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संख्या/No.: NESAC/GH/ NERDRR/17:00/2022

नवंबर/November 4th, 2024

सेवामें/To,

The Executive Director,
National Institute of Disaster Management,
(Ministry of Home Affairs, Government of India),
Plot no. 15, Pocket-3, Block-B, Sector-29, Rohini, Delhi -110042

विषय/Sub: Submission of Best Practice Titled "Building Vulnerability and Risk Assessment of Agartala City-reg.

संदर्भ/Ref:. F.1-8/2023 (SWAYAM) dated: 22nd October, 2024.

प्रिय महोदय/ Dear Sir,

I am pleased to submit the best practice titled "Building Vulnerability and Risk Assessment of Agartala City as an entry for the Call for Best Practices by the Knowledge Platform on Urban Resilience, hosted by NIDM.

This best practice highlights the successful implementation of the HVRA "Risk Information Master Plan" project for Agartala City. It stands as an exemplary model for leveraging advanced technology to mitigate the risks posed by natural disasters, particularly flooding. This work, offers valuable insights into urban flood management using advanced Remote Sensing (RS) and Geographic Information System (GIS) technologies.

We are confident that this submission will resonate with NIDM's readership and contribute meaningfully to the body of knowledge on urban resilience and practical disaster risk solutions.

Please find the document attached. We appreciate your consideration of this submission and look forward to your feedback.

Thank you for your time and attention.

आदर के साथ/With kind regards,

आपकाभवदीय/ Yours Sincerely,

4/11/24

(डॉ. के.के.शर्मा/Dr. K.K. Sarma)

GH, RSAG

Copy:

1. Dr. Jenita M. Nongkynrih, Head, URD.

Thematic Area: Disaster Risk Reduction (DRR)

Sub-thematic area: Hazard Vulnerability and Risk Assessment and GIS Mapping

Title and Location: Building Vulnerability and Risk Assessment of Agartala City, Tripura

1. Introduction

Floods are among the most devastating natural disasters, particularly in flood-prone areas with rapid urbanization and unregulated land use. Moreover, floods are perceived as devastating occurrences in various regions of India, causing loss of life, widespread destruction of public infrastructure, and leaving residents, particularly in rural areas, grappling with profound despair. Their economic ramifications are substantial, impeding business operations and consequently slowing down national economic growth (Mansoor et al., 2014). The northeastern state of Tripura, India, is particularly vulnerable to flood in the valley area due to its geographical features, intense monsoon rainfall, and river overflow. To mitigate such risks to address the problem of flood especially in the urban area, the project titled "Remote Sensing and GIS-based Input for Hazard, Vulnerability, and Risk Assessment (HVRA) for Agartala, Bishalgarh, Belonia, Kumarghat, Khowai, Udaipur, Dharmanagar and Ranir Bazar towns in Tripura" was taken up. The initiative, executed by the North Eastern Space Applications Centre (NESAC) in collaboration with the Tripura Space Applications Centre (TSAC), set out to develop Hazard Zonation Maps and evaluate vulnerability and risk associated with floods, landslides, and thunderstorms in these urban centers. This research provides a detailed account of the project's success, outlining key achievements, challenges, and lessons learned related to flood inundation mapping and vulnerability and risk assessment in Agartala City.

Various factors contribute to the recurring flooding problems in a river basin; among them are the imminent risks of bank erosion and sediment buildup in both the main channel and its tributaries, leading to significant drainage blockages (Minakshi and Goswami, 2014). Another crucial factor is the escalating population pressure encroaching upon the floodplains of the river. Each monsoon season brings about significant damage to infrastructure, properties, and livestock within the basin (Bhatt et al., 2013). Looking ahead, disaster managers will confront formidable challenges due to the heightened risk of flooding stemming from extreme precipitation events and the continued expansion of development in areas prone to hazards (Intergovernmental Panel on Climate Change, 2012).

In this study, Sentinel 1A SAR of Agartala City with VV polarization has been used to extract flood inundation layer using SNAP software. Microwave SAR data is chosen over optical data because SAR has the ability to sense the ground over day and night and in any weather condition. The flood vulnerability assessment was analyzed using socio-economic and historical hazard datasets which was collected using Socio-Economic Survey Mobile Application developed by NESAC.

