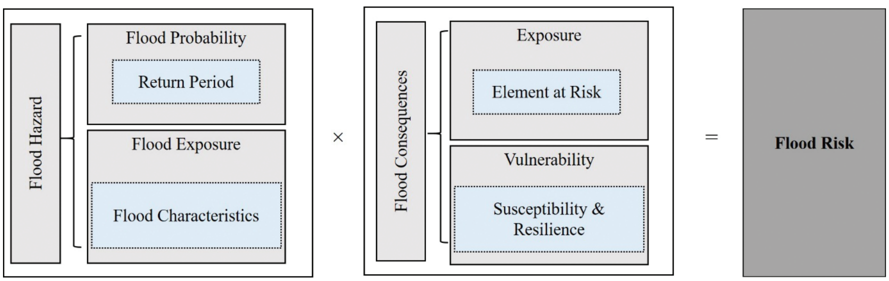

Figure 1: Conceptual Approach of Flood Risk Management

(Source: Adapted from Pieterse et al. (2015); Wright (2016)

3. Components of Flood Risk

Flood probability relates to the probability that a region will be flooded, either in case of unprotected areas by high water levels in a river or in the case of protected areas. The probability of occurrence is dependent upon flood's magnitude gauged by the status of risk (Pieterse et al., 2015). Stream gage helps us to record the level of water when it is in above the danger mark. The technique uses to define probability of flood or to predict the return period of certain flow value is flood frequency analysis. The flood frequency analysis uses statistical information such as mean, standard deviation, and skewness to calculate frequency distribution graphs. The statistical method used in analyzing distribution are Gumbel, Normal, Log-normal, Exponential, Weibull, Pearson and Log-Pearson. Samantaray and Sahoo (2020) discussed the four common used methods for calculating flood frequency for Mahanada river basin from four stations on Mahanadi River, in Eastern Central India. The statistical methods employed in the study for different time period to forecast stream flow are, Normal, Gumbel max, Log-Pearson III (LP III), and Gen. extreme value method. Flood frequency plays a vital role in providing probability of flood occurrence that can be use in planning the regions.

Flood Exposure: It is defined as the intensity of flood based on its physical characteristics. Flood duration, river discharge, flow velocity, and flood water depth are some of the physical characteristics of flood used for measurement of hazard intensity of flood (Balica, Douben and Wright, 2009). Pieterse et al., (2015) classified the flood water depth in three categories and this can be used as a parameter to classify hazard:

1. Depth less than 0.5m – walkable limit to evacuate the area.
2. Depth between 0.5 - 2 m – Rooftop of second floor of building
3. Depth greater than 2 m – immediate evacuation should take place.

The classification of physical characteristics of flood with the probability of flooding in a particular area help in developing detailed hazard map which helps in assessing risk associated with corresponding flood.

Flood Consequences: The second component of flood risk management framework is the consequences of flood. Flood consequence is the impact of certain magnitude of flood on the region affecting social, economic, and ecological aspects (Pieterse et al., 2015). Ernst et al., (2008) discussed three parameters to assess flood consequences i.e. exposure, elements at risk, and vulnerability. Ernst et al., (2008) and Pieterse et al., 2015 defined exposure as the characteristics of flood. Klijn et al., (2009) referred to exposure as impact of flood on people and infrastructure. Balica, Douben and Wright, (2009) used social, economic, and ecological components to define exposure and its impact due to flood. Indicators like population density, population in flooded area, closeness to inundation area, percentage of rural population, land-use, proximity to river, etc are used to assess exposure. Exposure is the value of areas which face the flood regularly (Beevers, Walker and Strathie, 2016). Thus exposure and elements at risk can be grouped under one umbrella for analysing flood consequences and physical characteristics of flood exposure need to be studied under flood hazard.

Vulnerability: According to the International Panel of Climate Change (IPCC), the magnitude and character of disasters are defined as the exposure of people, assets at risk and susceptibility to harm i.e. vulnerability of human and natural systems (IPCC, 2014). IPCC (2012) outlines the vulnerability as the magnitude and consequences of hazards. UNISDR (2009, p.30) adds the dimension of characteristics, circumstances, and susceptibility dimensions while defining vulnerability. Hyogo Framework for Action (HFA) 2005-15 specified vulnerability with gender perspective, cultural diversities, age, etc. and its integration ed with disaster risk management policies and plans related to sustainable development (UNISDR 2005). The HFA provides a framework for action focusing on disaster response, which includes rescue and providing post-disaster assistance. However, it does not elaborately address the hazards, risk and vulnerabilities. Its progress is the weakest in the area of social vulnerabilities (UNISDR 2015a). The successor of HFA, the Sendai Framework for Disaster Risk Reduction 2015-30, apprehends the importance of vulnerability to improve disaster risk management. The first two goals of this framework are substantial reduction of the mortality rate and the number of affected people by 2030. HFA aimed to lower the average global figure per 100,000 in the decade 2020-30 as compared to 2005-15 (UNISDR 2015b). This could be achieved by understanding the vulnerability of the populace. Vulnerability is the function of three variables i.e. exposure, sensitivity and adaptive capacity (Marshall et al., 2010; Yates, 2010). Beevers, Walker and Strathie, (2016) quantified the vulnerability as three-dimensional unit by assessing exposure, susceptibility, and resilience as three different axes. The exposure and sensitivity are directly proportional to the vulnerability whereas adaptive capacity is inversely proportional to it (Nguyen, Nguyen and Man 2016). The vulnerability to floods is dependent on various factors. The social, economic, and cultural factors influence the vulnerability of the population. The factors such as wealth and its distribution across society, demographics, migration, access to technology, employment pattern, education, societal values, and governance structures play an important role in addressing the vulnerability of society (IPCC 2014).

There exist numerous definitions of vulnerability by various authors (Marshall et al., 2010; Yates, 2010; Morgan, 2011; Beevers, Walker and Strathie, 2016; Nguyen, Nguyen and Man, 2016). All these definitions are formed by combining components vulnerability. The conceptual expression of vulnerability incorporating concepts of exposure, susceptibility and adaptive capacity is given in figure 2.

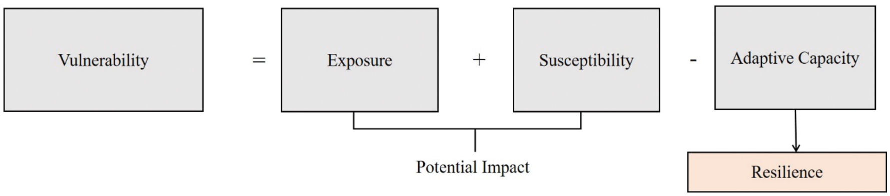

Figure 2: Conceptual expression of Vulnerability

(Source: Balica, Douben and Wright, (2009); Morgan, (2011); Beevers, Walker and Strathie, (2016)

The assessment of vulnerability is an important step for risk analysis. Nasiri et al., (2019) Flood vulnerability index is a method to assess flood vulnerability at various spatial scale (river basin, sub-catchment, district, block or village level) (Nasiri, Mohd Yusof and Mohammad Ali, 2016; Marzi, Mysiak and Santato, 2018; Nasiri et al., 2019). It is done by categorizing social, economic, environmental and physical components of flood prone areas based on numerous indicators. Kim and Gim, (2020) assessed the social vulnerability to floods at the municipality level on Java, Indonesia by developing two indices; the socioeconomic vulnerability index (SEVI) and the built environment vulnerability index (BEVI).

Susceptibility: It relates to system characteristics that influence the probabilities of flood consequences. The characteristics of social, economic and environmental aspects of system that triggers the impact of hazard are considered under vulnerability assessment. Balica, Douben and Wright, (2009) used literacy rate, past experience, child mortality rate, population access to water supply, unemployment, Regional GDP, rainfall, evaporation, etc. as the indicators for analysing susceptibility. Morgan (2011) used sensitivity of the elements at risk as the potential impact due to flood. The term 'exposure or elements at risk' includes all elements of the human system, the built environment and the natural environment that are exposed to flooding. Morgan (2011) interprets adaptive capacity as the resilience of a system to bear disturbances induced by floods while managing its efficiency level. In order to assess flood susceptibility, many researchers have used different models such as fuzzy logic simulation method (Oladokun, Proverbs and Lamond, 2017), HOWAD/GRUWAD model (Schinke et al., 2016), logistic regression (LR) model (Song, Huang and Li, 2017), evidential belief function (EBF), random forest (RF), and boosted regression trees (BRT) models (Rahmati and Pourghasemi, 2017).

Table 1: Components Involved in Risk calculation

Term	Definition
Flood Hazard	• event causing losses, disruptions, and damages to both personnel and built resources. • depends upon flood probability and its physical characteristics.
Element at Risk	• social, physical, economic, environmental or any other assets exposed.
Vulnerability	• impact of conditions and factors on susceptibility of resources.
Consequence	• expected losses in an area
Resilience	• specific set of elements at risk
Total Risk	• calculated by integrating the consequences of a hazard.

(Source: Adapted from Westn and Jetten (2015)

4. Empirical Derivation of Flood Risk

Flood risk is defined by the sum of the product of hazard by consequences. Risk can be presented empirically with the following framework as indicated in equation 1:

Risk = Hazard * Consequences(1)

Risk = (Probability + Exposure) * (Elements at Risk + Susceptibility – Resilience)

This equation focuses on the analysis of social, economic, environmental and physical losses, using vulnerability data. It studies the impacts and consequences and compares the results to determine the acceptable level of risk in a region. The equation gives the possible scale of analysis for different scale of vulnerability and the possible approaches. It discusses the qualitative approaches and quantitative approaches to calculate the risk. The equation can be integrated in flood modelling such as hydrodynamic model (MODCEL) formulating Flood Resilience Index as proposed by Miguez and Veról, (2017).

5. Conclusions and Recommendations

The flood control measures are limited to structural measures to control flood water to inundate the settlements. It does not guarantee an absolute safety from flood, as there is always a possibility of having a greater flood than the safety of designed structures. The design solution of these flood control infrastructures may withstand with 100-year flood or 500-year flood but it will turn out ineffective for 1000-year flood. It is necessary to understand and live with the possibility of flood and to accommodate them, rather than in controlling flood. The effective flood protection system is the combination of structural and non-structural measures in the spirit of sustainable development. The flood risk management approach deals with non-structural measures to live with flood. The non-structural measures such as response-recovery plan, land-use planning, bye-laws, insurance system, evacuation plan etc. have shown better results in managing the flood consequences. The understanding of flood and its impact helps in managing the flood risk efficiently.

The flood risk is interpreted as an interaction of hazard and its consequences. Hazard is the combination of flood probability and flood characteristics. The accepted definition of flood hazard is product of flood probability and flood exposure. It forms a basis for risk informed decision upon probability of occurrence of hazard. The probability of flood is a quintessential element in assessing flood risk. It is the likelihood of flood event. Flood exposure in the intensity of flood based on physical characteristics. The another component of flood risk is its consequences. Flood consequences is the impact of flood on social, economic, and environmental aspect of region. Flooding is the exposure of systems and its environments. It is assessed through analyzing 'elements-at risk' which in turn defines the vulnerability of the region. Vulnerability is the function of susceptibility and adaptive capacity of region.

The paper recommends that the integration of flood control approach and flood risk management approach is required for developing a flood resilient region. Flood needs to be assessed empirically to recognized the change within flooding system. A definite set of indicators for all components of flood risk need to be identified for varied spatial scales. The paper demonstrated the flood risk equation based on existing approach that fitted in coherent framework. In India, flood risk management is at nascent stage and needs to be propagated. The flood risk management should consider the gaps present in analyzing its components. It should begin with correcting gaps in existing components and its related definitions.

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Building Resilience of the Shimla City Towards Seismic Hazard: Challenges and Opportunities

Mohd. Mudassir[1]*, Hari Kumar[2] and Harkanchan Singh[2]

Abstract

The Himalayas are among the most disaster risk-prone regions in the world. The city of Shimla in state of Himachal Pradesh of India, home to about 169,578 people as per 2011 census, is a tourist spot. It is located in the foothills of the Himalayan Mountains fall under seismic risk zone IV and V and could be affected by seismic hazard with intensity IX and above. Any major earthquake originating in the nearby Himalayas can affect Shimla and setback years of development in the city. The rapid growth of the population has put tremendous pressure on the built environment. Unplanned urbanization has led to an expansion of the city onto more and more vulnerable land areas. In the absence of risk-sensitive land-use policies and plans, inadequate enforcement of building rules and regulations, lack of granular risk assessment, more and more communities within Shimla are building in hazard-prone areas increasing the risk profile of the city almost on a daily basis. The analysis of this study may be taken into consideration for civil engineering, local development planning and disaster risk reduction in this region for making the new urbanization earthquake risk resilient.

1. Introduction

The city of Shimla is located in the actively growing Himalaya Mountains, with a population of 169,578 people as of the 2011 census. The city is a tourist place that attracts several visitors in the summer season. The city has been growing rapidly over the years with an economy depends mostly on tourism.

Shimla is a multi-hazard prone city with a high seismic risk zone as per the Vulnerability Atlas Map of India (figure 1). It is located in the foothills of the Himalayan

1 **Mohd. Mudassir,** UNDP India.
2 **Hari Kumar and Harkanchan Singh,** GeoHazards Society.
* Corresponding Author Email: mudassir.afz@gmail.com

Mountains. The geoscientists believe that enormous earthquakes with magnitudes of 8.0 or above are overdue. Historically, an M_w7.9 Kangra Earthquake in 1905 had epicenter approximately 170 kilometers north of Shimla. The most recent earthquake, an M_w7.6 struck in Kashmir in October 2005 was significantly smaller than the impending earthquakes. There has not been a major earthquake for a long time in the region that worries seismic engineers. The long return period of earthquake has created a 'seismic gap' that appears to be a potential region for next great earthquake (Gahalaut, 2008).

