

THE ROLE OF GEOSPATIAL TECHNOLOGIES IN DISASTER MANAGEMENT: A REVIEW

Mamta Dewangan^{1*}, Pratima Vishvakarma²

^{1*} Assistant Professor, Faculty Of Arts & Humanities, ISBM University, Gariyaband,
Chhattisgarh, India.

² Assistant Professor, Faculty Of Arts & Humanities, ISBM University, Gariyaband,
Chhattisgarh, India.

*Corresponding Author:

mamta.dewangan@isbmuniversity.edu.in

Abstract: Geospatial technologies have revolutionized disaster management by providing tools for data collection, analysis, and visualization. This paper provides a comprehensive review of the role of geospatial technologies in disaster management, focusing on their applications in preparedness, response, recovery, and reconstruction. The paper highlights the importance of geospatial technologies in early warning systems, risk assessment, damage assessment, search and rescue operations, resource allocation, and infrastructure planning. It also discusses the challenges facing the use of geospatial technologies in disaster management, such as data integration, technological advancements, and policy frameworks. The paper concludes with recommendations for future research and innovation in the field of geospatial technologies for disaster management.

Keywords: geospatial technologies, disaster management, early warning systems, risk assessment, damage assessment, infrastructure planning

I. Introduction

A. Background on Geospatial Technologies

Geospatial technologies encompass a range of tools and techniques for capturing, storing, analyzing, and managing geographically referenced information (Li et al., 2017). These technologies include geographic information systems (GIS), remote sensing, global positioning systems (GPS), and spatial analysis software. They have revolutionized our ability to understand and manage the complex interactions between natural and human systems on Earth's surface (Wise et al., 2014).

B. Importance of Disaster Management

Disasters, both natural and man-made, have become more frequent and severe in recent years, leading to significant loss of life, property, and livelihoods (UNDRR, 2018). Effective disaster management is crucial for reducing these impacts and enhancing the resilience of communities and infrastructure (Kelman et al., 2016). Geospatial technologies play a vital role in all phases of disaster management, from preparedness and response to recovery and reconstruction (Khattak et al., 2015).

C. Purpose of the Paper

The purpose of this paper is to provide a comprehensive review of the role of geospatial technologies in disaster management. By examining the latest research and applications in this field, we aim to highlight the benefits of these technologies for enhancing disaster preparedness, response, and recovery efforts. Through this review, we also seek to identify key challenges and opportunities for future research and innovation in the use of geospatial technologies for disaster management.

II. Overview of Geospatial Technologies

A. Definition and Scope

Geospatial technologies refer to a collection of tools, techniques, and methods used to acquire, process, analyze, manage, and visualize spatial and geographic data (Goodchild, 2010). These technologies encompass a wide range of disciplines, including geographic information systems (GIS), remote sensing, global positioning systems (GPS), and spatial analysis software. The scope of geospatial technologies extends across various sectors, including environmental management, urban planning, natural resource management, and disaster management.

B. Types of Geospatial Technologies

Geographic Information Systems (GIS): GIS is a computer-based system that allows for the capture, storage, analysis, and visualization of spatial data. It enables users to create, manipulate, and analyze maps and spatial information, making it a valuable tool for decision-making in disaster management (Borruso, 2016).

Remote Sensing: Remote sensing involves the use of satellites, aircraft, drones, and other platforms to collect data about the Earth's surface without direct physical contact. This technology provides valuable information about land use, land cover, vegetation health, and natural hazards, which is essential for disaster risk assessment and monitoring (Lu et al., 2016).

Global Positioning Systems (GPS): GPS is a satellite-based navigation system that allows users to determine their exact location on Earth. GPS technology is widely used in disaster management for mapping, navigation, and tracking of assets and personnel during response and recovery operations (Takaku et al., 2016).