The capital and main city of Tripura state is Agartala, which is situated near the banks of the Haora River. It is located around 2,499 kilometers (1,552 miles) from New Delhi, the capital of India, and about 2 kilometers (1.2 miles) east of the border with Bangladesh. According to the 2022 census, it is the third largest city in Northeast India, behind Guwahati and Imphal. Agartala is being developed to become India's third international internet gateway as part of the Smart City Mission. Geographically, Agartala extends into low-lying hills in its northern sections as well as across flat land near the Haora River. These rivers are characterized as rain-fed and ephemeral, deriving their origin from hill ranges. Being ephemeral in nature, the flow of these rivers is intricately linked to the patterns of rainfall in the region (NESAC Report 2024).

In addition to being necessary preconditions for flood evacuation plans, flood hazard mapping and flood inundation modeling are critical components of land use planning and flood mitigation initiatives. Floods cannot be avoided completely, but their effects can be lessened with careful preparation and community readiness. Therefore, it is critical to evaluate the degree of risk in various floodplain zones. As a result, zoning for flood hazards becomes essential to a comprehensive flood control plan. Some of the factors responsible for flooding are:

(a) Heavy and intense rainfall over a short duration.
(b) Inadequate channel capacity for a particular discharge of high magnitude.
(c) The shifting of a river channel from one course to another.
(d) Poor drainage facilities due to anthropogenic activities.
(e) Intense erosion along the riverbank resulting in embankment breach.
(f) The alignment of floods in the primary and smaller rivers, along with their slowdown caused by tidal influences.
(g) Siltation of embankment beds leading to loss of channel capacity.
(h) Failure of upstream dam.

2. About NESAC

The North Eastern Space Applications Centre (NESAC), an autonomous institution under Department of Space (DOS) is a society registered under the Meghalaya Societies Registration Act, 1983. The Centre has provided more than 24 years of dedicated service to the eight states of North Eastern Region (NER) of India using space science and technology.

The Centre aims to establish an operational remote sensing and GIS-based natural resource information system to support development, resource management, and infrastructure planning in the region. It seeks to provide satellite communication services for education, healthcare, disaster management, and developmental communication. Additionally, the Centre focuses on advancing research in space and atmospheric sciences by creating an instrumentation hub and fostering academic partnerships within the Northeast Region (NER). It also strives to facilitate comprehensive space-based disaster management support through a single-window service and develop regional infrastructure to enhance capacity in geospatial technology. To support these objectives, a disaster risk reduction node named the North Eastern Regional Disaster Risk Reduction (NER-DRR) node has been established at NESAC. This node is dedicated to enhancing disaster preparedness and resilience in the region, leveraging advanced geospatial technologies and satellite-based support for comprehensive disaster management.

3. Building Vulnerability and Risk Assessment of Agartala City

3.1 Flood Inundation Mapping

The project's primary achievement was the preparation of detailed flood inundation map of Agartala city. Various remote sensing (RS) techniques and Geographic Information System (GIS)-based modelling tools were employed to identify flood inundated areas. The use of Sentinel-1A Synthetic Aperture Radar (SAR) data enabled flood inundation mapping, especially in conditions where optical sensors fail due to cloud cover or night-time events. Between August 20th and August 26th 2024, heavy rainfall led to widespread flooding across Tripura. This study generated a Near Real-Time (NRT) flood inundation map for Agartala using Sentinel-1A SAR data (Figure 1). Table 1 highlights the flood-affected areas (in hectares) and the extent of flooding in different wards of Agartala city. Based on satellite data and limited ground verification, an estimated 374.49 hectares of land of Agartala City were inundated on August 21, 2024.

Table 1 Ward-wise Flood Inundation Area of Agartala City

Ward Name	**Area in Hectares (ha)**	**Area in %**		**Ward Name**	**Area in Hectares (ha)**	**Area in %**
Ward 01	2.80	0.75		Ward 27	0.54	0.14
Ward 02	108.00	28.84		Ward 28	0.15	0.04
Ward 03	8.13	2.17		Ward 29	0.03	0.01
Ward 04	15.78	4.21		Ward 30	0.10	0.03
Ward 05	0.05	0.01		Ward 31	0.09	0.02
Ward 06	1.02	0.27		Ward 32	0.04	0.01
Ward 07	0.04	0.01		ward 33	0.09	0.02
ward 08	11.27	3.01		Ward 34	0.06	0.02
ward 09	47.48	12.68		ward 35	1.00	0.27
Ward 10	53.25	14.22		Ward 36	8.20	2.19
Ward 11	0.01	0.00		Ward 37	0.84	0.22
Ward 12	0.19	0.05		Ward 38	13.26	3.54
Ward 13	-	-		Ward 39	0.06	0.02
Ward 14	24.64	6.58		ward 40	0.02	0.01
Ward 15	11.50	3.07		Ward 41	15.06	4.02
Ward 16	-	-		Ward 42	1.77	0.47