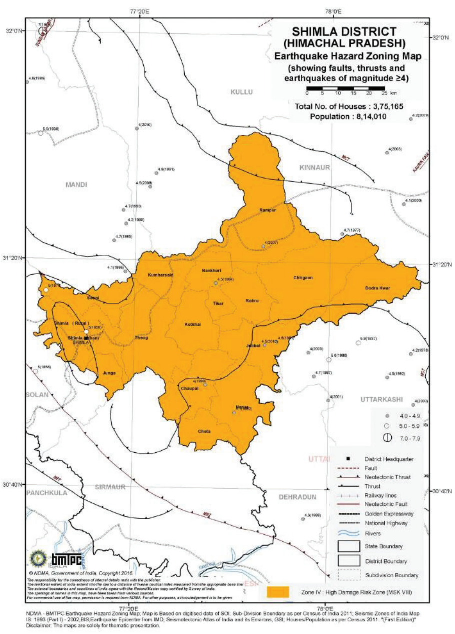

Figure 1: Earthquake Hazard Zoning Map, Source: BMTPC

The increase of seismic risk in the city continues to happen due to a spurt in unplanned development activities caused by urbanization, economic development, and tourism. Shimla is a representative of many cities in the Himalayan region that are rapidly growing and overwhelming the subject-matter experts. Landslide hazard (figure 2) is becoming more intense and frequent in and around the city. It poses potential risks that are mostly frequent in monsoon season triggered by heavy rainfall. If heavy monsoon strikes, it can also trigger many landslides in a short span of time. Besides these, the landslide event in Shimla has been exacerbated by human activity, with indiscriminate slope cutting and modifications in the ecologically fragile mountains. Moreover, Earthquake shaking can also trigger hundreds to thousands of landslides all at once (Rodgers et. al., 2014). The landslide events may result in damage to critical utilities such as water, electricity, roads, bridges, and telecommunication systems, which are interlinked systems.

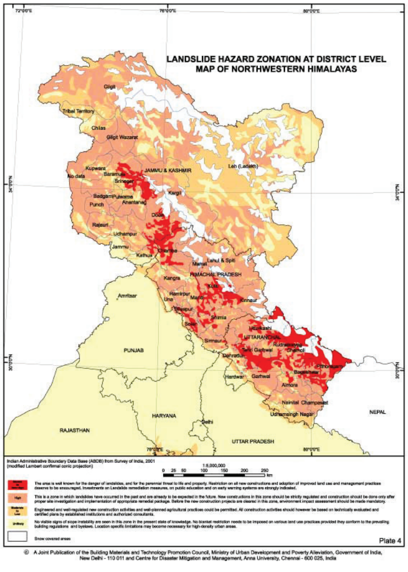

Figure 2: Landslide Hazard Zonation: Source, BMTPC

2. Methodology

The technical approach was used to develop this paper utilizing the World Bank's Building Regulatory Capacity Assessment Level 2 guidance. A comprehensive desk review of local building bye-laws, and regulations, city DM plan, and other publicly accessible policies and relevant guidelines were also conducted. *Lifelines: The Resilient Infrastructure Opportunity* report of World Bank was also reviewed to gain an understanding of the subject. We have employed multi-stakeholder approach and conducted some semi-structured detailed virtual consultations and interviews with key government agencies, non-government stakeholders to obtain insights on the gaps and capacity of the city towards building regulations, rules, and resilience, as well as disaster management system for synthesizing the interactions within this study. To analyze the wide range of data both from primary as well as secondary sources, 'the thematic analysis' technique was used. Thematic analysis is one of the most common forms of analysis within qualitative research. It emphasizes identifying, analyzing and interpreting patterns of themes within qualitative data.

3. Analysis

Thematic analysis (cf. Guest, 2012; Gibbs, 2007) was used for synthesizing findings within this research paper as the primary qualitative research method to identify and organize key themes from qualitative data under BRCA Level 2 guidance. To analyze the wide range of data both from primary as well secondary sources, this technique has allowed for a rich, detailed, and complex description of the topic. The findings of the research have been generated using combined approaches (i.e. research-driven and participatory), with a combination of illustration and visualizations in their construction.

4. Result

4.1. Building Resilience

There are 3,75,165 houses in Shimla city (BMTPC, 2019). As per the City Disaster Management Plan (CDMP), the land distribution of Shimla shows that major land use is residential that is 75% of the total built-up area. The CDMP highlights that 90% of structures in the city are 'poorly built' that can collapse during moderate to high earthquake shakings. The most damage could be experienced in the areas such as Lakkar Bazaar, New Shimla, Vikas Nagar and Ruldu Bhatha, are the part of slopes of the ridge. The underlying factors that caused haphazard construction in the city include the huge demand for urbanization triggered by migration and tourism. As a result of these factors, a lot of construction of buildings has started on steep and unstable slopes with improper construction practices.

A survey conducted by Town and Country Planning (TCP) based on vulnerability atlas for the country (based on building census for the year 1991 for Shimla) shows that less than 2% of houses in the city are safe. According to TCP surveys, 78.64% of the buildings fall in category A, 12.96% in category B, 6.88% in category C, and 1.25% in category X as presented below in table (1). The Vulnerability Atlas Map of India developed by BMTPC following the publication of Census 1991 data on buildings in India is based on predominant materials used for the construction of roofs and walls are widely used to determine the vulnerability of the built environment in the country.

Table 1: Seismic Vulnerability of Different Types of Buildings in Shimla

Category of Buildings	Features	Seismic Impacts	Percentage
Category A	Made of mud, stone and random stones	Suffer partial damages	78.64
Category B	Large blocks and poor quality of timber	Liable to develop deep cracks	12.96
Category C	RCC Buildings	Only small cracks	6.88
Category X	Seismically safe	Totally safe	1.25

There has not been a scientific study conducted so far on the seismic vulnerability of buildings of the city. A Rapid Visual Screening (RVS) *study of important buildings, transportation and communication systems for Shimla city* was conducted by UNDP India with Municipal Corporation Shimla with technical support by NIT Hamirpur in the year 2015-16. The draft RVS report is available on MC's website that has a list of buildings/structures that were assessed. However, it does not provide detailing on structural integrity, stability, and resilience of these important buildings and systems, and the final report that seems to have details is not available in public domain to avoid creating public fear. The MC Shimla instructed the authorities concerned to undertake retrofitting measures with the technical support of NIT Hamirpur for important buildings through official letter however; no actions have been taken yet.

There is no detailed and systematic scientific study showing vulnerabilities of buildings and systems in the entire state of Himachal Pradesh. Himachal Pradesh has a digital HRV Atlas that enables the generation of hazard, vulnerability, and risk maps of the State down to the block level. This is an effective tool for risk analysis for all stakeholders across all sectors at all levels. The HRV Atlas has mapped the intensities of six hazards, of which four are natural (e.g. earthquake, landslide, flood, drought, and GLOF) and the remaining two are human-induced (forest fires and industrial accidents).

This Atlas is based on data obtained from primary as well as secondary sources and overlays the same on the GIS platform showing physiographic, critical utilities and facilities, and administrative boundaries at various levels (state, district and local) at a scale of 1:50,000. However, the scale of the risk assessment is not appropriate for local planning and regulatory purposes.

Many of the residential and commercial buildings continue to come up in the city. It has a congested built-up area now with haphazard developments happening in sinking zones, steep slopes, and landslide-prone locations. For landslide safety, the basic factor checked prior to construction of roads and buildings is the stability of the slope, which is critical in Shimla terrain. The local building bye-laws restrict hillside constructions on slopes steeper than 45 degree, however, quite a large chunk of the buildings have been constructed violating the hillside construction norms. The building regulations have provisions for slope cutting and construction that allow slope cutting not more than 3.5 m. In addition, the local building standards contain provisions to check the stability of the slope and carry out site specific inspection for landslide resilience. However, there are no geotechnical engineers available in the planning team. It is the Executive Engineer Roads and Buildings (EE - R&B, MC Shimla) along with the design engineer responsible to carry out inspection. In case of violation of this provision, a joint inspection is carried out by a committee led by the Executive Engineer to stop such illegal construction in dangerous slopes, or restrict the slope cutting within permissible limits. Moreover, landslide hazard maps are available but the scale of these maps is inadequate therefore not useful in construction activities per se. In case of critical infrastructure projects, technical support is sought from government technical institutes such as Indian Institutes of Technologies etc.

The Municipal Corporation (MC) Shimla is responsible to oversee planned and systematic development in the city. Most of the staff in the MC office is on deputation from other government departments of Himachal Pradesh. In most of the cases, the MC office finds it difficult to keep checks on constructions provided that they have acute shortage of staff. During building approval, producing a structural stability certificate is the responsibility of the owner. Structural engineers who are registered with the MC carry out the certification of the structural safety components in the building plans and drawings. This gap highlights the need for structural safety inspections and certification to be handled by a qualified structural engineer.

The enforcement capacity of the city is inadequate provided that construction fraternity such as site engineers, overseers, artisans, and other workforce are largely unaware about the seismic resistant constructions. In addition, the rules in the building bye-laws do not explicitly point out site inspections at various stages (pre, during and post) of constructions. The Development Authority, Housing Department and Engineering and Designing Wings in PWD and TCP do not have adequate number of staff members and lack sufficient expertise in structural safety components to check the constructions that make local enforcement and implementation poor further resulting into unsafe construction without meeting the required seismic code standards. For example, The Urban Development Directorate which controls development in jurisdictions of all urban and municipal bodies does not have a dedicated town planner. 61 ULBs under Urban Development within Himachal Pradesh have 1 junior engineer each and 5 Assistant Engineers altogether in Shimla.

In addition, the Public Works Department in Shimla is engaged in planning, construction and maintenance of roads, bridges, hospitals, ropeways and buildings (both residential and non-residential buildings including government departments) in the state. This department is one of the biggest and important departments that adhere to the latest NBC. However, the PWD does not have any specific hillside construction guidelines and therefore adheres to prevalent seismic zone codes by BIS for any hillside constructions. The department has a design wing division, but does not have any structural engineers. It is the Chief Engineer who works as a Structural Engineer approves structural drawings for any construction projects. The department conducts structural safety audits of the buildings. These audits are carried out by the department itself without the involvement of the third party in the audits process.

The development authorities (i.e. UD, PWD, TCP, MC Engineering Wing etc.) in the city do not have in-house mechanisms to test the materials and soil of the construction sites. They also lack a required instrument or lab with them so all testing work is outsourced through various pre-identified agencies. The authorities do not have a pre-identified list or data of registered masons with them. They hire contractors via an online tender process who bring in labor, mostly from plain areas and these masons are seasonal labor and keep floating. The staff members in the development authorities lack sufficient knowledge on the structural safety aspects. Only a few numbers of construction professionals from various departments have been imparted training on safe construction practices on theoretical aspects. There is an immense need to provide hands-on training on various practical aspects covering cost-effective earthquake resilient construction in hill areas, safe and resilient constructions, retrofitting techniques, and post-disaster reconstructions and repairs.

4.2. Critical Infrastructure Resilience

Critical infrastructure system provides vital services and resources to the communities, public and private entities, and commercial activities. This term is being widely used to describe assets and services that support important societal functions. Critical infrastructure not only covers technical assets but also functional sector and essential services (Pescaroli and Alexandra, 2016). These systems heavily depend upon interconnections with one another; therefore, an effect of disaster on one system generatescascading and escalating failure that could scale up the impact. It is therefore important to prepare, invest, and protect all types of infrastructure including lifeline networks (e.g. electricity, water, telecommunication, roads and bridges) and life support networks (e.g. emergency services, public health).

The term resilience has been used in various fields since the last few decades. Now this concept has been well incorporated into the management of critical infrastructure systems (Dahlberg et al., 2015). This paradigm shift in traditional risk management to include resilience is fundamentally based on the observation that it is impossible to be protected against all risks or to predict what is by definition unpredictable (Porod et al., 2012).

The resilience of critical utilities such as roads, water, electricity, and telecommunication etc. is crucially important for remotely located hill cities such as Shimla. It is a system of systems that are interconnected and interdependent. However, the resilience of a system is dependent on the weakest link of that system. The critical systems are only as resilient as their weakest link. The effects of seismic hazard may cause damage to critical systems, and the environment on which the system relies. For example if the electrical system is affected because the power transmission lines, poles or transformers could be damaged due to seismic shaking or landslide. The failure of the electrical system will further affect the water system as it depends on electricity to function. Similarly, the other critical system such as telecommunication consists of mobile towers and the internet also depends on power. If seismic shaking does not cause any direct damages to mobile towers, the failure of power will lead to mobile networks to remain non-functional once back-up sources run out.

In addition, the roads and bridges could also be damaged as a result of earthquake shaking or landslides making the road connectivity impassable for several days or weeks. In this scenario, the repair supplies, equipment and other essential goods will not be able to reach the city. These are quite common vulnerabilities of the critical system in the Shimla City. This paper briefly presents key challenges to the water system in the city in the context of seismic hazard to show interconnection of risks.

The water system in Shimla city is sourced from both pumping and gravity methods. The water is pumped from the rivers and springs in the vicinity of the city, and is also transported from spring sources located at higher altitude via gravity method. The prominent vulnerability features to water systems are pumping stations, tanks, reservoirs, pipelines, and other ancillary equipment. These elements of the water system are vulnerable to ground shaking and permanent ground deformations. For instance pumping stations, tanks, and reservoirs can be affected by earthquake shaking. Poor roof connections, inadequate anchorage to floor, undersized structural components, non-ductile concrete frame structures commonly have poor seismic performance. Numerous pipelines may break all at once in the distribution network from shaking, settlement, and landslides as was observed in the 1994 Northridge, 2008 Wenchuan, and 2015 Nepal earthquakes where similar materials were used in pipelines.

Even though Shimla has back-up generators, they are as dependent on electricity as the primary pumps. As a result, Shimla's ability to provide water following an earthquake has no redundancy regarding power source. Redundancy is an important trait of a resilient network. A redundant water supply does not need to meet daily or annual peak demands but should be able to provide a sufficient quantity during emergencies to meet minimum public health and safety needs.

Moreover, the network of roads used to reach water system components for repairs will likely have also suffered damage. Fuel (i.e. diesel) that is normally purchased in the city to operate the repair equipment may quickly run out if fuel supply tankers from out of town are blocked from reaching the city by impassable road. Lack of fueling supplies strongly inhibits ability to rapidly respond to earthquake impacts. Fueling resources are expected to be limited and in high demand following an earthquake. Ability to replenish will be difficult due to expected damages to the regional and local transportation system.

4.3. Health System Resilience

National and local health systems that provide health services for millions of people have been affected by damage to and destruction of thousands of health facilities during 2001 Bhuj earthquake (Mw7.7), Gujarat, India (Singh, 2015), 2004 Indonesia's northern Aceh province earthquake (Mw9.3), 2005 Pakistan's earthquake (Mw7.6), and 2008 Myanmar earthquake (Mw6.9) in past disasters. More than 11000 health facilities were damaged or destroyed by the earthquake that struck China on 12 May 2008 (WHO, 2015). The Pan American Health Organization (PAHO) and the World Health Organization (WHO) have defined: *"a Safe Hospital as one that will not collapse in disasters, killing patients and staff; can continue to function and provide its services as a critical community facility when it is most needed; is organized, with contingency plans in place and health workforce trained to keep the network operational."*

Moreover, the hospitals are also important symbols of social well-being. Destruction of or damage to a hospital may result in a loss of trust in local authorities as well as exposing patients and health workers to further vulnerabilities. The city of Shimla provides effective health services. The main Government Hospitals in the city are Indira Gandhi Medical College, Kamla Nehru College, Deen Dayal Upadhaya Zonal Hospital, Regional Ayurvedic Hospital. Health facilities, especially hospitals, are critical assets for communities both routinely and in response to emergencies, disasters and other crises. Yet hospitals and health workers are often among the victims of emergencies, with the result that health services cannot be provided to affected communities, when they are most needed. The continuing functionality of the hospital depends on a range of factors, including the safety of its buildings, critical systems and equipment, the availability of supplies, and the emergency management capacities of the hospital (WHO, 2015).The elements of a functional hospital are presented below in figure 2.

