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REVIEW ARTICLE

A review of challenges and solutions in adopting a participatory geographical information system for disaster management

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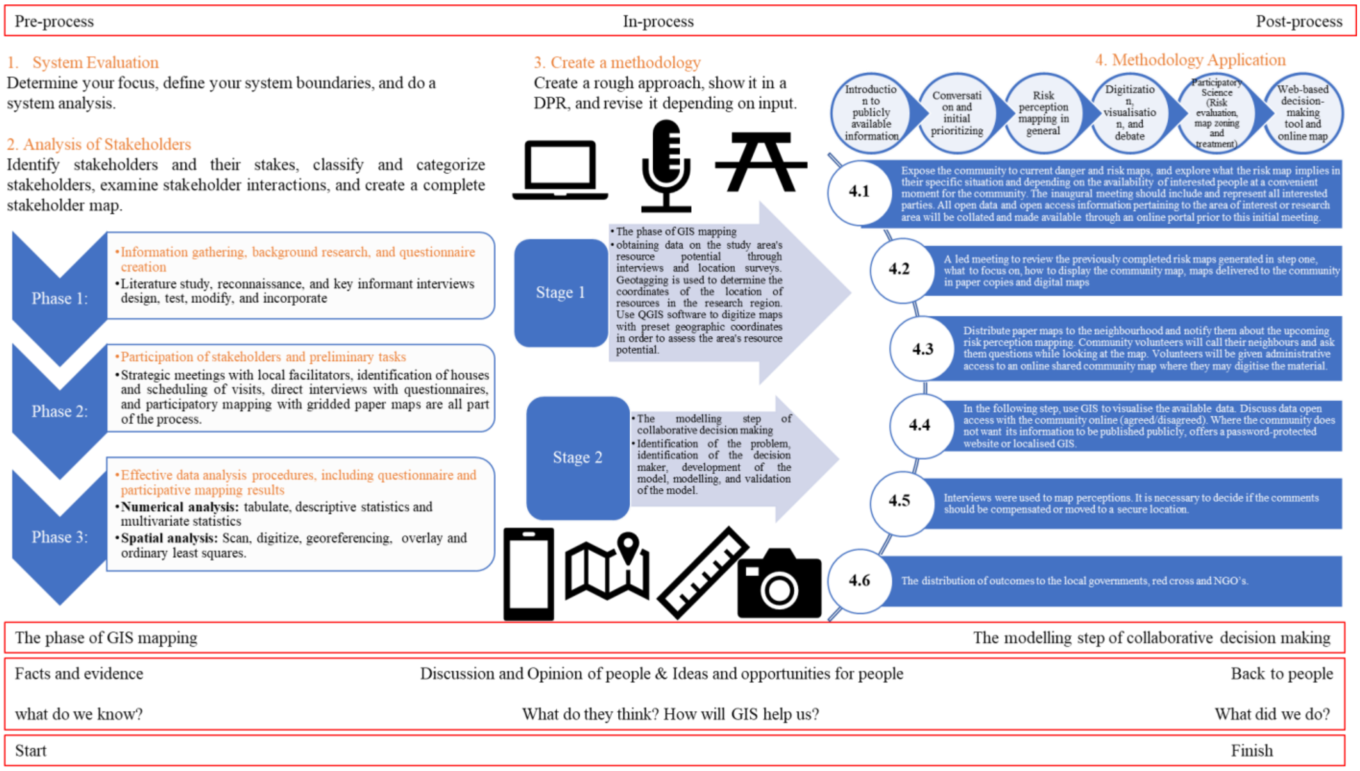
Graphical abstract