Ward 17	-	-		ward 43	0.31	0.08
Ward 18	0.02	0.01		Ward 44	15.80	4.22
Ward 19	-	-		ward 45	0.97	0.26
Ward 20	0.32	0.09		Ward 46	0.01	0.00
Ward 21	0.05	0.01		Ward 47	7.69	2.05
Ward 22	0.02	0.01		Ward 48	0.27	0.07
Ward 23	0.63	0.17		ward 49	0.11	0.03
Ward 24	0.79	0.21		Ward 50	2.32	0.62
Ward 25	-	-		Ward 51	0.44	0.12
Ward 26	19.25	5.14				

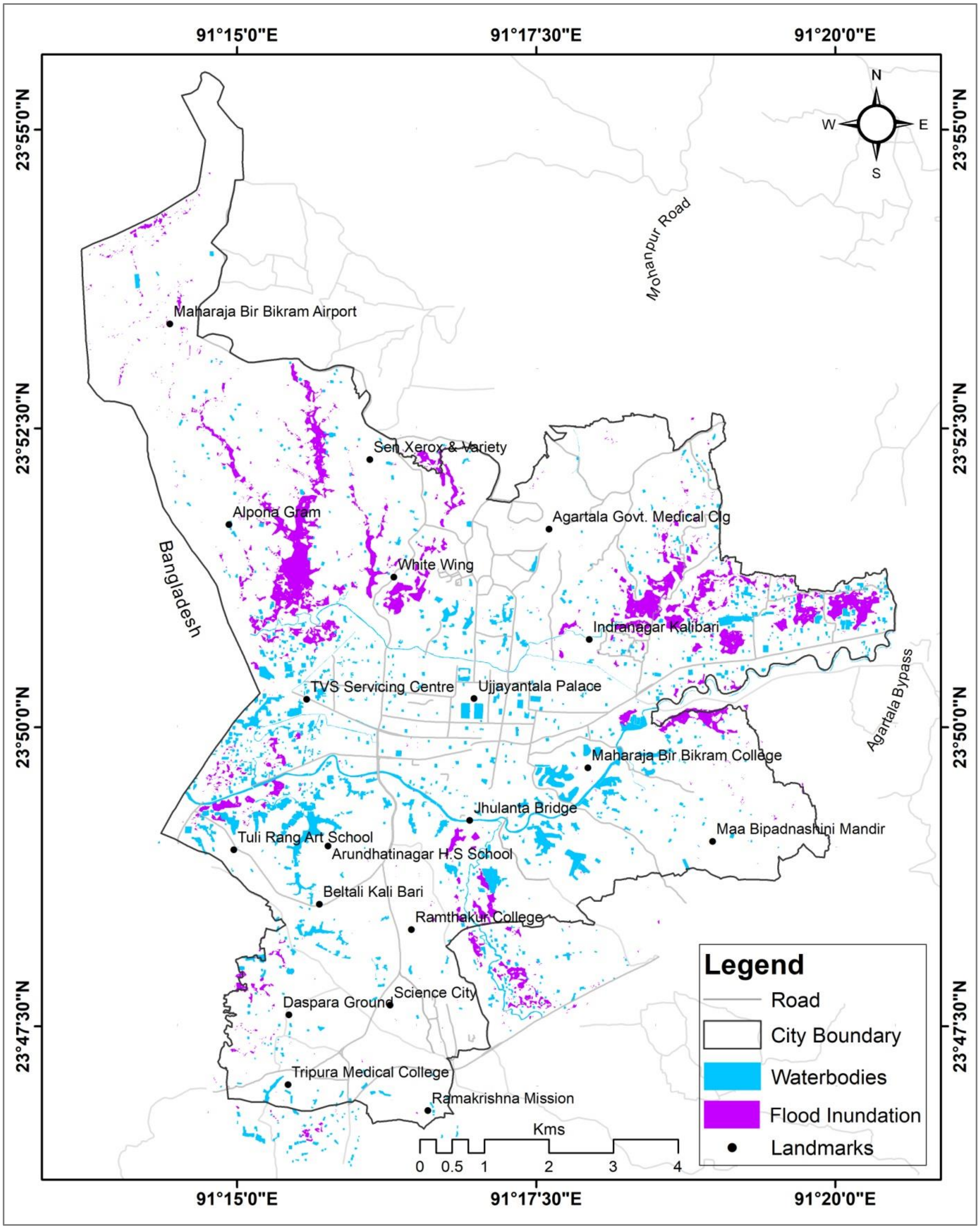

Figure 1 Flood Inundation Map of Agartala City for 21st August 2024 Using Sentinel 1A SAR