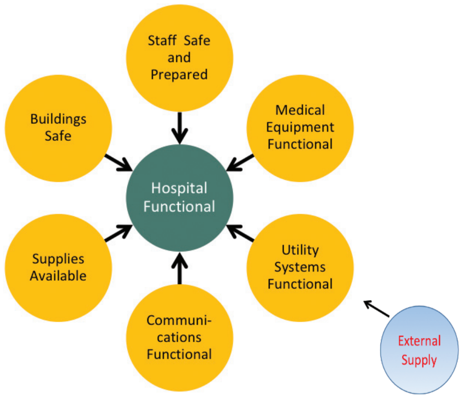

Figure 3: Ingredients of Functional Hospital

(Source GeoHazards International, 2010)

In the case of seismic hazard, the surge capacity of the hospitals in the city may be overwhelmed with a large influx of patients. The hospitals can themselves be affected by earthquake events and/or its cascading effects. After most earthquakes, it has been observed that medical resources are scarce to meet the needs of the earthquake survivors, especially in hilly terrain. In the absence of adequate medical resources, minor injuries can aggravate limb/life-threatening injuries among the affected community.

The health facilities indicated above in the city are highly prone to earthquakes. Hence, it is important that safety and functionality of these facilities should be enhanced on priority basis. The health facilities indicated above should be also examined from the seismic safety point of view, and required retrofitting measures must be undertaken. As a major earthquake has not affected Shimla city for almost a century, the health facilities' response to a mass casualty event such as would happen in the aftermath of an earthquake has not been tested. However, elsewhere in the world, in the last two decades, critical hospitals have become victims rather than saviors that their communities expected these critical facilities to be in earthquakes as examples cited above.

Besides structural safety of these health facilities, the resilience of water and electricity becomes important to ensure their functionality. Water supply is critical for the smooth functioning of any hospital, as hospitals not only represent a concentrated area of patients but also a concentrated area of infection sources. In order to maintain an optimum level of safety in disaster situations, hospitals must maintain a basic health environment with a reliable supply of good quality water, facilities to provide access to safe hygiene, sanitation and health care waste management in order to control the spread of infections, which are major causes of morbidity and mortality after disasters. These health facilities are dependent on the supply of the water from municipal sources. Most of the water (nearly 90%) is pumped from river sources that heavily depend on electricity. Moreover, the water piping in the city is exposed to both seismic hazard and landslides that can break water pipes and distribution network. If the water system fails, the healthcare services will be rendered unless.

The hospital's most important utility system is the electrical power system. Without power, the hospital's essential medical equipment, life support equipment, lighting and other safety-critical items will not function. Following a moderate or major earthquake, it is highly likely that the supply from the electrical grid will be disrupted; and grid power will be lost for a significant period of time. During the critical response period immediately following the earthquake, and perhaps for weeks afterward, the hospital will need to rely on backup power supplied by the emergency generators. However, the generators and backup power system in the hospitals are vulnerable to earthquake damage that could prevent them from supplying the hospital with power when it is needed most.

A Case of IGMC Shimla hospital

Indira Gandhi Medical College (IGMC), the State Hospital and Medical College, is an 800-bedded health facility that not only caters the city's residents, but also population across the state. It was constructed by PWD and consists of five blocks that house 37 departments including ED, OTs, ICUs etc. The blocks of IGMC are connected via ramps and staircases. The hospital campus is located on a hillside and is prone to seismic and landslide hazards. A new campus is being constructed to shift EDs and OTs. Being an important facility, it is essential that IGMC should be critically examined based on structural safety standards. An annual safety audit must be conducted at least for critical departments. The emergency plan of hospital developed in 2018 needs to be reviewed and updated. The non-structural elements (architectural, contents, peoples and medical equipment) and critical utilities in the hospital are not seismically protected. The hospital has shortfalls of water and power storage capacity as indicated below.

The water tanks store about 554800 liters. WHO recommends that hospitals have in-campus storage of water of three days' supply calculated at the rate of 300 liters daily per bed capacity of the hospital. For IGMC, this works out to 800x300x3 =720,000 liters. Therefore, the IGMC currently has a shortfall of 165,200 liters water compared to accepted standards for water storage.

In case of power failure, the hospital has nine generators. The total consumption of fuel if all nine generators in the hospital are working will is about 4.78 liters per hour (1000 total diesel / 209 total consumption per hour). Presently, the campus keeps 1000 liters fuel in storage in addition to the fuel in the generators. This will hardly be enough to keep the hospital functional for a maximum of 5 hours. In normal times, diesel is brought from nearby petrol pump (20-minute drive) from Sanjauli. In addition, the petrol pumps and roads may not be functional following post-earthquake scenarios. It is extremely important to have adequate diesel in storage to run the critical facilities of the hospital for at least 72 hours.

5. Discussions

The review analysis shows that while the local development authority intends for digital Atlas map to be used to control development in areas of high hazard, information is not available at a sufficient scale to be used for this purpose. This lack of actionable and high resolution hazard information at the local level affects many regulatory functions including planning, zoning, and plot-level building permit approvals, and also post-disaster relocation and rebuilding in the city. This shortcoming also affects the development of regulations; if there are no actionable hazard maps, building and land use regulations are not written to mandate their use. Other key gaps relate to older, hazard-vulnerable, and unsafe buildings. The CDMP highlights the needs in this area, but the lack of scientific study, inadequate standards for assessment and retrofit, and limited provisions to deal with them are desired to improve regulatory frameworks. It is envisaged that there are key potential interventions needed for building resilience of the city to earthquake.

5.1. Revision of Municipal Regulations

Unlike other places in Himachal Pradesh, Shimla Municipal Corporation (MC) has its own bye-laws; known as MC Shimla Building Bye-Laws 1998 brought out under the HP MC Act 1994 and published in 1998. In addition, the Himachal Pradesh Town and Country Planning Rules (TCPR) 2014 are also applicable to Shimla. There have not been any revisions made since then in these laws and rules making them insufficient for ensuring building resilience of the city. Following revisions in the National Building Code in 2005 (third revision) and 2016 (fourth revision) besides a few national standards for hillside construction by central agencies (BIS, NDMA), the critical review of the local building bye-laws in the context of the latest NBC and IS codes remain wanting.

The building safety codes (NBC and IS) and guidelines developed at the national level agencies must be adapted to Shimla context, and have to be reflected in the local building rules. But many of the codes referenced in the local building rules and regulations are a decade old, and during the last decade, the state has witnessed many geophysical events that have affected communities and infrastructure, including property losses. The city needs to establish a techno-legal and techno-financial regime in consultation with NDMA. These should be tailored to address the hazards to which they are at risk and sensitive to priorities of the city. It is best to evolve these through consultative process. Municipal regulations, such as development control regulations (DCRs), building bye-laws and structural safety features, are primary determinants of the safety of the built environment. They should be reviewed periodically to identify safety gaps (especially from the point of view of earthquake, flood, landslide and other hazards) and modifications made to align them to the revised building codes of the Bureau of Indian Standards.

5.2. Licensing and Certifications

The construction fraternity such as engineers, architects, planners and artisans are the backbone of the built environment. It is therefore imperative that all-service engineers, architects and planners working in various departments of the state government, dealing with construction are to be trained through a capacity development process, and only the competent ones among them are to be licensed through an assessment process. Besides these, the local construction workers (artisans) in their respective trades should be trained and their skills to be upgraded, and certify them after a due competence verification process. The city should create a database of the registered masons involving them in ongoing and future construction processes.

The provisions in the local Building Bye Laws and DCRs, should be incorporated requiring that only licensed engineers shall be permitted to undertake the structural design and construction of buildings and structures, and only certified artisans shall be employed to undertake the skilled work. The provisions and rules should be laid out to fix accountability of Licensed Engineers to empower the ULBs to take appropriate legal actions (such as blacklisting, debarring from services, cancellation of license etc.) for any violation by the Licensed Engineers.

5.3. Structural Safety Audit

For regulating safe and resilient construction practices require establishment of a techno-legal system. The municipal body of the city (to which the structural design calculations and drawings are submitted for approval) examines the documents and confirms compliance with the prevalent national standards. The audit is performed by Structural Safety Peer Reviewers. Two structural safety peer reviewers are needed, namely: (1) structural safety peer reviewers for the structural design, and (2) structural safety peer reviewers for the construction quality. Only legally licensed engineers should be commissioned to carry out these peer reviews. Currently, there is no legal system in Shimla (not even in the country) of Licensing of Engineers. Until a system is in place to license engineers, available engineers of repute should be trained to carry out these audits.

When Structural Design Peer Review and Construction Peer Review pertaining to design or to construction are performed by licensed engineers under the aegis of a statutory body, it is called the third party Structural Safety Audit. The CDMP emphasizes the importance of this Structural Safety Audit in the plan. Structural Safety Audit of the designs should be done ideally by a statutory body for each new structure before construction and each existing construction after specified durations of time.

5.4. Retrofitting of Existing Structures

Retrofit is a powerful proactive effort that builds resilience in communities by enhancing the capacity of the buildings and structures to resist the demand imposed on them when the expected hazard is realized. It is a resource-intensive technical activity.

Therefore, prioritization of buildings and structures (lifeline and important ones for which risk tolerance is zero) in the city is required, based on a formal Risk Assessment. An RVS study has also been carried out in the city. It is prudent to undertake retrofit as programs, each stretching over 5 years with mid-term strategic changes and technical improvements, extendable beyond 5 years with the revised plan, until the entire stock of prioritized buildings and structures are retrofitted.

5.5. Seismic Resistant New and Existing Structures

The entire stock of the building and structures in the development is seen in two parts, namely the existing and the new. It is relatively easy to design and construct new building and structures to be disaster-resistant. This requires robust design and construction standards, which are disaster-sensitive and regulate only desirable performance when the hazard expected at the site is realized. The five virtues of the built environment – safety, functionality, sustainability, aesthetics, and cost-effectiveness must be considered. The local government should have system perspective approach considering both physical and service functionality of new structure.

The existing built environment can be a biggest source of vulnerability in the city. For existing structures, besides retrofitting measures discussed above, it is important to develop some predictable financial mechanisms for quick recovery and restoration of large critical infrastructure. This can be managed through various financial institutions and mechanisms in place. Partnership with financial institutions and insurance companies provide whole recovery window of opportunity to build back forward, greener and safer.

5.6. Resilience of Health Facilities

The resilience of health facilities in Shimla city should be enhanced both in terms of safety and functionality. The periodic structural safety audit of these facilities can help facilitate the physical stability, integrity, and resilience of these important institutions. To make hospitals safer in Shimla, there are certain steps that must be followed. 1). Conduct a seismic risk assessment of health facilities; 2). Construct health facilities to withstand future seismic hazards. *Making new hospitals and health facilities safe from disasters is not costly. Incorporating mitigation measures into the design and construction of new hospitals accounts for less than 4 percent of the total investment*

(NDMA Guidelines – Hospital safety, 2016); 3). Enhance preparedness and emergency management for multi-hazard scenarios; 4). Retrofit and maintenance for critical facilities, secure medical equipment, and plan for critical utilities.

6. Conclusion

Systems and processes need to be built to assess, document, synthesize and share information to all stakeholders on the risk prevalent in the city against seismic hazard, and to use the same in local development planning in the city. The local authorities should carry out scientific micro zonation studies of the city to determine the following information; (a) Site-specific liquefaction; (b) Local geology and geotechnical properties of surface and subsurface strata; (c) Availability of known seismic faults; (d) Possible secondary hazards i.e. landslides; (e) Specific seismic behavior for engineering design, land use and urban planning.

Hazard maps should ideally be 1:5,000 scale, or 1:10,000 at minimum, to be useful for regulatory purposes. Current HRV Atlas scales are not detailed enough to be useful for planning or regulatory purposes in which decisions need to be made at the plot (parcel) level. There is a need for micro-level georeferenced cadastral and topographical maps showing hazard areas. Georeferenced cadastral and topographic maps should be the base map for building permit approval systems. The scrutiny officer at the local government could easily consult such maps to identify whether a particular area is hazard-prone, and what the hazard intensity would be, to guide development decisions and construction of hazard resilient structures in such areas.

Risk-informed land-use planning is essential to reducing Shimla's seismic risk by looking more holistically at the physical environment, hazards, and development practices. Risk-based planning would require new strategies in the city, such as (1) Conduct a comprehensive assessment at micro- levels of the nature of the hazard and its intensity at micro-levels. It will be important for the planning team to have access to 1:10,000 scale or better maps to depict local situations clearly on a cadastral map. (2) Assess levels of risk (acceptable level, medium risk, or high risk) based on measurable indicators. These indicators should be used to develop parametric models for land parcels and should be linked to land-use policies. (3) Monitor the risk levels over time, enabling the communities and authorities to undertake sustainable development practices to reduce identified vulnerabilities.

The city will have to create social demand on a large scale for seismic resilient constructions. Promoting and encouraging safe and resilient building construction will be a win-win situation for local governments, building owners, developers, and in the end for consumers and occupants. It is recommended that the suitable financial or in-kind incentives (such as enhancement of FSI, reduction in power/water tariffs, property tax, and speedier approval etc. can be built into the building regulations of Shimla after reviewing examples from other states of India. Incentives appeal to the owner, developer, builder, occupant, or corporation. For existing and future buildings, especially for lifeline structures, the city should develop a comprehensive program in which building infrastructure should be mandated to have an annual safety audit by engineers to ensure their structural integrity. Besides these, to address safety problems in the current and future buildings and encourage voluntary structural maintenance of buildings, the local development authority should set up incentive mechanisms for building owners for safety, resilience, maintenance, and auditsshould be carried out by structural engineers.

Local government capacity to implement and enforce the Bye-Laws is not sufficiently adequate. There are only a few engineers and no geologists available to support the design and construction of buildings. Since the local governments are solely entrusted with the task of enforcement, the capacity of the Municipal Corporation is critical for safe buildings. The local government should make disaster resilient infrastructure as economic case by underscoring the cost-benefit analysis principal that shows *$ 4 benefit for each 1 $ invested in resilience* (Lifelines report WB, 2019).