Abstract – Disaster management is a critical component in mitigating the impacts of various natural, and other disasters such as floods, cyclones, forest fires, earthquakes, disease spreading etc. The primary aim of disaster management in a specific region is to empower the local neighborhood to higher determine its natural danger instincts and therefore migrate closer to options for lowering that risk. Conventional techniques of disaster management are majorly driven by the quantitative information collected from various events. Some of the recent techniques have used more advanced data-driven and non-linear approaches such as machine learning, and spatial analysis tools such as GIS for making more informed decisions. However, these techniques cannot often represent the dynamics of demographic units, and event impact in small regions due to a multitude of reasons such as lack of data, equipment, more generalized approaches, etc. Participatory Geographic Information System (PGIS) overcomes some of the limitations present in the traditional techniques by incorporating local communities as stakeholders in making various policies, distributing risk information etc. PGIS has been adopted in various fields such as land cover planning, agriculture information systems, data collection systems etc. Other than these applications, the effectiveness of PGIS in disaster management in handling various natural disasters such as floods, cyclones, forest fires, and disease spread has been demonstrated in several studies. However, in many places, PGIS is not yet evolved and its implementation is still at the infancy level due to several reasons. Despite many advantages, PGIS presents many problems comprising insufficient infrastructure, training facilities, engagement and education of the community members towards a combined decision, etc. therefore provision of necessary infrastructure can improve the overall impact of implementing PGIS. Involving the local community and educating them on the right approach for the success of PGIS is a complex task. Further, the conflict of opinions between technical personnel and locals can be another factor that limits the usage. However, from the results of various studies, the advantages of PGIS implementation can outweigh the limitations of implementation.

Keywords – PGIS, Participatory GIS, Public Participatory GIS, Disaster preparedness, Disaster risk reduction, Disaster management.

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INTRODUCTION

The term disaster comes from the French word “disaster” and is made up of two words: 'des' for terrible and 'aster' for a star. which means a bad or unfavorable event. It is a type of misfortune by man-made/artificial or natural that results in great loss of life or property. Disaster is a common cause of distress and destruction in a society (Shibin Tad and Janardhanan, 2014). Disasters are classified as geophysical disasters such as earthquakes, landslides, and land subsidence. They can also be categorized as climate disasters, hydro-meteorological disasters, and lightning risk assessments. Some of these include Coastal erosion risk assessment, landslide risk mapping, wildfire damage assessment, and Real-time early warning (Shi, 2019). A tragedy occurs when there is a mix of danger, vulnerability, and insufficient capacity or risk-reduction measures in place (Goyet, Marti, and Osorio, 2006). A disaster occurs when the danger hurts a vulnerable population, resulting in disruption, destruction, and casualties (Norsuzila Ya’acob et al., 1989). Activities aimed at dealing with disasters are referred to as disaster management. Effective disaster management practices are very much essential for reducing the catastrophic effects that are triggered by floods (National Research Council, 2013).

Disaster management is often defined as the organization and administration of resources and responsibilities for dealing with all humanitarian elements of disasters, such as disaster preparedness, response, and recovery, to reduce the effect of disasters (Pawar 2008; Flanagan et al., 2020). In general, disaster management consists of three major steps i.e., i) Pre-disaster management ii) Management during Disasters iii) Post-disaster management (Todd, 2008). Effective disaster management practices can be handicapped by limitation in the availability of sufficient data at different times of the disaster event (Osuteye, Johnson, and Brown, 2017).

Conventionally, knowledge-based approaches driven by quantifiable historical evidence are used in various applications such as flood forecasting, impact analysis, development of preventive tools, and facilities, etc. However, in many places that are susceptible to flood this type of knowledge is required for making the necessary projections, and facilities are often not available (Diakakis, 2017). Small-scale events triggering the inundation at local levels are very difficult to monitor, and the information on such events is very scarce and not consistent (Seneviratne et al. 2012; Canevari-Luzardo et al., 2017). Further, a lack of infrastructure to collect required data during the disaster event can act as redundancy in taking appropriate measures (Morton and Levy, 2011). These limitations demand the requirement of gathering additional knowledge to improve the understanding and communication of the risk and uncertainty associated with the event for effective disaster management (Weichselgartner and Pigeon, 2015). However, it can be impractical to deploy a huge amount of infrastructure and resources to an entire area of any country, particularly if the occurrence of such events is less. With the use of technology and scientific equipment, the likelihood of their recurrence may be adequately anticipated (Rathore, 2016). It has been determined that there is a certain pattern in their occurrences, allowing us to lessen the impact of harm to some level.

