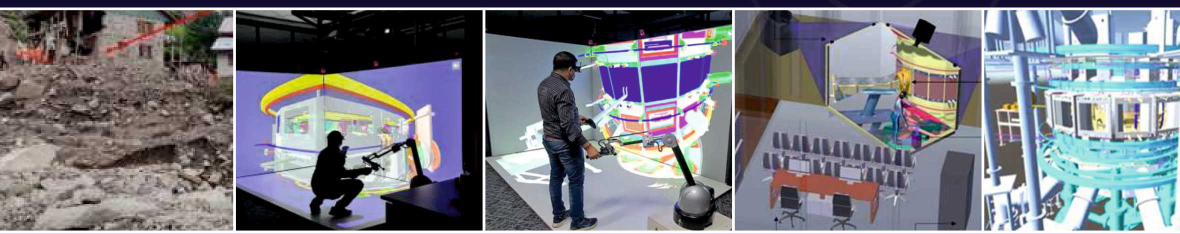
DISASTER
Response & Management

Volume-IX, No. 1, March 2024
ISSN: 2347-2553



CENTRE FOR DISASTER MANAGEMENT
Lal Bahadur Shastri National Academy of Administration,
Mussoorie - 248179, Uttarakhand

DISASTER
Response & Management

Volume-IX, No. 1, March 2024
ISSN: 2347-2553

Centre for Disaster Management
Lal Bahadur Shastri National Academy of Administration
Mussoorie - 248179, Uttarakhand, INDIA
EPABX: (0135) 2632236, 2632489, 2632374
Phone & Fax: (0135) 2632655, Fax: 2632350, 2632720
Email: cdm.lbsnaa@nic.in

ISSN: 2347-2553

Designed & Processed by
Chandu Press, D-97, Shakarpur, Delhi-110092
Ph.: 011-22526936, 09810519841
E-mail: chandupress@gmail.com

Sriram Taranikanti, IAS
Director,
Lal Bahadur Shastri National Academy of Administration,
Mussoorie-248179

Director's Message

India, due to its unique geographical and geological conditions, is vulnerable to various natural disasters. In India, the incidents of flood, drought and other natural disasters are on the rise and pose a tremendous challenge to the society in general and administration in particular. Each disaster heightens the sense of urgency to equip ourselves better in coping and managing them. In this context, the training of Civil servants in Disaster Management assumes critical significance.

There is a need to move from the paradigm of responding to disasters to building resilience against disasters in all aspects of decision making. A key challenge to administrators would be increasing the level of awareness in the society regarding the cost of disasters and to build resilience specifically in infrastructure and community in general. It gives me immense pleasure to note that Centre for Disaster Management, Lal Bahadur Shastri National Academy of Administration is bringing out the edited Journal "Disaster Response and Management" Volume-IX, No. 1 for the year 2023-24 under the project "Capacity Building on Disaster Management for IAS/Central Civil Services Officers" sponsored by National Disaster Management Authority (NDMA), Government of India, New Delhi. This is the compilation of research articles providing insights about recent trends in Disaster Management. I hope this volume will add to the knowledge base for Disaster Management in the country and will be useful for both the Officers Trainees and the Administrators in the field. It can also serve as a good reference material for ATIs and CTIs for their in house courses.

I hope this compilation will be useful for both the Officer Trainees and the Administrators in handling disasters and emergency situations across the country. I want to congratulate the CDM team for this publication and also place on record my appreciation for the contribution made by the faculty & staff of the CDM who contributed in various capacities for bringing out this Journal.

(Sriram Taranikanti)

Abhiram G. Sankar, IAS
Deputy Director & Director
Centre for Disaster Management

Preface

The Centre for Disaster Management (CDM), Lal Bahadur Shastri National Academy of Administration (LBSNAA), Mussoorie is a training and research Centre working under the aegis of LBSNAA, Mussoorie. The Centre is involved in training IAS and other Group-A civil service officers at induction as well as at in-service level in various aspects of disaster management, besides undertaking, action research projects, documentation of best practices, development of case studies, etc.

The magnitude and frequency of disasters has increased drastically in terms of human, economic and environmental losses. Under the conventions on SDGs, Paris agreement, Sendai framework for Disaster Risk Reduction, there is a need to document the research carried by individuals in the field of Disaster management to achieve the committed goals of India as a signatory.

Disaster Response and Management in recent times, received increased attention, both within the country and abroad. In a caring and civilized society, it is essential to deal effectively with the devastating impact of disasters. It is our pleasure to publish Volume-IX, No. 1 of the Journal "Disaster-Response and Management" for the year 2023-2024. The journal will provide an insight to administrators about the recent trends in response, planning and scientific interventions towards Disaster Risk Reduction.

I would like to thank the Centre for Disaster Management, Lal Bahadur Shastri National Academy of Administration who have been able to compile by faculty and staff of CDM who have contributed in various capacities for bringing out this Journal.

I would like to place on record the contribution made by faculty and staff of CDM who have contributed in various capacities for bringing out this Journal

(Abhiram G. Sankar)

Contents

Role of Open Source Geospatial Technologies for Natural Disaster Management and its Mitigation Measures

Rohit Sambare

Abstract

Due to its diverse geography, India deals with different varieties of disasters. The region, which were less susceptible, are also facing disaster due to most probable reason of climate change. The present article is giving detailed information of availability of geospatial tools and techniques, which are open source and less complex to download and process unlike earlier scenario. All major space agencies are distributing their geospatial data with moderate resolution free of cost. There are also open source software and tools to process such data. These data along with tools can be game changer in the coming years for the disaster planning and mitigation measures if used wisely with proper training.

Key words: *Remote Sensing data, GIS and image processing tools, Disaster Planning, Early Warning system.*

1. Introduction

The South Asian region is constantly dealing with the disasters related to the climate change. The Indian subcontinent has the diverse geography compared to the other parts of the world, which also makes it prone to disasters that are more natural. This is verified by the fact that, India has the region, which receives highest amount of rainfall in the world, i.e. Mawsynram, Meghalaya and other regions like in Maharashtra, Telangana, Karnataka, Bundelkhand face droughts almost every year. Landslides has become more challenging problem in the mountainous regions of Uttarakhand, Himachal Pradesh and North East regions which can be somewhat attributed to the several developmental activities going on in these regions. Cyclones hit coastal regions of West Bengal, Odisha, Andhra Pradesh and Tamil Nadu on regular basis, which requires large human evacuation exercise by National Disaster Management Agencies. Floods are not new to the India as every year certain regions of India face this problem such as Assam, Bihar etc. In recent years, more climate change induced floods like 2015 Chennai floods, 2018 Kerala floods, 2021 Maharashtra floods etc. had been occurred. In these entire events, one thing is common i.e. high intensity rainfall in the short event or lack of sufficient rainfall and loss of lives and economic losses due to the unchecked development in the disaster prone areas. In this year 2022, large part of country faced severe heatwave, which may have caused loss of human and animal lives. This will also affect the precipitation pattern in the monsoon season. Few districts of Assam has faced severe flooding early because of the heavy rainfall in early season. These are all indicators of the rapidly changing weather in the region. That is why; there is an urgent need to develop innovative methods for creation the early warning systems and better disaster management practices which are more robust, trustworthy, and easy to understand and based on the data, which are accessible to all.

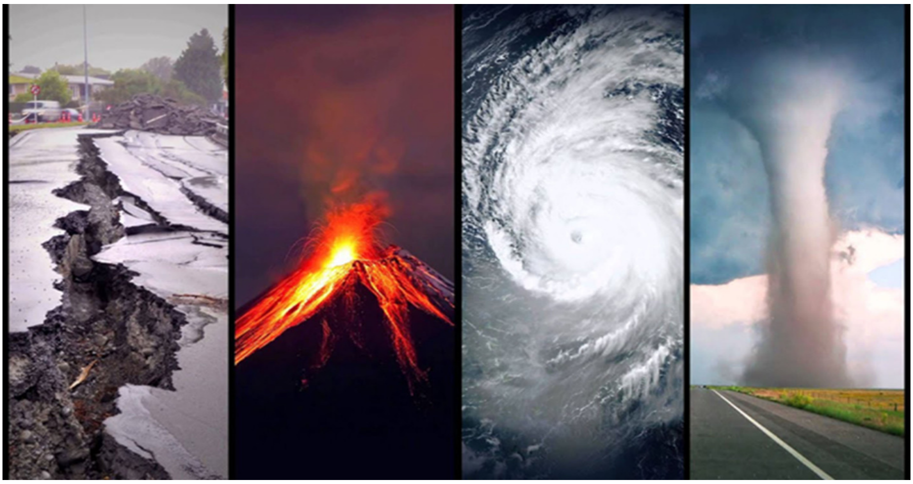


Figure 1: Different Natural Disasters

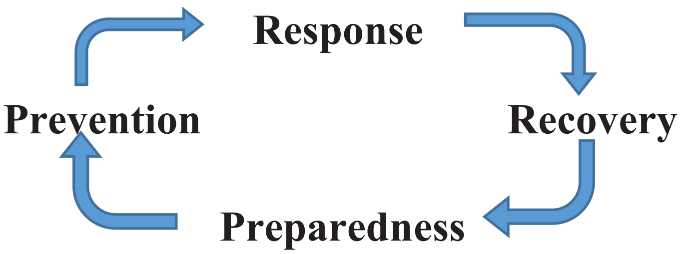


Figure 2: Cycle of Disaster Management

Disaster management is an integration of the policy and administrative decisions, operational activities, actors and technologies about different disaster phases at various levels (Ghawana et al., 2021). Disaster management is defined as 'the integration of all activities required to build, sustain and improve the capabilities to prepare for, respond to, recover from, or mitigate against a disaster' (Norris et al., 2015). Risk (prevention, preparedness) and crisis (response and recovery) management is the key components of the disaster management. These all activities are interdependent and sequential. Response to any disaster should initiate immediately after the disaster but recovery may take longer duration as it will include health and recovery of victims of disaster. The information of such disaster can be used for the further preparedness and prevention of such disasters.

Due to availability of accessible or open source data, it is very easy to assess the results by third party users and change it whenever the need arises. The system based on such data can also be open to modification because there is continuous research is going on for development of new state of art techniques and tools for better interpretation of data and good quality assessment of current and future scenarios and these research can be implemented also. This will also lead to betterment of the early warning systems of disasters from time to time.

In the recent past, open source data availability is very poor. Whatever the data was available, it was of very course resolution. The possibility of building early warning system on such data was not advisable. Thus, for creating early warning system one has to depend on the commercial and expensive remote sensing data, which requires state of art softwares to process. Those tools were also very expensive for researchers to buy and use. In this information age, where all data and knowledge are getting free, geospatial industry had also developed itself towards the open source methodologies (Priyanta et al., 2019).

Also, new insights in to the Artificial Intelligence (AI) and Machine Learning (ML) will play an important role in the coming future as far as disaster management is concerned. These techniques with big data processing will successfully attempt to reduce the dependency on the sophisticated software and hardware which is required for the processing of large volumes of data which is perhaps the biggest challenges to be faced by civil defense, police, fire departments, public health and other government organizations managing disasters. To manage such increased frequency of disasters, updated approaches should be adopted. That is why, more automated processes can be utilized to remove human induced errors in the disaster management. Also, on social media platforms have enabled every individual to an opinion and thus possible input to the disaster management practices with better local knowledge (Yu et al., 2018). Smartphone connectivity had been reached to almost every populated region of the country. These tools can be used as the empowerment of the local people to tackle the disaster in more effective way and also enable the authorities for distributing relief materials where its necessities are more.

This article is presenting various types of open source data available, software tools, and new techniques which can be incorporated in the preparedness of early warning systems of natural disasters which can be more generalized and more accessible to general public

2. Geospatial Technology

This technology was primarily used for the defence purposes but scenario changed when NASA (National Aeronautics and Space Administration), USA have started the Landsat mission in 1980s with launching of series of remote sensing satellites which are to be used for the civilian purposes. The open source data from this mission have paved the way for other space agencies to launch their missions which provides the free remote sensing data. In the subsequent years, all space agencies have launched numerous satellites which primarily based on the optical remote sensing principle. Indian space agency has also launched its earth observation satellites starting from the Bhaskara-I. Almost all open source remote sensing images are of moderate to course resolution. This has been hindrance to use these data for the disaster management. Also, earlier its interpretation was also very complex which requires more field knowledge. With data, user also need various tool to process these images for analysis and interpretation. But because of the technological advancement, the data capturing has been more evolved and the resolution of these data has been improved significantly. Also, there are many number of portals have been developed by various space agencies. With the more usage in various research studies, various open source tools and methodologies had been developed. Hence, the usage of such datasets has been increased in the disaster studies. The following article will describe various types of open source datasets, tools, techniques etc. which can be explored for the more robust disaster management plan."

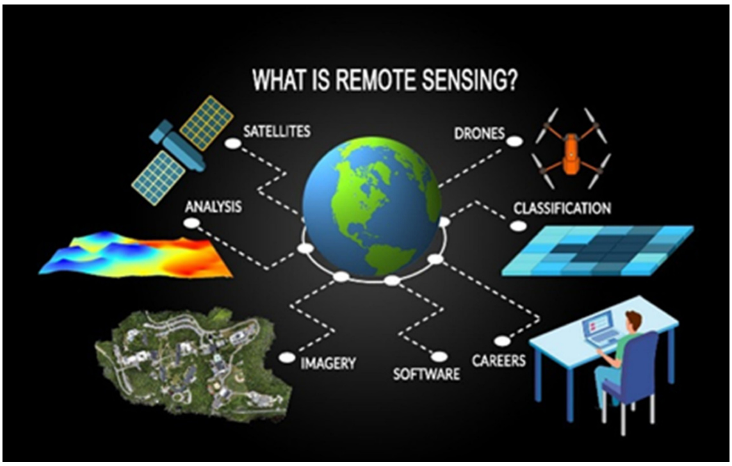


Figure 3: Remote Sensing System
(https://gisgeography.com/remote-sensing-earth-observation-guide/)

2.1 Datasets: The open source datasets are not only limited to the satellite images, but there are numerous data products derived from the satellite images or other techniques which are useful for the disaster management. Mainly most remote sensing images are acquired by optical sensors which works in the range of 0.4 to 14 µm (i.e. visible to thermal infrared) of EMR (ElectroMagnetic

Spectrum). Many features have been visible or can be analysed by the interpretation of these images. But various limitations of optical sensors and further advancement in these technique have led scientists to develop various other datasets which are derived from the optical datasets or based on the other types of remote sensing.

2.1.1 Optical Remote Sensing Images: As mentioned above, these images are more common for usage and its sensors work in the visible to thermal infrared of EMR. These sensors generally are of multispectral i.e. captures the images of the earth different spectral bands of optical range. That is why these satellites are called multispectral satellites. The most popular optical satellite images are from the Landsat series. Recently, Landsat 9 was launched by NASA with eleven spectral bands. Many research studies have been done and many applications had been developed on this series alone. Landsat has the global coverage. ISRO (Indian Space Research Organization) have also launched its Resourcesat programme in 2003 which distributes the AWiFS and LISS 3 images of Indian region for free. These images are of coarse resolution.

Table 1: Open Source Optical Remote Sensing Satellites and brief information

Satellite Name		Agency	Launch Date	Resolution
Landsat	1	NASA	23 July 1972	68m × 83m
	2		22 January 1975	68m × 83m
	3		5 March 1978	68m × 83m
	4		16 July 1982	68m × 83m
	5		1 March 1984	68m × 83m
	7		15 April 1999	15m, 30m and 60m
	8		11 February 2013	15m, 30m and 100m
	9		27 September 2021	15m, 30m and 100m
Resourcesat (AWiFS, LISS 3)	1	ISRO	17 October 2003	56m, 23.5m
	2		20 April 2011	56m, 23.5m
	2A		7 December 2016	56m, 23.5m
Sentinel 2	2A	ESA	23 June 2015	10m, 20m, 60m
	2B		7 March 2017	10m, 20m, 60m

European Space Agencies have launched its Sentinel programme which distributes its optical images in the name of Sentinel 2. In present, Sentinel 2 images are of most high resolution image i.e. 10m which are available for free. This mission is also of global coverage. The table 1 describes these datasets, its resolution along with its launch dates.

As far as, disaster management is concerned, these images are useful in various aspects such as delineation of the most probable disaster prone area, Land use mapping, demarking of various natural features such rivers, coastlines, forest fire lines, lake boundaries etc. Also, the disaster zone mapping in post disaster scenarios can be done using such images. These images can be used in the vulnerability studies. Hence risk mapping can be done on these optical satellite images.

Above table is mentioning few popular optical remote sensing data which are useful for the management and mitigation of the extreme events. But these datasets are not much useful in the cloudy weather and they are dependent on the natural illumination of the targets hence data can only be captured in the daytime only.

2.1.2 Microwave Remote Sensing Data: The limitations of the optical datasets have inspired the usage of the microwave remote sensing data in the events of the disasters. Therefore, microwave remote sensing datasets are useful in the cloudy weather and these data can capture the information about the target from the night time also. The microwave sensors acquire the information from the microwave range (1cm to 1m of wavelength) of EMR. Hence it can penetrate the clouds also. Based on its incident wavelengths, these sensors can be classified in various bands i.e. Ka, K, Ku, X, C, S, L and P. These datasets can also be classified into the Active and Passive Remote Sensing. The data capture from the target illuminated by the natural light i.e. sun is categorized into the passive remote sensing and targets illuminated by its own source is called active remote sensing. The RADAR (Radio Detection and Ranging) is a type of Active Remote Sensing. Active Remote Sensing can further be classified as imaging and non-imaging radars. Imaging radars are the normal imaging satellites like SAR (Synthetic Aperture Radar) and Non-imaging radars are the scaterometers and altimeters which use single narrow beam to acquire the data. All major space agencies have launched their microwave missions such as RADARSAT, ENVISAT, ALOS, RISAT etc. But these all datasets are commercial.

In 2014, ESA has launched the Sentinel 1A satellite, a C band microwave satellite and distributes its data free of cost for the analysis. Since then many microwave based studies has been initiated in the field of disaster management. In 2016, Sentinel 1B had also been launched. These datasets have global coverage and used for the numerous studies in the field of the flood inundation mapping, landslide detection has been done. Huge extraction of the groundwater can be one of the main reason of the land subsidence which is the disaster in the making. The interferometry technique on the Sentinel1 data can detect such land subsidence. Hence the extent of the groundwater extraction can be investigated with other indicators also. There are numerous incidents in the past regarding huge oil spills in the ocean from the cargo ships which endangers the marine and coastal ecosystem. Such oil spills can be detected and mapped using Sentinel

1 data. It has applications in the high altitude regions also. Glacier velocity can be estimated hence variations in such phenomenon can be correlated some kind of future disaster and hence policies can be made to mitigate such disasters. Earthquake causes the deformation of landmass; interferometry can detect such deformations. In this way, Sentinel 1 data can be more useful for the disaster management authorities.

The altimeters which are mainly used for the estimation of the variations in the surface heights. These sensors are mainly designed for the ocean monitoring. But these can be used for the land purposes. The slight increase in ocean heights can be the indicator of the effects induced by the climate change i.e. more melting of ice at the Polar Regions. The altitude increase of inland water bodies can be the indicator of the high sedimentation of the lakes and reservoirs in the absence of unusual discharge in it. This the breeding ground of the impending disasters for the downstream regions. NASA has its Jason series satellites, ISRO has the SARAL AltiKa and more recently ESA has launched its Sentinel 3 satellite which provides the data freely via their different portals. The following table 2 is mainly giving information regarding various microwave sensors.

Table 2: Open Source Microwave Remote Sensing Satellites and brief information

Satellite Name		Agency	Launch Date
Sentinel (Radar)	1A	ESA	3 April 2014
	1B		25 April 2016
Sentinel (Altimeter)	3A	ESA	16 February 2016
	3B		25 April 2018
Jason (Altimeter)	1	NASA	7 December 2001
	2		20 June 2008
	3		17 January 2016
SARAL ALtiKa (Altimeter)		ISRO	25 February 2013

Thus, microwave remote sensing has the numerous applications in the field of disaster management and its usage must be more encouraged. It is also hoped that more space agencies will launch the microwave sensors and make its data open source for the greater good of the society.