It is important to build local capacities in risk-sensitive land use planning so as to enable and capacitate the policymakers, associated planners, engineers, and architects to effectively address seismic resilience. The city should develop a comprehensive land-use management policy, introduce necessary amendments in the existing regulations, and formulate a model and localized development control regulations for different areas within cities.

Technical Assistance is needed for specific sectors. As local bodies cannot afford to have a team of in-house experts for seismic resilient construction, options for receiving technical assistance should be explored, such as constituting a peer review group for advisory inputs including from national as well as state technical research agencies, institutes, and universities.

To address the lack of clarity and gaps in existing construction safety provisions, it is recommended that Standard Operating Procedures be laid out on (i) Regularization of informal, unsafe, and unauthorized construction including maintenance of database (ii) Provisions for demolition of old (dangerous) buildings and (iii) Procedures for retrofit, repairs, and restoration of buildings.

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Probabilistic Evaluation of Landslide Vulnerability along the National Highways of Shimla Tehsil, Himachal Pradesh

C. Prakasam[1*], Aravinth. R[2] and B. Nagarajan[3]

Abstract

The research has been conducted to prioritize the landslide prone regions along the National Highways of the Shimla Tehsil, Himachal Pradesh. National Highway spanning 119.3 kms with a buffered radius of 1000 mts has been taken for the study. The research conducted provides an insight into the vulnerable zones of the National Highways (NH) of the study area through statistical modelling and landslide inventory datasets. The total geographical area of the study is 9351.45 ha. Landslide preparatory factors such as Landuse Landcover, Slope, Geology, Geomorphology, Normalized difference vegetative index (NDVI), aspect etc. have been used for the preparation of landslide vulnerability maps. The layers are integrated in the GIS environment using Weighted Overlay Model for the vulnerability mapping. Based on the results Landslide Vulnerability Mapping has been divided into 4 classes based on the rating ranging from low to very high. Based on the landslide inventory it has been estimated that 40.6% of the landslide occurs in the high category and 27.8% occurs in the very high category list. About 27.3% occurs in the moderate category. The research conducted reveals that out of the 44 landslide inventories 68% of the landslides occurred in the high and very high categories. 27% occurred in the moderately vulnerable category.

Keywords: *Weighted Overlay, National Highways, Shimla Tehsil, Landslide Vulnerability, Landslide Inventory*

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[1] **C. Prakasam,** Department of Geography, School of Earth Sciences, Assam University, (A Central University), Diphu Campus, Karbi Anglong, Assam, India.
* Corresponding Author Email: cprakasam@gmail.com
[2] **Aravinth. R,** Department of Geography, School of Earth and Atmospheric Sciences, University of Madras, Chennai, India.
[3] **B. Nagarajan,** National Centre for Geodesy, Indian Institute of Technology Kanpur, Uttar Pradesh, India.

1. Introduction

Landslides are mass movements that are caused under influence of gravity, monsoon rainfall and Unstable Roadcut slopes, exposed barren land on rugged terrains, nature of soil, torrential rainfall, flash floods and earthquakes etc (John et al., 2020; Kaur et al., 2018; Kutlug et al 2020). These landslides are results of both natural disasters and manmade activities (Prasad & Siddique 2020; Singh & Meena, 2020; Youssef & Pourghasemi, 2020).. In India, landslides are one of the most frequent disasters occurred during the rainfall season compared to other natural hazards. Globally landslide causes more social and economic losses than other major disasters (Sekhri et al. 2020; Sridharan & Gopalan, 2020; Thakur et al. 2020). According to IAEG "International Association of Engineering Geology" 14% of the disaster causalities in the world are due to landslide events. Geological Survey of India has said that 0.42 million sq.km of country's surface are prone to landslides where most of it are situated in the Himalayan region and the Western Ghats (Saha & Saha, 2020). Himalaya being one of the youngest mountain constantly undergoes surficial and sub surficial movements due to tectonics and earthquake related activities. As such landslides pose a considerable threat to the various settlements, transportation corridors and barren lands of the Himalayan region where regional climatic condition are the main source of triggers for landslide initiation (Bera et al. 2020; Kutlug et al. 2020; Panahi et al. 2020). Even though monsoon rainfall and earthquake are the main causative factors, anthropogenic activities like slope excavation without proper toe support, forest plantation, building construction along unstable slopes also contribute to mass movements (Prakasam et al. 2020a). Data retrieved from the Regional Meteorological Centre, Shimla suggest that Shimla has been receiving 1250 to 1600 mm of rainfall in recent years. Highly jointed rocks and varying soil nature coupled with the high intensity rainfall made Shimla highly prone for landslide activities (Gobinath et al. 2020; Sridharan & Gopalan, 2020; Prakasam et al., 2020a; Prakasam et al., 2020b). Increased ground vibrations along the unstable road cut slopes due to heavy traffic movement is also of major contributing factor for the reduced slope strength (Ashutosh & Panthee, 2016; Martha, van Westen, Kerle, Jetten, & Vinod Kumar, 2013; Sarkar, Roy, & Raha, 2016). There is no one methodology or model to successfully predict or mitigate landslide scenario and events. Based on the literatures studied statistical methodology combined with field collection of landslide inventory provides best scenario in prediction of landslide vulnerable zones.

The current research is focused on evaluating the landslide prone areas along the National Highways of the Shimla Tehsil, Himachal Pradesh. The research has been carried out based on weighted overlay method coupled with frequency analysis using landslide inventories for the year (2002 to 2020).

2. Study Area

The study area chosen for the research work is the National Highways of the Shimla Tehsil, Himachal Pradesh (Figure 1). The total extend of the NH is 119.33 km. The geographical extent of the study area is 30˚59'3" to 31˚14'10" N and 76˚58'19" to 7˚19'21" E. The total geographical area of the study is 9351.45 ha. The National Highways connects the major locations along the upper reaches of Himachal Pradesh such as Kinnaur, Lahul & Spiti and Chamba to other parts of the country. The NH serves as an important transportation and tourism corridor across the Himachal Pradesh. For research purpose a buffer of 1000mts of the National Highway is taken for the study. Based on the geomorphology of the region retrieved from Soil and Landuse survey of India (SLUSI) maps is highly dissected with steep to moderate slopes in many areas. The study area has fine and coarse loamy soil types extending most of the region. The soil particles are poorly sorted and disintegrates during monsoon season. Slate and Schist are the most common types of rock material found in this part which are weak to moderately strong according to Geological Strength Index (GSI). Settlements, Forest, Shrub land and Barren land are the most dominant Landuse types found along the study area. In recent years Shimla received an annual rainfall of 1250 to 1600mm most of which are monsoon and winter rainfall.

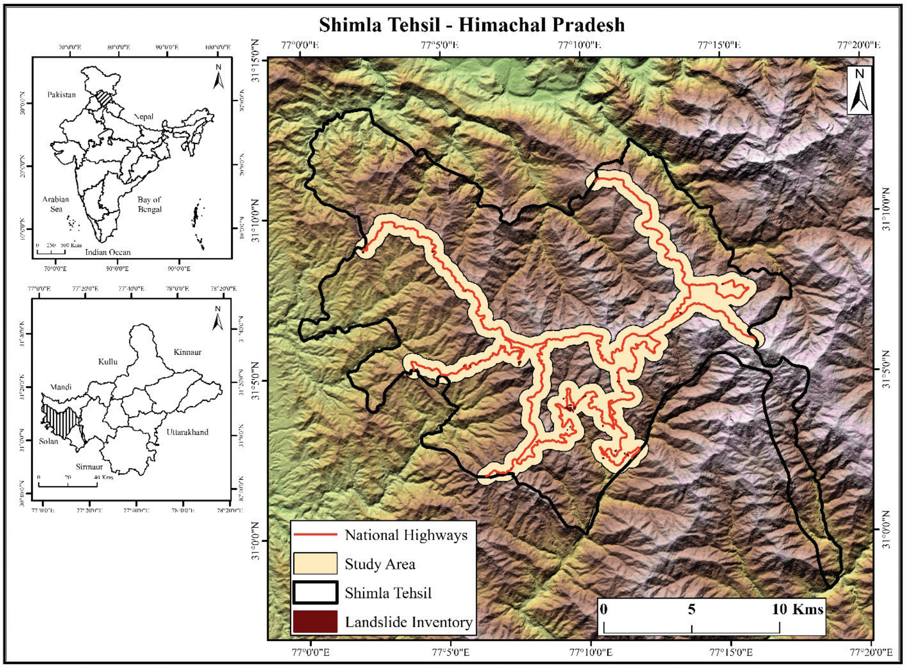

Figure 1: Study Area

3. Materials and Method

The research is focused on evaluating the vulnerability of the Shimla Tehsil and to assess the risk posed by the different vulnerability zones on various landslide factors. Topographic sheets from the Survey of India, Sentinel 2B satellite imageries, Soil, Geology and Geomorphological data retrieved from the "Soil and Landuse Survey of India (SLUSI)" and PALSAR DEM have been used as a data source for studying various causative factors. Various data source used are given in (Tab 1).

Table 1: Datasets

Sl. No	Data Type	Source	Date	Resolution
1	Sentinel – 2B	European Space Agency	2020	10 mts
2	PALSAR DEM	Alaska Satellite Facility	2008	12 mts

3	Topographical maps	Survey of India (53E/04)	1974	1:50,000
4	Landslide Inventory	Google Earth, Sentinel – 2B	2002 to 2020	0.4 mts to 10 mts
5	Geology	Soil and Landuse Survey of India (SLUSI)		1:50,000
6	Soil	Soil and Landuse Survey of India (SLUSI)		1:50,000
7	Geomorphology	Soil and Landuse Survey of India (SLUSI)		1:50,000

The present study uses Weight of evidence model (WOM) to categorize the landslide vulnerable areas of the region. The WOM is a bivariate statistical method that uses various training such as landslide inventory data to predict landslide occurrences (Kaur et al. 2018; Rana et al., 2016; Reichenbach, Rossi, Malamud, Mihir, & Guzzetti, 2018). The WOM model is most suited for regional scale studies of landslide hazards to develop hazard and vulnerability maps with higher accuracy for mitigation strategies. The WOM model used in the current research includes both data driven (statistical method) and knowledge based method for developing accurate Landslide vulnerability and risk maps. Landslide causative factors such as Landuse Landcover, Slope, Soil, Geology, Geomorphology, Aspect, Elevation and Drainage density where differentiated into five types ranging from very low to very high on a numerical scale of 1 to 5 vulnerability and risk assessment. Vulnerability assessment are derived based on the fusion of landslide risk zones and landslide inventory data collected from field work. The causative factors are integrated into the GIS environment to produce Landslide Vulnerability maps. The landslide inventory is then used to evaluated the percent of various class that falls under different scale of vulnerability. The final vulnerability maps are then integrated with the LULC maps to produce risk Assessment map (Fig. 2) of various Landuse features that falls under different vulnerable categories (Nandy, Singh, Das, Kingma, & Kushwaha, 2015; Rautela & Lakhera, 2000; Torkashvand, 2014).

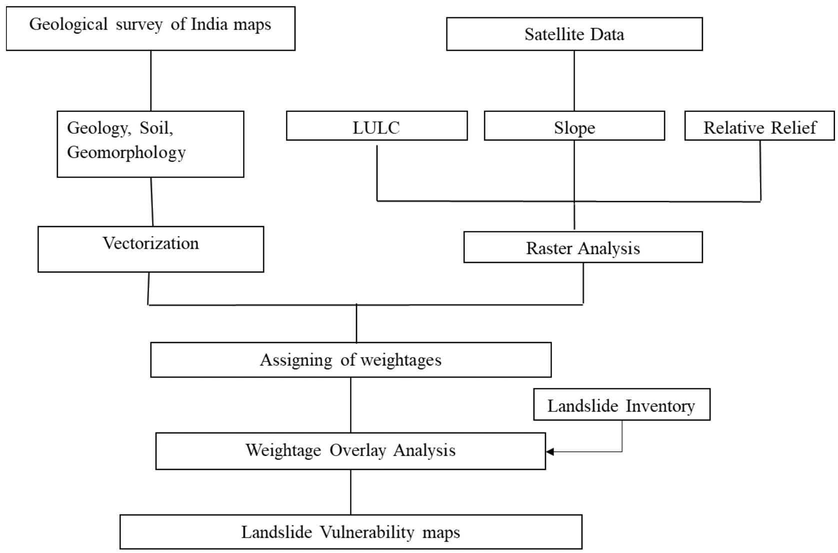

Figure 2: Research Methodology

4. Results and Discussion

4.1 Landslide Inventory

Landslide Inventory data was collected from Google Earth and Sentinel – 2B imageries using Visual Image Interpretation techniques. A total of 44 landslides were demarcated between (2002 to 2020) within 1000 mts of the National Highways and Metalled Roads (Fig 3). Most of the landslides demarcated were debri slides and rock slides were found at few locations. The landslides occurred along the hill cut slopes and along the downside of the slopes where there is bare or no vegetation cover.

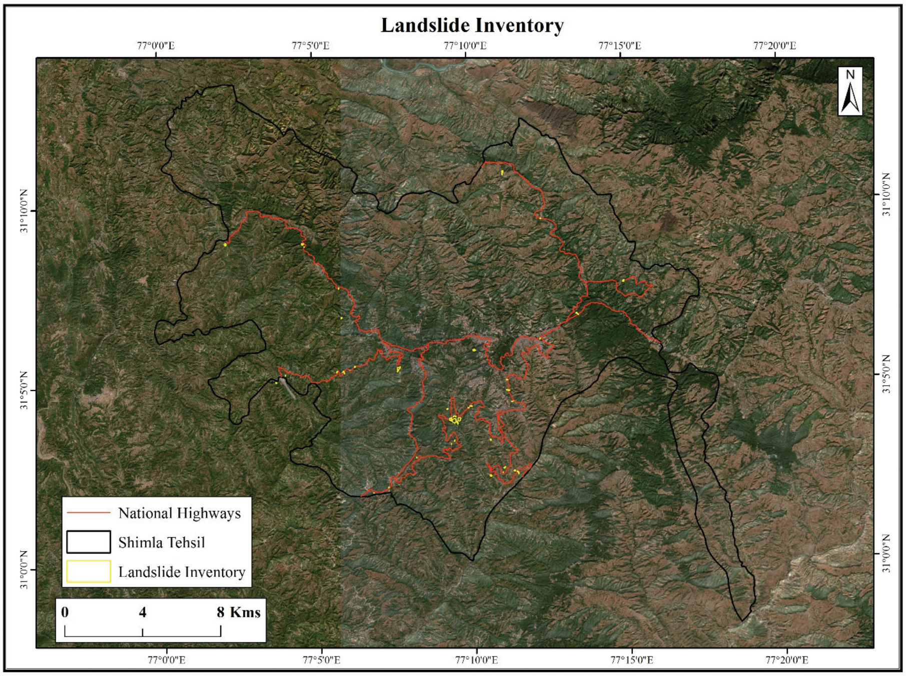

Figure 3: Landslide Inventory

4.2 Landuse Landcover

LULC was interpreted using the Sentinel - 2B satellite Imagery through supervised classification (Fig 4). The LULC was classified based on the NRSC level 1 classification. Four major types were identified in the region namely Built-Up land. Barren land, Forest and Shrub Land (Tab 2). 51% of the area is covered under forest. Shrub Land and Barren land covers about 21% and 17% of the study area. Built-Up land covers only 10%. The landslides are predominantly found in the shrub and barren land where there is less or no vegetation coverage. Bare soil exposed to monsoon rainfall gets dislodged due to gravity and soil overburden leading to slope failure.