3.2. Building Vulnerability Assessment

In the modern age, the evolution of urban structures significantly shapes the vulnerability patterns of buildings within urban areas. It is crucial to understand the physical structure and characteristics of buildings but also their present condition, spatial distribution and density. This comprehension is essential for assessing the vulnerability of a group of buildings, which is closely tied to the urban growth of city. The assessment incorporates various criteria, and rankings, along with assigned weightages, are essential components in evaluating building vulnerability, considering both the type of hazard and the structural conditions of the buildings. The resulting vulnerability zones are then classified into categories ranging from Very High to Very Low based on the observed degree of vulnerability. Consequently, the study examines the physical and social vulnerability of buildings in the Agartala town area, focusing on floods hazard.

In this project, building vulnerability was assessed based on physical characteristics such as construction materials, elevation, and proximity to water bodies. The project classified 1,179.59 hectares (27%) of built-up areas as low vulnerability, 1,939.49 hectares (43%) as moderate, 798.62 hectares (18%) as high, and 225.37 hectares (12%) as very high vulnerability (Table 2). These vulnerability assessments were critical in determining areas where flood impacts could be the most severe. For instance, the northern parts of Agartala, categorized as very high in vulnerability, were inundated during the August 2024 floods (Figure 2). The combination of SAR flood mapping and building vulnerability assessments provided a clear picture of risk distribution.

Table 2 Building Vulnerability and Distribution of Area for Flood Hazard in Agartala City

Vulnerability Level	Area in Hectares	Area in %
Low	1179.59	27
Moderate	1939.49	43
High	798.62	18
Very High	552.37	12
Total Built Up Area	**4470.07**	**100**

