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GIS based participatory mapping: A tool for disaster risk reduction and adaptation

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Abstract: GIS holds a very important position in disaster management as disasters are spatial in nature. Sustainable disaster risk reduction requires local community involvement. The accessibility of GIS tools have increased with advancements in computer and GIS technology, such that communities can use GIS to manage their local knowledge and community data collection. Therefore, an attempt was made to study on the effectiveness of GIS based participatory mapping as a tool for disaster risk reduction and adaptation. Literature studies on disaster management, GIS in disaster management and participatory mapping were conducted. Further analysis was carried out based on disaster risk reduction and adaptation strategies as well as the level of community participation in GIS based mapping, Participatory mapping and GIS based participatory mapping to choose the most efficient tool for disaster risk reduction and adaptation. Strategies and recommendations were then formulated based on the analysis to develop GIS based participatory mapping as tool to enhance disaster risk reduction and adaptation

***Index Terms* - GIS based participatory mapping, disaster risk reduction and adaptation.**

I. INTRODUCTION

Disasters are a global phenomenon. According to EM-DAT, one of the foremost international databases of such events, over the last twenty years, 7,348 disaster events were recorded worldwide. Over 4 billion people were affected by disasters, which resulted in an estimated 1.23 million fatalities, or 60,000 annually (many on more than one occasion). Additionally, disasters led to approximately US$ 2.97 trillion in economic losses worldwide (UNDRR, 2020). Local communities are both the primary victims and the first to respond to emergencies when disasters strike (E.Maceda, 2009). The main focus of the 2004 World Disasters Report is "Building Community Resilience." Recent disaster experiences have shown that empowering communities to combat disasters is a much better policy option than strategies for addressing immediate vulnerabilities. The 2015 Sendai Framework for Disaster Risk Reduction emphasizes the need of educating volunteers, communities, and civil society about disaster risk reduction. Critical knowledge gaps seriously hinder efforts for building disaster resilience at all levels, especially in disaster-prone least developed countries (W.Liu,2018). Information deficiency is most serious at local levels, especially in terms of spatial information on risk, resources, and capacities of communities (W.Liu,2018). It is crucial to integrate local knowledge, GIS and maps into the process of disaster risk management (Twigg, 2004). It is this local knowledge that will allow planners to survey rapidly the needs and opportunities for mitigation (Twigg, 2004).

Communities can plot desired and practical risk reduction strategies and identify places they believe to be vulnerable and prone to risks using participatory mapping. More recently, advances in computer and GIS technology have increased the accessibility and mobility of GIS tools, such that communities can use GIS to manage their local knowledge and community data collections using mobile GIS and Global Positioning System (GPS) technologies (Tran, Shaw, Chantry and Norton, 2009). As a consequence, GIS has now become a fundamental component of community-based methodologies (Hatfield, 2006). Therefore, GIS based participatory mapping is a vital tool for disaster management.

II. NEED OF THE STUDY

A natural disaster is one that results in the loss of life or property. Unfortunately, it is inevitable that disasters will grow in number, scale, and severity. GIS is essential to disaster management since disasters are fundamentally spatial in nature. One of the key features of GIS that will enable one to comprehend how and why a crisis situation evolved is the capability to swiftly alter the statistical display of data in GIS. GIS can be crucial in controlling the information flow that disaster management professionals need to be aware of and assess events. Sustainable disaster risk reduction requires community participation. Community-based disaster risk reduction (CBDRR) encourages the involvement of communities in danger in both the assessment of risk (including hazards, susceptibility, and capacity) and the development of mitigation strategies. Currently, community beneficiaries and NGO facilitators are the only groups involved in most CBDRR activities. For bottom-up and top-down catastrophe risk reduction strategies and integration of indigenous and scientific knowledge, local government and scientists must be involved in CBDRR.

III. RESEARCH METHODOLOGY

The methodology section outlines the plan and method in which the study is conducted.

3.1 Data and Sources of Data

Secondary data has been sourced for this study from various reports, research papers and books. About 6 research papers were referred to for collecting data on community based disaster management and participatory mapping by integrating local knowledge and GIS. Also manuals and reports were referred for collecting facts and figures regarding disasters and participatory mapping.