Table 2: LULC

Sl. No.	Class	Area (ha)	Area in Percent (%)
1	Built-up Land	941.9	10.07%
2	Barren Land	1625.5	17.38%
3	Forest	4775.4	51.07%
4	Shrub Land	2008.3	21.48%
	Total	**9351.2**	**100.00%**

4.3 NDVI

NDVI stands for Normalized Difference Vegetative Index. NDVI is calculated based on the spectral output of the various features present in the earth surface ranging from -1 to +1. NDVI is calculated using the Infra-Red and Red band of the Sentinel – 2B satellite imagery based on the formula

NDVI = (NIR – R) / (NIR + R)

Where, NIR = Near Infra-Red
R = Red

Table 3: NDVI

Sl. No.	Class	Area (ha)	Area in Percent (%)
1	- 0.2 to 0.25	534.1	5.59%
2	0.26 to 0.44	1201.8	12.58%
3	0.45 to 0.59	1662.7	17.41%
4	0.6 to 0.71	2724.7	28.53%
5	0.71 to 1	3427.0	35.88%
	Total	**9351.2**	**100.00%**

NDVI has been classified into five different classes ranging from -0.2 to 1 (Tab 3). NDVI values between 0.6 to 1 accounts for about 64% of the study area which includes moderate to dense vegetation. Sparse vegetation and Barren land accounts for 30% of the study area (Fig 5). Landslides are predominantly located in the Barren land and Shrub land areas which has no vegetation.

4.4 Drainage Density

Drainage Density (DD) estimates the frequency of drainages within a particular area. Drainage Density is an important parameter as water percolation and rainfall runoff are discharged in huge amount through the drainage channels. Drainages are interpreted from the Survey of India Toposheets. The results reveal that DD of 1.7 to 3.8 per sq.km makes around 63.6% of the total study area. The rest makes for only about 12%, 16% and 8% (Tab 4 & Fig 6).

Table 4: Drainage Density

Sl. No.	Class (Density/km2)	Area (ha)	Area in Percent (%)
1	0 to 1.6	1129.3	12.08%
2	1.7 to 2.7	2953.2	31.58%
3	2.8 to 3.8	3007.2	32.16%
4	3.9 to 5.2	1506.0	16.10%
5	5.3 to 7.5	755.5	8.08%
	Total	**9351.2**	**100.00%**

4.5 Soil

Soil plays important role in landslide initiation based on the particle size and sorting. Soil data was extracted from the data retrieved from Soil and Landuse Survey of India (SLUSI). Four major types namely Fine & Coarse loamy, Habitation and loamy skeletal were found along the region (Fig 7). Fine loamy covers about 94% of the study area while the rest of the types covers a total of 6% combined (Tab 5). The soils are poorly sorted and arranged in this region causing landslide initiation.

Table 5: Soil

Sl. No.	Class	Area (ha)	Area in Percent (%)
1	Coarse Loamy	77.7	0.83%
2	Fine Loamy	8824.8	94.37%
3	Habitation	342.8	3.66%
4	Loamy Skeletal	106	1.13%
	Total	**9351.2**	**100.00%**

4.6 Geology

Geology refers to the rock types formation. The study area two major dominant rock formations Schist and Slate. Slate accounts for 93% of the study area and Habitation accounts for only about 5.33%. Schist covers a mere 1.43% (Fig 8). The rock types found along these area ranges from weak to moderately strong. The rocks are heavily jointed along the rock cut slopes and pose threatening to landslide during monsoon seasons. Most of the landslides noted occurred along the slate rock types (Tab 6). Some of the landslides occurred near the settlements are structurally controlled rock slides involving wedge failure.

Table 6: Geology

Sl. No.	Class	Area (ha)	Area in Percent (%)
1	Habitation	498.9	5.33%
2	Schist	139.1	1.49%
3	Slate	8713.3	93.18%
	Total	**9351.2**	**100.00%**

4.7 Geomorphology

Only a single geomorphological type is found in the area. Undifferentiated Mountainside Slope with a total coverage of 94.6% has been found (Fig. 9). The hillside has rugged terrain and highly dissected regions in the valleys and peaks. Drainage system are more dendritic and parallel in nature in Shimla tehsil (Tab 7).

Table 7: Geomorphology

Sl. No.	Class	Area (ha)	Area in Percent (%)
1	Habitation	498.9	5.33%
2	Undifferentiated Mountainside Slope	8852.3	94.67%
	Total	**9351.2**	**100.00%**

4.8 Elevation

Elevation is being considered as parameter to determine the landslide frequencies occurring at particular elevation. PALSAR DEM has used to classify elevation and estimate other elevation based ranges. The ranges were classified into five types based on the equal interval method. Elevation range more than 2200 covers only 9.9% of the study area (Fig. 10). The other classification covers a total area of 16.1%, 29.7%, 23.2%, 20.9% etc. (Tab 8).

Table 8: DEM

Sl. No.	Elevation (mts)	Area (ha)	Area in Percent (%)
1	< 1500	1513.2	16.18%
2	1,501 to 1,800	2781.3	29.74%
3	1,801 to 2000	2170.7	23.21%
4	2,001 to 2200	1959.5	20.95%
5	> 2200	926.5	9.91%
	Total	**9351.2**	**100.00%**

4.9 Slope

Slope indicates the dip of a rock bed with respect to the horizontal earth surface. Slope is a major landslide causative factor as such landslide and mass movements tend to occur along the steeper slopes compared to the flat regions. The slope is classified using the PALSAR DEM data into five classification ranging from very gentle to very steep (Fig. 11). The results reveals that moderate and steep slopes have a combined area of 51% and gentle slopes covers about 29.2% of the study area (Tab 9).

Tab 9: Slope

Sl. No.	Class (Degrees)	Area (ha)	Area in Percent (%)
1	< 17	1344.6	14.38%
2	18 to 25	2735.8	29.26%
3	26 to 32	2876.7	30.76%
4	33 to 42	1916.3	20.49%
5	> 42	477.9	5.11%
	Total	**9351.2**	**100.00%**

4.10 Aspect

Aspect estimates the direction of slopes. Aspect is a governing factor because landslides occurs along regions that are receiving high water percolation, soil burden and steep slopes etc. Aspect helps predicting the direction of landslide occurrence based on the landslide frequencies. Most of the slopes are equally distributed between various direction ranging from north east to north west (Fig. 12 & Tab 10).

Table 10: Aspect

Sl. No.	Class	Area (ha)	Area in Percent (%)
1	Flat	1.4	0.01%
2	North	572.8	6.12%
3	Northeast	1117.0	11.95%
4	East	1139.2	12.18%
5	South East	1109.6	11.87%
6	South	1149.6	12.29%
7	South West	1538.8	16.45%
8	West	1111.8	11.89%
9	North West	1077.2	11.52%
10	North	533.0	5.71%
	Total	**9351.2**	**100.00%**

4.11 Curvature

Curvature indicates the relief nature of the mountain region. Curvature is divided into five types ranging from -28 to 26 indicating the surface is extremely relief in nature (Fig. 13). Class III and IV type of curvature contributes a total of 82.8% of the study area indicating the surface is extremely rough (Tab 11).

Table 11: Curvature

Sl. No.	Class	Area (ha)	Area in Percent (%)
1	-28 to -3.9	135.7	1.45%
2	-3.8 to -1.4	1213.9	12.98%
3	-1.3 to 0.59	4069.1	43.51%
4	0.6 to 3.1	3587.0	38.37%
5	3.2 to 26	344.5	3.68%
	Total	**9351.2**	**100.00%**

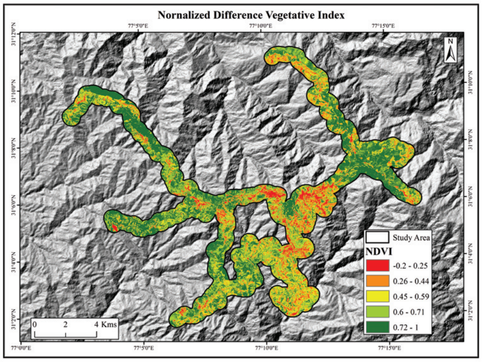

Figure 4: Landuse Landcover

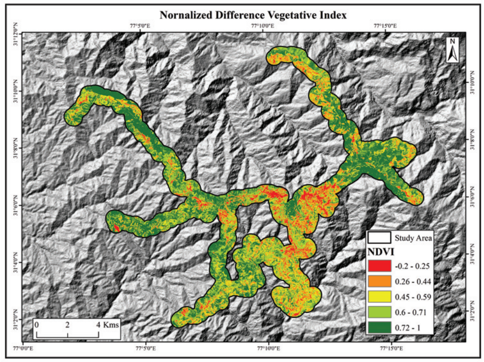

Figure 5: NDVI

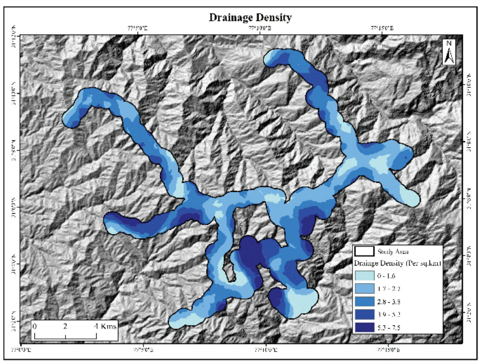

Figure 6: Drainage Density

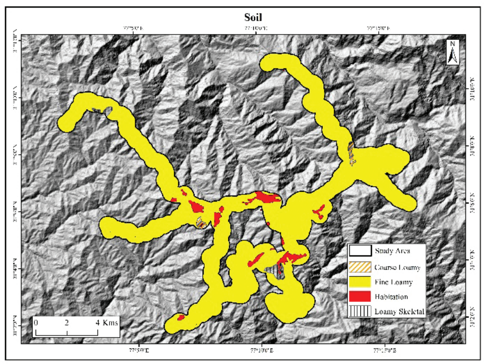

Figure 7: Soil

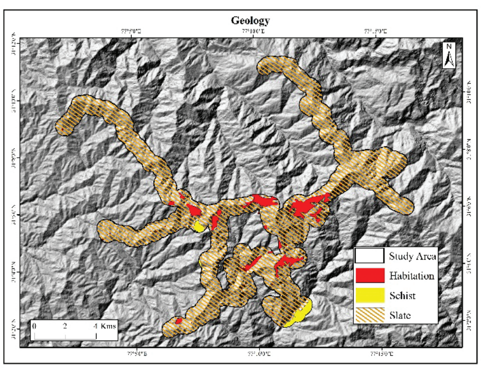

Figure 8: Geology

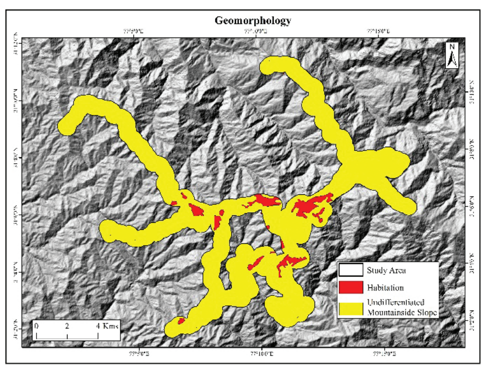

Figure 9: Geomorphology

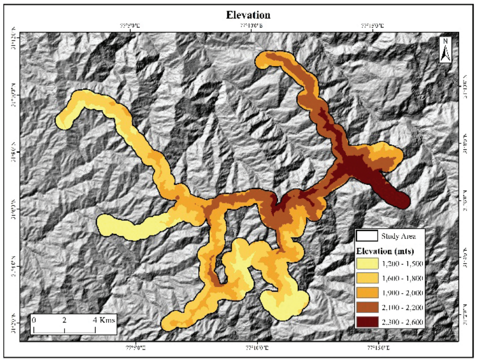

Figure 10: DEM

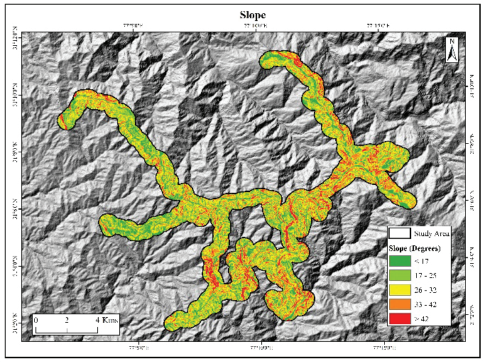

Figure 11: Slope

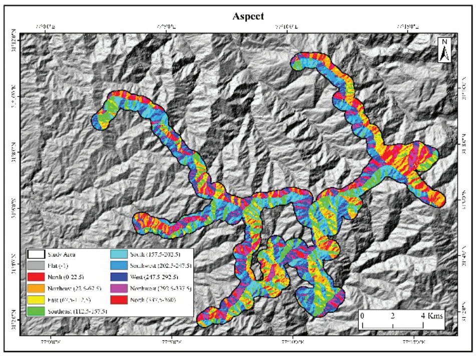

Figure 12: Aspect

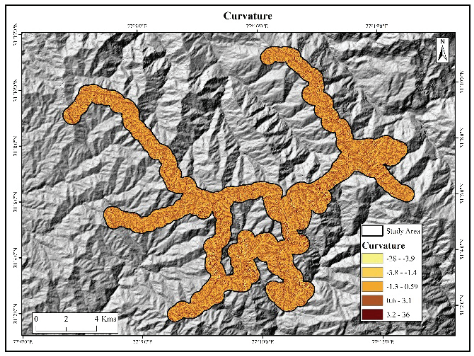

Figure 13: Curvature

5. Landslide Vulnerability Assessment

Vulnerability assessment was calculated using the Weighted Overlay method. Causative factors such as LULC, Soil, Geology, Geomorphology, Aspect, Slope have been taken into account for the vulnerability mapping. The weightage has been assigned based on the statistical model and experts knowledge. The final Landslide vulnerability map was prepared by integrating the all the raster layers in the GIS environment using the Weighted Overlay Sum model.

