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APPLICATIONS OF GEOSPATIAL TECHNOLOGIES IN DISASTER RISK MANAGEMENT IN PAKISTAN

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Abstract

Geospatial technologies, including Geographic Information Systems (GIS), Remote Sensing (RS), and Global Positioning Systems (GPS), have become indispensable tools in the field of Disaster Risk Management (DRM) worldwide. In Pakistan, which is prone to natural hazards such as earthquakes, floods, and landslides, the application of these technologies has proven essential for risk assessment, disaster preparedness, response, and recovery. This article explores the various applications of geospatial technologies in disaster risk management in Pakistan, focusing on the integration of GIS, remote sensing, and GPS in assessing and mitigating disaster risks. The research highlights how these technologies are utilized for hazard mapping, early warning systems, vulnerability analysis, and disaster response coordination. Through case studies, it also discusses the challenges faced in adopting these technologies, including data availability, technical expertise, and institutional frameworks. The article concludes by offering recommendations to improve the integration of geospatial technologies in disaster risk management, emphasizing the need for enhanced training, infrastructure development, and policy support.

Keywords: *Geospatial Technologies, Disaster Risk Management, Geographic Information Systems (GIS), Remote Sensing, Global Positioning Systems (GPS), Pakistan, Natural Hazards, Disaster Preparedness, Vulnerability Assessment.*

INTRODUCTION:

Pakistan is one of the most disaster-prone countries in South Asia, facing a wide range of natural hazards, including earthquakes, floods, droughts, and landslides.

The frequency and intensity of these disasters have increased over the past few decades due to climate change and rapid urbanization. In response, there has been an increasing recognition of the role those geospatial technologies, including GIS, Remote Sensing (RS), and GPS, can play in disaster risk management. These technologies provide powerful tools for mapping hazards, assessing vulnerabilities, predicting future risks, and coordinating disaster responses. Despite their potential, there are numerous challenges associated with the use of these technologies in Pakistan, including insufficient infrastructure, lack of trained personnel, and difficulties in data integration. This paper aims to examine the applications of geospatial technologies in Pakistan's disaster risk management efforts and offers insights into the ways these technologies can be effectively integrated into disaster mitigation strategies.

1. Geospatial Technologies in Hazard Mapping and Risk Assessment

o GIS in Hazard Mapping

Geographic Information Systems (GIS) are a fundamental tool in hazard mapping for disaster risk management. GIS allows for the integration and analysis of spatial data, which can be used to identify hazardous areas, analyze their spatial distribution, and assess the vulnerability of regions to specific natural disasters. In Pakistan, GIS has been applied to various hazard mapping efforts, such as flood zones, earthquake-prone areas, and landslide risks. By overlaying various layers of geospatial data (e.g., topography, land use, population density, and infrastructure), GIS helps to pinpoint areas that are at risk and provides valuable information for disaster preparedness and response. For instance, floodplain mapping using GIS allows local authorities to establish flood risk zones, informing the allocation of resources for flood mitigation measures. GIS also supports the creation of dynamic hazard maps, which can be updated in real-time, providing accurate and up-to-date information for decision-makers during disaster events.

o Remote Sensing for Disaster Risk Assessment

Remote sensing technologies, such as satellites and aerial imagery, are pivotal in disaster risk assessment. Remote sensing enables the collection of large-scale and detailed data on environmental conditions, even in remote or inaccessible areas.

For example, during flood events, remote sensing can provide critical data on water levels, land inundation, and the extent of the damage. Similarly, satellite imagery can be used to assess deforestation, soil erosion, or the movement of tectonic plates in earthquake-prone areas, allowing for predictive analysis. In Pakistan, remote sensing has been extensively used for monitoring flood risks, mapping land degradation, and evaluating the impacts of climate change on vulnerable ecosystems. Moreover, remote sensing data can be used in combination with GIS to improve disaster risk models, thus providing more accurate hazard assessments and enhancing the efficiency of response efforts.

o GPS for Mapping and Monitoring

Global Positioning Systems (GPS) provide real-time location data, which is critical for mapping and monitoring various natural hazards. GPS technology is especially useful for tracking the movement of tectonic plates, monitoring land subsidence, and following the path of earthquakes or landslides. In Pakistan, GPS technology has been deployed to map earthquake-prone regions, assess seismic activities, and support the construction of disaster-resistant infrastructure. Additionally, GPS plays a key role in post-disaster damage assessment, as it helps responders to navigate affected areas and efficiently allocate resources. In flood-prone regions, GPS is used to track water levels, identify flood-prone infrastructure, and assist in the development of evacuation plans. Furthermore, GPS can be integrated with GIS and remote sensing technologies to provide real-time data that enhances disaster preparedness and response efforts.