The advancement in technology to readily capture, analyze and transfer different types of spatial and other reference information from various stakeholders can be used as an approach for reducing the cost associated with building huge infrastructure and personnel, and also at the same time to improve upon the limitation of inconsistent and scarce data (Qadir et al., 2016). Integrating disruptive technology into smart cities strengthens the infrastructure required to respond to disasters. For future disaster management improvements in urban areas, disruptive technologies such as the Internet of Things (IoT), image processing, artificial intelligence (AI), big data, and smartphone apps are being employed and encouraged (Munawar et al., 2022). During natural disasters, the use of social media platforms such as Twitter skyrockets. Textual content analysis from millions of tweets published on Twitter during Hurricane Harvey (Karimiziarani et al., 2022). The findings might assist catastrophe management and responders in minimizing the event's repercussions.

Participatory Geographical Information System (PGIS) provides a way to accomplish this task of collecting evidence from various stakeholders such as the public and data interpreters and providing necessary processed information to various users. PGIS "refers to the integration of GIS with participatory techniques that encourage community participation in or involvement with the research processes to increase stakeholder knowledge, influence, and control". PGIS is a transdisciplinary mapping approach that elicits, represents, and validates local geographical knowledge using Geographical Information Technologies (GITs). It employs Participatory Active Research (PAR) concepts, such as a dedication to research-informed action, valuing processes as much as outputs, and challenging the norms of insular academic research through the development of inclusionary ways to knowledge coproduction (Canevari-Luzardo et al., 2017). Public stakeholders living in the event regions in general have more understanding of the event, its risk, and possible reasons for the event. Involving and engaging the public can result in the collection of highly specific local data, and wider acceptance of the driven decisions by the system. The concept of the participatory risk management system by PGIS aims to improve the resilience of communities affected by climate-related risks through the use of local knowledge. This approach encourages the involvement of local communities in the management of their environment. However, its use is still in the infancy stage in India.

The following is an outline of the current review article. The intricacies and foundations of PGIS are discussed in section 2, how various studies have used PGIS for flooding in India are summarized in section 4, the overall benefits and limitations of PGIS are present in section 2, and finally, a brief discussion addressing the challenges and way forward for implementation of PGIS for flooding and other disasters in given in section 3. Geographic information governance and ownership, representations of local and indigenous knowledge, size and scaling up, web-based methodologies, and some prospective future technological and academic projects are all investigated by PGIS. A Participatory GIS embraces the multiplicity of geographical reality, as opposed to the detached, objective, and technical solutions that have tended to define many traditional GIS applications (Dunn, 2007).

Participatory approaches such as semi-structured interviews, transect walks, and community mapping were utilized to collect primary data. In general, P-GIS approaches are ideally adapted to include people's knowledge and may be used to disaggregate complicated coherences in a way that is intelligible and adaptable to less-empowered individuals. Participatory development is characterised as a partnership based on interaction among multiple players, in which local perspectives and expertise are actively sought and valued. The focus is always on participation and participatory methods, rather than on GIS. The approach of participatory data collection was used. Although the PRA (Participatory Rural Appraisal) toolbox was not designed expressly for hazard risk assessments, it’s been used a lot in development projects and rural development planning (Kienberger and Steinbruch, 2005). The indications were broken down into physical, sociocultural, economic, and institutional vulnerability, resulting in a community's overall vulnerability.

The findings are used to determine the program's emphasis and needs for each community. Maps of the communities were also created. The major goal was to collect spatial data from communities using GPS surveys to visualize the community in a comprehensible fashion to assist residents and Disaster Risk Committees in identifying safe spots in the event of flooding. These maps were also an important element of the review process. Four communities in Mozambique were chosen for research based on their accessibility, desire to cooperate, vulnerability, and geographic position. The study's methodology was based on semi-structured interviews (Lombard and Ferreira, 2014). McCall provided criteria for evaluating participatory procedures that focused on community mapping exercises (2003 & 2004). Participatory techniques were generally one-sided, intending to acquire information with the community's support and participation. To record spatial information and people's views of disasters, map sketches were generated. There are different maps for independent non-governmental agencies in many municipalities. GIS (ArcView 3. x) was used to digitize the map, which was then passed on to the district administrator.