Tab 13: Landslide Vulnerability Class

Sl. No.	Class	Pixels (Causative Factor)	Pixels (Landslide)	Landslide (%)
1	Low	2290	45	4.27%
2	Moderate	266397	288	27.32%
3	High	219394	428	40.61%
4	Very High	110397	293	27.80%
	Total Pixel Count	**598478**	**1054**	**100.00%**

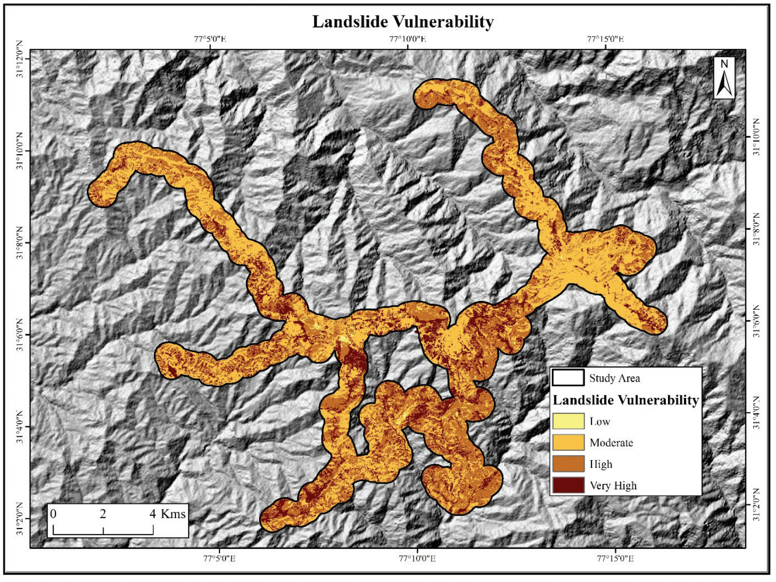

Figure 14: Landslide Vulnerability (Shimla NH)

Figure 15: Indicates landslides along major national highways of the Shimla town

Figure 16: Settlements located along highly jointed rock surface; Soil slipping along the NH

The Landslide Vulnerability Mapping has been divided into 4 classes based on the rating ranging from low to very high. Based on the landslide Inventory it has estimated that 40.6% of the landslide occurs in the high category and 27.8% occurs in the very category list (Fig. 14). About 27.3% occurs in the moderate category. Most of the soil and lithology is composed of Debri and mud particles leading to such type of landslides (Fig. 15 and Fig. 16). Most of the high and very high vulnerable regions are located along the central part and as well as southern part of the study area. The landslide vulnerability map reveals that 67% of the total study area are composed of high and very high vulnerable regions located within 1000 mts of the NH (Tab 13). These areas predominantly include Built-Up lands, Shrub lands and Barren lands adjoining the national highways.

6. Conclusion

National Highways of Shimla Tehsil are highly prone to landslide and mass movements especially during the monsoon and winter rainfall time. The research conducted reveals that out of the 44 landslide inventories collected from various source of satellite imageries 68% of the landslides occurred in the high and very high category. 27% occurred in the moderately vulnerable category. The research reveals that 96% of the study area which is less than 1000 mts from the National Highways are prone to landslide initiation. The research provides a quick and accurate estimation of landslide vulnerable areas using both statistical and expert based knowledge system. The research provides a quick and accurate estimation of landslide vulnerable areas using both statistical and expert based knowledge system. Landslide investigation should promote disaster preparedness and need to establish detailed network of communication that include Governmental, Non-governmental and local NGO's to provide effective disaster related activities during pre-disaster, actual disaster situations and post-disaster times.

Regions such as Shimla are highly prone to landslides. Careful consideration must be taken before any constructions. Due to the highly rugged nature of the terrain high-resolution 3D modeling and site-specific detailed investigations will provide more insight into the developmental activities along these landslide-prone areas. To help control the slides planting of different species of grass can be done. Planting fast-growing, deep-rooted trees along the crown and main scarp can be done and also in the lower reaches of slide zones help in stabilizing the slope.

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Key Issues of Disaster Management in India – During Cyclones and Flooding Emergencies

Anitha Karthik[1] and K Gireesan[2]

Abstract

The aim of this paper is to examine the factors which drive and impedes the implementation of disaster management protocols during selected emergencies in India. The paper further discusses in detail the existing national and state-led disaster risk management and the communication procedures, particularly highlighting the gaps in current methods and areas to improve in the future. Gaps within current Disaster Risk Management strategies and their practices before, during, and after the occurrence of the disaster were also identified which has assisted in the recommendations of Community-Based Disaster Risk Management (CBDRM). The paper highlights the outcome of the training programmes and how CBDRM can be a vital tool towards enhancing the nation's disaster risk management. This could contribute to a more responsible way of addressing disaster risks, and support towards future resilient communities and developments. The suggested approaches and measures may also help governments, planners, engineers, builders, forecasters, emergency managers, relief workers, regional bodies, insurance, civil protection organisations, public and private officials of all the developing countries, to reduce future losses, where there is not the same supportive development infrastructure.

Keywords: *Community-based Disaster, Communities, Climate Change Adaptation and Mitigation, Capacity Building, Local Government Institutions, Community Based Organisations.*

[1] **Anitha Karthik,** Research Fellow, University of Edinburgh, Edinburgh, United Kingdom EH093JW.
* Corresponding Author Email: anitha.karthik@ed.ac.uk
[2] **K. Gireesan,** Director, School of Government, MIT World Peace University, Pune – 411 038.
* Corresponding Author Email: gireesan.k@mitwpu.edu.in

1. Introduction

Natural, man-made or hybrid disasters, the three major types of disasters, impede and affect communities and their livelihood at various levels. India contributes to just less than one-fourth (24%) of the disasters in Asia. India ranks among the first five countries and is prone to almost all major natural disasters such as earthquakes, tsunamis, floods, cyclones, cyclones-triggered-storm surges, and droughts due to the country's geo-climatic conditions. About 7516 km of India's east coastline is prone to cyclones and cyclones-triggered storm surges and other coastal floodings (Khanna, 2009). The country's ever-growing population in combination with the changing hazard pattern further amplifies the socio-economic-environmental risks (Bathi & Das, 2016), (Kumar, Walia, & Chaturvedi, 2012). Many developing countries still lack a proper disaster management protocol in place or have yet to identify the best practices that mostly suit the local communities. By analysing the disaster governance and practices in India, insights into key lessons and future approaches may lead to potential areas of improvement within Disaster Risk Management (DRM).

2. Changes in Intensity and Frequency of Tropical Cyclones

The attribution of global warming to cyclone activity was not directly established until the 1990s. Soon after, some significant cyclone events which occurred globally were identified to have a link with the changing precipitation and the hydrological cycle of these tropical cyclones particularly the extreme weather events (Trenberth, 2008). In reflection of the Intergovernmental Panel for Climatic Change (IPCC) Fourth Assessment Report, climate change and global warming are said to bring both negative and positive impacts equally. The report reveals that Europe, America, and South-East Asia were likely to be affected by the negative impact of climate change. The negative impacts mentioned were different sources of flooding such as frequent in-land flash floods (from heavy downpours), coastal, river, and surface water flooding with increased soil erosion (IPCC, 2007), (IPCC, 2015). The report further comprehends that, with severely growing weather events and changes in climate patterns, many disastrous events are prone to occur in shorter intervals than previously.

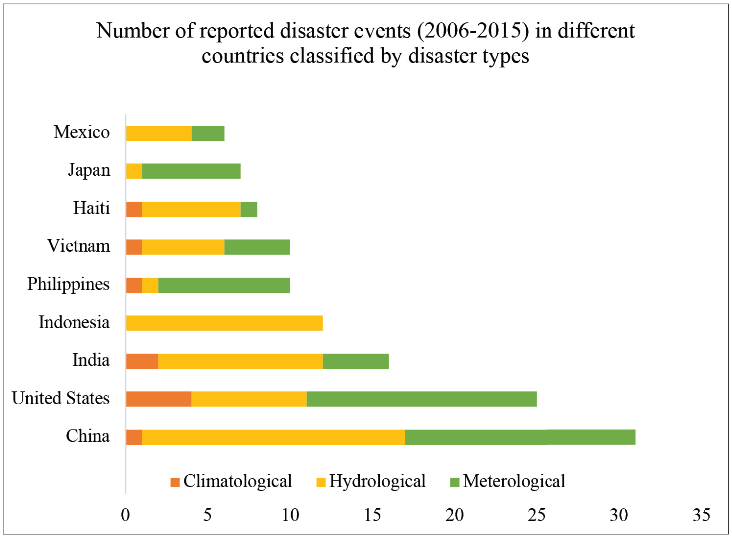

Figure 1: Annual Disaster Review 2016: Statistics and Rends for 2006-2015 (Guha-Sapir D, 2017)

The Emergency Management Database (EM-DAT) is an international database for globally reported disasters. Observed trends of disasters between the period 2006-2015 are shown in Figure 1 in which India is at the third place only after China and the United States of America. The figure also shows how each country is affected by a combination of hydrological (coastal, riverine, flash floods) and meteorological (tropical cyclones) more than climatological disasters (EM-DAT, n.d.), (Guha-Sapir D, 2017).

The Bay of Bengal is observed to have a 'deep layer of warm water', which fuels the energy of the tropical system to quickly organise and develop further strengthening within a shorter period (Hoarau, Bernard, & Chalonge, 2011). Observations listed in Table 1 highlight how the last decade was significant in the history of tropical cyclones in India.

Table 1: List of Disasters occurred in India (2011-2020)

Tropical Cyclone	Damages (Cost in US $)
Cyclone Thane (2011)	Affected the Puducherry and Cuddalore regions of Tamil Nadu.
Cyclone Nilam (2012)	Affected Tamil Nadu and Andhra Pradesh killing 75 people.

Cyclone Phailin (2013)	Made landfall in Odisha initiating a mass evacuation of more than a million people since 1999.
Tropical Depression ARB02 (2015)	US $260 million and 81 deaths affecting Gujarat.
Cyclone Komen (2015)	Made a landfall killing 285 people in East India.
Chennai Floods (2015)	Mainly occurred due to the poor decision-making by State Government. The Unofficial record states more than 500 killed with damage costing up to US$ 15 billion.
Cyclone Vardah (2016)	Killed 12 people with an estimated damage of US$ 4.3 billion.
Cyclone Mora (2017)	Made landfall in Bangladesh impacting adjacent North-East India killing 20 people.
Cyclone Ockhi (2017)	Official 318 and unofficial 800 (mostly fishermen) and many displaced affecting 30 km of the southern tip of Tamil Nadu.
Cyclone Titli (2018)	Made landfall in Andhra Pradesh killing 77 in Odisha.
Cyclone Gaja (2018)	52 killed and caused severe crop damage in coastal Tamil Nadu.
Cyclone Phethai (2018)	Reportedly 8 people were killed.
Cyclone Fani (2019)	Cost of damage was estimated at US$ 8.1 billion.
Cyclone Amphan (2020)	Landfall in West Bengal and 128 deaths were observed with US$ 13 billion damage cost.
Depression BOB 02 (2020)	Triggered torrential rain, resulting in flash flooding, and killed 80 people in Hyderabad.
Cyclone Nivar (2020)	Landfall in Tamil Nadu resulting in US$ 600 million and 14 direct deaths.

Table 1 does not only highlight the socio-economic losses resulting from cyclones and severe weather events but also underlines the impending future threats. It is essential to re-assess the risks, changing risks, and differential vulnerabilities to develop innovative approaches, emphasizing adaptation and resilience with continuous development as a key priority. But executing these strategic decisions and implementing them is not straight forward in many developing and less developed countries due to various social inequalities and economic imbalances. Community participatory approach could be one of the feasible solutions particularly for countries like India. Engaging community members in developing plans, adaptation strategies, and approaches to mitigation are critical, particularly for developing countries to prepare effectively.

3. Disaster Management Approaches in India

A typical disaster management life cycle involves four key phases such as (i) mitigation (ii) preparedness (iii) response (iv) recovery (Baird et al., 1975). This is a common approach to understand how a disaster is approached by a country or its government through different stages like before-impact, during-impact, and post-impact. However, a typical disaster management continuum comprises six stages as Prevention, Mitigation, Preparedness, Response, Rehabilitation, and Reconstruction making it a complete approach.

The Disaster Management Act was enacted in 2005 which further led to the formation of the National Disaster Management Authority (NDMA). The NDMA manages the integrated process of planning, organising, and coordinating necessary measures during disasters. The National Institute of Disaster Management (NIDM) is a statutory body established in 2006 under the Disaster Management Act, 2005 and operates under the guidelines of NDMA. The NIDM's mandate includes training, education, research, documentation, publication, policy assistance, awareness generation, and capacity-building measures on all aspects of DRM within India and outside. This approach, taken as a paradigm shift towards Total Risk Management (TRM), is a holistic and effective solution for DRM (NIDM, 2018), (Shah, 2011). These institutions work in a collaborative structure and do not operate autonomously during emergencies. Although they interact and associate at the national level, local authorities, and regulators were identified with a lack of synergy supported by these national and state-level associations. This often results in hampering the efforts of capacity-building activities in DRM.

In 2005, the United Nations adopted a 10-year plan focusing on reducing the disaster risk called the Hyogo Framework for Action (HFA) with a goal period from 2005-2015 in which 168 governments participated (PreventionWeb, n.d.). The HFA was aimed at reducing the socio-economic and environmental losses from disasters (UNISDR, 2007). The third UN World Conference on Disaster Risk Reduction proposed the Sendai Framework for Disaster Risk Reduction (SFDRR) which is the successor of the previous HFA with a goal period of 2015-2030 (PreventionWeb, n.d.). India is one of the participating countries of the SFDRR with disaster risk reduction as a key goal in achieving a disaster-resilient and sustainable society. India drafted its first Disaster Management Plan in 2016 (NDMA, 2016). Despite holding a multi-disaster risk profile, having a history of extreme weather events, and being one of the participating countries in SFDRR goals, NDMA released the first disaster plan only in the year 2016. Progress within DRM and Disaster Risk Reduction (DRR) strategies cannot sustain unless the process of ‘culture-driven community-based mitigation’ is integrated with a well-developed plan.