2.1.3 Data Products:

a. ***Digital Elevation Models (DEM):*** Various Digital Elevation Models are developed by the different space agencies and they have widespread applications wherever geospatial tools are required. Topographic information such as slope, aspect, valleys, ridges, altitude etc. can be extracted from the DEM. This information is useful in various disaster studies such as floods, landslide etc. There are mainly four types of methods with which DEM can be generated i.e. with stereo pair of images, interferometry, LiDAR (Light Detection and Ranging) and triangulation. There are several open source DEM which are available for the utilization. One of the most popular DEM is SRTM (Shuttle Radar Topography Mission). This mission has generated DEM of global coverage. DEMs are available in the 90m and 30m resolution. This DEM is generated using interferometry technique on microwave remote sensing image. The other popular DEM is ASTER Global DEM. Both DEMs were developed by the NASA having spatial resolution of 30m. ISRO had also developed its various versions of CartoDEM developed from stereo pairs of Cartosat imagery a high resolution satellite. It has the coverage of the Indian region only. It also has spatial resolution of 30m. The radiometrically terrain corrected (RTC) product of the ALOS-Palsar mission provides the global DEM of 12.5m spatial resolution. This is the highest resolution DEM which is open source. These are the examples of most popular DEMs. However, many developed countries have developed their own country's DEMs which are of 0.5m to 1m spatial resolution developed with the LiDAR technique which are freely available for the users. Our country should also make step forward to perform such projects. If user collects the topographical data of several point of its study area, then DEM can be generated using triangulation methods also. Hence the availability of good quality DEMs is essential of the robust disaster management plan.

b. ***Precipitation Products:*** Volume precipitation plays an important role in many natural disasters. Heavy or less precipitation along with several other factors causes floods, droughts, landslides. It can also enhance the effects of cyclonic winds. Amount of precipitation can be derived from the satellite sensors. Initially, NASA in collaboration with Japanese Space Agency JAXA had launched its TRMM (Tropical Rainfall Measurement Mission) in 1997 and subsequently it's GPM (Global Precipitation Mission) in 2014. Both satellite products provide the rainfall in 3 hourly, daily and monthly timeline with greater accuracies. There are several other products such as PERSIANN-CDR, CMORPH, GSMaP which are available for the analysis though their accuracies may differ.

c. ***Climate Models:*** These are primary tools for the investigation of the response of the climate system to different forcings and it makes climate predictions on seasonal and decadal time scales. That is why these models are used for the future climate projections throughout the century. The Atmosphere–Ocean General Circulation Models, Earth System Models and

Regional Climate Models evaluated here are based on fundamental laws of nature (e.g., energy, mass and momentum conservation). These models are developed by the different research institutions around the world under CMIP (Coupled Model Intercomparison Project) 3 and CMIP 5. The results with bias corrections of these models are freely available and widely used in the research studies dealing with the climate change. The GCMs (General Circulation Models) are downscaled either by statistical method or by dynamic method to the RCMs (Regional Circulation Model) which is more suitable for the regional climate scenarios. These models often take inputs from the weather satellites for rainfall, heat, wind velocity, ocean temperature etc.

2.2 Softwares: Due to the prohibition to edit the copyrighted computer codes of the softwares, the term Free and Open Source Software (FOSS) was introduced (Leidig & Teew., 2015). Along with fine quality datasets, software is also essential to process such data. Often, people are not well versed with the programming environment to analyse the data using different languages. Therefore, many private entities have developed the various GIS (Geographic Information System) and image processing tools for the analysis. But most of them were commercial and expensive. But today, there are number of softwares which are open source and developed for the greater good of the society. There are many hydrological and hydraulic tools available to simulate the extreme events and make predictions according to it. These tools are also open source. Few of them are described in the following article.

2.2.1 Q-GIS (Quantum GIS): It is most popular open source GIS tool. It is developed under the OSGeo (Open Source Geospatial Foundation). It is used for the viewing, editing and analysis of the geospatial data both raster and vector. It has many plugins developed by the various groups which can be utilized. It can also be used for the publishing the data. It can also integrate with the open source packages called PostGIS, GRASS GIS MapServer etc. Many researchers and practitioners use QGIS for their tasks as it provides continuous good support. It is constantly developing tool; hence it can be used for the disaster management activities efficiently.

2.2.2 SNAP (Sentinel Application Platform): As the name suggest, this tools is developed for processing of the satellite data from the various Sentinel missions managed by the European Space Agency. It is mainly image processing software. It can process both optical as well as microwave remote sensing images. Various versions having compatibility with Windows, Mac OS and Unix had been developed. Optical image processing such as supervised classification, NDVI, NDWI etc. can be done. Tools of the interferometry on the microwave images are also available. Hence it is very comprehensive open source tool. It has widespread applications in the disaster monitoring and management such as real time flood inundation mapping, landslide zone detection, land subsidence, volcano monitoring, oil spill detection etc.

2.2.3 BRAT (Broadview Radar Altimetry Tool): It is also developed by the ESA and it is the collection of the tools for the processing of the altimetry data from the various missions. The altitude variations of the oceans and inland water bodies can be estimated using this tool. It is very simple tool to extract the data from the radar altimetry signal to convert it into other formats such as NetCDF and ASCII.

2.2.4 HEC HMS and RAS (Hydrologic Engineering Center Hydrological Modelling System and River Analysis System): These are the most popular modelling tools dealing with the hydrological disasters. These developed by the US Army Corps of Engineers. HMS is used for the hydrological modelling which simulates the various components of hydrological cycle such discharge, snowmelt etc. RAS simulates parameters which states the mechanical behaviour of water such as flow velocity, flow depth and extent. These are widely used by various agencies for the flood studies. These tools incorporate various geospatial data and simulate flooding parameters. Outputs from these studies can be used for the flood management plans.

2. 3 Modern Technologies: Today, smartphone availability has been increased. There is a telecom revolution in the country in the last decade, therefore connectivity issues have been resolved in the most of the country. Mobile phones use navigation apps to locate its geographic location and several free apps can be used to export its navigational data (Zhang and Fang, 2015). These apps can also be used for the geological surveys, capture the photos and store special notes. Hence these apps can be game changer in the real time disaster relief activities.

The traditional method involves downloading of satellite data and process it in desktop software. If computer is not high end, then processing may take longer time. But several cloud based services are disrupting this. Most popular tool is GEE (Google Earth Engine). GEE contains the petabytes of open source data and it can process these data in within span of minutes depending on the speed of internet connection. The results can be visualized, edited, and downloaded. The GEE platform can also be used for the preparation of several apps according to the need of user. This type of services requires desktop computer with good quality internet connection. Hence cloud based processing of geospatial data is the future. Various apps deal with the disaster management operations can be designed on such platforms and can be disseminate to the general public.

A comprehensive and effective early warning system of disasters requires the large quantity of the data. It can be environmental, weather, topographical, geographical, financial, social media, and movement of masses, behavioural patterns etc. Here, in some aspects geo-informatics and open source remote sensing platforms can contribute. Remote Sensing data not only provides information about the natural features but also be used for the human transportation data through its navigation network. The social media updates can create the awareness about the disaster and can be the source of real time information of disasters. Generation of different geo-spatial maps are effective tools for the mitigation of disasters. Hence all these data can be integrated on the open source platforms such as Hadoop ecosystem which will support the data processing and storage for effective disaster preparedness (Arslan et al., 2017). 3D simulations large scale events can be created using big datasets. The AI and ML techniques is component of the big analytics. These techniques are integrated with various software packages and coding platforms. User can develop their own codes also. The AI and ML make decisions about any future event on the occurrence of past events and several disaster causative factors. Extraction of these factors and generation of data from the past events can be done using open source remote sensing data.

3. Conclusion

Preparation of the effective the disaster management plan is a big challenge. Many times, the availability of the data can cause hurdles. Few of these issues can be solved by the use of open source remote sensing data and its products. This paper presented few of the popular datasets in the research domain, their processing tools and other modern techniques for processing the data for the preparation of the management plan of the natural disasters. As no datasets is capable enough to cover all aspects management plan, therefore these datasets can be integrated on some platform to use them more efficiently. Cloud based processing and big data platforms should be actively used in the future projects by every agency and authority.

References

1. Norris, A. C., Martinez, S., Labaka, L., Madanian, S., Gonzalez, J. J., & Parry, D. (2015, May). Disaster E-Health: A New Paradigm for Collaborative Healthcare in Disasters. In ISCRAM.
2. Arslan, M., Roxin, A. M., Cruz, C., & Ginhac, D. (2017, December). A review on applications of big data for disaster management. In 2017 13th International Conference on Signal-Image Technology & Internet-Based Systems (SITIS) (pp. 370-375). IEEE.
3. Ghawana, T., Pashova, L., & Zlatanova, S. (2021). Geospatial Data Utilisation in National Disaster Management Frameworks and the Priorities of Multilateral Disaster Management Frameworks: Case Studies of India and Bulgaria. ISPRS International Journal of Geo-Information, 10(9), 610.

4. Abid, S. K., Sulaiman, N., Chan, S. W., Nazir, U., Abid, M., Han, H., ... & Vega-Muñoz, A. (2021). Toward an integrated disaster management approach: how artificial intelligence can boost disaster management. Sustainability, 13(22), 12560.
5. Perera, D., Seidou, O., Agnihotri, J., Rasmy, M., Smakhtin, V., Coulibaly, P., & Mehmood, H. (2019). Flood early warning systems: a review of benefits, challenges and prospects. UNU-INWEH, Hamilton.
6. Yu, M., Yang, C., & Li, Y. (2018). Big data in natural disaster management: a review. Geosciences, 8(5), 165.
7. Islam, M. A., Murshed, S., Kabir, S. M., Farazi, A. H., Gazi, M. Y., Jahan, I., & Akhter, S. H. (2017). Utilization of open source spatial data for landslide susceptibility mapping at Chittagong District of Bangladesh—an appraisal for disaster risk reduction and mitigation approach. International Journal of Geosciences, 8(04), 577.
8. Manfré, L. A., Hirata, E., Silva, J. B., Shinohara, E. J., Giannotti, M. A., Larocca, A. P. C., & Quintanilha, J. A. (2012). An analysis of geospatial technologies for risk and natural disaster management. ISPRS International Journal of Geo-Information, 1(2), 166-185.
9. Mohanty, A., Hussain, M., Mishra, M., Kattel, D. B., & Pal, I. (2019). Exploring community resilience and early warning solution for flash floods, debris flow and landslides in conflict prone villages of Badakhshan, Afghanistan. International journal of disaster risk reduction, 33, 5-15.
10. Perera, D., Agnihotri, J., Seidou, O., & Djalante, R. (2020). Identifying societal challenges in flood early warning systems. International Journal of Disaster Risk Reduction, 51, 101794.
11. Karnatak, H. C., Shukla, R., Sharma, V. K., Murthy, Y. V. S., & Bhanumurthy, V. (2012). Spatial mashup technology and real time data integration in geo-web application using open source GIS–a case study for disaster management. Geocarto international, 27(6), 499-514.
12. Leidig, M., & Teeuw, R. (2015). Free software: A review, in the context of disaster management. International Journal of Applied Earth Observation and Geoinformation, 42, 49-56.
13. Priyatna, M., Sutanto, A., Hidayat, T., Al Khudri, A., Effendy, I., Komaruddin, R., & Wijaya, S. K. (2019, September). Prototype of Remote Sensing Data and Information System Based on Open Source Technology to Support Disaster Management. In Proceeding The Fifth International Conferences of Indonesian Society for Remote Sensing (ICOIRS) 2019 (pp. 156-163). Itenas.
14. Subashini, M. J., Sudarmani, R., Gobika, S., & Varshini, R. (2021, February). Development of Smart Flood Monitoring and Early Warning System

using Weather Forecasting Data and Wireless Sensor Networks-A Review. In 2021 Third International Conference on Intelligent Communication Technologies and Virtual Mobile Networks (ICICV) (pp. 132-135). IEEE.

15. Acharya, A., & Prakash, A. (2019). When the river talks to its people: Local knowledge-based flood forecasting in Gandak River basin, India. Environmental Development, 31, 55-67.
16. He, Y., Zhang, D., & Fang, Y. (2017). Development of a mobile post-disaster management system using free and open source technologies. International journal of disaster risk reduction, 25, 101-110.
17. Alamdar, F., Kalantari, M., & Rajabifard, A. (2016). Towards multi-agency sensor information integration for disaster management. Computers, Environment and Urban Systems, 56, 68-85.

A Study on the Maximum Temperature Variation in Kottayam District using Observational and CMIP6 Model Data

Shinu Sheela Wilson

Abstract

This study delves into the evolving patterns of maximum temperature within Kottayam district, offering a comprehensive examination that is notably absent in the current literature. The district has witnessed abrupt temperature variations, a phenomenon that has not been thoroughly investigated to date. Furthermore, the study goes a step further by addressing temperature variations within each local administrative body in the context of a warming climate. The insights gleaned from this study provide valuable information for policymakers, enabling them to gain a deeper understanding of the intricate temperature dynamics within Kottayam district. Equipped with this knowledge, policymakers are better poised to formulate and implement essential measures to mitigate the effects of temperature variations, ensuring the well-being and resilience of the local communities.

Key words: *Temperature variation, Disaster Management plan, Local Action Plan, Mitigation*

1. Introduction

In recent times, the issue of global warming has taken center stage in newspaper headlines, reflecting a worrisome trend of increasing temperatures not only during the scorching summer months but extending into other seasons as well. Kerala, a coastal state known for its abundant atmospheric humidity, is witnessing a notable rise in heat levels. The India Meteorological Department declared a heatwave in Kerala in 2016. In 2019, Heatwave, Sun Stroke and Sunburn were notified as State Specific disasters. The Palakkad district has been consistently reporting the highest temperatures. The record for the highest maximum temperature in Palakkad stands at 41.9 degrees Celsius, recorded in 2016. This phenomenon is attributed to the Palakkad gap, which allows hot winds from Tamil Nadu to make Palakkad warmer than any other region in Kerala during summer season. The elevated temperature in Palakkad is a result of its geographical conditions and is not a recent occurrence. In recent years, Kottayam district has also witnessed abrupt variation in temperature from the normal during both the winter and summer seasons. This surge in temperature has far-reaching consequences, impacting not only the human population but also the environment. The abrupt changes in temperature pose challenges for humans, animals, and plants to adapt to, potentially leading to increased health problems, mental illnesses, crop damage, and more. With hotter summers becoming the new normal, the threat of heat waves, wildfires, and fire accidents is looming large, emphasizing the need for proactive measures to combat these climate-induced disasters.

Despite the fact that all districts in Kerala have disaster management plans, it is striking that none of them address the critical issue of heat-related emergencies. Furthermore, these plans contain a conspicuous omission concerning the impacts of climate change. It is imperative to integrate comprehensive strategies for coping with rising temperatures and climate-induced changes into each district's disaster management plan.

In a notable move, the Kerala State Emergency Operation Center published a Heat Action Plan in 2020, providing valuable insights and recommendations for various departments to navigate the challenges posed by high temperatures during the hottest months from March to May. However, the plan currently offers a general analysis of heat without delving into the specific changes attributable to climate change.

To address this gap, a thorough examination of the heat conditions in each district of Kerala is essential. Such an analysis should inform the development of tailored measures for each region, taking into account the local nuances and potential impacts of climate change. By incorporating these insights, disaster management plans can become more robust and adaptive to the evolving environmental challenges faced by Kerala.

As mentioned above, an increase in temperature has been observed in Kottayam district. In light of this, an analysis of the variation in maximum temperatures in Kottayam district, considering both winter and summer seasons has been conducted.

2. Material and methods

To analyze the daily maximum temperature data over Kottayam, station data from the India Meteorological Department for the period 1989 to 2020, specifically for January to May, is utilized. Kottayam has only one station (lat and lon). Additionally, CMIP6 model data is incorporated into the analysis to comprehend future variations. The bias-corrected gridded daily maximum temperature data, developed by Mishra et al. (2020), is employed for this purpose. The CMIP6 models, with various resolutions of daily maximum temperature, have been statistically downscaled and bias-corrected to a resolution of 0.25

X 0.25 degrees. The data is taken from https://zenodo.org/record/3987736#.YP_kp_nhVH5. The reliability of the five CMIP6 models—namely, ACCESS-CM2, ACCESS-ESM1-5, CanESM5, EC-Earth3, and MPI-ESM1-2-HR—has been established for the temperature conditions of the west coast of India (Neethu et al., 2023). In this study, an ensemble mean of the maximum temperature from these five models is utilized for both historical data (1991-2014) and projections (2015-2040) under the SSP245 scenario. The SSP245 scenario represents a medium-range future forcing pathway, characterized by a radiative forcing of 4.5 watts/m^2 by 2100. Methods used in data analysis explicitly to be described here.

3. Results

The analysis focuses on the daily maximum temperature recorded at the Kottayam station from 1989 to 2020. The daily mean value of the maximum temperature in Kottayam is calculated by averaging the daily maximum temperatures for the period 1991 to 2020. The temperature deviation is determined by finding the difference between the value and the mean of 1991-2020. A positive deviation indicates a rise in temperature, while negative values signify a decrease. The deviations are categorized into intervals: less than -1, -0.9 to 0, 0 to 0.5, 0.6 to 1, 1.1 to 1.5, 1.6 to 2, 2.1 to 2.5, 2.6 to 3, 3.1 to 3.5, 3.6 to 4, and greater than 4.

Daily deviations of the maximum temperature for the months of January, February, March, April, and May from 1989 to 2020 are analyzed. Figure 1 illustrates the frequency of temperature variations for (a) January and February, (b) March, April, and May. The findings reveal a year-by-year increase in temperature variation. In January 2020, for instance, seven days experienced more than a 2.5-degree Celsius variation, a rare occurrence in this month. Among these, four days had a 3.6-degree variation. Since 2013, deviations of more than 2.5 degrees Celsius have become common in February, with seven days exceeding this threshold in February 2020. Notably, there were more than four-degree variations in 2020, indicating a hotter-than-usual winter season in Kottayam.

Moving into the hotter months of March to May in Kerala, March shows a less noticeable positive variation in temperature, except for the years 2018, 2019, and 2020, which experienced days with more than a 2.5-degree Celsius variation. In April, warm days are on the rise, particularly in 2019 and 2020, with days featuring temperature variations of more than 2.5 degrees. May 2019 saw about 15 days with more than a 2.5-degree Celsius variation in temperature. In 2019, more significant temperature variations were observed from March to May, while in 2020, these variations were more pronounced in January and February. Overall, it is evident that warm days are increasing in frequency in all these months compared to previous years.

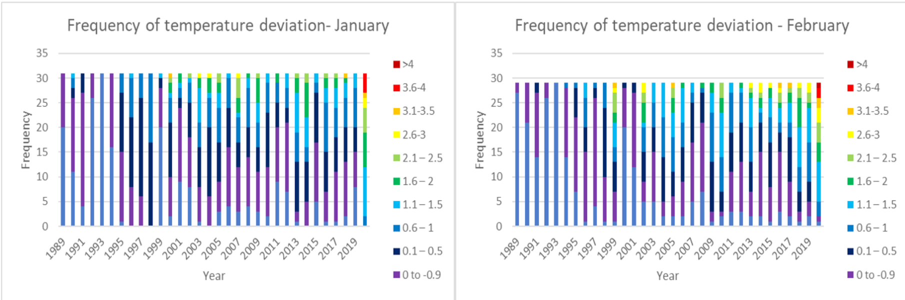


Figure 1a. Frequency of maximum temperature deviation for the winter season (Jan-Feb)

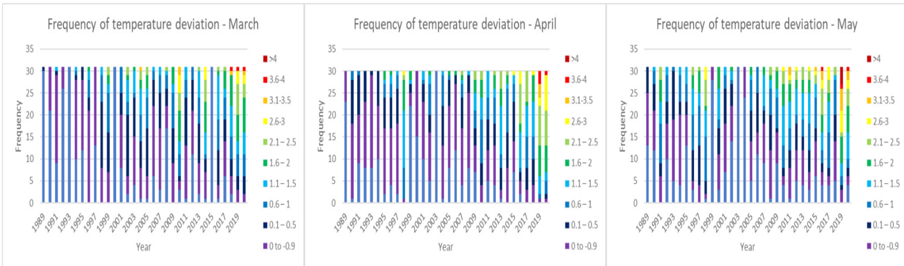


Figure 1b. Frequency of maximum temperature deviation for the summer season (March - May)

Analyzing the projected changes in temperature at the local level is instrumental in developing tailored strategies for each locality. Despite the relatively coarse resolution of the data (0.25 X 0.25 degree), an effort has been made with the available information. To comprehend the anticipated changes in maximum temperature, an ensemble mean of data from five statistically downscaled CMIP6 models has been employed. The study examined the density probability of daily temperatures from January to May by comparing the baseline (1991-2014) temperature data with future simulations (2015-2040) for Kottayam under the SSP245 scenario.