2. Applications of Geospatial Technologies in Disaster Preparedness

o Early Warning Systems

Geospatial technologies are essential in the development and implementation of early warning systems for natural disasters. By integrating GIS, remote sensing, and real-time data from sensors, early warning systems can predict the occurrence and intensity of disasters such as floods, earthquakes, and tsunamis. In Pakistan, early warning systems have been particularly important for flood forecasting, where GIS-based flood modeling helps to predict flood-prone areas and provide alerts to affected communities. Satellite data, combined with weather forecasting models, can help monitor rainfall patterns and river levels, providing advanced

warning of potential floods. Additionally, early warning systems supported by geospatial technologies enable timely evacuation, resource mobilization, and disaster mitigation efforts, thus reducing the loss of life and property.

o Risk Communication and Awareness

Effective risk communication is a critical component of disaster preparedness, and geospatial technologies play a significant role in disseminating vital information to the public and authorities. GIS-based platforms can be used to create maps that display areas at risk, evacuation routes, and emergency shelters, making it easier for citizens to understand their vulnerability and take appropriate actions. Remote sensing data can be used to generate real-time updates on disaster events, such as wildfires or floods, which can be communicated through various media channels, including mobile apps and websites. Additionally, GIS tools can be used to provide targeted information to specific communities based on their geographic location, ensuring that risk communication is tailored to the needs of those at greatest risk. In Pakistan, geospatial technologies have supported government agencies, NGOs, and local communities in raising awareness about disaster risks and promoting disaster preparedness behaviors.

o GIS-based Decision Support Systems for Preparedness

Decision support systems (DSS) powered by GIS are crucial for disaster preparedness, as they assist in making informed decisions about resource allocation, risk mitigation, and emergency planning. GIS-based DSS integrate multiple layers of spatial data, such as population density, infrastructure vulnerability, and environmental factors, to assess disaster risks and prioritize areas for intervention. In Pakistan, GIS-based DSS have been employed to plan disaster preparedness strategies for various natural hazards. For instance, before a flood event, decision-makers can use GIS to identify vulnerable populations, determine evacuation routes, and allocate resources for shelters and medical assistance. In the case of earthquakes, GIS-based DSS can help assess building resilience and guide the planning of retrofitting measures for at-risk structures. By integrating real-time data, GIS-based DSS also enhance the ability to respond dynamically during a disaster, ensuring that resources are deployed efficiently and effectively. Geospatial technologies, through their applications in hazard mapping, early warning systems, and preparedness planning, significantly contribute to

improving disaster risk management in Pakistan. By combining GIS, remote sensing, and GPS technologies, decision-makers can enhance their understanding of natural hazards, improve preparedness, and reduce the impact of disasters on communities.

3. Geospatial Technologies in Disaster Response and Recovery

o Role of GIS and RS in Post-Disaster Response

Geospatial technologies such as GIS and remote sensing (RS) play a critical role in post-disaster response by providing essential data for assessing the extent of the damage and coordinating emergency operations. After a disaster, rapid damage assessment is required to direct resources to the most affected areas. GIS helps in analyzing the distribution of affected populations, damaged infrastructure, and environmental conditions, enabling effective response strategies. Remote sensing, with its ability to capture real-time data through satellite imagery and aerial reconnaissance, is crucial in monitoring the evolving disaster situation. For instance, following floods in Pakistan, satellite imagery and remote sensing data were utilized to identify flood-affected regions, infrastructure damage, and areas requiring urgent relief. These technologies provide a comprehensive and timely understanding of disaster impacts, which aids in decision-making for response teams. Additionally, GIS allows for the mapping of access routes for emergency responders, ensuring the swift delivery of aid, while also assisting in the coordination of medical, food, and shelter supplies.