3.2 Theoretical framework

The study focusses on three topics: Disaster management, GIS in disaster management and Participatory mapping. Through these topics, possibilities of integrating GIS and participatory mapping are explored. The effectiveness of integrating GIS based participatory mapping is analyzed using data obtained from literature and case studies based on three parameters such as Disaster risk reduction and adaptation, Community participation and comparative analysis of all case studies.

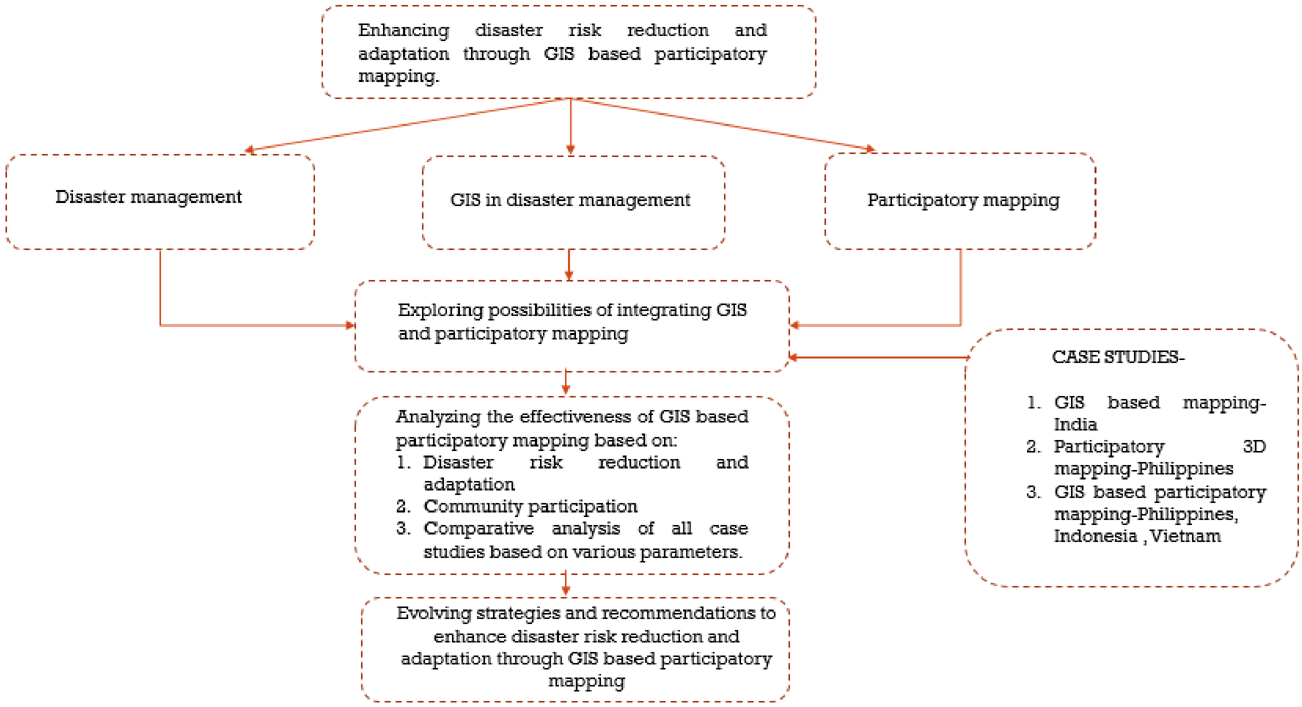

Figure 3.2 Research methodology

IV. LITERATURE STUDY

The literature study deals with 4 main topics: Disaster management, GIS in disaster management, Participatory mapping and GIS based participatory mapping.

4.1 Disaster Management

According to UNDRR, a disaster is "A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts". Disaster Management is a strategic planning and procedure that is administered and employed to protect critical infrastructures (also known as "critical assets") from severe damages when natural or human made calamities and catastrophic even occur (IWA). A natural disaster is one that results in the loss of life and or property. The magnitude of disasters is growing to a point where it is significantly beyond the ability of governments and conventional emergency personnel to manage them. Disasters affect people on an individual and group level, thus both are crucial to minimizing their effects. In order to increase resilience and, by extension, achieve sustainable development, disaster risk reduction aims to prevent future disasters, reduce existing disaster risk, and manage residual risk. The 5 major activities that are a part of disaster risk reduction and adaptation include:

1) Hazard avoidance: Hazard avoidance can lessen the disruptive effects of a natural disaster on communities through awareness, education, readiness, and prediction and warning systems.