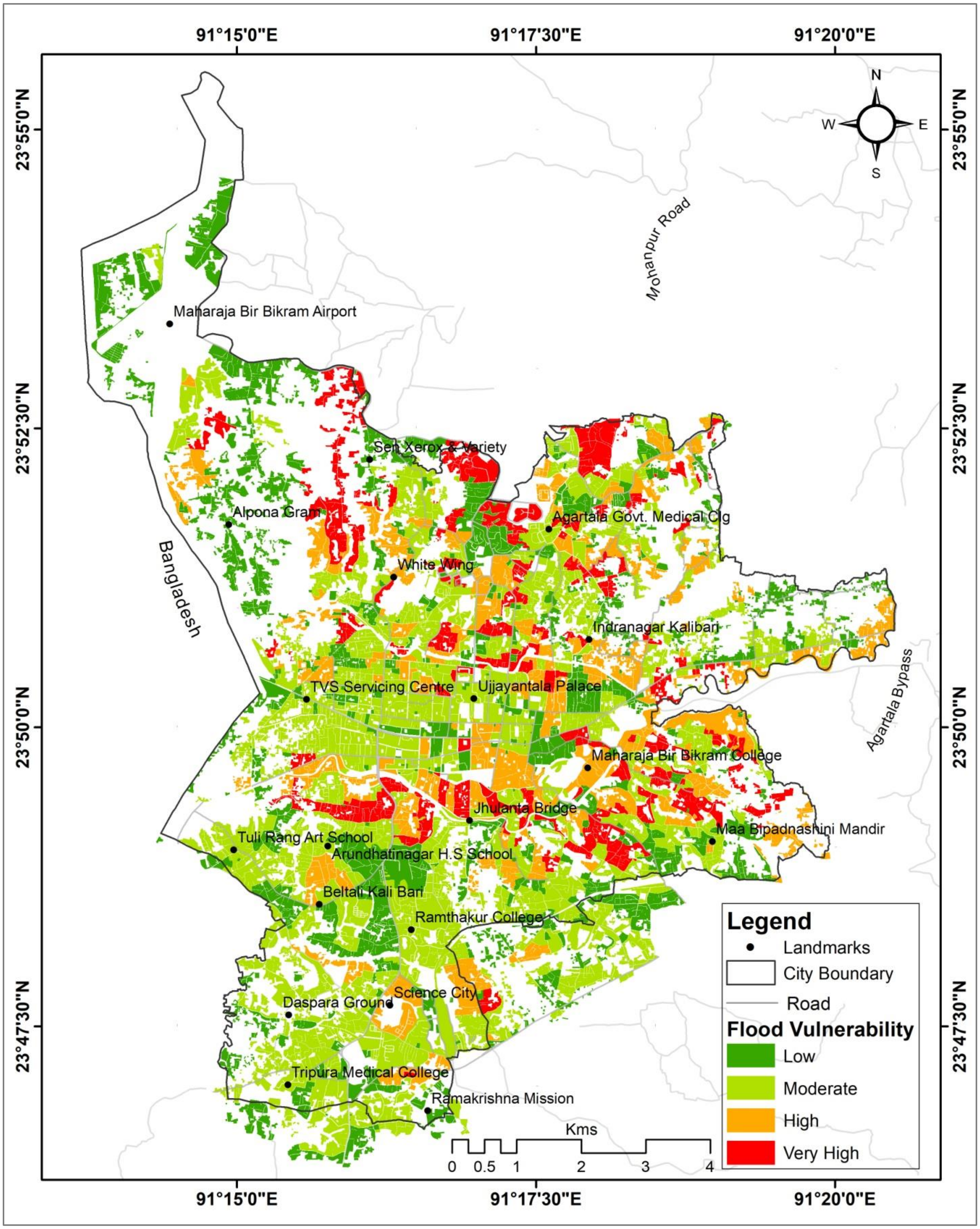

Figure 2 Flood Building Vulnerability Map of Agartala City

3.3. Integration of Socio-Economic Data

In addition to assessing the physical vulnerability of buildings, this study also integrated socio-economic data to provide a more holistic view of vulnerability. This integration highlighted how poorer sections of the population are often more susceptible to flood impacts due to weaker building structures and less access to resources for recovery. By combining both physical and socio-economic factors, the study was able to prioritize areas for disaster mitigation interventions more effectively.

3.4. Flood Risk Assessment

Geographical spatial distribution of vulnerability and hazard zones form the basis for estimating risk. To accurately assess the risk associated with a specific hazard, detailed information about elements at-risk such as buildings, socio economy, and population must be used. For hazard risk assessments, specific data related to buildings, including residential location, building type, number of floors, construction material, and roofing, are required. This information was collected through field surveys across various locations, supported by high-resolution satellite imagery, ground-truth verification, and census data to establish building structures and footprints. The Multi-Criteria Decision Analysis (MCDA) technique was applied to assess flood hazard risk in Agartala city by integrating hazard data with vulnerability layers. Flood hazard risk mapping and assessment provide a comprehensive approach to identifying multiple hazards a region may face, aiding in proactive disaster management and planning.

Table 3 Flood Risk and Distribution of Area for Agartala City

Flood - Risk Level	Area in Hectares (Ha)	Area in %
Low	1160.48	26%
Moderate	1562.31	35%
High	1466.35	33%
Very High	280.92	6%
Total BU	**4470.07**	**100**

In case of flood risk, Agartala City lies in a very low-risk zone due to its topographical structure. Flood risk assessment of Agartala city depicts that only 280.92 hectares (6%) area comes under very high risk zone and 1160.48 hectares (33%) is coming under low risk zone. A multifaceted strategy that incorporates early warning systems, scientific modeling, and a mix of structural and non-structural solutions is necessary to effectively manage flood risk (Figure 3 & Table 3).