The National Disaster Response Force (NDRF) is a trained team of emergency responders which operates under the Ministry of Home Affairs, Govt. of India. NDRF consists of standard battalions of para-military forces who are deployed in disaster-affected areas to perform the search, rescue, and relief operations (Misra, et al., 2011), (Satendra, Kumar, & Naik, 2014). The NDRF team has effectively operated during the Gujarat Floods (2007) to the most recent glacial outburst floods in Chamoli District, Uttarakhand (2021). The NDRF is responsible for several organised rescues as part of the response and recovery phases of the disaster management cycle (Misra, et al., 2011). Although these teams and military forces were involved in the disaster phase, they mainly engage during the response and the recovery phases i.e., the post-disaster phase. The other key phases such as preparedness and mitigation were mostly overlooked and in most of the disaster situations, the local population used to be the first responders.

To promote the right attitude among the rural communities towards better preparation for tropical cyclones and flooding as well as to enable them to take ownership in the management of disasters, a community-centric approach could be beneficial. It is viewed that ‘local-residents and communities themselves were the best to understand and interpret the local opportunities and constraints better than the government and authorities, whose involvement is essential in the identification and resolution of disaster risk-related issues. Nobody is more interested in understanding the local affairs than the community whose survival and well-being are at stake’ (Abarquez & Murshed, 2004).

As India is a multi-diverse country with varied cultures being the central part of the system, a Community-Based Disaster Risk Management (CBDRM) could benefit much more in the long run. In the operationalization of CBDRM at the field level, the Local Government Institutions (LGI) could play a significant role. It is significant to note that ‘Local Government is in a better position to understand the social vulnerability of the disasters with differential impacts on children, women, differently-abled, the sick and the elderly, which is imperative in disaster preparedness and risk reduction’ (Gireesan K. , 2013). It is noted that ‘ignoring the potentials of local resources and capacities will increase the vulnerability of the community. The emphasis is on community-based disaster management, which provides adequate space for active involvement of the vulnerable population in the planning and management of various measures along with the state and non-state actors (Gireesan & Sreeja, 2017). A study identified how CBDRM was effective within the fisherman communities during the 2018 Kerala floods. The gaps identified through the study also highlighted the importance of CBDRM as a bottom-up approach in DM, and how they are capable of promoting training and workshops and preparing these vulnerable communities for any future disasters (Joseph, et al., 2020).

A selected group of volunteers from Community-Based Organisations (CBO) such as Youth Organisations, Women Organisations, and other grassroots organisations can act as flood-wardens. Their association with the elected members and officials of LGIs as well as key functionaries of different government departments at the field level can potentially lead the communities during mitigation and preparedness phases. In the case of communities living in a tribal hamlet or in a distant settlement, a single flood warden can perform the activities. These volunteers could be trained in the mapping of resources and facilities in the locality, preparation of emergency kits, disaster-specific drills, operation of emergency power and communication equipment, application of first aid, safe evacuation procedures, etc. The designated volunteer shall be trained to act as a primary focal point to disseminate the disaster-specific information received from authorities and comprehend the same to the residents.

4. Training Programmes in Rural and Remote Areas of India

Several training programmes were organized in different parts of India drawing participants from the youth organisations such as National Service Scheme (NSS) and Nehru Yuva Kendra Sangathan (NYKS); young, elected members of LGIs and key functionaries of Women's Groups such as Mahila Mandals/Self Help Groups. The second author was personally engaged in conceiving and organizing programmes in Chamoli District of Uttarkhand and in several districts in different Indian states such as Gujarat, Jammu and Kashmir, Kerala, Odisha, and Tamil Nadu. As part of the programme, lectures and practical sessions were organised. Each programme included topics such as the overview of Disaster Management Act (2005) and National Disaster Management Policy (2009); Impact of disasters in socio-economic development; Disaster preparedness and health; Role of local governments in disaster preparedness; Gender dimensions in disaster; Role of youth and youth organizations in disaster preparedness; Disaster preparedness – Mock drills and other precautionary measures; Safe evacuation procedures; Resource mapping; Vulnerability mapping; Use of community radio and Ham radio; Village Disaster Preparedness Plan and Preparation of the action plan for the area/region.

The training programmes incorporated a perfect blend of theory, demonstration, and practical sessions to empower the local leaders, youth volunteers, and other community members in disaster preparedness. Most of the participants were ignorant about the practical aspects of disaster preparedness. The sessions on resource mapping, vulnerability mapping, mock drills, emergency kit preparation, first aid, safe evacuation procedures, application of communication and stand-by power supply sets, etc. were received with a lot of enthusiasm by the participants. The resource persons used different tools and techniques to enhance the knowledge, attitude, and skills of the participants. Resource persons were drawn from different departments and institutions such as Education, Health, Rural Development, Youth Affairs, Women and Child Development, NDRF, Indian Army, Indo-Tibet Border Police, Indian Red Cross Society, etc.

Training programmes were organised for five to seven days with a minimum of two days exclusively earmarked for providing practical exposure to the delegates. On the first day of the programme, a training need assessment was done to understand the specific needs to plan and operationalize the programmes in the subsequent days while considering the local context and priorities. In view of the unique needs, specific sessions were added to the planned training schedule. A feedback session was held on the last day to seek their responses on the content, delivery, and effectiveness of the sessions. Analysis of the feedback from the delegates enabled incorporation of necessary changes in the contents, approaches, techniques, and strategies for organising subsequent training programmes.

5. Areas of Improvement Identified through Training Programmes

Weather prediction has improved considerably in recent times. The weather prediction models of the Indian Meteorological Department (IMD) were recognized for their technological advancement in plotting the likelihood of impending tropical cyclones. Modern science can even identify the possible track or path of the tropical cyclones and expected landfall locations. On par, the effective way of communicating the identified risks still has several gaps. The following aspects on the gaps and recommendations were given based on the observations gathered during the training programmes.

5.1. Emergency Communication

Communication plays a critical role throughout the different phases of a disaster such as pre-disaster, during and post-disaster emergencies. The gap in risk communications was witnessed to have occurred when the authorities failed to understand their audience. Communication has seen extensive improvements with the support of technology in modern urbanised areas and states within India. As rural communities were not homogenous entities, different sections of societies require different methods of communications. The performance of early warning systems and risk communications significantly differ with rural and sub-urban areas, and this is commonly observed across many states in India (Porathur, 1994). An effective risk communication shall include communicating the risk while monitoring the outcome. This not only ensures understanding of the community members about the hazard but also induces their participation once the received communication is understood properly. The training programmes also identified how a set of standard operating procedure (SOP) could benefit in the dissemination of communication or early warning system to manage any disaster. This further enabled the thought of observing the community response to such standard operating procedure in better escalation and disposal of resources.

5.2. Decision Making

Decision-making is another important factor. Delayed evacuation may directly result in loss of lives. The primary mitigation action towards an approaching tropical cyclone is evacuation, followed by an escalation in the deployment of resources to the victims. Although this sounds like a straight forward action, execution and planning mass evacuation is a complex process. This implies that a dynamic understanding and assessment is needed to achieve successful evacuation before every event. A more transparent and explanatory evacuation plan, provision of continuous drills and training at regular intervals, and realistic communication of anticipated hazards can enhance public participation during evacuations.

5.3. Role Clarity

Understanding the roles and responsibilities to execute the contingency plan appropriately is the key to implement the response plan and related strategies. This is achievable when the interaction between the national, sub-national, and local response follows a horizontal linkage. Escalation of roles and responsibilities may sometimes be procedural, and this can become critical during emergencies, offsetting the primary focus of responding to emergency situations.

5.4. Horizontal Linkages Over Vertical During the Implementation of Response

Kapucu (2016) discusses the advantages of horizontal escalation of roles and responsibilities during emergencies. The suggestion as shown in Figure 2 was given based on the disadvantages identified in a vertical escalation with a hierarchical pattern, and with an assumption of possibly executing the key activities and sharing the responsibilities simultaneously.

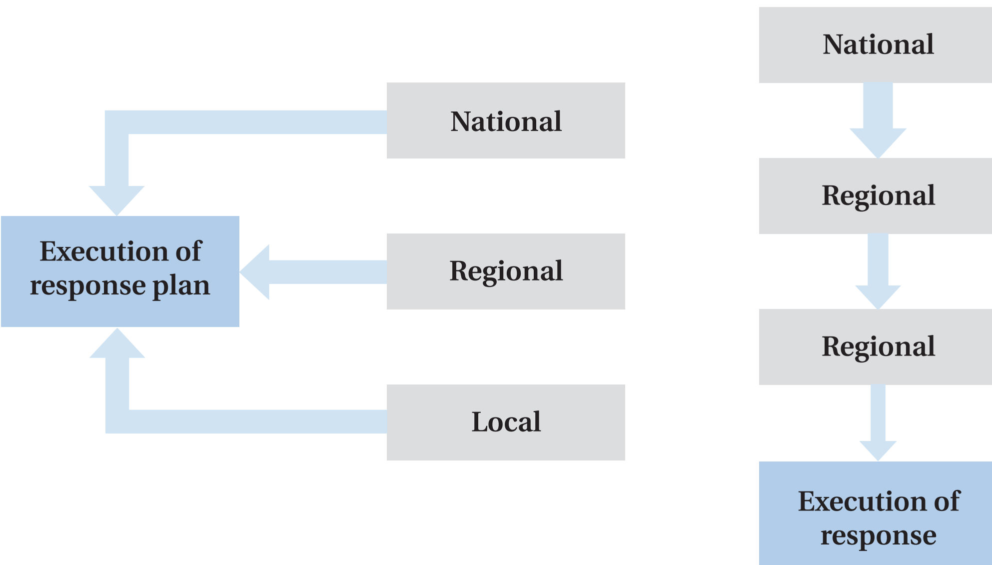

Figure 2: Recommendation on horizontal escalation (left) of responsibilities versus a vertical (right) approach.

5.5. Linking NGOs and Volunteers for Multi-level Networking

The role of Non-Government Organizations (NGOs) during and post-impact periods was widely accepted and recognized (Verayanti, 2011). During cyclone Gaja (2018) in southern India, the first author was engaged in community-based disaster recovery (food and essential supplies through crowdfunding) using local youths during which it was observed that it took almost a week for the state government and corresponding administrators to reach the remote rural areas where youth volunteers and local NGOs were already functioning. A key comparative study identified how India lack in transparency in utilising the disaster management funds, especially at state and local-levels. The study also identified the challenges faced in mobilising, and various issues at preparedness phase which is one of the key phases that minimises the mortality rate (Shakeri, Vizvari, & Nazerian, 2021) These young volunteers, with the support of youth organisations and NGOs, have a competitive edge over the Government institutions while engaging with the local community. Their partnerships and collaborations with LGIs, CBOs and private organisations were laudable in most of the situations, especially during the recovery and extended recovery phases.

NGOs and volunteers were also observed to have the potential to support capacity building at greater levels by building community-level participation. This may be mainly due to their resources and flexibility to act locally and especially with the local-acting NGOs with the support of international NGOs. Although local NGOs have limited access than the local governments, their knowledge from various previous disasters can be greatly beneficial to communities. By adapting to a cross-sectoral partnership, the lack of risk knowledge could be reduced by working with trained volunteers or NGO functionaries operating in the field. Linking NGOs could be one of the most resourceful communication media strategies in the process of creating awareness in remote and rural as well as coastal areas of India.

5.6. National Disaster Database

This is one of the key points observed. Establishing accurate death and damage statistics from disaster events are often critical for governments and their authorities (Guha-Sapir D, 2017). Guha-Sapir (2017) also describes how increased death or damage rate may expose the inefficiencies of the country's poor infrastructure or inadequate preparedness and responses to tropical cyclones. Inaccurate disaster data may further lead to mis-calculation of socio-economic damage thereby resulting in underestimation of actual risk from tropical cyclones. As disaster damage data are vital to analysing the underlying risk, lack of data or inaccurate data can result in the underestimation of actual risk. Therefore, maintaining a disaster database with close-to-accurate data will support the analysis of risk assessment and can create awareness about the risks anticipated. This is a low-cost effort that helps in future analysis and return-period calculations.

5.7. Construction or Adaptation for 'Safe Community Zones'

In low elevated coastal zones with high population densities and insufficient funding to adapt existing buildings, one option may be to develop and construct safe havens. This could be in the form of a Multi-Purpose Shelter (MPS) which may house *Anganawadi* (Child-care Centre), Health sub-centre, School, Public Distribution System outlet, Community Halls, etc. The MPS can be constructed on an elevated site or artificially raised site, for communities to retreat to safe havens during cyclones and floods. Some units in the MPS can work on a time-sharing basis as well during normal times, thus resulting in the use of minimum land for the creation of structures, reduced cost of construction, optimum utilisation of the infrastructure facilities, lesser transaction cost, etc.

5.8. Implementing Previous Lessons Learnt

Lessons learnt from past events, especially from the most recent events, highlight the significant gaps such as lack of implementation of the lesson learnt and lack of investment in protective infrastructure and resilience measures. Education plays a key role in communicating and enhancing public participation. Properly educated and trained youth volunteers, under guidance and supervision, could be of great help in the recovery phase. These trained volunteers could be engaged in search and rescue operations with thrust on the provision of first aid, setting up emergency evacuation shelters and assisting in the evacuation of the local community.

5.9. Community Participation

Lack of funded and organized community initiatives which creates public awareness was not observed in many rural and interior parts of India. Therefore, participation of the community shall be encouraged, through continuous drills on accessing the evacuation routes, user-friendly risk maps to key locations, transportation modes and routes, etc. Community-partnered recovery efforts have proven to aid during quick recovery. Training programmes to kick-start the disaster readiness stage and exercises related to emergency kits and supply checklists should be practised among the communities. As an extension to the public awareness about the risk, schools and colleges shall incorporate disaster preparedness education as an essential element in the curriculum. Students shall be informed about hazards and risks. These measures are of special significance in states but vary considering the vulnerability of areas, points, and communities. Educating about disaster preparedness activities and evacuation drills in schools and colleges is recommended, involving students and their families. This approach will make the process of evacuation to the operational level and will avoid complications in carrying out evacuation during unforeseen situations. Initiation of capacity building programmes and developing community-based DRM initiatives for a future scenario is recommended to enhance public awareness.