2) Vulnerability reduction: Vulnerability reduction includes hazard avoidance and mitigation, vulnerability assessment, and emergency preparedness. The goal of vulnerability reduction is to make a community more resilient and less susceptible.

3) Preparedness for response: A community's collective experience in preparedness and disaster response can be used to analyze the capacities, strengths, and weaknesses of the community.

4) Preparedness for recovery: Planning for recovery increases community resilience to risks, particularly for those who regularly deal with the same hazards. A disaster recovery plan's goal is to fully describe the consistent steps that must be performed before, during, and after a disaster.

4.2 GIS in disaster management

Any system that combines, collects, stores, analyses, shares, manages, and displays data that is linked to place, or so-called geographic data, is referred to as a geographic information system (GIS). Some of the essential disaster management map layers include:

1) Cadastral data: Spatial data required to depict the geographic range of the past, present, and future rights and interests in real property.
2) Digital orthoimagery: The visual qualities of an aerial photograph with the spatial accuracy and dependability of a planimetric map are combined in high-resolution aerial photos.
3) Elevation: Height relative to a particular vertical reference
4) Geodetic control points: A collection of control points with geodetic surveying-derived coordinates.
5) Geographic area boundaries: Set of boundaries that depicts the edge of an object (may or may not follow a visible feature).
6) Hydrography: Locations, connections, and characteristics of elements in the surface water system.
7) Transportation: A collection of components that permit the transportation of people and products between different locations.

For disaster planning and preparation activities, GIS is mainly used in evacuation route and zone planning where an understanding of how and where to evacuate people during a disaster is very crucial during various disasters such as hurricanes, wildfires, snowstorms, storms, and other situations that demand people move swiftly to safe regions. People may be evacuated to specific areas based on a variety of context-specific characteristics, including shelter locations, elevation, availability to medical facilities and transportation networks, and other context-specific factors.

For disaster response, damage assessment is one of the first tasks performed using GIS where information about the extent of destruction, casualties, and other factors during a disaster are gathered to determine the level of response and recovery required. Esri's Collector for ArcGIS is a data collection application that works even when disconnected from the internet. ODK collect is an open-source software that is designed to run android operating system based environments which can be used efficiently for disaster assessment where financial constraints act as barriers.

For disaster recovery, GIS can be employed as a management tool for both short-term and long-term recovery efforts such as the restoration of vital infrastructure, such as the water, power, and transportation systems through the depiction of physical proximity and distribution of crucial capabilities across a region. GIS can serve as an effective auxiliary tool for organizing, analyzing, and modelling debris cleanup operations.

For disaster mitigation, GIS can be helpful in spatial indexing using which the vulnerability level of an area can be represented.

4.3 Participatory mapping

Participatory mapping is a mapmaking process that strives to make visible the relationship between a place and local communities through the use of cartography (Aberley 1999; Flavelle 2002). The different types of participatory mapping include:
1) Ground mapping: The map is drawn on the ground using fingers or sticks. It is a temporary form of mapping with limited signs and symbols and without proper scale.
2) Stone mapping: The map is prepared using stones, branches, paper and other locally available materials. Inspite of being flexible it is a temporary form of mapping without proper scale.
3) Sketch mapping: The map is drawn on a sheet of paper with coloured pens. This mapping is cheap but inflexible and can be stored locally.
4) GPS mapping: People walk around the area to be mapped and plot features using GPS device. This mapping is scaled and reliable to the government officials but requires technical expertise.
5) Participatory 3D mapping: Standalone maps are made up of locally available materials with thematic layers of geographical information. It is reusable, easily understandable and can accommodate a lot of information but it is a time-consuming process with difficulty in storage and transportation.
6) Web-based and interoperable GIS mapping: Map is prepared by people's contribution to a web-based GIS database from their own computer.