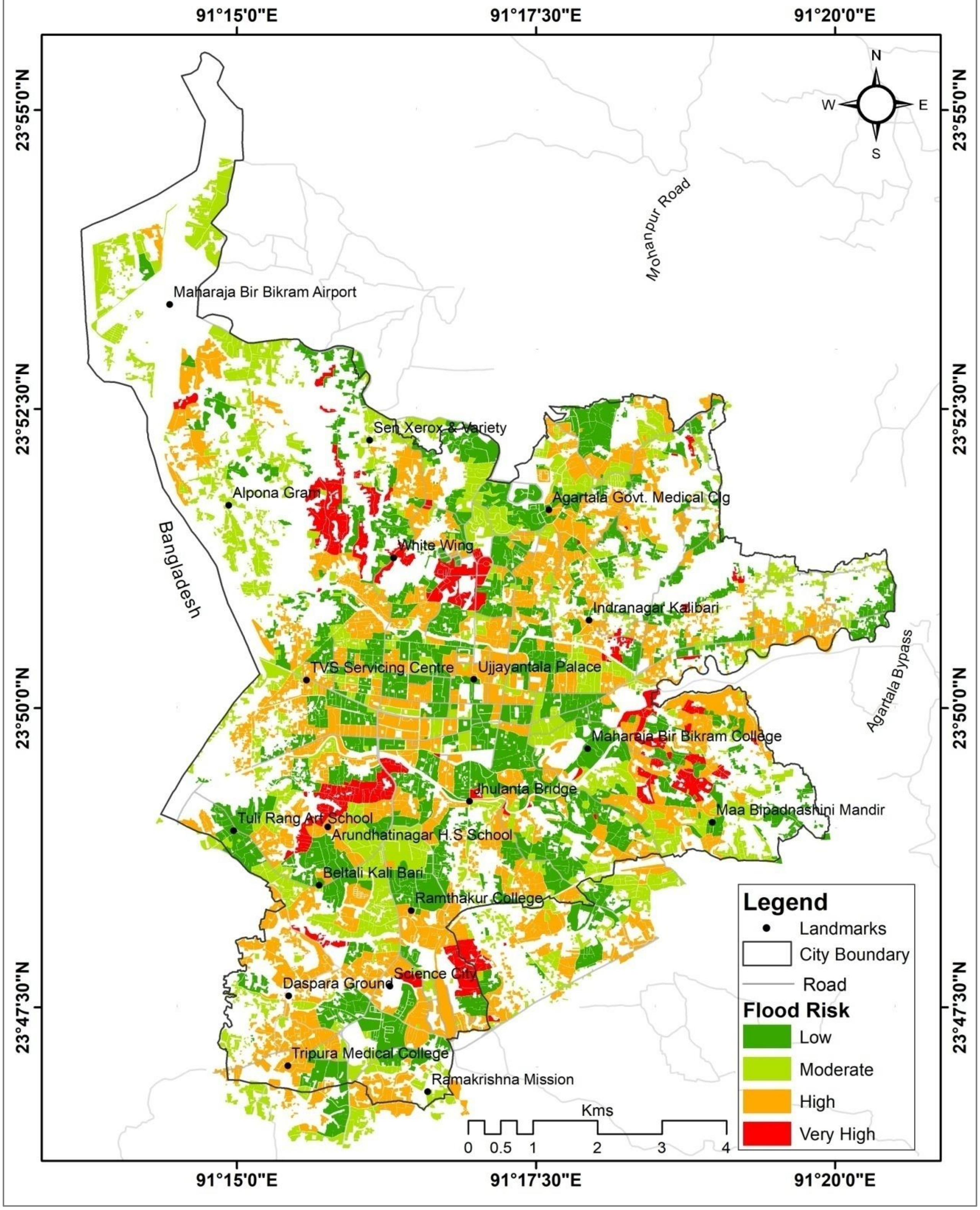

Figure 3 Flood Building Risk Map of Agartala City

3.5. Validation of the Flood Vulnerability from the 21st August 2024 flood in Agartala City

Combining the building vulnerability and the inundated area under flood on the 21st August 2024 of Agartala city, the result is presented in Figure 4. The figure reveals that the northern part of the city which has been categorized as very high in building vulnerability is inundated.