Figures 2a-e depict the probability density of maximum temperature during the historical period and the future period under the SSP245 scenario for six Local Self Governments (LSGs) in Kottayam. These figures collectively represent the overall temperature variations in Kottayam. The results indicate a noticeable shift toward warming in the future for all months. Extreme temperature values are on the rise, and the frequency of the most occurring temperature is increasing in the majority of Local Self Governments (LSGs) in Kottayam.

Table 1 displays the difference between the most frequently occurring temperatures in the future period and the historical period for the 77 Local Self Governments (LSGs) in Kottayam, covering the months of January to May.

This data illustrates that temperatures are on the rise in the future scenario. Projected temperature variations range from +0.46 degrees Celsius to +1.28 degrees Celsius in March, +0.47 degrees Celsius to +1.26 degrees Celsius in April, +0.59 degrees Celsius to +1.13 degrees Celsius in May, +0.41 degrees Celsius to +0.88 degrees Celsius in February, and +0.25 degrees Celsius to +0.53 degrees Celsius in January.

Table 1. Difference in the most occurring maximum temperature in the future period (1991-2014) under SSP245 scenario and historic period (2015-2040)

Local Self Government	Jan	Feb	Mar	Apr	May
Chempu	0.53	0.887	1.283	1.26	1.133
Maravanthuruthu	0.53	0.887	1.283	1.26	1.133
Udayanapuram	0.53	0.887	1.283	1.26	1.133
Velloor	0.53	0.887	1.283	1.26	1.133
Thalayolaparambu	0.53	0.887	1.283	1.26	1.133
Mulakulam	0.53	0.887	1.283	1.26	1.133
Thiruvarppu	0.422	0.537	0.538	0.538	0.707
Aymanam	0.422	0.537	0.538	0.538	0.707
Arpookara	0.422	0.537	0.538	0.538	0.707
Kaduthuruthy	0.422	0.537	0.538	0.538	0.707
Neendoor	0.422	0.537	0.538	0.538	0.707
Kumarakom	0.422	0.537	0.538	0.538	0.707
Vechoor	0.422	0.537	0.538	0.538	0.707
TV Puram	0.422	0.537	0.538	0.538	0.707
Thalayazham	0.422	0.537	0.538	0.538	0.707
Kallara Ktm	0.422	0.537	0.538	0.538	0.707
Vaikom Municipality	0.422	0.537	0.538	0.538	0.707
Neezhoor	0.327	0.47	0.508	0.505	0.645
Kadanad	0.327	0.47	0.508	0.505	0.645
Uzhavoor	0.327	0.47	0.508	0.505	0.645
Veliyannoor	0.327	0.47	0.508	0.505	0.645
Ramapuram	0.327	0.47	0.508	0.505	0.645
Vellavoor	0.373	0.492	0.5	0.513	0.677
Changanassery Municipality	0.373	0.492	0.5	0.513	0.677
Karukachal	0.373	0.492	0.5	0.513	0.677
Vazhappally	0.373	0.492	0.5	0.513	0.677

Local Self Government	Jan	Feb	Mar	Apr	May
Kurichy	0.373	0.492	0.5	0.513	0.677
Paippad	0.373	0.492	0.5	0.513	0.677
Madappally	0.373	0.492	0.5	0.513	0.677
Nedumkunnam	0.373	0.492	0.5	0.513	0.677
Thrickodithanam	0.373	0.492	0.5	0.513	0.677
Kottayam Municipality	0.345	0.467	0.49	0.493	0.645
Kooroppada	0.345	0.467	0.49	0.493	0.645
Akalakunnam	0.345	0.467	0.49	0.493	0.645
Kadaplamattom	0.345	0.467	0.49	0.493	0.645
Manarcadu	0.345	0.467	0.49	0.493	0.645
Elikulam	0.345	0.467	0.49	0.493	0.645
Athirampuzha	0.345	0.467	0.49	0.493	0.645
Bharananganam	0.345	0.467	0.49	0.493	0.645
Panachikkad	0.345	0.467	0.49	0.493	0.645
Pampady	0.345	0.467	0.49	0.493	0.645
Manjoor	0.345	0.467	0.49	0.493	0.645
Vazhoor	0.345	0.467	0.49	0.493	0.645
Pallickathodu	0.345	0.467	0.49	0.493	0.645
Ayarkunnam	0.345	0.467	0.49	0.493	0.645
Ettumanoor Municipality	0.345	0.467	0.49	0.493	0.645
Marangattupilly	0.345	0.467	0.49	0.493	0.645
Vijayapuram	0.345	0.467	0.49	0.493	0.645
Kozhuvanal	0.345	0.467	0.49	0.493	0.645
Meenachil	0.345	0.467	0.49	0.493	0.645
Puthuppally	0.345	0.467	0.49	0.493	0.645
Kanakkary	0.345	0.467	0.49	0.493	0.645
Kangazha	0.345	0.467	0.49	0.493	0.645
Kidangoor	0.345	0.467	0.49	0.493	0.645
Meenadom	0.345	0.467	0.49	0.493	0.645
Vakathanam	0.345	0.467	0.49	0.493	0.645
Pala Municipality	0.345	0.467	0.49	0.493	0.645
Thalappalam	0.345	0.467	0.49	0.493	0.645
Karoor	0.345	0.467	0.49	0.493	0.645

Local Self Government	Jan	Feb	Mar	Apr	May
Kuravilangad	0.345	0.467	0.49	0.493	0.645
Mutholy	0.345	0.467	0.49	0.493	0.645
Erumely	0.295	0.428	0.473	0.492	0.617
Koruthodu	0.295	0.428	0.473	0.492	0.617
Manimala	0.295	0.428	0.473	0.492	0.617
Melukavu	0.25	0.41	0.472	0.47	0.597
Moonnilavu	0.25	0.41	0.472	0.47	0.597
Kanjirappally	0.275	0.417	0.465	0.478	0.608
Thidanad	0.275	0.417	0.465	0.478	0.608
Thalanad	0.275	0.417	0.465	0.478	0.608
Poonjar Thekkekara	0.275	0.417	0.465	0.478	0.608
Teekoy	0.275	0.417	0.465	0.478	0.608
Koottickal	0.275	0.417	0.465	0.478	0.608
Mundakayam	0.275	0.417	0.465	0.478	0.608
Parathodu	0.275	0.417	0.465	0.478	0.608
Chirakkadavu	0.275	0.417	0.465	0.478	0.608
Erattupetta Municipality	0.275	0.417	0.465	0.478	0.608
Poonjar	0.275	0.417	0.465	0.478	0.608

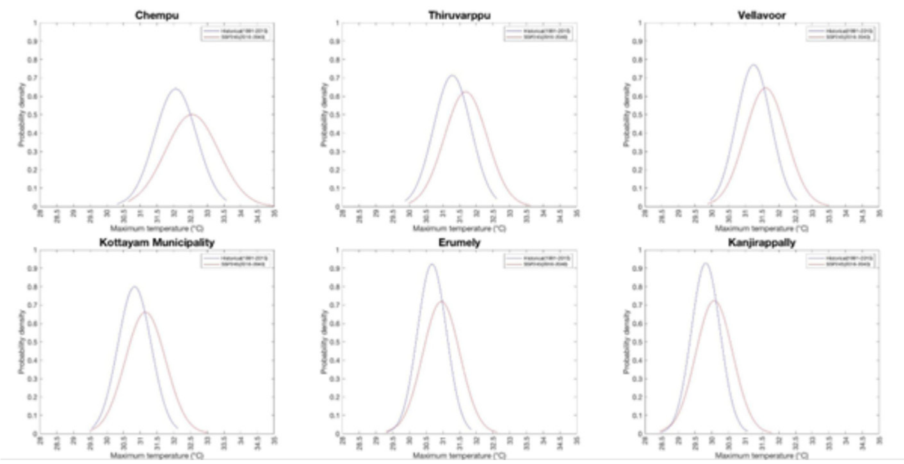


Figure 2a: Probability density of maximum temperature in the month of January for historic and future scenario (SSP245)

The changes are more pronounced in LSGs like Chempu, Maravanthuruthu, Udayanapuram, Velloor, Thalayolaparambu, and Mulakulam, while they are less significant in areas like Kanjirappally, Thidanad, Thalanad, Poonjar Thekkekkara, Teekoy, Koottickal, Mundakkayam, Parathodu, Chirakkadavu, Erattupetta Municipality, Poonjar, Melukavu, and Moonnilavu across all five months. Notably, temperature variations are more pronounced in LSGs on the western side and gradually taper off towards the eastern regions of Kottayam. This detailed analysis provides valuable insights into the localized impact of changing temperature patterns.

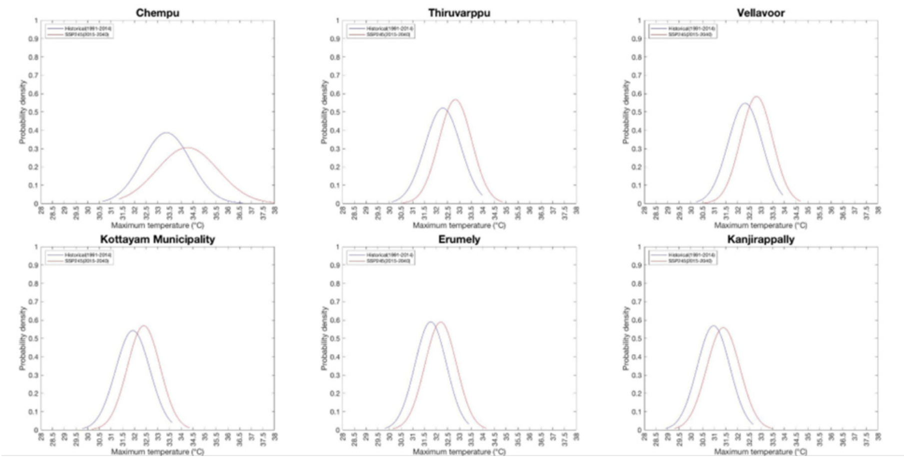


Figure 2b: Probability density of maximum temperature in the month of February for historic and future scenario (SSP245)

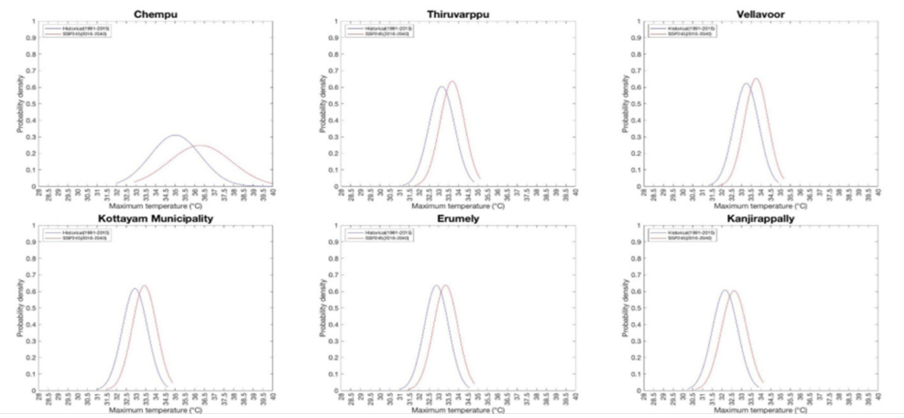


Figure 2c: Probability density of maximum temperature in the month of March for historic and future scenario (SSP245)

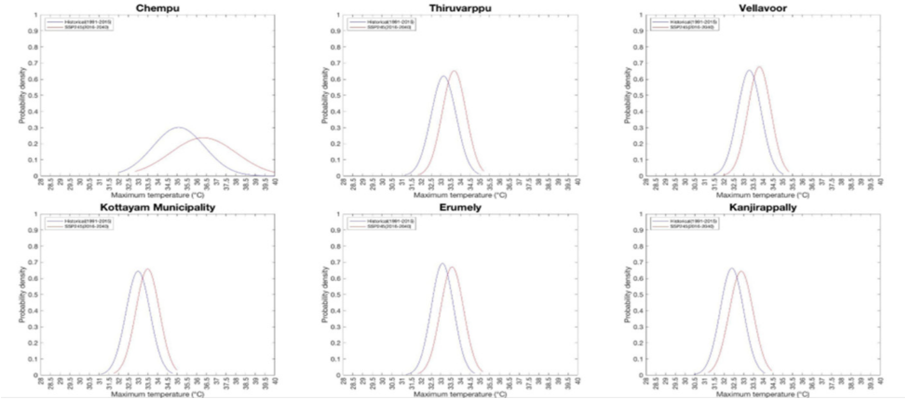


Figure 2d: Probability density of maximum temperature in the month of April for historic and future scenario (SSP245)

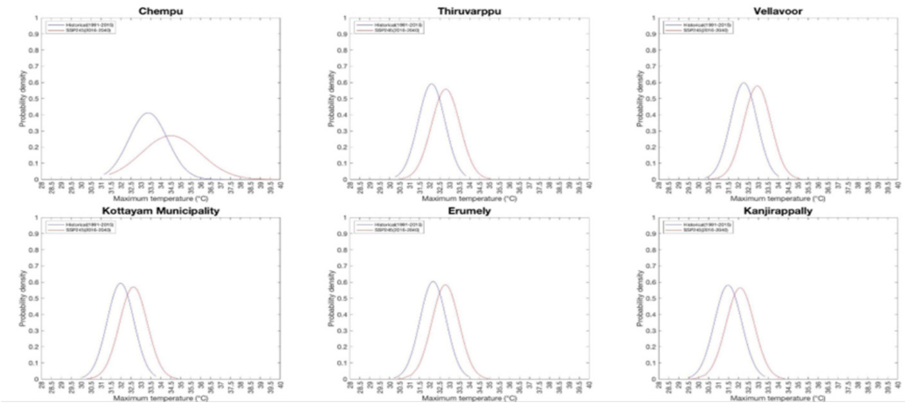


Figure 2e: Probability density of maximum temperature in the month of May for historic and future scenario (SSP245)

In addressing the challenges posed by rising temperatures and the potential variations in the future, it is crucial for both the District Disaster Management (DM) plan and the corresponding Local Self Governments' (LSGs) action plans to integrate comprehensive information about temperature variations. This information should encompass historical data and projections for the future, as it forms the basis for developing effective strategies to mitigate and adapt to changing climatic conditions.

Including temperature variation data in the District DM plan and LSGs' action plans will provide several following benefits:

a) ***Risk Assessment:*** Detailed temperature information allows authorities to conduct a thorough risk assessment. This assessment helps identify vulnerable areas and communities that may be disproportionately affected by temperature variations, such as heatwaves or extended periods of high temperatures.

b) ***Resource Allocation:*** With a clear understanding of temperature trends, decision-makers can allocate resources, both financial and logistic, to where they are most needed. This includes investments in infrastructure, healthcare facilities, and emergency response systems to cope with temperature-related challenges.

c) ***Healthcare Preparedness:*** Knowledge of temperature variations helps health authorities prepare for potential health issues. For instance, an increase in heat-related illnesses during hot spells can prompt the procurement of necessary medical supplies and the training of healthcare professionals to handle such cases.

d) ***Infrastructure Resilience:*** Infrastructure planning can be adjusted to ensure resilience against extreme temperatures. This could include improvements in building design, transportation systems, and utilities to cope with temperature-related stress.

e) ***Public Awareness:*** The information can be used to raise public awareness about the changing climate and the potential risks associated with temperature variations. This can promote behavioural changes and preparedness at the community level.

f) ***Disaster Response:*** Local action plans should include strategies for disaster response in the event of temperature-related emergencies, such as heatwaves or wildfires. Having this information in place allows for quicker, more effective responses to protect lives and property.

g) ***Sustainable Development:*** Development plans for the region should consider temperature variations to promote sustainable development practices. This might include energy-efficient initiatives, urban planning that reduces the urban heat island effect, and the preservation of green spaces to mitigate rising temperatures.

Incorporating temperature variation data into these plans, at both the district and local levels, enables a proactive and coordinated approach to climate change. This approach not only enhances the community's resilience but also contributes to a more sustainable and adaptive future for the region.

4. Conclusion

This study examines the maximum temperature trends in Kottayam district, uncovering a consistent rise in temperature year by year. Days are becoming progressively warmer compared to previous years, and the frequency of extreme temperatures is on the rise. The projected changes in maximum temperature highlight spatial variations across Kottayam district, with the most significant deviations occurring in the west and gradually diminishing towards the east. Notably, this temperature increase is not confined to the summer season but extends into the winter months, indicating a trend towards warmer days in the future. Consequently, it is imperative to address the potential impacts of these projected temperature changes and implement appropriate mitigation measures.

References

1. Mishra V, Bhatia U, Tiwari AD. 2020. Bias- corrected climate projection for South Asia from Coupled Model Intercomparison Project-6. Sci.- Data 7(1):1-13. https://doi.org/10.1038/s41597-020-00681-1
2. Neethu C, Ramesh KV. 2023. Projected changes in heat wave characteristics over India. Climatic Change 176: 144. https://doi.org/10.1007/s10584-023-03618-w

Cloudburst Catastrophe: Impact of Cloudburst Triggered Debris Laden Flash Flood at Honzar Village, Kishtwar District, Jammu and Kashmir

Imran Khan*, Parveen Kumar and Harish Bahuguna

Abstract

Debris-laden flash floods due to cloudbursts are a common occurrence during the monsoon season in the Jammu and Kashmir Himalaya. Cloudburst is associated with sudden heavy rain/rainfall over a very short time span in a very small catchment area. The high discharge after the heavy downpour in higher altitude areas results in erosion of slope forming materials as well as sediment-laden flash-floods in the low-lying areas. The high floods triggered by a cloudburst uproot any infrastructure that comes in its path resulting in loss of life and property, bringing life to a standstill. One such incident of cloudburst occurred on 27 July 2021 at 20:30 hrs in the high-altitude area of Honzar village of Kishtwar district of Jammu and Kashmir, in which seven people lost their lives, 19 people were missing, affected around 80 people and caused damage to property worth lakhs, which is being discussed here.

Key words: *Cloudburst, flash flood, debris flow, Extreme weather event, Northwestern Himalaya*

1. Introduction

The Himalayan region is characterized by parallel to sub-parallel high mountain ranges and intermontane valleys with steep slopes on both sides. These slopes are occupied by loose overburden material which is susceptible to failure during excessive rainfall, cloudburst, flash flood, earthquakes etc., (Jamieson 2004; Hobley 2010; Dortsch 2011; Sangode 2011; Scherler 2011; S.J. Sangode, 2017). The unconsolidated overburden material is, therefore, readily transported during such extreme weather events (Bookhagen & Burbank 2006; Das 2006; Medina 2010; Immerzeel 2010; Herman 2011; Rasmussen & Houze 2012; Kumar 2014; Haeberli 2016; Linsbauer 2016).

According to the Indian Meteorological Department (IMD), a cloudburst occurs when a small area receives high intensity rainfall (>100 mm/h) over a short period of from 30 minutes to 1 hrs). However, when rainfall intensity is >200 mm/day, it is termed 'extremely heavy', while intensity >130 mm/day is termed as 'very heavy' (IMD 2003). This usually occurs during the monsoon period between late June and early September (Sah and Mazari, 2007), due to strong convection and orography with steep inclination that causes flash floods or slope failures in the region. (Dimri et al., 2017).

A cloudburst is the result of a torrential downpour of rain at a high intensity associated with thunder, bursts and discharges of an entire cloud at once over a relatively small area (Woolley et al. (1946). Most of the flash floods in the Himalayan terrain occur due to cloudburst, heavy rainfall, landslides, earthquakes, release of water from the Dam, outbursts of lake, etc. Often during flash flood events, the discharge in the stream/river exceeds its normal carrying capacity, resulting in colossal damage to the property, infrastructure, human life and livestock.

Flash floods are quite common in the northwestern Himalayan region (Uttarakhand, Himachal Pradesh and Jammu and Kashmir) due to extreme rainfall events like cloudbursts. In India, the maximum number of cloudburst events have occurred between altitudes of 1000 to 2500 m (Dimri et al. 2017). DMMC (2014) and Khanduri (2018) have studied several cloudburst events based on the distribution of different geomorphic and topographical factors associated with extreme precipitation events, concluding that most of the events occur in first and second order stream slope of higher reaches. The cloudburst that occurred in the upper basin catchment area of Honzar village on July 27, 2021, at around 20:30 hrs (UTC+05:30), is likely one of the major incidents in the history of Kishtwar district, Jammu & Kashmir. The main factors responsible for cloudburst associated debris flow activity are steep slopes, high relative relief, high ruggedness, high stream power index and thick loose overburden material (Lewin and Warburton, 1994; Bahuguna et al., 2021; Paul at al. 2021). In the past few years, a sudden increase of habitation along the banks of the river is becoming a cause of devastation, due to which the channel width of the river is also decreasing day by day.