INTRICACIES AND FOUNDATIONS OF PGIS

PGIS is a technology that has been hailed as the ideal platform for harnessing the power of data from local communities across the country and applying it to natural resource management. The purpose of PGIS is to combine local and indigenous knowledge with 'expert' data. Inclusion of underrepresented groups; organizational application through partnerships; practical implementation through a variety of formats and data sources; and connections to social theory and qualitative research methods are all aspects of PGIS. Participatory GIS is an effective tool for extracting information from people, and it may be used to model and investigate flood events.

PGIS investigates issues such as geographic information control and ownership, representations of local and indigenous knowledge, scale and scaling up, web-based techniques, and some potential future technical and academic initiatives. Instead of the detached, objective, and technical 'solutions' that have tended to characterize many traditional GIS applications, a Participatory GIS celebrates the diversity of spatial realities (Dunn, 2007). Questions about participatory research as a suitable and relevant manner of bringing about desired change are central to representations of indigenous knowledge in PGIS. Some have claimed that this is not the case, particularly in the context of "progress".

For mapping reasons, PGIS can be simplified to incorporate several groupings collectively. In PGIS, mobile applications may be utilized to make mapping simpler and more efficient. Because of the capabilities for creating questionnaires and storing data on the server, ODK (Open Data Kit) is the ideal open-source mobile platform for PGIS (Joy, Kanga, and Singh, 2019).

The team used a Geographical Information System (GIS) assisted Transect walk, Agro-ecological map, Resource map, Timeline, Seasonal calendar (activities) and Seasonal analysis (problems), Bio-resource flow, Indigenous technical knowledge, Technology map, social map, Consequence's diagram, and problem prioritization tools, as well as focus group discussions and opinion leaders (Meena et al. 2018; Muralikrishnan et al., 2021).

Participatory GIS (PGIS) has emerged as greater popular, it's far designed to supply spatial representations of nearby expertise through network mapping exercises. The beliefs of PGIS revolve around the idea of public participation withinside the use of spatial records main to extended network involvement in coverage putting and decision-making. In this paper how the PGIS facts enhance the technical ("official") records being generated with the aid of using the UK government on those issues, after which is going on to talk about the classes from this example study, thinking about whether or not this system may be transferred to the evaluation of noise pollution (Cinderby, Snell, and Forrester, 2008).

IMPLEMENTATION OF PGIS

Implementation of PGIS comprises various activities that involve the participation of different stakeholders comprising the local community and technical personnel. The generalized process of implementation starts with specific goals and objectives concerning the target community or study region. The assignment of unique digital identifiers and digitization of the community dwellings in the study region forms a premise for collecting various data and initiating various tasks in a GIS environment. The necessary data for such digital database creation in GIS is accomplished by conducting household surveys in the local communities with the help of technical personnel and residing community. The information collected from such surveys and community feedback is typically based on the PGIS objectives which are framed based on the disaster event and persistent risk to the region. Following the initial responses from the community mapping of infrastructure, risk-prone areas, and mitigation measures will be considered for further feedback from the community.

This information from 1st community feedback session is validated, digitized, and represented in the form of different maps or other forms for further processing. Following that, the digitized infrastructure, risk zones and identified mitigation measures are presented for feedback from different stakeholders by carrying out another community feedback session. During the feedback session opinion and assessments on the validation of digitized assets, vulnerability criteria, and usability of vulnerability maps are collected. This helps in establishing vulnerability criteria and maps, that are typically approved by the residents of the community. These identified criteria and assessments contributed by the local community are considered for further improving the database in GIS and thereby vulnerability maps.

The developed and processed information in such a manner is represented to the community representatives before finalization and distribution to the relevant risk management authorities and community units. Thus, the information developed and distributed through the GIS environment essentially comprises the participation of people residing in the community along with different others. Hence, compared to various other information that is normally distributed to manage disasters, this information can have a higher acceptance rate from individuals concerning the foreseen risk and necessary measures that are to be adopted.