4.4 GIS based participatory mapping

It is difficult to learn from people's knowledge and experiences of enduring hazards by using earth observation products or geographical analysis alone. On the other hand, it is likely that local knowledge can become antiquated given the rapid changes that both natural and anthropogenic surroundings are undergoing. Participatory GIS (PGIS) is sometimes also referred to as "soft" GIS (Kahila and Kyttä, 2010; Ratanen and Kahila, 2009) and "Resident Generated GIS" (Talen, 1999). PGIS is effective because it allows residents to "express their views and perceptions of the neighbourhood in a highly visual, dynamic, and spatially contextualized format" (Talen, 1999). The layering capabilities of GIS allow multiple voices and perspectives to be viewed simultaneously. PGIS is often seen as an element of decision-support rather than a tool for decision analysis (Greene, Devillers, Luther, and Eddy, 2011) PGIS users can reinforce empowerment through the exploratory function of GIS-based decision tools (McCall, 2003 citing Carver 2001), and these tools will aid in fulfilling the bottom-up planning, democratic empowerment, and advocacy (McCall, 2003 citing Weiner & Harris, 2002 and Gonzalez, 2000; Brown and Kyttä, 2012; Rantanen and Kahila, 2009).

V. CASE STUDY

This section involves case studies catering to the 3 different types of mapping. GIS based participatory mapping involves 3 case studies.

5.1 Case study 1: GIS based disaster management

1) **Location:** Sadar sub-district, Allahabad, India
2) **Key focus:** To explore the scope of combining Disaster Management and GIS.
3) **Reason for choice of mapping:** GIS-based flood mitigation and management program would improve the current practices of disaster management process. If implemented properly, it would result in proper and quick decisions for the rescue and safety of the general public, which in turn would help in minimizing loss of life and property.
4) **Tools for GIS based mapping**: ArcGIS 9.1
5) **Methodology:** Firstly, an integrated geo-database was created using a GIS environment that includes multiple thematic maps, socioeconomic and demographic information, and infrastructure amenities at the village level.

Secondly, using GIS, the district's utilities, including those for electricity, roads, irrigated and non-irrigated areas, telephone and telegraph services, and education and medical facilities, are spatially represented.

Thirdly, information pertaining to unique and individual disasters as well as planned for developmental programmes is appropriately supplemented on the Survey of India (SOI) maps. Fourthly, several thematic maps have been created, including a map of the study area's land use, a map of the road and water supply networks, fire control offices, and urban sprawl.

5.2 Case study 2: Participatory three dimensional mapping for disaster risk reduction

1) **Location:** Divinubo, Philippines

2) **Key focus:** Integrating traditional and scientific knowledge, and bottom-up and top-down risk reduction measures facilitating large stakeholder involvement.

3) **Reason for choice of mapping**: Community Based Disaster Risk Reduction and Participatory Three Dimensional Mapping project proposed by scientists after identification by the local government of a gap in the disaster risk reduction framework.

4) **Tools for GIS based mapping:** Pushpins (points), yarns (lines), paint (polygons)

5) **Methodology:** Firstly, a relief map is constructed of the scale 1:5000 to 1:10000.Secondly, community members identify features which they depend on for their livelihoods. Pins of different colours represent different structures and people also identify the most vulnerable individuals in the area. Thirdly, the hazard-prone areas are delineated based on the knowledge and experience of the people. Fourthly, disaster risk-reduction measures are planned through multi-stakeholder discussions.

5.3 Case study 3: GIS based participatory mapping- Vietnam, Philippines and Indonesia

Table 5.3.1 GIS based participatory mapping case studies

Parameters	Vietnam	Philippines	Indonesia
Key focus	Identifying high flood risk residential areas.	Identifying and analyzing factors resulting in floods and converting into spatial information for determining vulnerability to floods.	Identifying and analyzing flood level, disaster risk and refuge locations.
Reason for choice of mapping	People have greater knowledge about their surroundings which are vulnerable to floods and the families most vulnerable to flooding.	GIS-supported collaborative assessments make it easier to include local expertise, participatory needs assessments, problem analysis, and local priorities..	Participatory mapping and crowdsourcing are the best cost effective choices for data procurement solutions when compared to terrestrial surveys and aerial photographs based on UAV.
Tools for participatory mapping	GPS device, computers with GIS software	GPS device and mobile GIS tools.	Smartphones, meters, bamboo sticks, instrument sheets, GIS software etc.
Integration of local knowledge and GIS	•Focus group discussions among villagers. •Conducting household survey. •Data collected using GPS is transferred to the computer.	•Conducting workshops and meetings with the local community and collection of secondary data to get an idea of the flood situation. •To gain an understanding of the perception of people related to flood through household survey, interviews, field mapping etc. •To implement notions of flood hazard, vulnerability, mechanisms for coping and risk in risk assessment. •Hydrodynamic modelling is done on the basis of community perception of flood. •Analysis of aspects that determined spatial vulnerability based on participatory exercises such as housing type, land ownership, education, health status, environmental quality, provision of basic services and development related infrastructure and availability of assistance during crisis times. •Qualitative and quantitative risk assessment was done for various flood scenarios.	•Flood level data is obtained through participatory mapping and verified with geotagging and SAR imageries to find footprint. •Flood risk analysis is done using several aspects such as threat, vulnerability and disaster capacity. •Flood capacity is determined using indicators such as school number, health facilities or workers, and flood disaster preparedness. After that, flood disaster risk generated by a union and intersect overlay analysis. •Determination of refuge locations in the region considering the flood threat and evacuation route efficiency.