The area around Honzar village exposes granite gnessic rocks of Kibar Formation which are jointed, fractured and weathered in nature. The flanks of the stream channels are occupied by overburden material of thickness up to 3m which is susceptible to erosion and degradation during high precipitation or cloudburst. Therefore, underlying geology, thick overburden cover, relative relief, stream gradient, stream power index and high relief are important parameters in controlling and influencing damages and slope instability in the area (Khan et al. 2019; Bahuguna et al. 2021; Khan et al. 2021; Bahugana et al. 2022).

The present study is based on the post event study conducted after the incident to assess the impact, interpret the signatures of the cloudburst generated flash floods and to provide suitable remedial measures to avoid such damages in the future. The results of the study will be beneficial to the local administration, state/central government agencies and also researchers for their further planning the development activities like urban settlements and infrastructural facilities like roads, bridges and canals etc.

2. Study Area

Honzar village is located approximately 80km and 310km from the district headquarter Kishtwar and Jammu respectively and falls in Survey of India Toposheet number 43O14. The area can be approached up to Dangrooru from Kishtwar by the motorable road and Dangrooru to Honzar village by the foot track (approximately 16 km in distance). Geographically, the affected area is located at latitudes 33°30’18.81” N and longitudes 75°52’33.85” E (Figure 1).

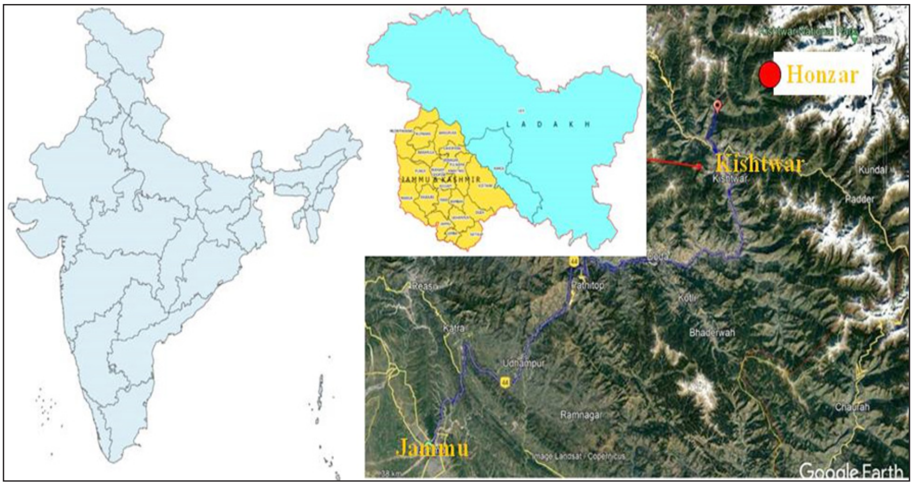


Figure 1. Location map of the Honzar village

3. Materials and Methods

Drainage map has been prepared and the basin boundary has also been demarcated using Survey of India toposheet at 1:50,000 scale. ASTER DEM (Digital elevation model) of 30 meters resolution has been utilized for delineating slope categories. The slope, stream power index, relative relief maps have been generated from resampled 50m ASTER Digital Elevation Model (DEM) on Geographic Information System platform. Geological map was taken from the compiled geological map at 1:50,000 scale of Geological Survey of India.

4. Physiography and drainage

The topography of the area is steep, uneven and rugged and is characterized by high peaks with elevation ranging from 2000m to 4380m (Figure 4). The highest peak is present in the northeastern direction to the Honzar village with an elevation of 4380m. The hills are rocky and bare to sparse in vegetation at the upper reaches and are generally moderately forest covered at the lower levels. The cultivated part is very small in extent and is confined to colluvium, alluvium and river borne materials. Nanth Nala is forming the main drainage flows in a south-westerly direction through a gentle to deep gorge in the area. Malo Rar Nala is a tributary to Nanth Nala joining on the right bank. Drainage pattern of the basin reflects mainly dendritic – sub dendritic and trellis pattern. The slope plays a key role in controlling the stability of the hills which in this case are occupied by highly jointed rock mass, overburden material and scree deposits (Figure-2 and 3).

5. Regional Geology

Geologically, the area exposes rocks of Kishtwar window zone, which are divisible into three parts that is i) Kibar Formation, ii) Lopara Formation and iii) Dul Formation. The Kistwar window zone is separated from rocks of Salkhalas Formation by Kajai Thrust in the south and from the rocks of Suru Crystalline group by Atholi thrust in the north.

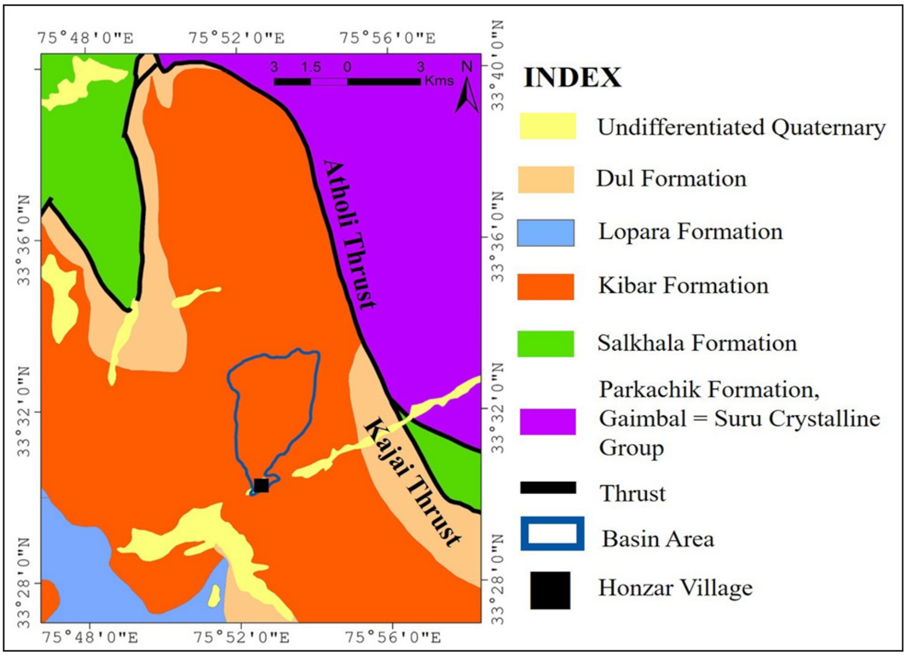


Figure 2. Geological map of the area (Source: www.gsi.gov.in).

Geology at the site: Geologically, the area exposes biotite-gneiss rocks of Kibar Formation belonging to Kishtwar Window Zone of Meso-Proterozoic age (Figure-2). The rocks are slightly to moderately weathered, massive and compact in nature. The general orientation of rock, recorded in and around proposed location is N50°W- S50°E to with dips ranging from 35°- 55° towards NE direction. The overburden thickness in and around the area is about 08 meter forming the foothill slopes. Rock exposures are at the higher reaches and are represented by the granite gneiss of Kibar Formation, however scanty outcrops are also exposed at lower elevations.

6. Results and Discussion

The reported cloudburst event took place in the upper reaches of Honzar village in the catchment of Malo Rar which triggered a flash flood and huge debris flows, which in turn damaged households Honzar village in the downstream of Malo Rar stream (Photo 1, 2 and 3). The reported incident of cloud burst, took place in the night of 27th July 2021 in the upper reaches of Malo Rar Nala. The mark of muddy water on the tree stems on either bank reflects that the vertical column of the water in the Malo Rar Nala might have risen to approximately 30m from the initial stream bed level (Photo 1). It was the most devastating one as it generated huge debris laden flash flood, caused damage to everything in its path which resulted into loss of property, infrastructure (more than 8 houses), several hectares of agricultural land/forest land and loss of human lives (7 killed, 19 missing and several injured). The region was more affected by the increase in anthropogenic interference near the Malo Rar stream or near the confluence of the Malo Rar and Nanath streams. The slopes of the affected area are occupied by the Quaternary deposits mainly colluviums and river borne material, which largely covers the area near the confluence of Malo Rar Nala and Nanth Nala. Malo Rar Nala flows in 185° N direction whereas the Nanth Nala flows in 235° N direction. The affected village Honzar is situated on the left bank of the Malo Nala, however few houses are also on the right bank. The Malo Rar Nala has been prepared from ASTER DEM using ArcGIS software which reflects the nala gradient of around 40° (Figure 3 and 4) and is a clear indication of steep slope gradient steep gradient that facilitated rapid transfer of flood water to the downstream stretches (Figure 5).

The Stream Power Index (SPI) is a measure of the erosive power of flowing water and shows moderate to very high SPI and moderate to high relative relief index (Figure 5 and 6). The SPI along Malo Rar i.e. upstream of the settlement of Honzar village is moderate to high which indicates that the region is very much prone to soil erosion and other soil degradation activities during sudden discharge capacity of stream. It has been observed that larger parts of the hill slopes in and around Honzar village are covered by rock mass and the piedmont slope by overburden material. Both banks of the Malo Rar Nala are mostly occupied by the Quaternary deposits. The overburden material is varying in thickness from 1-10m at different places on the piedmont slope. The angular to sub-angular rock fragments are embedded in thick cover of matrix of different size finer material.

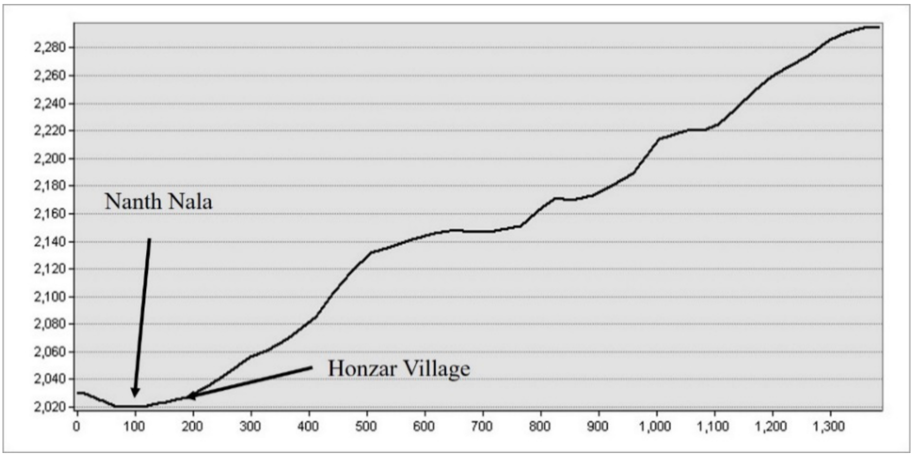


Figure 3. Profile gradient along Malo Rar Nala

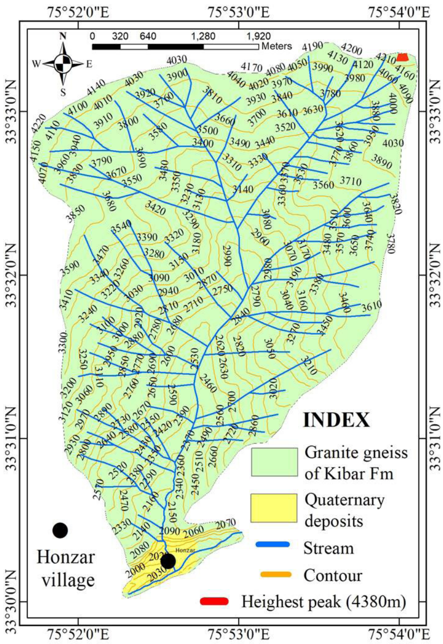


Figure 4. Drainage/Contour Map of area.

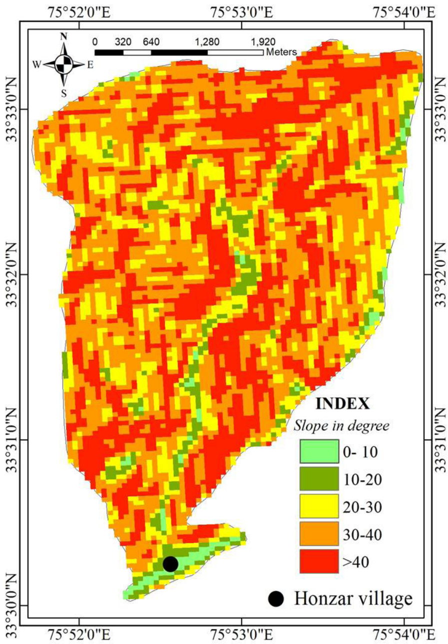


Figure 5. Slope Map of area.

Impact of cloudburst in and around Honzar village: The mixture of water and debris material brought by the Malo Rar Nala from the upstream slope moved towards southeast direction, supposedly with a high velocity and hit the hamlet of Honzar village, resulting in loss of livestock (number not known), death of 07 persons and missing of 19 persons, burial of cowsheds and agricultural land (Photo 2, 3 & 4). It is assessed that the velocity of the water

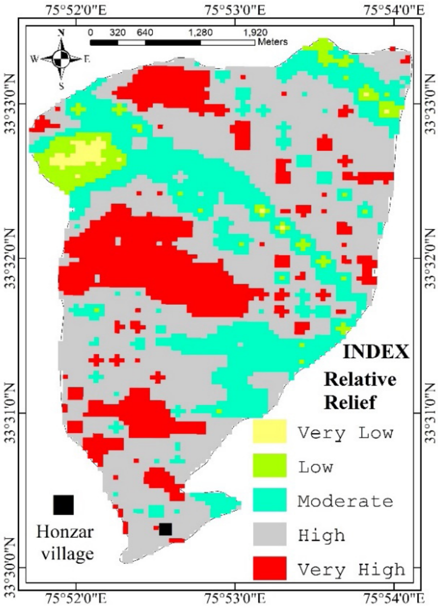


Figure 6. Relative Relief Map of the area.

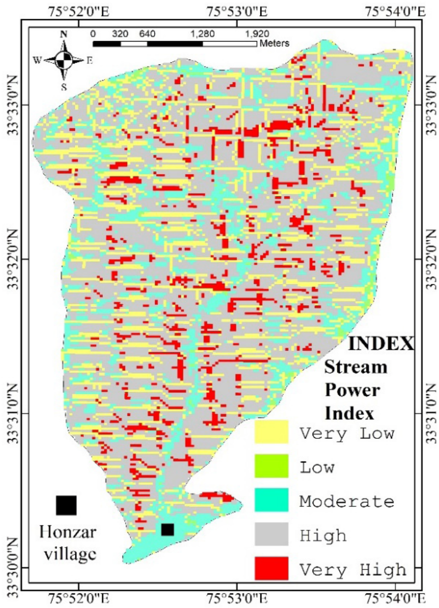


Figure 7. Stream Power Index Map of the area.

was too high that could roll down a huge boulder of dimension of 10mX7mX6m from the 500m upstream slope. The channel of the stream is still occupied by huge debris material ±20m thick, consisting mainly of a mix of fine and huge boulders of gneissic rock. It is assessed that these big boulders acted as a tool of destruction and the cumulative impact of large volume of water, laden with tools of destruction, inflicted the damage on the lower part of the settlement of Hoznar village. Impact of debris flow was restricted to T0 and T1 river terraces only and the higher slopes have not been affected. Small toe erosion/bank erosion has been observed in the overburden material on the banks of both the nala (Malo Rar and Nanth, Photo 4). The accumulation of debris material in the form of a fan has been observed at the junction of the Malo Rar Nala and Nanth Nala (Photo-3). As such, the measures for arresting bank erosion/toe erosion, below the location of lower hamlet of Honza village, were found missing.

Assessment of the Impact of cloudburst: Settlement and agricultural activities are mostly located on colluvium, alluvium and river-borne material and these areas are most affected by flash floods generated by cloudbursts. The settlement and agricultural land located on both banks of stream has been affected over a length of about 500-meter distance along Malo Rara Nala, flowing in southeast direction, resulted into damage to 8 houses, several hectares of land, loss of

Photo 1. Flood level and bank erosion along Malo Rar Nala.

Photo 2. Debris accumulated on the gentler slope along Malo Rar Nala.

Photo 3. Debris deposited as a fan shape near the confluence of Malo Rar and Nanth Streams.

Photo 4. Huge boulder rolled down from upslope along stream

Photo 5. Damaged house and toe erosion

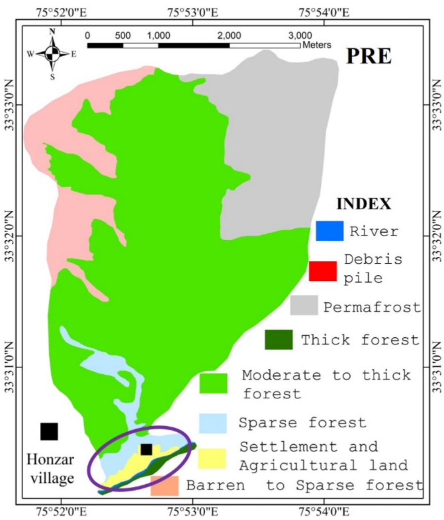


Figure 8. Landuse and landcover pattern before the cloudburst incident

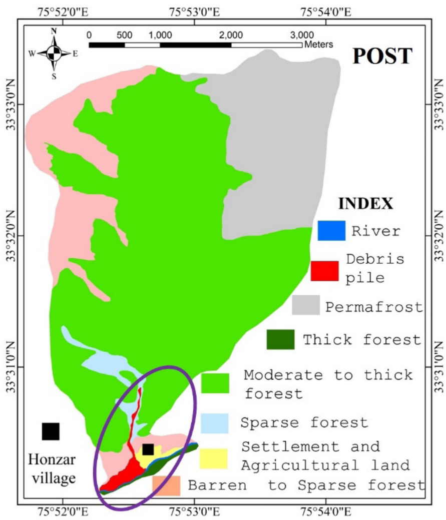


Figure 9. Landuse and landcover pattern after the cloudburst incident

human life, livestock (Image 1, 2 and Table 2). The flow of Nanth Nala also got diverted/ shifted due to the force of huge amount of debris accumulation at the confluence of both Nala, causing partial damming and collateral damage to the opposite bank due to erosion (Photo-6 and Table 1). Therefore, the land-use land-cover pattern has been widely affected on the both banks of nala, resulting into conversion of several hectares agricultural land into the barren land/debris pile (Figure 8, 9, 10 and Table 1). The houses situated on the higher slope on either bank of Malo Rar Nala have not been affected. Prior to the incident, the morphology of the channel was the one with deep narrow valley profile but after this incidence of cloudburst, the level of the bed level of the stream rose to about ±20 meters due to accumulation of huge debris material as per local people (Figure 11 and 12).

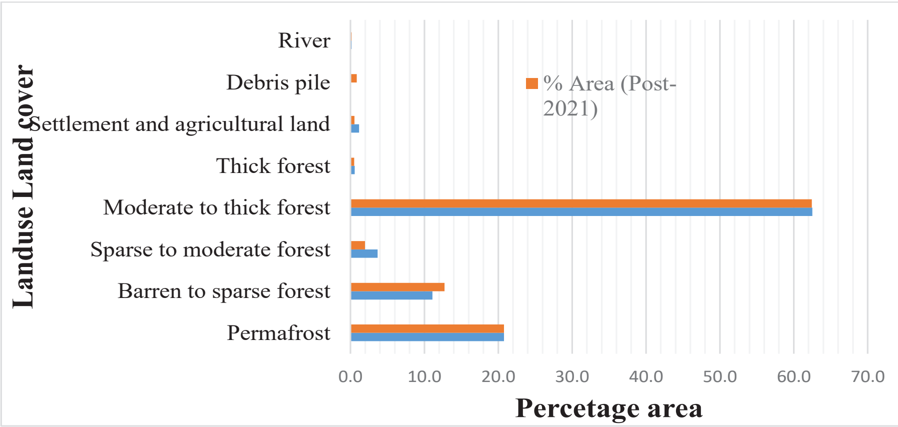


Figure 10. Change in landuse and landcover pattern before and after the incident of cloudburst

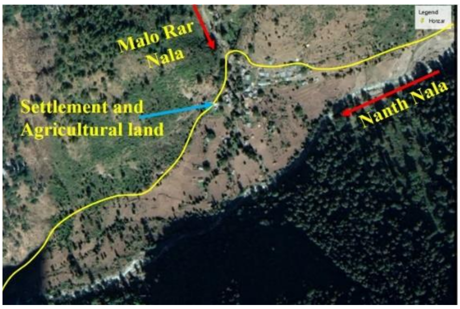


Figure 11. Google earth imagery before the incident

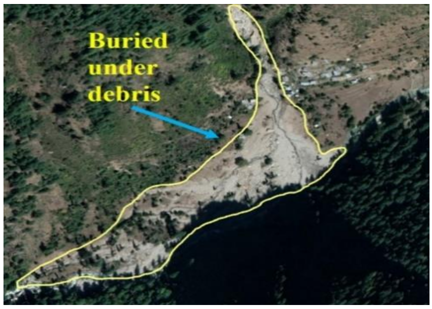


Figure 12. Google earth imagery after the incident

Photo 6. Collateral damage to the opposite bank (left) of Nanth Nala due to erosion.