Various risk mapping activities are carried out in this framework, such as climate change risk zone mapping, biological disasters risk zone mapping, and wildfire damage assessment. They also provide real-time early warning systems.

APPLICATIONS OF PGIS

The design and framework of PGIS facilitate its adoption in managing various disasters. Some studies have demonstrated the utility of PGIS in handling weather and climate-related disasters such as floods, cyclones, and health-related disasters such as covid, cholera, malaria etc.

PGIS IN DISEASE-RELATED HAZARDS:

Understanding the physical and social environments of a community is very vital and often is a prerequisite for developing strategies for preventing as well as handling risks associated with different diseases. Several studies emphasized the importance of participatory research methods in preventing the spread of diseases such as HIV/AIDS, Covid-19, malaria etc. The advance in GIS has facilitated the participation of community members in collecting and analyzing the data for making necessary guidelines as well as for producing relevant information in different applications. Several case studies also emphasize the advantage of using community-driven GIS in collecting heterogeneous data at the local scale, particularly where the resources are limited. GIS combined with participatory techniques is used in representing and analyzing the accessibility of different members in the community to health facilities based on spatial, social and economic aspects (Kuupiel et al., 2020). Further, the disease risk of different population clusters is widely analyzed over different regions in several studies. Aggregated analyses of geographical and social patterns associated with disease transmission were investigated using PGIS in several studies.

PGIS also facilitates the identification of zones within a region where Prevailing poor facilities within a region can be identified with help of PGIS, further it is also possible to provide information in efficient planning of health and social facilities. Certain diseases such as malaria and cholera also majorly depend on the local demographic, topographic, and environmental conditions such as population density, vegetation, humidity, temperature, rainfall etc. PGIS has been effectively used to collect various information related to sizable demographic units and further in designing effective preventive strategies in countering the disease spread in various countries including Kenya, Tanzania etc. Recent applications of PGIS in the health sector include the analysis and mapping of COVID-19 disease in several countries. Tracking of population and vehicular movement, and disease spreading patterns were analyzed spatially and temporally to formulate the COVID-19 clusters and evaluate the situation and forecast the further spread of the disease (Franch-Pardo et al., 2020). Further, the advantages of PGIS can be used for the provision of emergency health facilities to patients to reduce the excess movement of affected patients and carry out sanitation services, vaccination services are also in planning vaccination drives effectively. In PGIS, in addition to the data gathered from communities, remote sensing data was also used in different applications to track the changes in demographic and topographic conditions required in planning efficient strategies for disaster management. On the other hand, crowdsourcing applications are crucial instruments for real-time mapping and monitoring, according to these studies, allowing health authorities to make decisions and build successful management strategies.

PGIS IN NATURAL HAZARDS:

Management of nature-related disasters such as floods, cyclones, earthquakes, avalanches etc., is another key area where PGIS can be implemented. Further, these events stress that effective disaster risk management requires the implementation of local knowledge in various preparedness and planning activities. Collection and organization of information at a fine scale (local level) are important for handling the risk associated with natural disasters at the community level. The data at finer resolution is limited in general approaches planned for handling disasters at large scale (Ravinder, Ramu, and Srinivasarao, 2020). The importance of local communities in disaster preparedness has grown due to a lack of resources and a dearth of trustworthy scientific data. Hence, the mapping of demographic units, infrastructure, and risk zones is carried out in several studies using the PGIS approach. Though remote sensing data are widely used for flood mapping, and cloud cover, limitations in spatial and temporal resolution often hinder their effective utilization. To account for this limitation, a PGIS approach consisting of Open data kit (ODK) tools and GIS is used to collect various geographic and flood information for developing a flood inundation map in a study by joy (Joy, Kanga, and Singh, 2019).

The information collected from community interactions and field investigations were incorporated into the analytical hierarchy process framework for developing flood vulnerability zones in Kogi state, Nigeria (Buba et al. 2021; Ndukson Buba et al., 2021). This study demonstrates that PGIS can complement conventional flood research in designing a more acceptable and effective, mitigation and response strategy for local communities. The PGIS studies related to natural hazards are driven to engage and empower the local community to effectively assess the implications involved with the hazard and thereby plan and adopt solutions for handling the risk (Kemp, 2008).