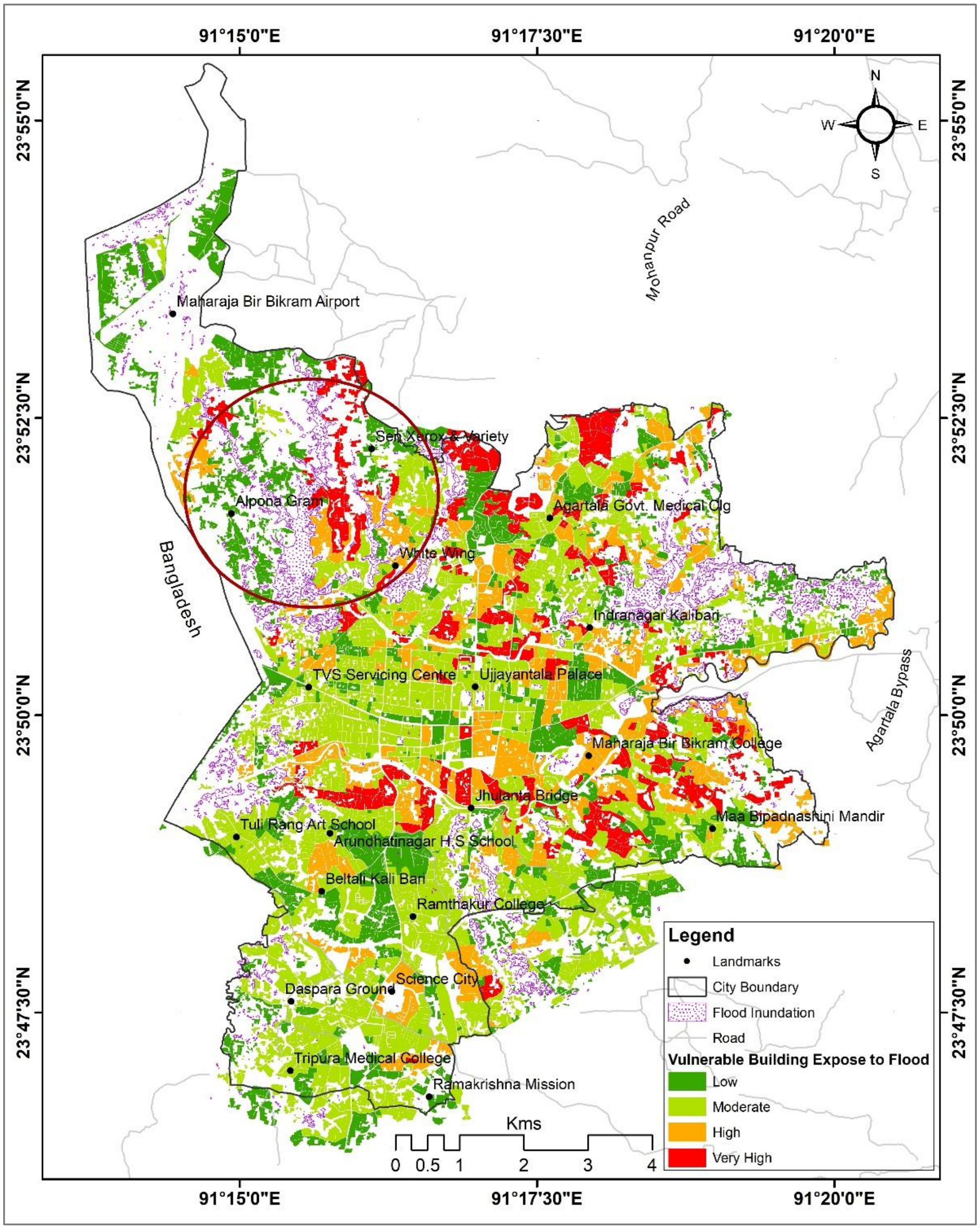

Figure 4 Flood Building Vulnerability exposed to flood on 21.08.2024 of Agartala City (Area in the circle indicated the high to very High built up area affected by flood inundation)

3.6. Urban Planning and Flood Mitigation Strategies

The study's success also extended to urban planning recommendations. By overlaying flood hazard and vulnerability maps, decision-makers in Tripura were able to identify zones where urban development should be regulated to minimize flood risk. The study's outputs supported the formulation of non-structural flood mitigation strategies such as early warning systems, land-use regulations, and community-based disaster preparedness programs. The results have already been incorporated into local development planning for Agartala and other urban centres.

4. Challenges

4.1. Data Gaps and Inconsistencies

One of the major challenges encountered was the inconsistency of building and infrastructure data across urban centres. Satellite data provided near to accurate geospatial information and it required validation through ground surveys. In Agartala city, rapidly changing urban landscapes due to expansion of urban settlement and construction posed challenges for accurate building vulnerability assessments. Moreover, the risk information master plan (RIMP) has been generated using very high resolution satellite image on a 1:4000 scale. But the flood inundation layer for Agartala city has been generated using sentinel 1A satellite data with a coarse spatial resolution which may create lack of consistency.

4.2. Complexity of Socio-Economic Integration

Although the study successfully integrated socio-economic factors into its vulnerability assessment, collecting and standardizing this data across different towns was complex. In particular, variations in the availability of socio-economic data from various sources like primary ground data survey and also from secondary source made it difficult to apply a uniform methodology across Agartala city, requiring localized adjustments that occasionally slowed the study's progress.