Table 1. Change in Landuse and Landcover pattern in and around the Honzar village area

Landuse and landcover pattern	**Area m^2 (Pre-2020)**	**% Area (Pre-2020)**	**Area m^2 (Pre-2021)**	**% Area (Post-2021)**
Permafrost	3009816	20.8	3009816	20.8
Barren to sparse forest	1609600	11.1	1845667	12.7
Sparse to moderate forest	531702	3.7	286933	2.0
Moderate to thick forest	9057585	62.5	9047181	62.4
Thick forest	84002	0.6	71401	0.5
Settlement and agricultural land	171467	1.2	79436	0.5
Debris pile	0	0.0	124641	0.9
River	24816	0.2	23914	0.2
Total	**14488988**	**100%**	**14488988**	**100%**

Table 2. Nature of impact due to cloudburst in the Honzar village area

S. Nos.	**Nature of Loss/Damages**	**Remarks**
1	Number of houses damaged	8
2	Number of casualties	7
3	Number of missing people	19
4	Number of death/missing livestock	number not known
5	Damage to agricultural and forest land	Several Hectares
6	River bank erosion	On both banks
7	Shifting of Nanth Nala channel	Lat bank of Nanth Nala
8	Damages to electric poles	4 (approx.)

7. Rainfall data

An attempt has been made to assess this incidence with the help of rainfall data from Indian Meteorological Department (IMD). As pe the rainfall data (Figure 13), the heavy rainfall that occurred on 28.07.2021 continued intermittently with few spells of heavy downpour up to 29.07.2021. The rainfall recorded from the Honzar village area on the day of the incident was about 29 mm (Pai et al., 2014).

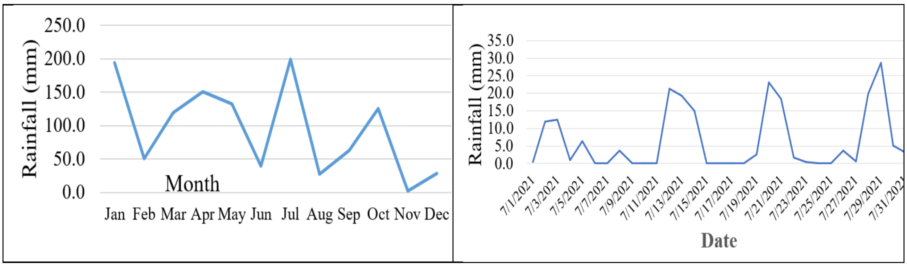


Figure 13. Rainfall data of Honzar, Kishtwar region

7. Conclusions

Prima-facie, the damages observed at the lower hamlet of Honza village, are assessed to have been inflicted by the gush of water laden with big size boulders flowing with a high velocity. The exact location of the cloudburst is not yet known and is assumed to be about 5.5 kilometers in the upstream of Nala from the village of Honzar. The study also suggests that this event may have occurred only in the first or second order stream in the basin catchment area of about 56,094 square meters. High relief, presence of overburden material, weathered rock mass, forces near thrust zone are highly influential for landform modification during high precipitation conditions in the Himalayan region. The debris flow along with water was the main cause of destruction at Honzar village. However, debris has covered about 1 km2 area in a gentle slope with a debris thickness of up to 10 m. The thick pile of debris spread in fan form buried agriculture land along with human dwellings and other structures which resulted in loss of human lives and livestock. Due to lack of bank erosion/toe erosion protection measures, the piedmont slope of Honzar village was more affected by debris laden gush of water. The impact was so sudden that the people were unable to comprehend the event and had little time to react.

8. Recommendations

Considering the recent incidence of cloudburst impacts, following temporary measures may be implemented to reduce the risk to life and property-

- Efforts should be made to avoid construction of human dwellings close to the nala beds or on the flanks of tributary nala. This may be ensured specially on T0/T1 level terraces.
- Construction of suitably designed retaining walls at nala level to minimize the toe erosion.
- Present flood levels of stream/Nala may be taken as a crucial factor for assessing the risk factor for future planning and construction of human dwellings and other infrastructural facilities in the area.

- Considering the increase in the frequency of such incidents, it is highly recommended that better land use practices should be adopted in high-risk areas to minimize the risk. In addition, an early warning system should be set up and with the help of this warning system, advisories can be issued in the area.

References

1. Bahuguna Harish, Paul, Q. Abdul, Khan, Kumar Parveen, Khan Imran, 2021: Geological Assessment of Hazards Associated with Cloud bursts and Extreme Weather Events - A Case Study from Kishtwar and Anantnag Areas of Jammu and Kashmir, Conference: 5th World Congress on Disaster Management, 24th - 27th November, New Delhi, India.
2. Bahuguna Harish and Khan Imran, 2022: Analysing of Genetic Controls of Landslide Distributions in Jammu and Kashmir Himalaya. Bulletin Series B No. 74, ISSN: 0445-622X, Geological Survey of India, July 2022.
3. Bookhagen, B., Burbank, D.W., 2006: Topography, relief, and TRMM-derived rainfall variations along the Himalaya. Geophysical Research Letters,33, L08405, 1-5, doi:10.1029/2006GL026037.
4. Das, S., Ashrit, R., Moncrieff, M.W., 2006: Simulation of a Himalayan cloud burst event. Journal of Earth System Science, 299-313.
5. Das, P.K., 2015: Global warming, glacial lakes and cloud burst events in Garhwal-Kumaon Himalaya: A hypothetical analysis. International Journal of Environmental Sciences 5 (4), 697-708.
6. Deoja, B., Dhital, M., Thapa, B., Wagner, A., 1991: Mountain Risk Engineering Handbook, Part I&II. ICIMOD, Kathmandu, Nepal. 875.
7. Dimri, A.P., Chevuturi, A., Niyogi, D., Thayyen, R.J., Ray, K., Tripathi, S.N., Pandey, A.K., Mohanty, U.C., 2017: Cloudbursts in Indian Himalayas: A review. Earth-Science Reviews 168, 1- 13.
8. DMMC, 2014: Geological investigations of Rudraprayag district with especial reference to slope instability. Disaster Mitigation and Management Centre, Department of Disaster Management, Government of Uttarakhand, 106.
9. Dortch, J.M., Owen, L.A., Schoenbohm, L.M., Caffee, M.W., 2011: Asymmetrical erosion and morphological development of the central Ladakh Range, northern India. Geomorphology, doi:10.1016/j. geomorph.2011.08.014.
10. Haeberli, W., Schaub, Y., Huggel, C., 2016: Increasing risks related to landslides from degrading permafrost into new lakes in deglaciating mountain ranges. Geomorphology, doi: 10.1016/j.geomorph.2016.02.009.
11. Herman, F., Beaud, F., Champagnac, J.D., Lemieux, J.M., Sternai, P., 2011: Glacial hydrology and erosion patterns: A mechanism for carving glacial valleys. Earth and Planetary Science Letter, 310, 498-508, doi:10.1016/j.epsl.2011.08.022.

12. Hobley, D.E.J., Sinclair, H.D., Patience,A.C., 2010: Processes, rates, and time scales of fluvial response in an ancient post glacial landscape of the northwest Indian Himalaya. Geological Society of America Bulletin, 1569-1584.

13. Immerzeel, W.W., van Beek, V.P.H., Bierkens, M.F.P., 2010: Climate Change will affect the Asian Water Towers. Science, 328/5984, 1382-1385, doi:10.1126/science.1183188.

14. IMD, Climatology of the Himalayas and neighborhood, 2003: Published by India Meteorological Department, NCC, ADGM(r) Office.

15. Jamieson, S.S.R., Sinclair, H.D., Kirstein, L.A., Purves, R.S., 2004: Tectonic forcing of longitudinal valleys in the Himalaya: morphological analysis of the Ladakh Batholith, North India., (1-4), 49-65.

16. Khan Imran and Mandotra Varun, 2019: Landslide Susceptibility Mapping Using Remote Sensing, GIS and Field Inputs: A case study from Basohli- Bani Road corridor, Northwest Himalaya, Jammu and Kashmir, India, Conference: INDOROCK-2019 (8th Indian Rock Conference), New Delhi

17. Khan Imran, Kumar Parveen, Bahuguna Harish, 2021: Geogenic Control over the Landslide Incidences along Mughal Road, Jammu and Kashmir, ISEG - Indian National Group of IAEG, Proceedings of International Conference EGCON – 2021, 9th to 11th December 2021 (Virtual Mode), Page no. 478-483.

18. Khanduri, S., 2018: Hydro-meteorological disaster in Chamoli district of Uttarakhand Himalaya, causes and implications. Scholar's press, Germany, 45.

19. Khanduri, S., Sajwan, K.S., 2019: Flash floods in Himalaya with especial reference to Mori tehsil of Uttarakhand, India. International Journal of Current Research in Multidisciplinary 4 (9), 10-18.

20. Kumar, M.S., Shekhar, M.S., Rama Krishna, S.S.V.S., Bhutiyani, M.R., Ganju, A. 2012. Numerical simulation of cloud burst event on August 05, 2010: over Leh using WRF mesoscale model. Natural Hazards, 62 (3), 1261-1271.

21. Linsbauer, A., Frey, H., Haeberli, W., Machguth, H., Azam, M.F., Allen, S., 2016: Modelling glacier bed over deepenings and possible future lakes for the glaciers in the Himalaya-Karakoram region. Annals of Glaciology, 57, (71) (doi:10.3189/2016AoG71A627).

22. Masoudian, M., 2009: The topographical impact on effectiveness of flood protection measures (Ph.D. thesis). Faculty of Civil Engineering, Kassel University, Germany.

    <http://www.uni-kassel.de/upress/online/frei/978-3-89958-790-6.volltext.frei.pdf>. Visited on 2013-12-10.

23. Medina, S., Houze Jr., R.A., Kumar, A., Niyogi, D. 2010. Summer monsoon convection in the Himalayan region: Terrain and land cover effects. Quarterly Journal of the Royal Meteorological Society, 593-616.

24. Pai D.S., Latha Sridhar, Rajeevan M., Sreejith O.P., Satbhai N.S. and Mukhopadhyay B., 2014: Development of a new high spatial resolution (0.25° X 0.25°)Long period (1901-2010) daily gridded rainfall data set over India and its comparison with existing data sets over the region; MAUSAM, 65, 1(January 2014), pp1-18.
25. Paul, Q. Abdul, Khan Imran, Bahuguna Harish, 2021: Analysing the recent incidence of reported cloudburst near Shri Amarnath Ji Holy Cave area, district Anantnag, Jammu and Kashmir, ISEG - Indian National Group of IAEG, Proceedings of International Conference EGCON – 2021, 9th to 11th December 2021 (Virtual Mode), Page no. 573-581.
26. Rasmussen, K.L., Houze Jr., R.A., 2012: Flash flooding at the steep edge of high terrain: Disaster in the Himalayas. Bulletin of the American Meteorological Society, 93,1713-1724.
27. Sangode, S.J., Phadtare, N.R., Meshram, D.C., Rawat, S., Suresh, N., 2011: A Record of Lake Outburst in the Indus Valley of Ladakh Himalaya, India. Current Scienec, /9,1712-1718.
28. Sangode, S.J; Meshram, C.D., Rawat S., Kulkarni Y., Chate M. D., Gudadhe S.S., 2017: Sedimentary and Geomorphic Signatures of a Cloud burst and triggered flash floods in the Indus valley of Ladakh Himalaya, Himalayan Geology, Vol. 38 (1), 2017, pp. 12-29.
29. Scherler, D., Bookhagen, B., Strecker, M.R., 2011: Spatially variable response of Himalayan glaciers to climate change affected by debris cover. (Online publication), doi: 10.1038/NGEO1068.
30. Sah, M.P., Mazari, R.K., 2007: An overview of the Geoenvironmental status of the Kullu Valley, Himachal Pradesh, India. Journal of Mountain Science 4, 3-23.
31. Singh, G.S., Sen, K.K., 1996: Causes and Consequences of Cloudbursts at Kullu district in the Himanchal Himalaya. Himalaya Paryavaran 4 (1), 13-16.
32. R.R. Woolley, R.E. Marsell, N.C. Grover, 1946: Cloudburst Floods in Utah, 1850-1938 US Government Printing Office (1946).
33. **Web Source:** www.gsi.gov.in

Immersive Virtual Reality Applications to Train Operators for Emergency Preparedness

Naveen Rastogi*, Krishan Kumar Gotewal, Ravi Ranjan Kumar, Manoah Stephen Manuelraj and Jigneshkumar P. Chauhan

Abstract

A tool capable of simulating various types and intensities of emergencies and providing users of the tool an opportunity to interact with such situations for effective mitigation helps in capacity building of the users/operators in management of emergencies effectively without actually going through the emergency. This not only ensures in understanding the emergency and its behavior but ensures proper and quick response strategy for emergency situations. This not only ensures safety of operators but also equipment/machinery. This paper presents applications of immersive virtual reality as an advanced tool for quick and interactive training of the operators by simulating different customized disaster scenarios without need of costly mock up facilities and also without any risk to operator or equipment. Considering dynamic nature of emergencies the decision making process has to be quick and for an inexperience operator is critical as well as complex task. Handling and taking important decisions in such scenarios require complete concentration as humans are prone to commit errors in such stressful conditions. The best possible way to ensure proper response is through rigorous training by simulating all probable scenarios with realistic conditions. Using immersive virtual reality, highly realistic and interactive training scenarios can be modelled, programmed and configured to suit the actual conditions as expected in the real world. It also does not have any limitation with respect to the scale and conditions as would be expected in developing physical mock up training facilities. This paper presents the virtual reality applications in emergency preparedness & handling. It also presents the virtual reality systems and applications developed at IPR, Gandhinagar for disaster management.

Key words: *Virtual Reality, Emergency Preparedness, Disaster Management, Operator Training*

1. Introduction

A well trained and experienced response teams who have practically handled emergencies can work more efficiently in relief & rescue. All industries/ organizations though will like to have 100% experienced response force/staff who have handled emergencies but practically it is not feasible. Firstly because of dynamic nature of emergency and secondly cost involved for creating he scenario as well as safety of the staff. To give the operator a real and/or believable experience of various types and categories of emergencies, Virtual

Reality (VR) technology can be extremely useful in equipping operators to deal with different types and category of simulated virtual emergency situations. IVR is a man–machine interface between human and computer, 3-D objects, objects having a spatial presence independent of the user's position, and the user manipulating objects using a variety of motor channels. This also can be effectively used for familiarizing staff with routine operating and maintenance procedures. As Emergency response drills are very difficult to be practiced under real-world operating conditions, standardized & customized virtual environments can be developed and programmed to simulate the actual operating conditions which allow operators to learn how to respond accurately to critical situations and also to carry out routine operation and maintenance tasks more efficiently (Xie et al. 2021). VR-based operator training simulators are adopted by various government/private organizations globally.

A well trained and experienced response teams who have practically handled emergencies can work more efficiently in relief & rescue. All industries/ organizations though will like to have 100% experienced response force/staff who have handled emergencies but practically it is not feasible. Firstly because of dynamic nature of emergency and secondly cost involved for creating he scenario as well as safety of the staff. To give the operator a real and/or believable experience of various types and categories of emergencies, Virtual Reality (VR) technology can be extremely useful in equipping operators to deal with different types and category of simulated virtual emergency situations. IVR is a man–machine interface between human and computer, 3-D objects, objects having a spatial presence independent of the user's position, and the user manipulating objects using a variety of motor channels. This also can be effectively used for familiarizing staff with routine operating and maintenance procedures. As Emergency response drills are very difficult to be practiced under real-world operating conditions, standardized & customized virtual environments can be developed and programmed to simulate the actual operating conditions which allow operators to learn how to respond accurately to critical situations and also to carry out routine operation and maintenance tasks more efficiently (Xie et al. 2021). VR-based operator training simulators are adopted by various government/private organizations globally.

2. What is Immersive Virtual Reality?

Immersive Virtual Reality (VR) is an advanced technique to provide a realistic perception to the users if they are located in the environment. These virtual environments are created with the high quality graphic rendering, images of real environment, programming the sounds and other effects etc. (Zheng, Zhu, and Yu 2020). The user's experience of a virtual environment has improved greatly, in the last decade, with the advent of visualization techniques such as 3D stereoscopic projectors and head mounted devices (HMD), faster graphical computation capability of desktop systems and tactile feedback devices like haptic force feedback joysticks and data-gloves. This has also opened new application areas of VR, from just being a gaming/entertainment platform to an advanced technological tool for training, simulation, design and collaborative reviews. VR environments are consistently used for CAD product development, product design, gaming, operation management etc.

2. Objective of the Paper

This paper provides a perspective on how VR technologies can be explored to plan, schedule and prepare vital operator training scenarios for emergency preparedness. The paper is divided into four sections. Section 1 gives the introduction and brief overview of the VR applications in operator training. Section 2 provides a background on the past and ongoing activities on the use of VR as a training tool for disaster management. Section 3 discusses in detail the facilities available and applications and expertise developed at the Institute for Plasma Research, Gandhinagar to develop the VR based customized training platforms and the scheme for generating the VR based scenarios along with the hardware and software requirements and Section 4 provides the conclusions.

3. Virtual Reality in Disaster Management Training

The paradigm shifts in Disaster Management (DM) from Response & Relief to Preparedness entails visualization of disaster scenario and prepare community in efficient management of such scenarios to prevent/ minimize loss of life and property. Disaster being dynamic poses variety of situations for the same incident, which is difficult to create on ground for community to be trained. In most cases Table Top exercises/full scale dress rehearsals are conducted where assumptions are made not the real life scenario and hence lack realism. VR has been successfully demonstrated globally as a tool for operator training for responding to the emergency situations. The security and safety departments in the United States of America are extensively using VR based operator training platforms over the conventional training means like physical trials or mock drills. The users find the VR based interactive training interesting as it gives clear perceptions as expected in a real world scenario. This can be repeated multiple times without any need of a trainer or a classroom based teaching. VR based training scenarios provide real-life drills and tabletop exercises of varying scales. VR has been is categorically useful in cases where in an optimization of cost, time and labor is required to achieve a desired goal with minimum risk factors. (Kim 2014).

The VR based operator training finds application at various stages of the disaster management. Typically the operators can use it to prepare themselves for different use cases and scenarios, diagnosis of the type of disaster and can devise strategies to mitigate the risks involved. It can be extremely useful in ensuring preventive safety to personnel and the equipment. Certain disasters include human beings requiring evacuation which if not done properly results in stampede, chaos etc.

4. Taxonomy of Virtual Reality Application in Disaster Management

With VR, operators can be trained for decision making in such conditions by simulating scenarios with past experiences. This training can also be applied for search and rescue operations. Once the disaster is over, the complete efforts are put on assessing and reducing the damages, reconstructing the areas etc. With VR interactive platform, users can be trained for such tasks and also can use the platform as an assisting tool to carry out these operations. The figure 1 as presented by the authors in (Zhu and Li 2021) presents the taxonomy of VR applications in disaster management.

A general philosophy is that the more people are involved in what they are doing; the more information their brain retains. The authors in (E. Baukal, B. Ausburn, and J. Ausburn 2013) proposed a Multimedia Cone of Abstraction (MCoA) as an upgrade to the conventional Edgar Dale's Cone of Experience (CoE) (Wagner 1970). This cone presents the classification of various modes of user interactions and relating this to retention in the user's brain. With the technological advancement in the user experiences, one can now develop realistic scenarios by combining the images, videos, sounds etc. and add interactions with the help of software programming. It has been found that users can retain the learning far better by using the VR based realistic experiences than the conventional mode of learning through books, classroom teaching, multimedia presentations etc. The cone in image indicates that one can have maximum retention in brain if using virtual reality (refer figure 2).