Numerous other applications related to natural hazards such as flood frequency analysis, inundation mapping, earthquakes, and avalanches are carried out globally by researchers using the PGIS framework. Detection and modelling of the avalanche runout path, followed by spatial resolution improvement using a high-resolution DTM and expert knowledge. The most common approaches for monitoring landslides (slow and rapid) vary depending on the availability of data to be used: Digital Image Correlation (DIC) is a technique for generating 3D displacement from optical pictures. Reconstruction and comparison of photogrammetric datasets from people in the International Archives of Photogrammetry, spatial information (Yordanov et al., 2021).

PGIS IN OTHER RISK STUDIES:

Other than natural hazards, and disease risks, PGIS is also widely used in applications related to air and noise pollution, resource mapping, agricultural practices, land cover and land use planning etc. The information and results arising from such case studies can be possibly used for establishing policies for abating noise and air pollution at different levels by prioritizing the maximum responses from the community. Location-based climate-driven smart agricultural models are also designed at different places using the PGIS approach. These models can contribute in quickly delivering the important information associated with climate, crops, production and other information to the farmers.

A variety of farming difficulties were identified using the PGIS application in agriculture. The rankings were based on the severity of the situation and the proportion of the loss that the farmers individually face. Some techniques were used to identify and manage the various problems faced by farmers in a village (Muralikrishnan et al., 2021). The results of the exercise were presented in a report. The data was gathered through focus groups and a resource mapping exercise. The exercise involved creating mental maps of the various LULCs (Malaki et al., 2017). For the exercise, two decades were split into two halves. Each half had its subject. The goal was to detect changes in the way people looked at the world around them. The maps revealed various information about their neighborhood.

DISCUSSIONS

Geographic information system (GIS) technologies and approaches have been used to monitor and analyse circumstances, anticipate occurrences and guide policy choices. A GIS system that combines top-down expert knowledge with bottom-up local knowledge, driven by scientific inquiries and experiences of the residing community, is more capable of reflecting the more robust scientific and acceptable solutions for effective disaster management practices. Although the process of reconciling expert knowledge and local knowledge requires rigor, flexibility, and pragmatism, the fusion should result in a single system that is comprehensive, valid, and accepted. There are several challenges in implementing PGIS. Primary among them is the failure to fully engage the people in the decision-making process during critical times, especially when there are obvious conflicts between local and expert knowledge.

The mutual coordination between technical experts and the community often tends to deter when expert knowledge is imposed in such instances. Although a lot of research has been done to improve the usability of PGIS systems, not much has been done about how to effectively engage and represent local community knowledge in PGIS. Together with the application of overly complex systems to manage hazards and disasters, these factors impact the credibility of PGIS. This is a common problem in PGIS, as observed in several studies. The sources of such difficulties are often associated with the failure to acknowledge that social and economic mechanisms operate in the context of sociocultural and political contexts, which limit the application of PGIS systems. The availability of skilled local experts and data needed for analysis is another limiting factor in the implementation of PGIS. Most communities focus mainly on the foreseeable, short-term problems they have to address. Further, PGIS has relatively less history compared to conventional procedures for disaster management and other applications. Educating and involving different stakeholders in adopting PGIS is difficult, particularly when addressing issues about the local knowledge and practices related to disasters in different communities.

Despite the difficulties, PGIS implementation can yield efficient results, particularly in isolated communities compared to traditional techniques, which adopt a holistic approach. Following a strategic scheme that identifies the problems and solutions can solve several of the limitations stated earlier. The key aspects of PGIS should be kept in mind to run a successful PGIS facility in different communities: (1) technical knowledge and skills are not required for using PGIS; and (2) training for local users of the results. These two points can be further broadened by recognizing that PGIS requires the construction of a collaborative environment for product improvement, to bridge the "knowledge gap" among different stakeholders. This is the essence of PGIS. For such a collaboration and knowledge link to be established, the following key components should be considered: (1) identification of the minimum datasets required for research and training purposes; (2) creation of simple yet reliable systems for users; (3) development of technical skills, including specific training on PGIS if necessary; and (4) ensuring institutional sustainability and keeping the knowledge alive in the community. The success of PGIS implementation requires not only technical skills but also social skills. Training and education of relevant knowledge should be included in the design process. Detailed information about the study area should be collected in a consistent manner using different approaches through active participants from the community.