VI. RESULTS AND DISCUSSION

This section deals with analysis, inference, strategies and recommendations.

6.1 Analysis

The methodology of the case studies on GIS based mapping, participatory mapping and GIS integrated participatory mapping are analyzed based on:

1) The 5 steps under disaster risk reduction and adaptation – avoidance of hazard, vulnerability reduction, preparedness for response, and preparedness for recovery and risk assessment.

2) Community participation

Also a comparative analysis of case studies based on various parameters is also done to finally arrive at the inference.

Table 6.1.1: Case study 1 analysis

GIS-based disaster management: A case study for Allahabad Sadar sub-district, India		
Disaster risk reduction & adaptation strategies	**Steps involved**	**Participation**
Avoidance of hazard	Collection of reference spatial data	Scientists, NGOs
	Identification and mapping of areas prone to hazards	GIS experts, affected citizens, NGOs
	Identification and mapping of critical values at risk	GIS experts, scientists, NGOs
	Identification of values at risk that reside within the impacted areas of natural and/or technological hazards	GIS experts, scientists
Vulnerability reduction	Data processing and analysis	GIS experts, scientists
	Developing site-specific strategies for mitigation to reduce losses.	

Table 6.1.2: Case study 2 analysis

Participatory mapping for 3-dimensional mapping for disaster risk reduction		
Disaster risk reduction & adaptation strategies	**Steps involved**	**Participation**
Avoidance of hazard	Building the relief map	Community
	Plotting land use and other geo-referenced features	
	Delineating hazard-prone areas based on participants' own knowledge and experience	
	Identification of values at risk that reside within the impacted areas of natural and/or technological hazards	
Vulnerability reduction	Planning disaster risk reduction measures	Multi-stakeholder participation (community, local government officials and scientists)
Preparedness for response	Input of data from the Participatory 3 dimensional map into GIS	Scientists and GIS experts.

Table 6.1.3: Case study 3 analysis

GIS-based participatory mapping-Vietnam, Philippines and Indonesia		
Disaster risk reduction & adaptation strategies	**Steps involved**	**Participation**
Avoidance of hazard	Exploratory scoping and data collection	Community members, leaders, local authorities
	Hazard mapping and assessment	
	Data processing	Scientists and GIS experts.
Vulnerability reduction	Spatial multi-criteria evaluation for vulnerability assessment	Community leaders and local authorities
Preparedness for response	Data integration and analysis	Scientists and GIS experts.
Risk assessment	Qualitative and quantitative flood risk assessment	Community members, GIS experts, scientists
Vulnerability Reduction	Planning and disaster risk mitigation	Community and local authorities (based on qualitative and quantitative risk assessment)