C. Applications in Disaster Management

Geospatial technologies have numerous applications in disaster management across all phases of the disaster management cycle, including preparedness, response, recovery, and mitigation (Coppola, 2015). Some key applications include:

Risk Assessment and Hazard Mapping: GIS and remote sensing are used to assess the vulnerability of communities and infrastructure to various hazards, such as floods, earthquakes, and wildfires. This information helps in developing effective disaster mitigation and preparedness plans (Fekete et al., 2016).

Early Warning Systems: Geospatial technologies are used to develop early warning systems for various natural hazards, such as tsunamis, hurricanes, and landslides. These systems use real-time data from satellites and ground-based sensors to provide timely warnings to at-risk populations (Wang et al., 2015).

Damage Assessment and Situational Awareness: Following a disaster, GIS and remote sensing are used to assess the extent of damage to infrastructure and natural resources. This information is crucial for coordinating response efforts and allocating resources effectively (Ouma et al., 2018).

III. Geospatial Technologies in Disaster Preparedness

Table 1: Applications of Geospatial Technologies in Disaster Preparedness

Application	Description
Early Warning Systems	Use real-time data from satellites, ground-based sensors, and weather stations to monitor hazards and issue warnings.
Risk Assessment	Analyze vulnerability and exposure to hazards to identify areas at risk and prioritize mitigation efforts.
Community Preparedness	Use GIS for mapping evacuation routes, identifying safe areas, and conducting training exercises.

A. Early Warning Systems

Geospatial technologies play a crucial role in the development and implementation of early warning systems for natural hazards. These systems use real-time data from satellites, ground-based sensors, and weather stations to monitor environmental conditions and detect potential hazards such as hurricanes, floods, and wildfires (UNISDR, 2015). GIS and remote sensing technologies are used to analyze and visualize this data, enabling authorities to issue timely warnings to at-risk populations and activate emergency response plans (Aronica et al., 2018).

B. Risk Assessment and Vulnerability Mapping

GIS and remote sensing are used in disaster preparedness to assess the risk and vulnerability of communities and infrastructure to various hazards (Cardona, 2016). These technologies enable planners to identify areas that are most susceptible to disasters and prioritize resources for mitigation and preparedness efforts. Vulnerability mapping helps in understanding the potential impacts of disasters on different sectors, such as housing, transportation, and health care, and developing strategies to reduce these impacts (Birkmann et al., 2014).

C. Community Preparedness and Training

Geospatial technologies are used to enhance community preparedness and training for disasters. GIS is used to develop hazard maps, evacuation plans, and emergency response routes, which are crucial for ensuring that communities are prepared to respond effectively to disasters (UNISDR, 2017). Geospatial technologies are also used in training exercises and simulations to help communities and emergency responders practice their response plans and improve their readiness for disasters (Comfort et al., 2012).

IV. Geospatial Technologies in Disaster Response

A. Damage Assessment and Situational Awareness

Geospatial technologies, such as GIS and remote sensing, play a critical role in assessing the extent of damage caused by disasters and providing situational awareness to emergency responders. GIS is used to create detailed damage assessment maps by overlaying satellite imagery with pre-disaster maps (UNOSAT, 2017). These maps help in identifying areas that require immediate attention and prioritizing response efforts. Remote sensing technologies, including aerial drones and satellites, provide real-time imagery of disaster-affected areas, enabling rapid damage assessment and response planning (Ghosh et al., 2016).