The best approach is to start with a community that already has a high level of awareness and participation, and then gradually involve more communities. How to promote PGIS in different communities is an important challenge for the further implementation of this system. However, the benefits associated with PGIS can outweigh the inherent limitations and constraints associated with implementation. Small-scale pilot studies in specific communities are of great importance to testing and evaluating the feasibility of large-scale projects. There is, thus, a need to invest in community-based PGIS and disaster management. This can be done through the development of policies, strategies, and legal frameworks by government agencies and research organizations. Only once issues related to lack of local knowledge, expert knowledge, and procedural aspects are reconciled, will the full value of PGIS in the day-to-day management of natural hazards be realized. To make local experts' knowledge mainstream, facilitated community-based participatory disaster risk reduction should be encouraged to establish more inclusive governance mechanisms. In the framework of the 'democratization of GIS,' PGIS investigates topics of control and ownership of geographic information, representations of local and indigenous knowledge, size and scaling up, web-based methodologies, and some potential future technological and academic possibilities.

CONCLUSION

PGIS offers a unique and robust framework to engage various stakeholders comprising the general public in the community, technical persons, and decision-makers in the process of decision-making. This framework incorporates local knowledge and helps in accomplishing a more agreeable solution to a variety of problems in different areas which also includes disaster management. Particularly in the case of micro-communities, the integration of local knowledge, and stakeholders is extensively useful in designing solutions as well as in disseminating important information at right time. Web-based tools, enhanced data sharing, and real-time information are at the heart of the latest PGIS technologies help to make decisions, and share them with users.

The PGIS approach is iterative and adaptable enough to adjust in response to local circumstances and agreements reached with stakeholders. The dashboards in PGIS show these values (i.e., decisions, feedback and other information) and have proven to be very popular for sharing and understanding the transmission of disaster risk. People around the world can access information through map-based dashboards, making it easy to protect yourself and your community. This type of solution improves data transparency and helps government agencies disseminate information.

PGIS has proven its worth in many events and problems related to disaster management. Despite the unique solutions and framework, it offers, its implementation is at a nascent stage in India. There exist challenges in terms of infrastructure, and educating people to effectively implement PGIS in addressing different issues. Further, most of the studies carried out so far are limited to a single event or single community. Additionally, these studies are most of these studies are performed by non-profit organizations and research institutes to understand the effectiveness of PGIS. This illustrates the lack of widespread implementation of PGIS even at a community level. However, by designing tools that can be conveniently transformed to integrate a variety of information from different stakeholders it will become more adoptable.

This however poses a challenge, i.e., the development of such generalized tools and framework requires the conceptual knowledge of multiple fields. A stronger framework for the implementation and development of more robust tools is only possible by carrying out more studies. Other problems with PGIS include monitoring the quality of data and standardizing the collected data. This is a difficult task as the data is collected from several stakeholders, and exchanged through multiple phases. Additionally, it is also important to see the possible scenarios which can threaten the quality of data, and thereby PGIS. Engaging more people, and increasing participation is a key activity in PGIS. Incentivizing the participants is a good strategy to increase the pace of PGIS development.

The use of tools that are readily available to most of the stakeholders such as mobiles (with GIS functions), laptops, etc., can help in improving data collection. So far, the studies are mainly carried out by academicians and researchers whose primary focus is on the development of tools rather than an evaluation of their effectiveness. Therefore, it is also important to assess the performance of PGIS during the implementation, as well as after the implementation to improve its usage and utility. However, there is no universal approach for evaluating the effectiveness of implementation, as the conditions prevailing in different communities are different. In this aspect, the availability of simplified interfaces, and open data policies can help evolve the PGIS. Overall, despite PGIS's potential merits and advantages, it is important to acknowledge that PGIS is in a nascent stage of growth in India, and shall be used after careful evaluation for decision-making in different applications.