5.10. Media Participation in Disaster Management

The media's prominence not only ends with the tasks of boosting awareness but also supports the victims by gaining international attention (Dave) and drawing requests from the international humanitarian organization and their participation to instigate further relief funds. The use of diverse communications such as social media platforms shall be enhanced for countries whose land-based telecommunication infrastructure is limited. Many developed and developing countries consider social media as an emerging substitute for risk communication. The current COVID-19 pandemic in many countries is an example of how social media and diverse media communications have reached out to a large population and specific groups. Image/video sharing, threaded communications under a common hashtag has generated a new dimension in risk communication over the traditional practices by use of radios, telephones and teleprinters. New channels broadcasting disasters and live field situations have sustained in gaining public attention worldwide. Stakeholder participation from trusted news channels and other media sources shall be enhanced to support the increased focus of attention by the public.

6. Conclusion

It is important *'to know'* what is being done in the past and present to determine what *'to do'* for the future, and to fix the gap (Peffer & Sutton, 1999). It is necessary to understand the key factors affecting vulnerability assessment, resilience, and adaptive measurements for re-assessment of existing technology and new findings. Assessing the risk of a country to increase the adaptive capabilities and resiliency to weather events is strategically important not only to a country's government but also to all the stakeholders involved. The continuous migration of people and coastal investments within Low Elevated Coastal Zones (LECZ's) or cyclone-prone zones not only amplifies the vulnerability and risk of exposure but also necessitates continuous monitoring and re-assessment of risk. This also instigates how continuous assessment and analysis of strategies to mitigate future disaster risk in terms of cyclones and floods is crucial. To overpass these identified areas of improvement and to fill the gap, future training, and community-based disaster risk management with an in-depth understanding of the root causes that impeded the execution of DRM is essential. Combined community support has contributed towards the improvement of livelihoods, mental health, and well-being of the communities through enhanced public participation. With an effort to address the 'risk blind spots', the recommendations particularly emphasizing CBDRM were given to the identified areas of improvement. The suggested areas will act as an enabler to all its major participants including governments, organisations, institutions, industries, and community members to strengthen the current national disaster management plans in an effective and efficient manner.

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Concept of One Health and Future Prospective in India

Raju Thapa[1]*, Surya Parkash[1], Harjeet Kaur[1],
Anil Kathait[1] and Priyanka Singh[2]

Abstract

The One Health Initiative is an effort by the scientific, animal health, public health, and veterinary communities to better understand biological hazards that might affect people or animals. It seeks to address the underlying problems of responding to infectious animal diseases when they cross the species barrier. One example is when humans get infected with an influenza virus strain from pigs. The goal is to advance our understanding of how human health and ecological systems are intertwined.

Keywords: *One Health; Human Activities; Geography; Ecology, India*

1. Introduction

Over the last three decades, it has become progressively obvious that a lot of novel, emerging zoonotic infectious diseases originate in animals, particularly wildlife, and that the primary drivers of their emergence are human activities, such as changes in ecosystems and land use, agricultural intensification, urbanisation, and international travel and trade. To understand the ecology of each developing zoonotic disease and to conduct risk assessments and build response and control strategies, a multidisciplinary and multi-disciplinary approach spanning animal, human, and environmental health is required (Mackenzie J.S., Jeggo., 2019; Yasobanta et al., 2019).

One Health is a philosophy that acknowledges that human health is inextricably linked to the health of animals and our common environment. One Health is not a new concept, but it has gained traction in recent years. This is because a variety of reasons have altered how people, animals, plants, and our environment interact. One Health

1 **Raju Thapa, Surya Parkash, Harjeet Kaur, Anil Kathait,** National Institute of Disaster Management, Delhi.
2 **Priyanka Singh,** Global Health Security Agenda (GHSA), Liaison Coordinator, FHI 360.
* Corresponding Author Email: razoothapa44@gmail.com

is a method of developing and executing programmes, policies, and research in which diverse sectors collaborate to improve public health outcomes (Figure 1).

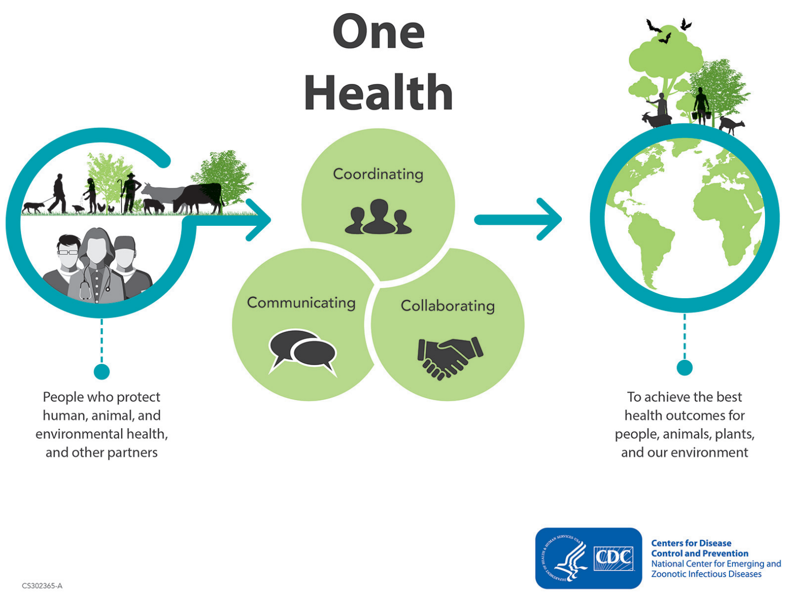

Figure 1: The Concept of One Health

(Source: CDC)

One Health is a philosophy that acknowledges that human health is inextricably linked to the health of animals and our common environment (Fig. 2). Human populations are increasing and spreading into new locations. As a result, more people interact with wild and domestic animals, including livestock and pets. Animals are vital in human life for a variety of reasons, including food, fibre, livelihoods, travel, sport, education, and friendship. Close interaction with animals and their environs increase the chances of disease transmission between animals and humans. Climate and land use changes, such as deforestation and intensive farming methods, have occurred throughout the planet. Changes in the environment and ecosystems might create new chances for illnesses to spread to animals. International travel and commerce have boosted the mobility of people, animals, and animal products. As a result, illnesses can swiftly spread across national borders and throughout the world (Mackenzie J.S., Jeggo., 2019; Yasobanta et al., 2019).

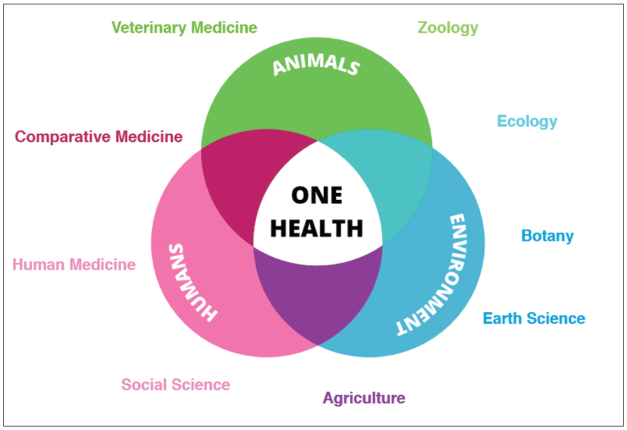

Figure 2: One Health as an intersection of human health, animal health, and environmental health.

(Source: wikipedia.org)

2. History of One Health

The unified concept of health has existed for a long time. In the 20th century, gaps in the prevention of zoonotic diseases were observed. In 1964, Dr. Calvin Schwabe in his book – 'Veterinary Medicine and Human Health' introduced the term 'One Medicine' and the Principles of Veterinary Public Health were also introduced. In 2004, Concept of 'One Medicine' changed to 'One Health'. The term 'One Health' was first coined in 2003–2004, in response to the occurrence of severe acute respiratory syndrome (SARS) in early 2003 and the resulting spread of highly pathogenic avian influenza H5N1, as well as a set of strategic objectives known as the 'Manhattan Principles,' formulated at a meeting of the Wildlife Conservation Society in 2004, which identified the link between human and animal health and the threats that diseases pose to food supply chains. These concepts were a vital step toward acknowledging the important implications of partnering, cross-disciplinary strategies for responding to emerging and resurgent diseases, and in specific, for including wildlife health as an important part of global disease prevention, surveillance, control, and mitigation.

3. Components of One Health – One World and its Relevance to COVID-19 Pandemic

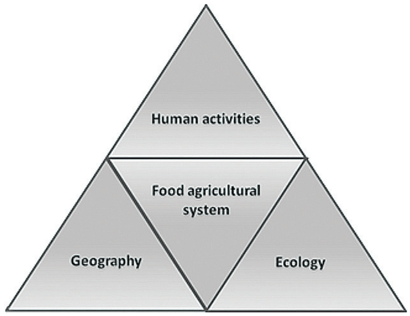

Figure 3: Components of One Health

(Source: Calistri et al 2013)

The interaction between humans, animals, and viruses may be shown as a tetrahedron (Fig. 3), with each of its four sides representing a distinct viewpoint that considers several components that play a major part in this interaction. COVID-19 caused by SAR-COV 2 transferred from animals and wet markets to people highlight the need for a supranational approach (the geographical component). From a single individual in Wuhan, China, to a pandemic affecting 220 nations and territories underlines the need to consider one health as a priority. All zoonotic illnesses (Nipah – fruit bats; COVID-19 – bats) – the involvement of animals and, more broadly, environmental variables in the propagation and maintenance of infections (the ecological component) underlines the critical importance of integrating veterinary and human medicine into a "one medicine" strategy, as well as the need for a multidisciplinary approach in general (the human activities component). Veterinary scientists and ecologists will need to collaborate with public health specialists and virologists to prevent future COVID-19 or similar outbreaks. The food-agricultural component highlights the necessity for a holistic perspective of the entire production chain, based on a "farm to fork" philosophy.

4. Scope of One Health

One Health encompasses zoonotic illnesses, antibiotic resistance, food safety and security, insect-borne diseases, environmental pollution, and other health issues that affect people, animals, and the environment. As per One Health Commission (2021), some other broad areas include:

- Agricultural production and land use
- Animals as Sentinels
- Antimicrobial Resistance – a quintessential One Health issue
- Biodiversity/Natural Resources Conservation
- Biosurveillance for Disease prevention and response
- Changing Climate
- Comparative Biology/Translational Research/Diseases common to both animals and people, cancer, diabetes, obesity
- Convergence of human, animal, and plant health and the health of the environment
- Disaster preparedness and response
- Economics/Complex Systems, Civil Society
- Environmental Health/contamination detection and response
- Food and Water Safety and Security
- Global trade and commerce
- Human-animal bond
- Interprofessional relationships/sharing of knowledge (clinical and basic)
- Non-Communicable/Chronic Diseases
- Plant and Soil health
- Planetary Health
- Professional education and training
- Public policy and regulation
- Vector-borne Disease Prevention and Treatment
- Welfare/Well-being of animals, humans, planet
- Zoonotic Diseases that pass between animals and humans

5. Potential Outcomes from the One Health Approach

As per One Health Commission (2021), some key Potential Outcomes from the One Health Approach are mentioned below:

- More information exchange linked to illness detection and diagnosis, as well as education and research

- More multidisciplinary programmes in education, training, research, and established policy
- More illness prevention, both infectious and chronic diseases
- New medicines and treatment techniques for unmet requirements

6. One Health Context and Highlights in India

The detail of One Health Context and Highlights in India are represented in Table 1. Ministry of Health & Family Welfare (MoHFW) and Department of Health & Family Welfare (DHFW) have crucial responsibilities to play in central and state respectively. Ministry of Health & Family Welfare (MoHFW) have a role to play in health policies; regulatory functions and control of diseases and outbreaks etc.

Table 1: One Health Context and Highlights in India

One Health Component	Responsible Ministries	Functions
Human Health	**Central** - Ministry of Health & Family Welfare (MoHFW) **State** – Department of Health & Family Welfare (DHFW)	**MoHFW** – health policies; regulatory functions and control of diseases and outbreaks **DHFW** – Health care delivery; training of staff **Vertical disease control programs** – NACP; NTEP **National Center for Disease Control** - IDSP
Animal Health	Department of Animal Husbandry, Diarying and Fisheries under Ministry of Agriculture and Farmer's welfare	**Livestock production, preservation, protection from diseases.** Surveillance system for animal health (NADRS and NIVEDI)
Environment Health	Ministry of Environment, Forest and Climate Change	Conservation of flora, fauna, forests and wildlife; Control of pollution; Afforestation; **Protection of the environment and animal welfare**

7. Strengths, Weakness, Opportunities & Threats – OH in India

7.1 Strengths

Some of the strengths of One Health in India are as follows:

- Zoonotic committees established at national, state and district level
- Surveillance systems and vertical programs in place
- Well functioning systems at national, state and district level with community outreach
- Funding available to Animal Husbandry Department for study of zoonotic diseases

7.2 Weakness

- Lack of overall One Health Policy
- Draft National Health Policy does not address zoonotic diseases
- Coordination only during disease outbreaks
- No integrated disease surveillance; risk analysis and programmatic action
- Poor manpower and labs for Animal Health
- Integration with Environment Health weak

7.3 Opportunities

- Different models of collaborative work (individual researchers; solution-based and third party-based collaboration)
- Veterinarian posted in human health surveillance system (IDSP)
- Medical and Veterinary colleges under one University
- One Health hub as part of South Asia hub

7.4 Threats

- Integrated Disease Surveillance Programme (IDSP) and National Animal Disease Reporting System (NADRS) – parallel systems
- Unavailability of large-scale population data
- Lack of regulations on veterinary bio-medical waste management
- Lack of regulations on use of pesticides
- Lack of involvement of environment and agriculture department

8. Future One Health Collaboration Model for India

Globally, inter-sectoral cooperation is generally regarded as critical for improving and integrating health systems. A conceptual One Health collaboration model for India is represented in Figure 4 (Mackenzie J.S., Jeggo., 2019).

Figure 4: A Conceptual One Health Collaboration Model for India

As the intricacy of the health system has grown within the area of the One Health approach, there has been an immediate requirement for collaboration to successfully implement the One Health approach. Before embarking on any collaboration strategy, it is critical to get a thorough awareness of the local requirements and opportunities for cooperation. Furthermore, additional research on the system and contextual elements that influence OHC techniques is needed before they are implemented.

9. Conclusion

One Health is a critical idea that must be strengthened in India to avoid and manage future disease risks, such as fresh COVID-19 waves. The success of One Health is dependent on the three Cs: coordination, collaboration, and communication. India must take One Health seriously by developing a One Health Policy, forming an Inter-Ministerial Task Force on One Health, and supporting inter-departmental collaboration on research, integrated service delivery clinics, and reporting mechanisms.

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5. Length of the paper should be maximum of 8000 words or 16, A4 pages including tables and illustrations (1.5 spaced with 1 inch margins and justified).

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