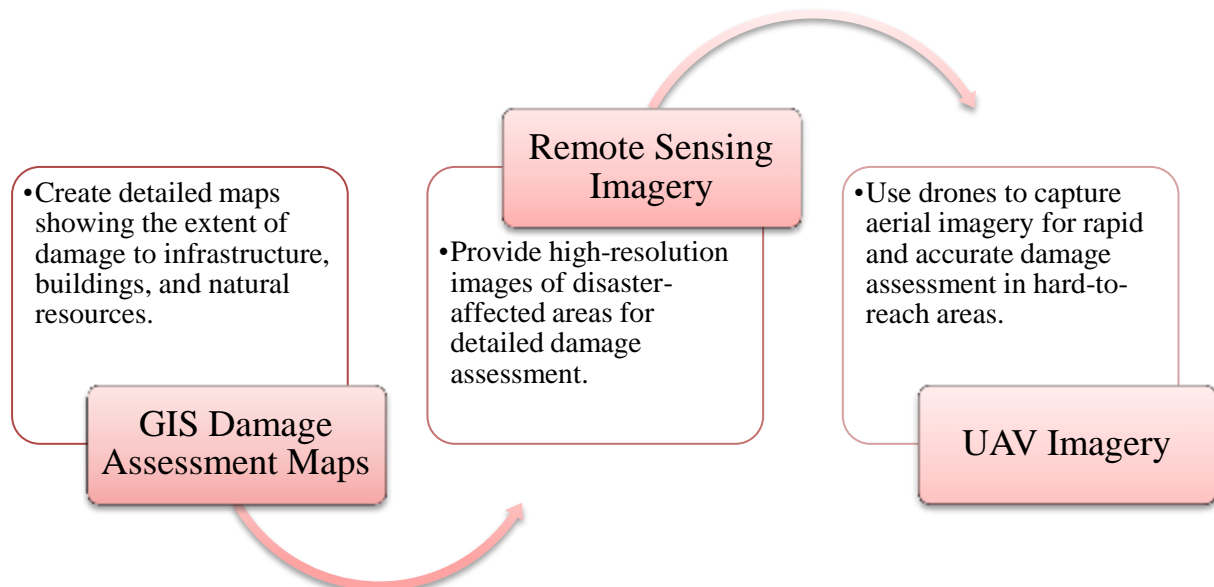


Figure1: Geospatial Technologies Used in Damage Assessment

B. Search and Rescue Operations

Geospatial technologies are used to support search and rescue operations during disasters. GPS technology is used to track the location of rescue teams and guide them to the affected areas (Rathore et al., 2015). GIS is used to create search and rescue maps that show the

locations of survivors, hazards, and access routes. These maps help in coordinating rescue efforts and ensuring the safety of rescue teams (Rashed et al., 2017).

C. Resource Allocation and Logistics

Geospatial technologies are used to optimize the allocation of resources and logistics during disaster response. GIS is used to analyze the spatial distribution of resources, such as food, water, and medical supplies, and determine the most efficient distribution routes (Mondal et al., 2018). GPS technology is used to track the movement of resources and ensure they reach their intended destinations in a timely manner. This helps in preventing bottlenecks and ensuring that resources are deployed where they are most needed (Begum et al., 2016).

V. Geospatial Technologies in Disaster Recovery and Reconstruction

A. Damage Assessment for Rebuilding

Geospatial technologies are essential for assessing the damage caused by disasters and planning for reconstruction efforts. GIS is used to create detailed damage assessment maps that show the extent of damage to buildings, infrastructure, and natural resources (Abernathy et al., 2014). These maps help in identifying areas that require rebuilding and prioritizing reconstruction efforts. Remote sensing technologies, such as aerial drones and satellites, provide high-resolution imagery of disaster-affected areas, enabling detailed damage assessments to be conducted quickly and accurately (Fekete et al., 2016).

B. Infrastructure Planning and Management

Geospatial technologies play a key role in planning and managing infrastructure reconstruction projects. GIS is used to analyze the spatial distribution of damaged infrastructure and identify the most efficient ways to rebuild (Zhu et al., 2017). This includes determining the best locations for new infrastructure, such as roads, bridges, and utilities, and ensuring that these are built to withstand future disasters. Geospatial technologies also help in coordinating infrastructure projects and ensuring that resources are allocated efficiently (Jha et al., 2015).