5. Virtual Reality in Operation & Maintenance of Critical Facilities

Virtual reality utilization pertaining to maintenance and safety management of nuclear reactors has also been explored at various installations. As reported in (Iguchi, Louka, and Johnsen 2004), the authors provide an in depth overview of the 'VRdose' software in context of the Fugen decommissioning project. The VR tool helps in planning and testing of operations in restricted places of the nuclear facility. A similar facility and application is also developed at CEA, France - Marcoule facility (Szke et al. 2014). A specialized software called 'iDROP' is developed that can be used for dose rate calculation, planning operations, human-environment interactions, monitoring and control of remote handling equipment etc. Immersive VR simulations will help to check preparedness of

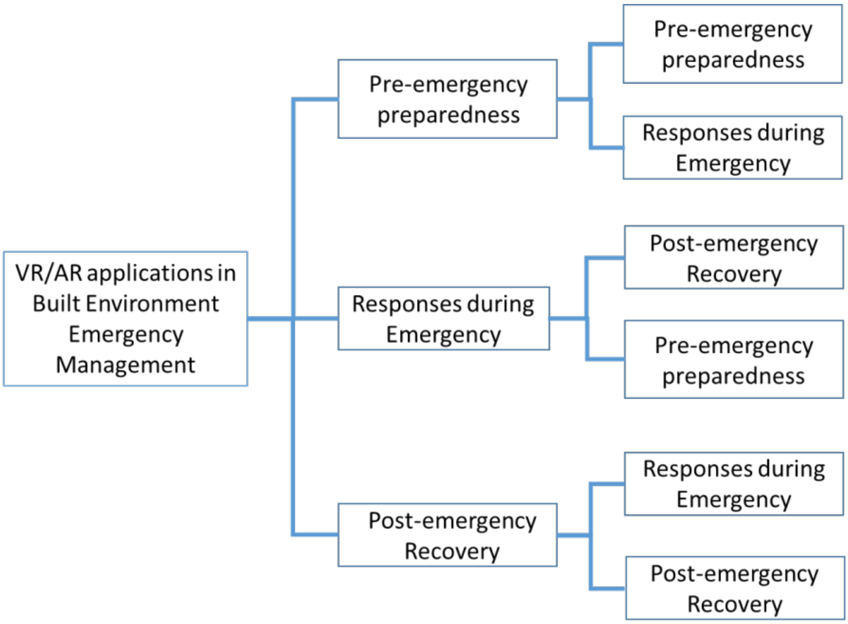


Figure 1. Taxonomy of VR applications in disaster management

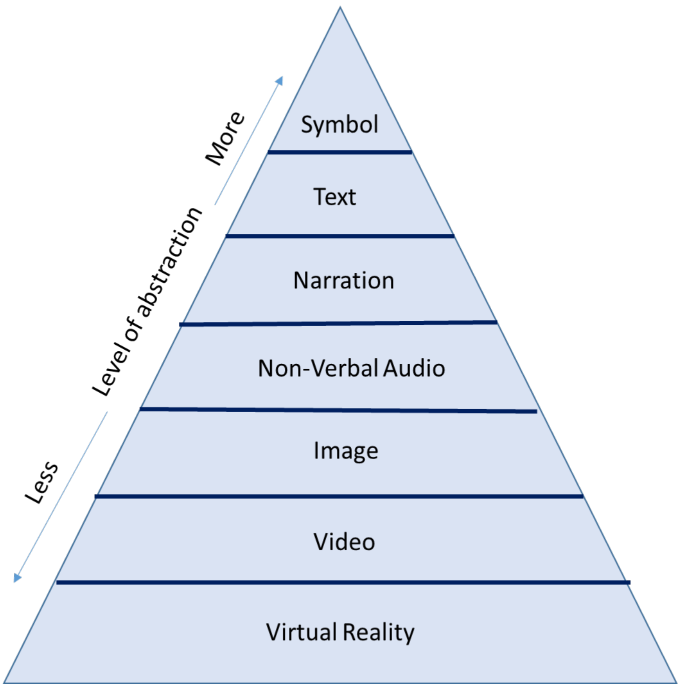


Figure 2. Multimedia Cone of Abstraction

future actions that involve verifying scenarios, designing remote handling systems, studying accessibility, optimizing the operating workstation and training operators. The VR software enables superimposition of radioactivity levels during from real-time monitors onto the virtual model. (Whisker et al. 2003) provides guidelines and approaches for using VR effectively for safety analysis, dose-rate monitoring and operation training in nuclear facilities.

6. Developments in the field of Immersive Virtual Reality- Institute for Plasma Research

The Facility: A three Sided fully immersive integrated Virtual Reality CAVE facility has been fully commissioned, tested and demonstrated successfully at RHRTD lab, IPR (refer figure 3 and figure 4). The facility is seamlessly compatible with various design and modelling software like CATIA v5, Solidworks, 3D via composer etc. The users can load the 3D models of the machines/systems in the VR facility and it can be instantly viewed as 3D immersive models using the stereoscopic glasses and feel as if they are actually present in the virtual environment. The facility has in built head/hand tracking and the haptic arm using which users can navigate and interact with the models.

Various features include virtual assembly, collision detection, animations, navigation, zoom in/out, fly through, cutting planes, snapshots etc. It is extremely useful is remote handling as the remote handling operations are very dynamic and it would be better if the operators controlling the remote handling equipment is well known with the environment and have access to all the task as well as environment details in the VR as it would have been if the user is physically located in the work-cell (Dutta, Rastogi, and Gotewal 2017).

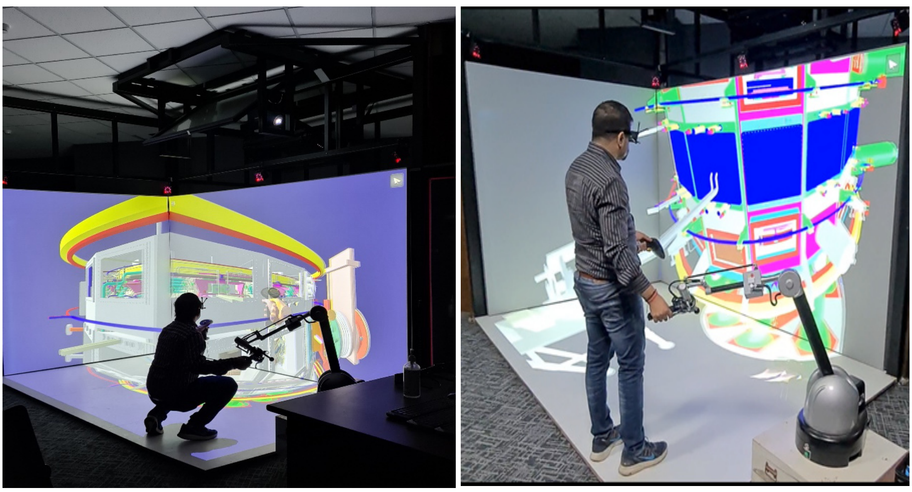


Figure 3. VR Cave facility at IPR

System Input Requirement: The major inputs required for modelling the virtual environments are CAD model or dimensions of the building/machine, the details of the disaster scenario and the corresponding actions required to set up a simulation case.

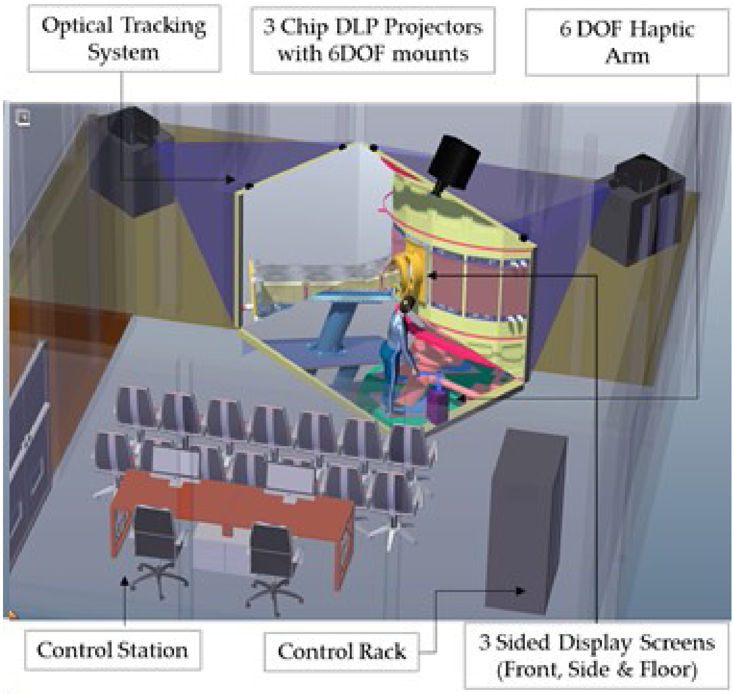


Figure 4. Layout of VR facility at IPR

System Application: Human resource training is one of the most essential requirement for any maintenance or decommissioning procedure. Operator training is a must when a human presence is required to perform a certain task to ensure personnel and equipment safety. In such cases it is mandatory to train personnel in carefully tackling the challenges of the task before entering the actual environment. The VR applications is such cases may involve making the personnel familiar to the environment using a VR platform and also to train the personnel for various interactive tasks.

An interactive operator training application as given in figure 5 is developed to train the manpower for a probable gas leak/fire scenario inside a tokamak device where the step by step instructions are made available to the operator. The user navigates and performs the steps in the virtual environment and properly extinguish the fire following all relevant safety guidelines. The user wears the HMD display and is tracked and can interact within the environment.

Once the steps are over and the fire is extinguished, a message of completion is displayed along with the time taken to complete the task. It was observed that the time taken can be reduced substantially with practice as the user becomes known with the environment.

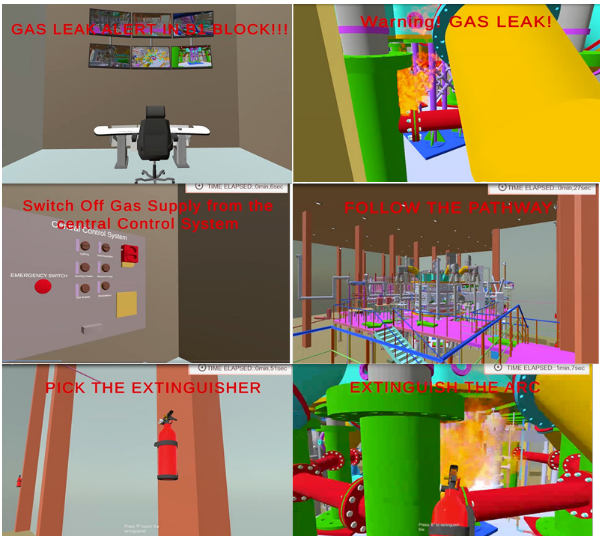


Figure 5. TOKAMAK Operator Training Module

Also, Figure 6 demonstrates a VR based operator training simulator has been developed at IPR which can be used for path planning inside a radiation environment such as nuclear reactors. In this simulator, the operator can use the immersive virtual reality to plan his path for a task while consuming minimum radiations. The system can be easily configured with the walking or running speeds, head movements, lighting conditions, etc. to develop a realistic scenario of the actual conditions as expected in the real world.

Figure 6. VR Navigation Simulator for Challenging Environments

Figure 7 shows an application on immersive virtual walkthrough of a tokamak like environment. Such VR based immersive walkthrough can be used to train personnel about the hazards and potential inaccessible/restricted areas in the real environment.

Figure 7. Virtual Walkthrough

The walkthrough uses a Head Mounted Display (HMD) to make the user feel immersed into the tokamak environment and can view all components in 1:1 scale. Using a simple industrial joystick, the user can get safely accustomed and navigate within the environment. Such simulations can also include details of known critical areas using spatial color mapping. This will enable the personnel for path planning & plan their entry and exit locations properly.

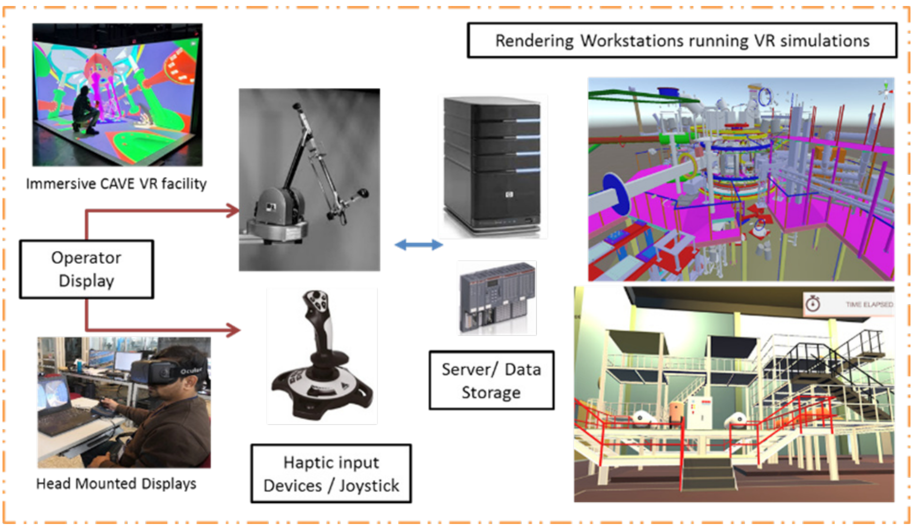


Figure 8. VR System Architecture

The VR simulations can be modelled using software tools and can be programmed for the desired scenarios. The operator can visualize the immersive views of the environment by using either Head Mounted displays (HMD) or a 3D projection display like CAVE VR facility. The VR training experience can be enhanced by integrating with various hardware devices to provide sensory feedback (refer figure 8). These devices include haptic arms, data gloves, pinch device, etc. The haptic arm provides force/tactile feedback on the operator's hands for perception of the forces during the interactions with virtual objects as experienced in actual conditions.

Also, advanced interactive features like collision detection, virtual measurements, virtual assembly, etc., can be made available to operators. VR can also be used during actual physical operations for assisting the operators and monitoring & controlling of the operations (Rastogi et al. 2017).The operator can use the haptic arm/joystick with VR visualization to remotely control real robotic devices/manipulators located far away from the control room. This can be very useful in search and rescue operations, bomb diffusion, etc.

Challenges Ahead: Global Warming as a result of Climate Change is largely impacting Decision Support System in most of the sectors. Convergence of disaster impacts for which statistical data are available and climate change which is predictive in nature, it will be a challenge before scientific community to converge impacts of both. This if developed the community will be prepared to meet future challenges.

4. Conclusions

With Immersive VR, a 3D artificial environment that looks exactly like real world can be created using a computer and the operator feels as if he/she is physically present in the environment and can also interact with virtual objects in the environment. Manpower can be trained with realistic 3D simulations representing actual disaster scenarios like Nuclear/ chemical/ biological accidents or Recovery/relief operations for Cyclone/ earthquake/ landslide/ flood scenarios, etc. Because of various constraints like legal, environmental, safety etc., it becomes extremely difficult to physically create the simulation environments of such scale and add all the effect as would be present during a disaster. Also, training costs are reduced as there is no need of any physical mock drills, The VR based training are easily scalable and with no limitations on size as 1:1 scale machines can be modelled. VR immensely helps the operator to get well acquainted with the task environment and the disaster scenarios. The simulations can be repeated any number of times to assess and understand the disaster effects, planning and quick decision making for the disaster management.

References

1. Dutta, Pramit, Naveen Rastogi, and Krishan Kumar Gotewal. 2017. "Virtual Reality Applications in Remote Handling Development for Tokamaks in India." *Fusion Engineering and Design* 118: 73–80.E.
2. Baukal, Charles, Floyd B. Ausburn, and Lynna J. Ausburn. 2013. "A Proposed Multimedia Cone of Abstraction: Updating a Classic Instructional Design Theory." *i-manager's Journal of Educational Technology* 9(4): 15–24.
3. Iguchi, Yukihiro, Michael Louka, and Terje Johnsen. 2004. "VRdose: An Exposure Dose Evaluation System Based on Virtual Reality Technology - Current Status and Future Possibilities." In HPR--363-V1, Norway.

   https://inis.iaea.org/search/citationdownload.aspx (August 4, 2022).
4. Kim, Wansub. 2014. "A BUILDING DAMAGE AND SAFETY ASSESSMENT WITH MOBILE AUGMENTED REALITY."
5. Rastogi, Naveen, Amit Kumar Srivastava, Pramit Dutta, and Krishan Kumar Gotewal. *2017. "Virtual Reality Based Monitoring and Control System for Articulated In-Vessel Inspection Arm." In 2017 IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI)*, IEEE, 1728–31.

   https://ieeexplore.ieee.org/document/8392009/ (June 28, 2018).
6. Szke, István et al. 2014. "Comprehensive Support for Nuclear Decommissioning Based on 3D Simulation and Advanced User Interface Technologies."

   http://dx.doi.org/10.1080/00223131.2014.951704 52(3): 371–87.

   https://www.tandfonline.com/doi/abs/10.1080/00223131.2014.951704 (August 4, 2022).
7. Wagner, Robert W. 1970. "Edgar Dale: Professional" Theory Into Practice 9(2): 89–95. http://www.jstor.org/stable/1475566.
8. Whisker, V. E. et al. 2003. "Using Immersive Virtual Environments to Develop and Visualize Construction Schedules for Advanced Nuclear Power Plants." *2003 International Congress on Advances in Nuclear Power Plants - Proceedings of ICAPP 2003*.
9. Xie, Biao et al. 2021. "A Review on Virtual Reality Skill Training Applications." *Frontiers in Virtual Reality* 0: 49.'
10. Zheng, Liguo, Meili Zhu, and Hongwei Yu. 2020. "A Virtual Environment Making Method for CAVE System." *Proceedings - 2020 International Conference on Computing and Data Science, CDS 2020*: 377–80.
11. Zhu, Yiqing, and Nan Li. 2021. "Virtual and Augmented Reality Technologies for Emergency Management in the Built Environments: A State-of-the-Art Review." *Journal of Safety Science and Resilience* 2(1): 1–10.

    https://doi.org/10.1016/j.jnlssr.2020.11.004.

Enhancing Disaster Resilience: An Examination

Abin George* and Manjunath P

Abstract

Disasters have significant social, economic, and environmental impacts, necessitating effective measures to reduce risks and mitigate their consequences. The purpose of this study is to examine the strategies and frameworks employed in disaster risk reduction and mitigation, with a focus on disaster resilience. This includes aligning frameworks with global best practices, evaluating stakeholder engagement, examining climate change adaptation integration and assessing resource allocation efficiency. These frameworks and strategies will be examined through case studies for their real-world outcomes. The insights gained in this study can enhance the effectiveness of disaster risk reduction and mitigation efforts in central government organizations.

Key words: *Disaster Risk Reduction, Mitigation, Frameworks, Strategies, Case Studies.*

1. Introduction

Disasters, whether natural or human-made, pose significant challenges to societies and require effective strategies and frameworks for risk reduction and mitigation. Central government organizations play a crucial role in disaster management, as they are responsible for formulating policies, coordinating response efforts, and ensuring the safety and well-being of their populations. In this context, the assessment of frameworks and strategies for disaster risk reduction and mitigation in central government organizations becomes essential to evaluate their effectiveness, identify areas for improvement, and enhance overall resilience. Assessing these frameworks and strategies involves a comprehensive examination of the policies, plans, and actions implemented by central government organizations to reduce disaster risks and mitigate their impacts. By conducting such assessments, governments can identify strengths, weaknesses, and gaps in their disaster risk reduction approaches, leading to evidence-based decision-making and the implementation of targeted interventions. By examining case studies, evaluating existing practices, and identifying areas for improvement, this research will provide insights that can inform policy recommendations, enhance resilience, and contribute to the overall goal of reducing disaster risks and protecting communities. The assessment of frameworks and strategies for disaster risk reduction and mitigation in central government organizations is a critical endeavor in building disaster-resilient societies. By evaluating and enhancing these frameworks, governments can better protect their populations, minimize the impacts of disasters, and foster sustainable development even in the face of increasingly complex and frequent hazards.

1.1 Background of the Study: Disasters, such as earthquakes, floods, hurricanes, and pandemics, have devastating consequences on societies, causing loss of lives, widespread destruction, and significant socio-economic disruptions. Recognizing the need to effectively address these risks, central government organizations play a crucial role in disaster risk reduction and mitigation. They are responsible for formulating policies, coordinating response efforts, and ensuring the safety and well-being of their populations. However, the effectiveness of disaster risk reduction and mitigation efforts undertaken by central government organizations varies across countries and regions. Factors such as institutional capacity, governance structures, financial resources, and "political will" significantly influence the outcomes of these initiatives. By conducting systematic assessments, policymakers and practitioners can gain valuable insights into the effectiveness of existing frameworks and strategies. These assessments can identify gaps, bottlenecks, and challenges in the implementation process, leading to evidence-based decision-making and the development of targeted interventions. Moreover, they enable cross-country comparisons, promoting knowledge sharing and the adoption of successful practices in disaster risk reduction and mitigation.

Understanding the strengths and weaknesses of frameworks and strategies employed by central government organizations is crucial in improving disaster management outcomes. By examining case studies, evaluating existing practices, and identifying areas for improvement, this research intends to contribute to the body of knowledge on disaster management and provide valuable insights for policymakers, practitioners, and stakeholders involved in disaster risk reduction efforts.