Table 6.1.4: Comparative analysis of case studies

GIS based disaster management: A case study for Allahabad Sadar sub-district (India)	**Participatory three dimensional mapping for disaster risk reduction**	**GIS based participatory mapping-Vietnam, Philippines and Indonesia**
Disaster risk reduction and adaptation		
Includes only avoidance of hazard and vulnerability reduction.	Includes avoidance of hazard, vulnerability reduction and preparedness for response.	Includes avoidance of hazard, vulnerability reduction, preparedness for response and risk assessment.
Community involvement		
Community involvement is limited to mapping and identification of hazard prone areas.	Community involvement in the first 4 stages: 1. Building the relief map. 2. Plotting of land-use and other features. 3. Delineation of hazard-prone areas. 4. Planning of disaster risk reduction measures	Community is involved in all the stages except the data processing stage requiring technical expertise.
Expenditure		
Expenditure is high as it involves the usage of sophisticated software and highly skilled persons.	Expenditure is low as it involves the usage easily available materials and does not require high technical skills.	Expenditure is high as it involves the usage of sophisticated software and highly skilled persons.
Data storage		
Information can be stored safely in a geodatabase which can be shared, reused or updated.	Requires dedicated storage space.	Information (local and scientific) can be stored safely in a geodatabase which can be shared, reused or updated.

6.2 Inference

Based on the analysis of case studies on three different types of mapping, the strengths and weaknesses of each type of mapping are drawn. This will help in inferring the type of mapping that will help in disaster risk reduction and adaptation and how it can be further improved.

6.2.1 Strengths and Weaknesses

Table 6.2.1 Strengths and weaknesses of each mapping type

GIS based disaster management: A case study for Allahabad Sadar sub-district (India)	**Participatory three dimensional mapping for disaster risk reduction**	**GIS based participatory mapping-Vietnam, Philippines and Indonesia**
Mapping type	**Strengths**	**Weaknesses**
GIS Based mapping	1. Visual format is easily understood by all and hence improves communication. 2. Easy recordkeeping. 3. Quick decision making	1. The results are dependent on the skills of the people operating the software 2. Implementation of GIS mapping is difficult where detailed information required for model based GIS analysis is not available. 3. Acquiring GIS-ready data is both financially costly in terms of hours spent collecting and editing data.
Participatory 3-dimensional mapping	1. Low cost and not technology dependent. 2. The 3d aspect of the model is effective and understandable.	1. In developing countries access to accurate topographic map is limited. 2. Labour intensive and time consuming. 3. Storage and transportation of the model can be difficult.
GIS based participatory mapping	1. Meetings provide local communities with the ability to identify and analyze their	1. People's flood related knowledge is diverse thereby

	surrounding risks. 2. The storage of local knowledge in a GIS ensures its safety and better visualization of results and also enables its reuse and updation. 3. GIS based local information can be shared with municipal authorities, NGOs etc. who are not part of the original community	making it difficult to systematically collect. 2. Municipal authorities pay less attention to how the flood risk can be mitigated.

From the analysis of the case studies involving different types of mapping we could infer that that community participation was high in both 3-dimensional participatory mapping and GIS based participatory mapping. But GIS based participatory mapping has the additional advantage of storing the information in a GIS database which can be shared, updated and reused easily when compared to that of 3 dimensional participatory mapping. While considering disaster risk reduction and adaptation steps:

1) GIS based mapping involves avoidance of hazard and vulnerability reduction.
2) Participatory 3D mapping involves avoidance of hazard, vulnerability reduction and preparedness for response.
3) GIS based participatory mapping involves avoidance of hazard, vulnerability reduction, and preparedness for response and risk assessment.

Therefore, GIS based participatory mapping is more directed towards achieving disaster risk reduction and adaption. It can be further improved by involving preparedness for recovery.

6.3 Strategies and Recommendations

This section involves: General strategies and recommendations for the 5 steps under disaster risk reduction and adaptation and recommendations for preparedness for recovery.

6.3.1 General strategies and recommendations

The general strategies and recommendations have been worked out based on the 5 steps under disaster risk reduction and adaptation:

1. Avoidance of hazard
2. Vulnerability reduction
3. Preparedness for response
4. Preparedness for recovery

Table 6.3.1 Strategy and recommendations for avoidance of hazard

Avoidance of hazard	
Strategy	**Recommendations**
To strengthen capacity building of local governments to coordinate with the local community to manage disaster risks.	Conduct capacity building programs periodically in collaboration with technical institutes and NGOs to improve knowledge of GIS software and disaster risk reduction capabilities of the local authorities and the community.
	Periodic up gradation of data with the involvement of the relevant institutions, considering climate change scenarios and their impact on disaster risk, facilitating, the participation of the community and relevant stakeholders through focus group discussions and workshops.
	Prepare hazard maps using data collected from household surveys and interviews with the help of GIS based spatial analysis techniques to get better insights into community perceptions of threat.