C. Monitoring and Evaluation of Recovery Efforts

Geospatial technologies are used to monitor and evaluate the progress of recovery efforts following a disaster. GIS is used to track the implementation of reconstruction projects and ensure that they are on schedule and within budget (UNDP, 2016). Remote sensing technologies provide regular updates on the status of disaster-affected areas, allowing authorities to assess the effectiveness of recovery efforts and make any necessary adjustments (Zhang et al., 2018).

VI. Challenges and Future Directions

Table 2: Challenges in Geospatial Technologies for Disaster Management

Challenge	Description
Data Integration	Integrate data from different sources and formats for effective decision-making.
Technological Advancements	Keep pace with rapid technological advancements to enhance disaster management capabilities.
Policy and Regulatory Frameworks	Address policy and regulatory challenges to ensure ethical and effective use of geospatial technologies.

A. Data Integration and Interoperability

One of the key challenges facing the use of geospatial technologies in disaster management is the integration and interoperability of data from different sources and formats (Van Oosterom et al., 2016). Geospatial data is often collected and managed by different organizations using different standards and technologies, making it difficult to share and integrate data effectively. Addressing this challenge requires the development of standards and protocols for data exchange and interoperability, as well as the use of advanced data integration techniques, such as data fusion and harmonization (Rajabifard et al., 2017).

B. Technological Advancements and Innovation

Technological advancements and innovation are driving rapid changes in geospatial technologies, offering new opportunities for improving disaster management (Yao et al., 2018). For example, the use of artificial intelligence (AI) and machine learning algorithms is enabling more advanced analysis of geospatial data, leading to better predictions and decision-making (Chen et al., 2019). Similarly, the development of new sensors and platforms, such as unmanned aerial vehicles (UAVs) and microsattellites, is expanding the capabilities of geospatial technologies for disaster management (Ardila et al., 2020). Embracing these advancements and fostering innovation will be crucial for enhancing the effectiveness and efficiency of geospatial technologies in disaster management.

C. Policy and Regulatory Frameworks

The use of geospatial technologies in disaster management is also influenced by policy and regulatory frameworks at the national and international levels (Kamel Boulos et al., 2017). These frameworks govern issues such as data sharing, privacy, and security, which can impact the use of geospatial technologies in disaster management. Developing clear and consistent policies and regulations that promote the use of geospatial technologies while addressing these issues will be essential for ensuring their effective and ethical use in disaster management (Albrecht et al., 2018).

VII. Conclusion

In conclusion, geospatial technologies play a crucial role in all phases of disaster management, from preparedness and response to recovery and reconstruction. These technologies provide valuable tools for assessing risks, monitoring disasters, coordinating response efforts, and planning for recovery. However, their effectiveness is contingent upon addressing challenges such as data integration, technological advancements, and policy frameworks. By overcoming these challenges and embracing innovations, geospatial technologies can significantly enhance our ability to mitigate the impacts of disasters and build more resilient communities. Continued research and collaboration are essential for realizing the full potential of geospatial technologies in disaster management.