1.2 Research Rationale: The research is rooted in the critical need to enhance the overall resilience of Nations and communities in the face of escalating natural and human made disasters. This rationale is driven by several compelling factors like increasing frequency and intensity of disasters, government responsibility, human and economic toll, global agreements and commitments, efficient resource allocation, learning from past experiences, rising climate change impact, accountability and transparency and innovation and technological advancements. The world is witnessing a rise in the frequency and intensity of disasters, including earthquakes, floods, wildfires, and extreme weather events. These events pose significant threats to lives, infrastructure, economies, and the environment. Disasters cause substantial loss of life, displacement of populations, and economic disruptions. Central government organizations bear the responsibility of minimizing these impacts and ensuring the safety and well-being of citizens. International frameworks like the Sendai Framework for Disaster Risk Reduction emphasize the importance of aligning national policies with global goals. Central governments need to assess their strategies to ensure compliance and effectiveness. Effective disaster risk reduction and mitigation strategies require proper allocation of resources. An assessment helps central government organizations identify gaps, redundancies, and areas that require increased investment. Historical disaster events offer valuable insights into the strengths and weaknesses of existing frameworks and strategies. Climate change amplifies disaster risks. Central government organizations need to ensure their strategies are adaptive and resilient in the face of changing climate patterns. Rapid technological advancements offer new tools and methods for disaster management. Disaster management is a dynamic field. An assessment allows central government organizations to identify areas for improvement, update policies, and ensure their strategies remain effective over time, for disaster risk reduction and mitigation.

1.3 Research Objectives:

- To study the alignment of disaster risk reduction and mitigation strategies and frameworks employed by central government organizations with global best practices and standards.
- To conduct case studies examining the real-world outcomes and experiences of disaster risk reduction and mitigation strategies and frameworks employed by central government organizations, identifying successful practices and challenges encountered.

These objectives questions collectively aim to provide a comprehensive understanding of the current state of disaster risk reduction and mitigation efforts within central government organizations, offering insights into their effectiveness and areas for improvement to enhance disaster resilience at the national level.

2. Review of Literature

A recent study by (Eden, Gonzalez, & Jose, 2023), mentioned that one approach is to involve experts and power-brokers stakeholders in qualitative systemic risk assessment and the development of risk mitigation strategies. The Sendai Framework for Disaster Risk Reduction (SFDRR) is an international framework that aims to advance DRR policy globally. However, its implementation at the local level remains low. Machine learning methods and applications for disaster management are explored by (Linardos et al., 2022), which demonstrate machine learning's potential for risk assessment, prediction, and decision-making. The framework proposed by (Muzamil et al., 2022) for flood disaster management in Malaysia can be used for planning and implementing strategies tailored to the particular circumstances of Malaysia. In a systematic review of crisis and disaster management for halal tourism, (Sofyan et al., 2022) recognize the need for specialized strategies in the tourism sector to mitigate risks and maintain consumer trust in the industry. In informal settlements, stakeholders play a crucial role in disaster management, and awareness of disaster risk reduction policies is essential. Risk assessment and incorporating national and international policies and guidelines are recommended for successful disaster reduction measures by (Muriuki, Kei, & Muchiri, 2022).

According to (Abid et al., 2021), artificial intelligence can be employed to enhance disaster preparedness, response, and recovery. (Phengsuwan et al., 2021) reviewed social media data's potential for dissemination of information, situational awareness, and public participation in disaster management. Among the applications of artificial intelligence in disaster management are data analysis, resource optimization, and enhanced emergency response, according to (Sun et al., 2020). (Sood and Rawat, 2021) present a scientometric analysis of Information and communications technology (ICT)-assisted disaster management, assessing latest trends and advancements in the use of information and communication technologies for disaster response and mitigation. According to Sood and Rawat, a timely coordination of relief efforts in disaster areas is essential in order to minimize the damages resulting from such catastrophic events. There are several promising Internet of Things (IOT) technologies that can assist in the various stages of disaster management, including the Internet of Things, cloud computing, and data analytics. (Kim et al., 2021) utilizes recent developments in the literature to examine the current outbreak scenario and causes of rapid global spread of COVID-19. It explores the epidemiological features relevant to public health awareness and provides a critical perspective on risk assessment and mitigation strategies. The paper emphasizes the need for improvement in the performance of risk mitigation practices of future pandemic crises.

To improve implementation, researchers from developed countries should collaborate with universities and research councils in transition countries to enhance policy development and communication of research outcomes by (Tolulope et al., 2020). The study of Li et al. (2020) can be applied to measures for rapid assessment of sponge city strategies in flood control and decision making on urban green infrastructure planning. The approach proposed here can be applied to disaster mitigation through sponge city technologies. Urban flooding is a severe problem and a growing development challenge for many cities around the world. Therefore, there is an urgent need to introduce mitigation measures through managing rainwater to reduce these risks. The sponge city system is regarded as an effective mechanism to manage rainwater and reduce flooding, as it is capable of promoting infiltration and retaining rainwater. (Alexander, 2020) mentioned that disaster risk reduction requires a combination of physical and social measures, with the full participation of affected populations and stakeholders. It also emphasizes the importance of resilience as a positive concept for organizing DRR processes.

(Lee & Chen, 2019) stated that strategies for disaster governance for persons with disabilities should cover all phases of disaster management and incorporate bottom-up mechanisms such as stakeholder participation and consultation. According to (Yu et al., 2018) Big data has opened new options for natural disaster management, including the visualization, analysis, and prediction of natural disasters. This paper reviews the major big data sources, the associated achievements in different disaster management phases, and emerging technological topics associated with leveraging this new ecosystem of Big Data. (Pollner et al., 2010), mentioned that preparedness has been enhanced through the early warning system, the strategic grain reserve, and the development of standard guidelines for assessment and intervention. Humanitarian response can currently count on an established risk financing mechanism, better coordination, and improved resource management and prioritization. A recovery strategic framework guides the community recovery from disasters and the protection of livelihoods.

(Nepal et al., 2018) followed a methodological framework which involves the analysis of policies, institutional structures, legislative systems, types of disasters, levels of governance, the disaster management cycle, roles and responsibilities, as well as strengths, gaps, and constraints in Nepal's disaster risk management system. Institutional and Legislative Systems (ILS) approach was adopted to analyze existing legislations, policies, strategies, and institutional organizational structures for disaster risk management. The ILS approach includes organizational structures, mechanisms, processes, strategies, policies, laws, regulations, resources, and procedures at all levels of administration. The elements of ILS were grouped into three categories: legal and regulatory frameworks, policies and programs, and institutional/organizational structures.

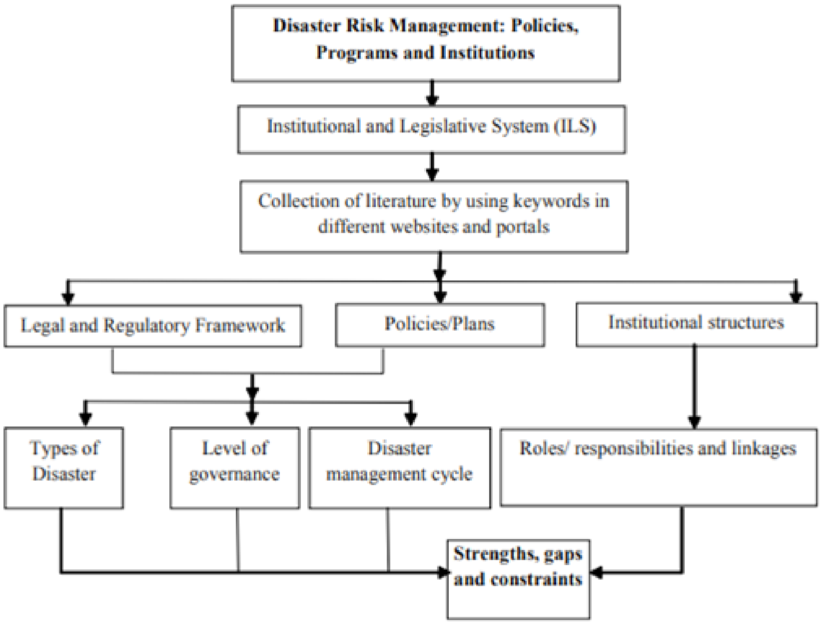


Figure1: Methodological Framework in "Policies and Institutions for Disaster Risk Management: A Review" by (Nepal et al., 2018)

3. Methodology

Thematic analysis, a qualitative research method is used to identify, analyze, and report themes within qualitative data. A SWOT analysis technique used to assess the strengths, weaknesses, opportunities, and threats related to the research topic. It involves identifying and analyzing internal and external factors that may impact the current study. SWOT analysis is primarily a subjective and exploratory approach, relying on the judgment and expertise of the researchers.

To provide a comprehensive overview of the disaster management framework in place, the Disaster Management Cell (DMC) for CSIR-NAL and CSIR-4PI, established in 2021, plays a pivotal role. The DMC comprises team members from various divisions and sections, viz., EBU (Estates and Building Unit), Electrical section, Security, Health Centre, Fire Safety Cell, ICTD (Information & Communication Technology Division). Transport and House Keeping sections are also supporting DMC. The team has worked out and published the "Disaster Management Plan for CSIR-NAL and CSIR-4PI, DMP-1.0". National Disaster Management Authority guidelines and reports were useful in preparation of our study. The following categories of disasters are recognized by the DMC as applicable to CSIR-NAL and CSIR-4PI.

A. ***Natural Disasters***

Cyclone (secondary effects in Bengaluru and not full cyclone)

Urban Floods

Lightning and Thunderstorms

Earth Quakes

B. ***Man Made Disasters***

Chemical

Biological

Fire

C. General Preparedness

Information & Communication

School

Health Centre

Training for Disaster Situations

Staff Quarters

For the identified disaster categories applicable to CSIR-NAL and CSIR-4PI, the disaster management plan contains the following:

a) Pre-Disaster: Plan for Prevention, Mitigation and Preparedness

b) During Disaster: Plan for immediate response

c) Post Disaster: Plan for recovery

Divisional/sectional representative are identified for DMC activities and they will be responsible for their own divisions and sections. They will get training and will be given lectures in fire safety and also in other appropriate aspects. For the differently abled persons of CSIR-NAL and CSIR-4PI, buddy pairs have been identified for each of the differently abled persons. The idea is to support and aid differently abled persons in a disaster situation. The DMC conducts monthly meetings to review and act largely on preventive aspect of disaster management on the various categories identified. In case of emergency situations, various sections, especially, Fire, Security, Health Centre, Electrical and Civil sections will work together to mitigate the effects of disasters.

3.1 Research Design: Given the topic's complexity and the need to assess multiple frameworks and strategies, a qualitative research design was adopted for the study. Qualitative methods allow researchers to capture the perceptions, opinions, and perspectives of various stakeholders involved in disaster management, including policymakers, government officials, and disaster management experts. Conducting in-depth interviews with key stakeholders can provide rich and nuanced data, allowing researchers to delve deeper into the complexities of disaster management. Qualitative research can involve analyzing documents, reports, and policy papers related to disaster risk reduction and mitigation. This analysis can provide historical context and reveal the evolution of policies and strategies over time.

3.2 Data Collection and Sampling: Data has collected using various qualitative methods to gather rich and in-depth insights from key stakeholders through in- depth Interviews, focus group discussions, document analysis, observations and case studies. Analysed relevant documents, reports, and policies related to the CSIR- NAL office, NDMA and its activities.

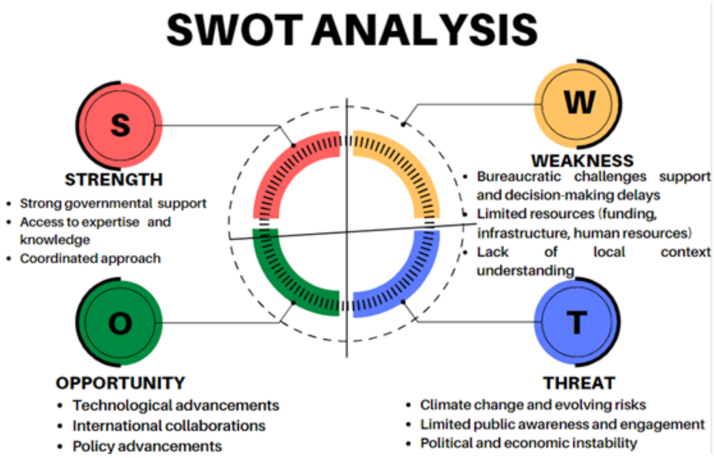


Figure 2: SWOT Analysis

The following are a few case studies illustrating how disaster risk reduction and mitigation strategies and frameworks can enhance disaster resilience around the globe.

Case Study 1: Community-Based Disaster Risk Reduction in Nepal: Turtoi, 2022 mentioned that the Nepal is a country highly vulnerable to earthquakes and landslides due to its location on the seismically active Himalayan belt. It highlights the need to reassess the concept of community and its role in disaster mitigation, taking into account issues such as indigenous people's participation, resource sharing, gender concerns, and communication. In response to the 2015 earthquake that caused significant loss of life and widespread damage, the government of Nepal implemented community-based disaster risk reduction (CBDRR) programs to enhance resilience at the local level. The case study reveals that CBDRR programs have empowered local communities through training in first aid, search and rescue, and early warning systems. The establishment of community disaster management committees has improved disaster response coordination, leading to reduced casualties and faster recovery during subsequent disasters. Despite the progress, challenges remain in ensuring sustainability and scaling up CBDRR initiatives to cover all vulnerable communities. The case study emphasizes the importance of community engagement and ownership in disaster risk reduction efforts. It underscores the need for continued government support and partnerships with NGOs to build community resilience in disaster-prone areas.

Case Study 2: Flood Mitigation and Coastal Resilience in the Netherlands: The Netherlands is a low-lying country with significant portions below sea level, making it vulnerable to flooding. According to (Tromp, te Nijenhuis, & Knoeff, 2022) Dutch Flood Protection Programme (DFPP) was established in response to the catastrophic floods of 1953, with the aim of preventing similar disasters and protecting the Netherlands from future flood risks. The Dutch government has implemented an integrated approach to flood risk reduction and coastal resilience, involving extensive flood defense systems and spatial planning. The case study reveals that the Netherlands' flood defense systems, including dikes, dams, and storm surge barriers, have been highly effective in preventing major flooding. Additionally, the country's approach to spatial planning has ensured that high-risk areas are designated for non-residential use, reducing exposure to flood hazards. The case study identifies challenges in maintaining and upgrading aging flood defense infrastructure and adapting to increasing sea level rise due to climate change. The Netherlands' successful flood mitigation and coastal resilience approach serve as a model for other countries facing similar challenges. The case study emphasizes the importance of long-term planning, investment in infrastructure, and adaptive strategies in managing flood risks.

Case Study 3: Wildfire Risk Management in Australia: Australia is susceptible to severe wildfires, especially during dry and hot weather conditions. (Keating & Handmer, 2022) stated that the Australian fires of 2019/20, known as 'Black Summer,' exemplify the increasing trends of wildfires and the potential impacts of climate change. Previously low-risk areas are increasingly exposed to wildfires, while already at-risk areas are experiencing more frequent and severe fires. In response to devastating wildfires, the Australian government has developed comprehensive wildfire risk management strategies, including early warning systems, fire prevention measures, and community education campaigns. The case study reveals that Australia's early warning systems and firefighting capabilities have contributed to faster response times and reduced wildfire spread. Community education programs have raised awareness and improved community preparedness. Challenges include balancing wildfire prevention measures with ecological concerns and the increasing threat of extreme weather events due to climate change. The case study emphasizes the importance of integrated approaches to wildfire risk management, involving coordinated efforts from various government agencies, firefighting services, and community stakeholders. It highlights the need for continuous adaptation to evolving wildfire risks and the role of public awareness in enhancing community resilience.

Case Study 4: Flood Management in Bangladesh: Bangladesh is situated downstream of more than 200 rivers, including the Ganges, Brahmaputra, and Meghna, making it vulnerable to floods by (Gulsan Ara Parvin et al., 2018). The country experiences a significant amount of rainfall, with an average of 2,200-2,500 mm annually, and 80% of the rainfall occurs during the monsoon period from June to September.

Bangladesh is a low-lying deltaic country prone to seasonal flooding and cyclones. The government of Bangladesh has implemented an integrated flood management approach, combining structural measures, such as embankments and flood shelters, with non-structural measures, such as early warning systems and community-based flood preparedness. The case study reveals that Bangladesh's flood management strategies, including the construction of embankments and cyclone shelters, have provided a measure of protection to communities during seasonal floods and cyclones. Early warning systems have enabled timely evacuations and reduced loss of life. Challenges include the need for continuous maintenance and improvement of embankments and flood infrastructure, as well as addressing the socio-economic impacts of recurrent flooding on vulnerable communities. The case study highlights the importance of a multi-faceted approach to flood management, combining engineering solutions with community engagement and disaster preparedness. It emphasizes the need for adaptive strategies in the face of increasing climate variability and sea-level rise.

4. Findings and Discussions

Theme 1: Community Engagement and Empowerment in disaster management: The establishment of community disaster management committees highlights the importance of collaboration among local stakeholders for effective disaster response coordination. The case study emphasizes the role of community-based programs in empowering local communities with essential skills and knowledge in disaster response, search and rescue, and early warning systems. The role of community-based programs in empowering local communities with essential skills and knowledge in disaster response, search and rescue, and early warning systems. The establishment of community disaster management committees highlights the importance of collaboration among local stakeholders for effective disaster response coordination. Countries with communities that are aware of and participate in disaster risk reduction (DRR) activities will suffer less damage from disasters. While Community Disaster Resilience (CDR) follows the community systems model, even though there is no operational definition of CDR or model demonstration of how best to apply these principles, in practice in vulnerable communities. The CBDRR programs in Nepal have empowered local communities through training in disaster response and coordination. This has led to improved disaster preparedness, reduced casualties, and faster recovery during subsequent disasters. While the CBDRR programs have demonstrated success, challenges remain in ensuring the sustainability of these initiatives and scaling them up to cover all vulnerable communities. Communities have developed capacities to respond effectively during disasters, leading to reduced casualties and better management of resources. The establishment of committees has enhanced coordination among various community members, authorities, and organizations involved in disaster management. Communities are better prepared to handle future disasters, reflecting increased resilience through community engagement. Despite successes, challenges related to long-term sustainability, resource allocation, and addressing diverse community needs remain.

Theme 2: Infrastructure and Integrated Approaches in disaster management: Netherlands' integrated approach to flood risk reduction involves flood defense systems and spatial planning. This has effectively prevented major flooding, minimized exposure to flood hazards, and served as a model for coastal resilience strategies. Adequate investment in robust flood defense infrastructure has played a critical role in preventing major flooding events. The case study highlights the importance of adaptive planning to address sea-level rise due to climate change and the need for ongoing upgrades to aging infrastructure. The Netherlands' flood defense systems have effectively prevented major flooding, protecting communities and critical assets. Spatial planning has designated high-risk areas for non-residential use, minimizing exposure to flood hazards. The country's integrated approach serves as a model for other nations facing similar challenges in flood mitigation and coastal resilience.

Theme 3: Adaptation and Resilience in disaster management: Australia's wildfire risk management strategies include early warning systems and community education has improved community preparedness, reduced wildfire spread, and highlights the need for continuous adaptation to evolving wildfire risks due to climate change. Australia's strategies include early warning systems, fire prevention, and community education. Balancing wildfire prevention with ecological concerns and understanding fire's role in ecosystems is a key consideration. The increasing threat of extreme weather events due to climate change necessitates ongoing adaptation in wildfire risk management. Early warning systems and firefighting capabilities have led to faster response times, containing wildfires more effectively. Community education programs have raised awareness, leading to improved community preparedness and safer evacuation procedures. Balancing wildfire prevention with ecological considerations and adapting to climate change-induced risks remains a challenge.

Theme 4: Engineering and Socio-Economic Considerations in disaster management: Bangladesh's flood management approach combines structural measures (embankments) with non-structural measures (early warning systems). While these strategies have provided protection during floods and cyclones, challenges include addressing the socio-economic impacts on vulnerable communities and the need for continuous maintenance of infrastructure. Bangladesh's vulnerability to seasonal flooding and cyclones necessitates comprehensive strategies. Strategies focus on building community resilience through both infrastructure and preparedness measures. Embankments and cyclone shelters have provided protection during seasonal floods and cyclones, reducing casualties. Early warning systems have enabled timely evacuations, minimizing loss of life. Addressing socio-economic impacts of recurrent flooding on vulnerable communities remains a challenge, requiring ongoing efforts.