Table 6.3.2 Strategy and recommendations for vulnerability reduction

Vulnerability reduction	
Strategy	**Recommendations**
To promote collaboration of scientists with the local community to resolve knowledge gaps in the understanding of disaster risk.	Conduct spatial multi-criteria evaluation for vulnerability assessment through focus group discussions among the local authorities and community leaders to identify and analyze various factors contributing to vulnerability.
	Modelling hazard scenarios using GIS software based on community inputs to understand the extent of the hazard and susceptibility of the community.

Table 6.3.3 Strategy and recommendations for response

Preparedness for response	
Strategy	**Recommendations**
To empower the local community to tackle risks.	Conduct evacuation route planning and evacuation zone planning utilizing local knowledge using network analysis tool in GIS software based on community inputs.

Table 6.3.4 Strategy and recommendations for preparedness for recovery

Preparedness for recovery	
Strategy	**Recommendations**
To enable the community to build back better.	1. **Recovery planning-**To consider the relocation of housing, public facilities and infrastructure to areas outside the risk range, wherever possible, in the post-disaster reconstruction process, in consultation with the people concerned through GIS maps and / visual artifacts placed on maps for better communication of information. 2. **Restoring critical infrastructure-** To carry out critical infrastructure such as (water, electricity, and transportation systems) through the visualization of physical proximity and distribution of critical capabilities across a region using network analysis in GIS software. 3. **Debris clean up-** To use GIS as an analytic support device for debris cleanup activities using service area networking algorithms.

6.3.2 Recommendations for recovery

In order to enhance recovery using GIS based participatory mapping, it can be further divided into short-term, mid-term and long-term recommendations.

1) Short term

The short term recovery is focused on the essential needs of citizens who were affected by emergency situations.

Table 6.3.2 Recommendations for short term recovery

Focus areas	**Recommendations**
Mass care/ Sheltering	1. To locate appropriate refugee locations based on evacuation routes worked out using GIS network analysis, people's participation and real time data for mass sheltering. 2. The approximate number of refugees and their requirements can be stored in databases which can be used for directing aid to the affected.
Debris cleanup	To plan immediate debris cleanup activities after proper damage assessment with the help of GIS using remote sensing and citizen reporting from affected areas to clear up the major transportation routes.

2) Mid term

The mid-term recovery is focused on getting people back to normal by providing necessary support.

Table 6.3.3 Recommendations for mid-term recovery

Focus areas	**Recommendations**
Housing	To conduct a proper damage assessment using people's participation and GIS to provide interim housing solutions to those severely affected.
Restoration of critical infrastructure	Planning immediate infrastructure repair and restoration activities based using GIS through the visualization of physical proximity and distribution of critical capabilities across a region.
Economy	To conduct an assessment of economic and livelihood losses on the basis of which areas severely affected can be mapped using community participation and GIS to facilitate support to boost economic activity.

3) Long term

The long term recovery is focused on large investments for providing necessary support to help people get back to normal.

Table 6.3.4 Recommendations for long term recovery

Focus areas	Recommendations
Housing	To conduct a follow up assessment using people's participation and the information collected using GIS of the housing status of the people and develop permanent housing solutions.
Restoration of critical infrastructure	1. To analyze the progress of infrastructure development using GIS which will direct investments towards areas requiring immediate assistance. 2. To identify the bottlenecks in infrastructure development through multi-stakeholder discussions.
Economy	To analyze economic progress using GIS assisted socio-economic surveys to accurately locate areas in need of support and to adopt appropriate economic revitalization strategies.

The study throws light into how GIS based participatory mapping encourages high level of community participation and enables the achievement of disaster risk reduction and adaption strategies. Recommendation for enhancing the same with an increased focus on preparedness for recovery increases the efficiency of GIS based participatory mapping as a tool in disaster risk reduction and adaptation.

GIS integrated participatory mapping helps depict local knowledge in an organized manner reducing knowledge gaps and ensuring safe storage of data for future use. The analytical properties of GIS help in quick decision making which when clubbed with community participation help respond to disasters better and recover faster.

According to social media entrepreneur Matt Mullenweg, "Technology is best when it brings people together". Hence local authorities need to accept this approach and build necessary capacities technical, financial and administrative to achieve efficient disaster risk reduction and adaptation.

VII. Acknowledgment

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