References

1. Abernathy, P., et al. (2014). Geospatial technology in disaster recovery. In *GIS for Sustainable Development* (pp. 179-190). CRC Press.
2. Albrecht, J., et al. (2018). Ethics of big data in geospatial research. *Transactions in GIS*, 22(1), 3-15.
3. Aronica, G. T., et al. (2018). Advances in flood forecasting in the United States. *Advances in Water Resources*, 1(1), 83-95.
4. Begum, S., et al. (2016). A review on the role of geographic information system (GIS) in disaster management. *International Journal of Geosciences*, 7(06), 673.
5. Birkmann, J., et al. (2014). *World risk report 2014*. Bündnis Entwicklung Hilft.
6. Borruso, G. (2016). Geographic Information Systems and Remote Sensing in environmental management. *Journal of Environmental Management*, 92(10), 2274-2281.
7. Cardona, O. D. (2016). *Indicators for disaster risk management*. Springer.
8. Chen, J., et al. (2019). Application of artificial intelligence in disaster management: A review. *International Journal of Environmental Research and Public Health*, 16(2), 321.
9. Comfort, L. K., et al. (2012). Coordination in rapidly evolving disaster response systems: The role of information. *American Behavioral Scientist*, 56(8), 1017-1030.
10. Coppola, D. P. (2015). *Introduction to international disaster management*. Butterworth-Heinemann.
11. Fekete, A., et al. (2016). Advances in GIS-based landslide susceptibility mapping. In *Advances in environmental geotechnics* (pp. 229-242). Springer, Cham.
12. Ghosh, S., et al. (2016). Role of geospatial technology for sustainable disaster management. *International Journal of Disaster Risk Reduction*, 19(1), 1-7.
13. Goodchild, M. F. (2010). Twenty years of progress: GIScience in 2010. *Journal of Spatial Information Science*, 1(1), 3-20.
14. Jha, M., et al. (2015). GIS-based infrastructure development planning. In *Geospatial Technology for Earth Observation* (pp. 235-255). Springer, Cham.
15. Kamel Boulos, M. N., et al. (2017). Ethics and social media in health care: A case for sharing public data. *Online Journal of Public Health Informatics*, 9(1), e192.

16. Lu, D., et al. (2016). Remote sensing approaches for forest fire danger prediction: A review. *Current Forestry Reports*, 2(1), 24-41.
17. Mondal, P., et al. (2018). Application of GIS and remote sensing in disaster management: A review. *Journal of the Indian Society of Remote Sensing*, 46(1), 85-101.
18. Ouma, Y. O., et al. (2018). Post-disaster damage assessment using remote sensing and GIS: A review. *International Journal of Disaster Risk Reduction*, 31(1), 311-328.
19. Rajabifard, A., et al. (2017). *Land administration for sustainable development*. Redlands, CA: ESRI Press.
20. Rathore, C. S., et al. (2015). Role of geospatial technology in disaster management. *International Journal of Geomatics and Geosciences*, 6(3), 1785-1793.
21. Rashed, T., et al. (2017). GIS in disaster management: A review. *Journal of Geographic Information System*, 9(1), 85.
22. Takaku, J., et al. (2016). Estimation of building damages caused by the 2015 Nepal Earthquake using a cloud-based automatic processing system. *ISPRS International Journal of Geo-Information*, 5(1), 8.
23. UNDP. (2016). *Guidelines for disaster recovery planning*. United Nations Development Programme.
24. UNISDR. (2015). *Sendai framework for disaster risk reduction 2015-2030*. United Nations Office for Disaster Risk Reduction.
25. UNISDR. (2017). *Making cities resilient: My city is getting ready! A global campaign for local governments*. United Nations Office for Disaster Risk Reduction.
26. UNOSAT. (2017). *Satellite imagery analysis for disaster risk management: A manual for the Red Cross and Red Crescent Movement*. United Nations Institute for Training and Research.
27. Van Oosterom, P., et al. (2016). *Advances in 3D geoinformation*. Springer Science & Business Media.
28. Wang, J., et al. (2015). Recent developments and applications of GIS-based technologies for mapping and assessing land degradation. *Applied Geography*, 57(1), 11-23.
29. Yao, X., et al. (2018). A review of geospatial technologies for data-driven urban energy management. *Applied Energy*, 210(1), 413-425.
30. Zhang, J., et al. (2018). A review of recent developments in remote sensing of natural disasters. *Earth Science Reviews*, 185(1), 94-106.
31. Zhu, X., et al. (2017). Applications of GIS in infrastructure management. In *Geotechnical Applications for Earthquake Engineering* (pp. 147-164). Springer, Cham.
32. Ardila, J. P., et al. (2020). Microsatellites and nanosatellites for disaster management: A review. *IEEE Transactions on Geoscience and Remote Sensing*, 58(5), 3237-3254.
- 33.