The implementation of community-based disaster risk reduction programs (Case Study 1) has shown significant success in empowering local communities and improving disaster response coordination, resulting in reduced casualties and faster recovery during subsequent disasters. The Netherlands' integrated approach to flood risk reduction as per Case Study 2, has demonstrated the effectiveness of flood defense systems and spatial planning in preventing major flooding and reducing exposure to flood hazards, setting a successful precedent for coastal resilience strategies. Case Study 3 indicates that the Australia's wildfire risk management strategies have resulted in improved community preparedness, faster response times, and reduced wildfire spread. The case study underscores the importance of continuous adaptation to evolving wildfire risks due to climate change. Bangladesh's flood management approach in Case Study 4 has provided protection to communities during seasonal floods and cyclones. However, challenges persist in maintaining infrastructure, addressing socio-economic impacts, and adapting to changing climate conditions. These case studies collectively highlight the importance of community engagement, integrated approaches, adaptation, and considering both engineering solutions and socio-economic factors in effective disaster risk reduction and mitigation strategies. They underscore the need for continuous improvement, adaptive strategies, and the role of community resilience in addressing the complex challenges posed by natural disasters.

These detailed themes show the complex and multifaceted nature of disaster risk reduction and mitigation strategies. They highlight the importance of community engagement, integrated approaches, adaptive strategies, and both engineering solutions and socio-economic factors to effectively manage and reduce the impacts of natural disasters.

5. Conclusions and Implications

The literature review reveals a diverse range of approaches and technologies employed in disaster management and climate change adaptation. Integrating emerging technologies like big data, artificial intelligence, and social media data can significantly enhance preparedness, response, and recovery efforts. Furthermore, the importance of gender considerations, community engagement, and specialized strategies for vulnerable sectors highlights the need for comprehensive and inclusive disaster management approaches. By synthesizing these findings, researchers and policymakers can better formulate effective strategies to build resilience and mitigate the impacts of natural disasters and climate change. By focusing on these central government organizations and associated bodies, the study seeks to provide valuable insights that can inform policy recommendations, enhance disaster management capabilities, and foster collaboration for effective disaster risk reduction and mitigation at both organisation level and also national level. The research is expected to contribute to the understanding and improvement of disaster management practices within central government organizations, ultimately leading to more resilient and efficient disaster response and mitigation efforts in India. It can lead to the refinement and adaptation of policies to address emerging risks, changing hazard patterns, and the impacts of climate change. The research can help central government organizations allocate resources more effectively towards disaster risk reduction and mitigation efforts. The findings can pave the way for the integration of advanced technologies, such as artificial intelligence, big data, and remote sensing, into disaster risk reduction and response efforts. The research can emphasize the importance of long-term planning and investment in resilience-building measures.

References

1. Colin, Eden., Jose, J., Gonzalez. (2023). The Strategic Management of Disaster Risk Mitigation.
https://doi.org/10.1007/978-3-031-34207-3_1

2. Linardos, V., Drakaki, M., Tzionas, P., & Karnavas, Y. L. (2022). Machine Learning in Disaster Management: Recent Developments in Methods and Applications. In Machine Learning and Knowledge Extraction (Vol. 4, Issue 2). https://doi.org/10.3390/make4020020

3. Muzamil, S. A. H. B. S., Zainun, N. Y., Ajman, N. N., Sulaiman, N., Khahro, S. H., Rohani, M. M., Mohd, S. M. B., & Ahmad, H. (2022). Proposed Framework for the Flood Disaster Management Cycle in Malaysia. Sustainability (Switzerland), 14(7). https://doi.org/10.3390/su14074088

4. Sofyan, A. S., Abror, A., Putra, T. W., Muslihati, M., Sofyan, S., Sirajuddin, S., Katman, M. N., & Darussalam, A. Z. (2022). Crisis and disaster management for halal tourism: a systematic review. Tourism Review, 77(1).
https://doi.org/10.1108/TR-08-2020-0390

5. Z., Muriuki., Robert, M., Kei., John, Munderu, Muchiri. (2022). Disaster Mitigation Measures as Strategies of Disaster Risk Preparedness in Informal Settlements of Nyeri Town, Nyeri County, Kenya. European journal of health sciences.
https://doi.org/10.47672/ejhs.1295

6. Keating, A., & Handmer, J. (2022). Wildfire risk management under climate change. In Handbook on Climate Change and Disasters (pp. 99-113).
https://doi.org/10.4337/9781800371613.00017

7. Tromp, E., te Nijenhuis, A., & Knoeff, H. (2022). The Dutch Flood Protection Programme: Taking Innovations to the Next Level. Water, 14(9), 1460-1460.
https://doi.org/10.3390/w14091460

8. Turtoi, Andrei. (2022). Community Participation Strategies in Nepal's Disaster Management. In International Handbook of Disaster Research (pp. 1-16).
https://doi.org/10.1007/978-981-16-8800-3_112-1

9. Abid, S. K., Sulaiman, N., Chan, S. W., Nazir, U., Abid, M., Han, H., Ariza-Montes, A., & Vega-Muñoz, A. (2021). Toward an integrated disaster management approach: How artificial intelligence can boost disaster management. In Sustainability (Switzerland) (Vol. 13, Issue 22).
https://doi.org/10.3390/su132212560

10. Kim, D-Y, Shinde, S. K., Lone, S., Palem, R. R., & Ghodake, G. S. (2021). COVID-19 Pandemic: Public Health Risk Assessment and Risk Mitigation Strategies. Journal of Personalized Medicine, 11(12), 1243.
https://doi.org/10.3390/jpm11121243

11. Phengsuwan, J., Shah, T., Thekkummal, N. B., Wen, Z., Sun, R., Pullarkatt, D., Thirugnanam, H., Ramesh, M. V., Morgan, G., James, P., & Ranjan, R. (2021). Use of social media data in disaster management: A survey. Future Internet, 13(2).
https://doi.org/10.3390/fi13020046

12. Sood, S. K., & Rawat, K. S. (2021). A scientometric analysis of ICT-assisted disaster management. In Natural Hazards (Vol. 106, Issue 3).
https://doi.org/10.1007/s11069-021-04512-3

13. David, Alexander. (2020). Disaster Risk Reduction.
https://doi.org/10.1093/ACREFORE/9780190228637.013.1538

14. Emmanuel, Tolulope, Busayo., Ahmed, Mukalazi, Kalumba., Gbenga, Abayomi, Afuye., Olapeju, Yewande, Ekundayo., Israel, R., Orimoloye., Israel, R., Orimoloye. (2020). Assessment of the Sendai framework for disaster risk reduction studies since 2015. International journal of disaster risk reduction.
https://doi.org/10.1016/J.IJDRR.2020.101906

15. Li, Y., Li, H. X., Huang, J., & Liu, C. (2020). An approximation method for evaluating flash flooding mitigation of sponge city strategies – A case study of Central Geelong. Journal of Cleaner Production, 257.
https://doi.org/10.1016/j.jclepro.2020.120525

16. Sun, W., Bocchini, P., & Davison, B. D. (2020). Applications of artificial intelligence for disaster management. In Natural Hazards (Vol. 103, Issue 3).
https://doi.org/10.1007/s11069-020-04124-3

17. Hsiang-Chieh, Lee., Hongey, Chen., Hongey, Chen. (2019). Implementing the Sendai Framework for disaster risk reduction 2015–2030: Disaster governance strategies for persons with disabilities in Taiwan. International journal of disaster risk reduction.
https://doi.org/10.1016/J.IJDRR.2019.101284

18. Nepal, P., Khanal, N. R., & Sharma, B. P. (2018). Policies and Institutions for Disaster Risk Management in Nepal: A Review. 11.
https://doi.org/10.3126/GJN.V11I0.19546

19. Yu, M., Yang, C., & Li, Y. (2018). Big data in natural disaster management: A review. In Geosciences (Switzerland) (Vol. 8, Issue 5).
https://doi.org/10.3390/geosciences8050165

20. Gulsan Ara Parvin, Rezaur Rahman, Kumiko Fujita, & Rajib Shaw. (2018). Overview of flood management actions and policy planning in Bangladesh. International Journal of Public Policy, 14, 423-443.
https://doi.org/10.1504/IJPP.2018.096700

21. Pollner, J., Kryspin-Watson, J., & Nieuwejaar, S. (2010). Disaster risk management and climate change adaptation in Europe and central Asia. Washington, DC: World Bank.

Gender-Responsive Planning and Implementation of Disaster Risk Management in the Palghar District, Maharashtra, India: A Case Study

Vivekanand Vijaykumar Kadam

Abstract

This research paper delves into the multifaceted dimensions of integrating gender-sensitive approaches into DRM strategies within this vulnerable region. With a focus on understanding the distinct vulnerabilities and capacities of various genders, the paper evaluates the effectiveness of gender-responsive initiatives in enhancing community resilience. This research not only contributes to the existing body of knowledge on gender and DRM but also seeks to inform future policy and research directions in disaster-prone regions, thereby fostering more inclusive and resilient communities. Employing a mixed-methods research design, the study conducts gender analysis within Palghar District to unravel the socio-economic and cultural factors shaping gender roles and to pinpoint the specific vulnerabilities and resilience-building potential inherent in different genders.

Key words: *Gender and disaster, DRM, Gender-responsive, DM training*

1. Introduction and background

Palghar district is a tribal-dominated district. It is located in a coastal area. The Main Livelihoods of the people are fishing, farming, and industrial activities. Bhabha Atomic Research Center and Tarapur Atomic Power Station are located in the district. More than 8,000 industrial companies are operating within the district. These circumstances make the district highly vulnerable to disasters from natural and technological hazards (Palghar, 2023).

Table 1. The population of the district (Male/female) as per the 2011 Census

The total population of the district			Population belonging to Scheduled Caste		
Male	**Female**	**Total**	**Male**	**Female**	**Total**
1545779	1444337	2990116	552218	565790	1118008 (37%)

Disaster risk is high in the district and requires disaster risk reduction measures that reduce the vulnerability of people and property, risk-sensitive management of land and the environment, improved preparedness, early warnings, mock drills, training for effective disaster risk management, etc.

Since the district population consists of tribal groups and scheduled castes there are specific gender and inclusion issues to be looked into.

Table 2. Taluka-wise main hazards affecting the district

Sl. No.	Taluka	Main Hazard
1.	Palghar	Lightening, Cyclone, Tsunami, Industrial Incidents, Nuclear Emergency, Flood, Fire, Tree falling
2	Vasai	Cyclone, Tsunami, Flood, Flash Flood, Fire, Road Accidents
3	Dahanu	Lightning, Cyclones, Tsunami, Nuclear Emergencies, Flood, Flash floods, Fire, Tree Falling, Earthquakes
4	Talasari	Lightning, Cyclone, Tsunami, Floods, Fires, Tree Falling, Chemical Tanker accidents, Earthquakes, Road Accidents.
5	Wada	Flood, Fire, Tree Falling, Industrial incidents
6	Vikramgad	Lightning, Flood, Fire, Tree Falling, Earthquakes, Land-slides.
7	Jawhar	Lightening, Fire, Tree Falling, Earthquakes, Road Bridges collapse, Road Accidents, Snakebite
8	Mokhada	Lightning, Flood, Fire, Tree Falling, Earthquakes, Road Bridges collapse, Road Accidents, Snakebite

2. Objective of the study

a) To study the main causes of poor participation of women in disaster management training.

b) To Improve the participation of women in disaster management training.

3. Study Area

The part of the country's largest urban sea-hill of Palghar District divided on 1st August 2014 and 36th new district of Maharashtra, Palghar came in to existence. Palghar District is one of the most industrialized districts in Western Maharashtra. Palghar District is located between 19°17' and 20°13' North latitude and 72°38' and 73°300' East longitude. The district has a geographical area of 5,344 sq.km, which is 1.74 % of the State total area. District consists of 8 administrative block i.e. Vasai, Palghar, Dahanu, Talasari, Vikramgad, Wada, Jawhar and Mokhada. It is bounded on the north by the state boundary of Gujarat; on north-east by the union territory of Dadar and Nagar Haveli; on the east by Nashik district; on the south by Palghar district, and and on the west by gigantic Arabian Sea, while Vasai- Virar is the only Metropolitan region. Palghar lies on the Western Line of the Mumbai Suburban Railway in the busy

Mumbai-Ahmedabad rail corridor. The town is located about 87 kilometers north of Mumbai, about 35 kilometers north of Virar and about 24 kilometers west of the Mumbai-Ahmedabad National Highway at Manor. It is the newly formed district in the state and covers 1.74% of the total geographical area of the state. There are 5 administrative sub divisions in the district. Total 473 Gram panchayat, l008 villages and 3818 Habitations in the district, out of that most of the area dominated by Tribe's. District comes under the Tribal Areas of the state of Maharashtra.

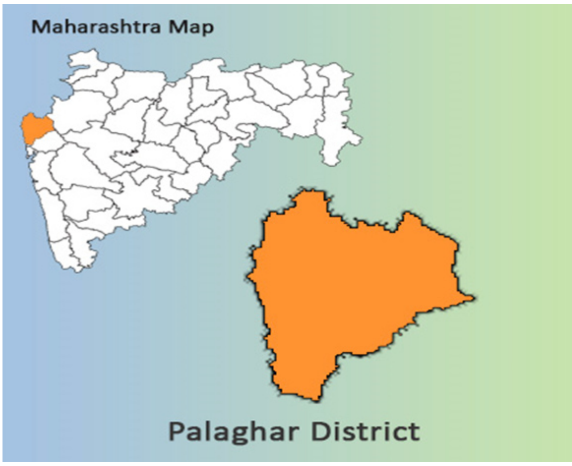


Figure 1: Location map of Palghar District

4. Methods of communicating early warning

- Electrical and print media -TV and Newspaper
- Social media - What's an app, Facebook, SMS Blaster
- The traditional early warning system of the village is called Davandi (playing the Halgi- a type of musical instrument to convey messages to people).

5. Gender and women-related issues related to the above-mentioned hazards, exposure to disaster risk, vulnerabilities specific to women/girls due to hazards and disasters in the district

- Most women are unaware of early warnings. Most women are unable to use social media. These are noted gaps in the early warning system
- Women lack awareness of how to respond to early warning messages because they are uneducated or untrained.
- Women are reluctant/unable to leave their homes and go to a shelter (social attitude):- For Example, families living in salt flats of Vasai Block

are not ready to leave their homes and go to the shelter in case of floods. The situation was similar in Satapati Village of Palghar block in case of a cyclone.

- Gaps in the facilities in temporary shelters: lack of separate toilets, sanitation, breastfeeding, and changing rooms discourage women from moving
- Evacuation process issues: most vulnerable groups such as girls, pregnant women, elders, and people with disabilities are not prioritized in evacuation. Those who are more powerful (generally men) move to shelter first.
- Women are not sufficiently prepared for disasters; despite government efforts, women do not participate adequately in preparedness activities.
- Gender roles and cultural norms prevent women from participating in disaster preparedness activities and gaining greater awareness
- Violence against women (including sexual violence) is observed in post-disasters at temporary shelters. (Kadam, 2019)

6. Activities women do for disaster risk management at the district/local/household level

- Women cooperate with the Administration. When any rules and orders are given to the community from the Administration women follow them properly.
- When women follow any disaster management training, they adopt the learning in daily life. For example, among the trainees, the wife of the sarpanch of Usarani Village in Palghar Taluka had given CPR when her husband lost consciousness.
- Women secure the whole family: For example, the mother in the family instructs everyone to turn off their mobile phones when there is lightning and thunder

7. What activities does the district disaster management planning and implementation process follow to ensure gender and women's issues are taken into account?

- ***Planning***
    - o Training programs for women are conducted as instructed by the District Collector (Chairman of the District Disaster Management Authority). As per the instructions, a minimum of 50 percent of women's participants should be included in the training.
    - o District Disaster Management Officer plans by visit, survey, and observation. Programs including women participants pay

attention to the location (safe places), language, and choice of trainers, facilities for privacy, and breastfeeding to encourage the participation of women.

- ***Implementation methods used:***
  - Set goals to make local policy for awareness building on disaster management for women.
  - Hiring local language lady teachers for training, who teaches other women as a master trainer. (Who serves as the link between local women and the district administration).
  - Laughing on Mistake and learning method
  - My family's safe method.
  - School & college girls centralized training method.

The above has led to systematic changes in practices.

8. What are the main challenges faced in addressing gender / women's issues in DRM in the District?

- Women do not identify themselves as having a responsibility to engage in DRM activities, or to participate in training, they prioritize child and elderly care as their main responsibilities.
- Language barriers (Instructors lack local dialect), lower levels of education, and poor awareness of the importance of DRM discourage women from participating in training
- Privacy and facilities at the training venues appear problematic for women, specifically when the programs are residential and far away from home
- Lack of financial resources to dedicate time for training and other DRM activities

9. What are the measures you take to address these challenges?

- Selecting a training venue in a central place of the village such as a school
- Women are informed of the programs/ dates well in advance.
- Conduct training in the local language, and engage local teachers as trainers.
- Engage women trainers so that women can communicate freely.
- Content of the training: provide training on regular, seasonal, and day-to-day disasters.
- Consider engaging women/getting feedback from women in designing the content of the training Programs

- Training venues are safe and sound to encourage women's participation, and there are adequate privacy and sanitary facilities for women

10. What kind of support do you require (external/internal) to build the capacities of women/to reduce their vulnerability and to increase women's resilience to disaster risk in the district?

- Provide remuneration per day minimum of 200/- Rupees for trainees
    - Training material should be developed in the local language, such as Audio and Video clips in local warli dialect, and warli paintings.
    - Women Master Trainers should be developed from the local community.
    - It should be mandatory that in every training there is 50 percent of women participants. This advice should be sent from the policy level to the ground level for implementation.
    - Training for every Panchayat Raj Institution (PRI) Member women's / government employee should be compulsory at the grass-root level (Since there is 50 percent reservation for women in PRI's elections).
    - Quarterly Evaluation should be mandatory by the State Disaster Management Authority (SDMA).

11. What more needs to be done to make DRM work in the district to be gender-responsive consistently?

- Awareness should be consistent through street play, poems, mini-marathons, and family-safe competitions.
- Appreciation should be the most powerful tool for consistency. The family should be awarded the ''Apada Rakshak'' Family award.
- Provide incentives to the households that engage women in the training (to encourage men to send women in the house for DRM training) such as location administrations should be given a 5 percent rebate on house and water taxes.

References

1. Kadam, V. V. (2019). Gender-based issues in disaster management training in Palghar district. ZENITH International Journal of Multidisciplinary Research, 27-40.
2. Palghar, C. (2023). Industrial Information. Palghar: Collector Office Palghar.
3. Walia, A. (2015). ToT Module on Gender and Disaster Management. New Delhi: National Institute of Disaster Management.
4. Madhavi Malalgoda Ariyabandu. (2005). Gender Dimensions in Disaster Management: A Guide for South Asia. New Delhi. National Disaster Management Authority, India.

5. Vasudha Gokhale. (2008). Role of Women in Disaster Management: An Analytical Study with Reference to Indian Society. Beijing, China. The 14th World Conference on Earthquake Engineering.
6. Mangathai Ramisetty, and Nandita Hazarika. (2008). Delhi. Training of Trainers Manual on Gender Mainstreaming In Disaster Risk Management.

Centre for Disaster Management

Centre for Disaster Management (CDM) is a research and training centre, and a unit of Lal Bahadur Shastri National Academy of Administration (LBSNAA), Mussoorie, Department of Personnel & Training (DoPT), Government of India. The CDM is a Nodal agency for training in Incident Command System (ICS). The Centre is involved in training officers belonging to the IAS and other Group-A civil services at induction as well as at Mid-Career level in various aspects of disaster management through classroom sessions, case studies, and experience sharing presentations, panel discussions, workshops, and mock drills. Apart from conducting training programmes on fire safety, search and rescue, IRS, DRR, DDMP, school safety, the centre is involved in various types of documentation and publication activities in terms of case studies, documentation of best practices, research papers, books and posters in national and international journals and developed course specific training materials in the area of Disaster and Emergency management and Science and Technology.

Disaster: Response & Management
Volume IX, No. 1, (March, 2024)
ISSN: 2347-2553

Published by
Centre for Disaster Management
Lal Bahadur Shastri National Academy of Administration
Mussoorie - 248179, Uttarakhand, India

CENTRE FOR DISASTER MANAGEMENT
Lal Bahadur Shastri National Academy of Administration
Mussoorie - 248179, Uttarakhand
EPABX: 0135-2632489, 2222000 (Extn-2385)
Telefax: 0135-2632655; Fax: 0135-2632350, 2632720
Email: cdm.lbsnaa@nic.in