4.3. Limited Local Expertise and Public Awareness

Despite the cutting-edge technology and methodologies used in the study, another challenge was the limited local capacity to interpret and apply the results in practice. Flood risk maps and vulnerability assessments need to be translated into actionable plans by local authorities, many of whom lacked the technical expertise to do so. Furthermore, public awareness campaigns regarding flood risks and mitigation strategies were often limited, making it difficult to ensure community preparedness for future flood events.

5. Lessons Learned

5.1. The Power of Remote Sensing and GIS Technologies

The HVRA study demonstrated the power of combining RS and GIS technologies to generate detailed hazard, vulnerability, and risk maps. The use of SAR data was particularly valuable for flood inundation mapping during the August 2024 floods in Agartala, providing near real-time information even in challenging weather conditions. These technologies have proven to be indispensable for urban planning and disaster management, particularly in flood-prone areas.

5.2. The Importance of Socio-Economic Considerations

A major lesson from the study is the critical role of socio-economic data in vulnerability assessments. While physical characteristics of buildings are essential for assessing flood risk, understanding the social and economic factors that influence community resilience is equally important. Future flood management study should ensure that socio-economic vulnerability is fully integrated into risk assessments to provide a more complete picture of the risks faced by different populations.

5.3. Building Local Capacity and Community Engagement

One of the key takeaways from this study is the need for stronger capacity-building efforts at the local level. While advanced tools and technologies can provide valuable insights, it is equally important to equip local governments and communities with the knowledge and resources to implement flood mitigation strategies. Public awareness campaigns and community-based disaster preparedness initiatives are vital for ensuring that vulnerable populations are adequately prepared for future flood events.

6. Conclusion

The HVRA "Risk Information Mater Plan" project for Agartala City stands as a model for leveraging modern technology to mitigate the risks posed by natural disasters, particularly floods. By integrating advanced Remote Sensing (RS) and Geographic Information System (GIS) techniques, the study was able to map flood-prone areas with unprecedented accuracy. The use of Sentinel-1A SAR data proved essential in preparing near real time flood inundation maps, even during challenging conditions like cloud cover and night-time events. This technology allowed the Government of Tripura to make informed decisions quickly and effectively, significantly improving disaster preparedness and response efforts.

A key success of the project was its detailed assessment of building vulnerability in urban centers such as Agartala, where different areas were categorized into low, moderate, high, and very high flood vulnerability zones. By combining these vulnerability assessments with socio-economic data, the project was able to provide a nuanced understanding of how different segments of the population are affected by floods. This holistic approach ensured that flood management strategies could be tailored not just to physical infrastructure, but also to the needs of the most vulnerable communities, such as those in lower socio-economic strata. However, the project faced significant challenges, including data inconsistencies and the complexity of integrating socio-economic factors into the flood vulnerability models. Additionally, a major hurdle was the lack of local expertise and public awareness, which highlighted the need for stronger capacity-building initiatives. Local authorities must be equipped with the tools and knowledge to interpret and apply the project's findings in disaster management planning, while the public must be better informed about flood risks and preparedness strategies.

Despite these challenges, the project has provided valuable insights and practical tools for flood risk mitigation. It has demonstrated the importance of combining technological innovation with community engagement and policy support. For future projects, the lessons learned from Tripura emphasize the need for continuous data validation, greater focus on building local capacity, and sustained efforts in public awareness campaigns. Additionally, as climate change intensifies the frequency and magnitude of floods globally, there is a critical need to scale similar projects across flood-prone regions in India and beyond. Ultimately, the HVRA project has laid the groundwork for a more resilient Tripura, where urban development and disaster preparedness can go hand in hand. Its success underscores the potential of integrated flood risk assessments in safeguarding lives, infrastructure, and economies from the growing threat of natural disasters. With continued advancements in RS and GIS technologies and stronger collaboration between scientific institutions, governments, and communities, future flood management strategies can be even more effective in reducing vulnerability and promoting long-term resilience in urban areas.

Contributors

Dr. Toushif Jaman, Dr Jenita Mary Nongkynrih, Sumanth BC, Shanbor Kurbah, Hunlinshisha Kurbah and Team TSAC. Document compilation supported by Dr. Rekha B Gogoi, Focal Scientist, Coordinator, NER-DRR, NESAC, Dr K K Sarma, Group Head, RSAG, NESAC.

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