Table 1: Advantages and disadvantages of PGIS

Benefits	**Limitations**
Integrates stakeholder views, knowledge, and beliefs about services (methodological and operational advantages).	The methods best practices or recommendations are still being developed.
Allows many stakeholder types to participate, raising awareness and encouraging social learning about ecosystem services.	PGIS methods have mostly been applied on a local basis, with the integration of results into larger-scale decision-making proving difficult.
Some ecosystem services (for example, cultural services) are well-suited to this mapping strategy (methodological and operational advantage).	The level of comparability between studies is frequently low.
Allows for the mapping of environmental services in locations where spatial data is scarce (methodological and operational advantages). The GIS abilities required to create this method are straightforward (methodology advantages).	For some services, the spatial resolution and accuracy of the results may be poorer than for other methodologies.

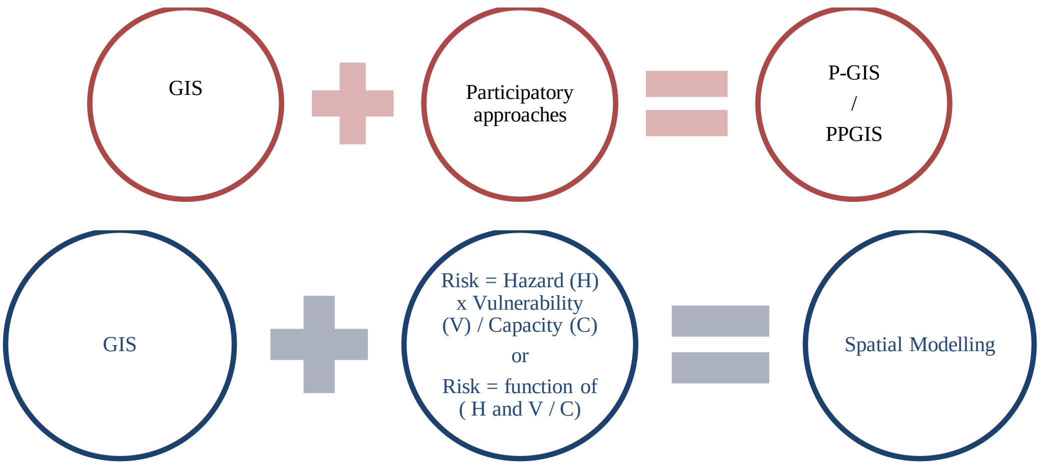

Figure 1: Difference between spatial modelling and PGIS/PPGIS.

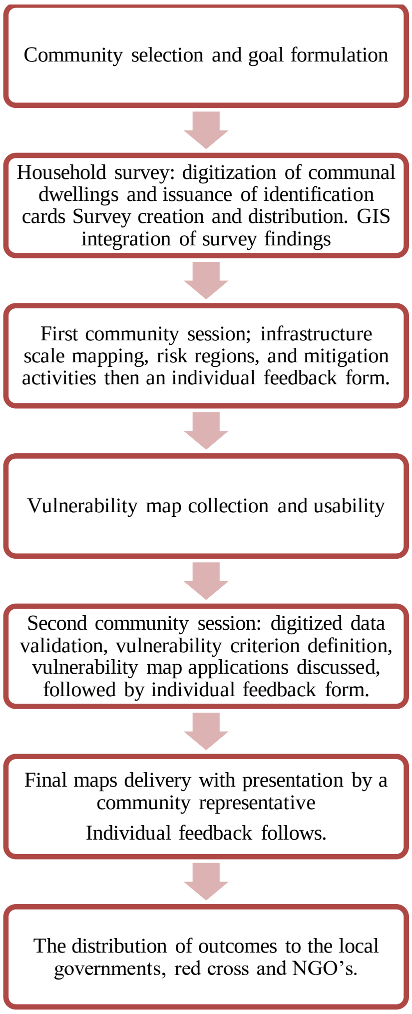

Figure 2: A graphic illustration of the key flexible and iterative P-GIS methodological steps.

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