o Geospatial Data for Damage Assessment

Geospatial data is indispensable for damage assessment during and after a disaster. This data, obtained from remote sensing, satellite imagery, and GIS, is used to quantify the extent of the destruction, monitor recovery progress, and evaluate the effectiveness of response efforts. In the aftermath of earthquakes, floods, or landslides, geospatial data allows authorities to identify the extent of land submergence, infrastructure collapse, or soil displacement. By integrating GIS with data from remote sensing, it is possible to create high-resolution maps that highlight areas of greatest damage, such as collapsed buildings, inundated regions, or blocked transportation routes. In Pakistan, the use of satellite imagery to assess damage after the 2005 earthquake and the 2010 flood allowed for a rapid, accurate

assessment, enabling the allocation of aid based on priority. Additionally, GIS-based damage assessment tools help track the effectiveness of response measures over time, ensuring that relief efforts are directed where they are most needed and providing a basis for future risk mitigation strategies.

o Geospatial Technologies in Recovery Planning

Geospatial technologies are vital in recovery planning after a disaster. These technologies assist in mapping out the areas that need rehabilitation and reconstruction, prioritizing tasks, and allocating resources effectively. GIS-based recovery planning involves using spatial data to assess the environmental, social, and economic impacts of a disaster, enabling authorities to plan for sustainable recovery. For example, GIS can help identify safe zones for rebuilding homes, suggest optimal locations for new infrastructure, and assess the risk of secondary disasters such as aftershocks or floods. In Pakistan, following the 2005 earthquake, geospatial data was instrumental in planning the rebuilding of infrastructure, ensuring that new constructions were resilient to future disasters. Remote sensing can also be used to monitor land-use changes and track the progress of recovery efforts, ensuring that resources are being used effectively and that long-term resilience is built into recovery strategies. Furthermore, geospatial technologies aid in monitoring environmental recovery, such as the restoration of water sources, forests, and agricultural lands, thus ensuring that disaster recovery is sustainable and equitable. Geospatial technologies are indispensable in disaster response and recovery. By enabling efficient post-disaster response, providing accurate damage assessments, and supporting recovery planning, GIS, remote sensing, and GPS technologies help reduce the impact of disasters, improve recovery efforts, and foster resilience. These technologies are essential tools for managing the complexities of disaster recovery, ensuring that resources are utilized effectively and that affected communities can rebuild in a sustainable manner.

4. Challenges in the Application of Geospatial Technologies in Pakistan

o Data Availability and Quality Issues

One of the primary challenges in the application of geospatial technologies for disaster risk management (DRM) in Pakistan is the availability and quality of data. Accurate and reliable data are essential for GIS, remote sensing, and GPS

technologies to provide meaningful insights into disaster risk assessment and response. However, in Pakistan, data availability remains a significant challenge due to various factors, including limited access to up-to-date satellite imagery, outdated mapping resources, and insufficient ground-level data. In many rural and remote areas, data collection efforts are hampered by logistical issues, such as difficult terrain, lack of technical infrastructure, and limited resources. Additionally, the quality of data may be compromised due to inconsistencies in data collection methods, human errors, and the lack of standardized protocols for geospatial data collection. This results in unreliable data that can hinder decision-making processes and lead to inefficient disaster risk management strategies. Moreover, gaps in data on the social and economic vulnerabilities of communities exacerbate the challenge of assessing disaster risks effectively.

o Technical Challenges and Infrastructure Gaps

Another significant obstacle to the effective application of geospatial technologies in Pakistan is the technical challenges and infrastructure gaps. The lack of skilled personnel, including GIS analysts, remote sensing experts, and IT professionals, poses a barrier to the proper use of geospatial technologies. Additionally, limited access to advanced geospatial software, equipment, and tools further impedes the ability of disaster management agencies to leverage these technologies effectively. Pakistan's infrastructure, especially in rural and disaster-prone areas, is often inadequate to support the full implementation of geospatial technologies. For example, internet connectivity and access to power grids may be unreliable, particularly in disaster-affected areas, which complicates the real-time collection and dissemination of geospatial data. Furthermore, many government institutions and local authorities lack the technical expertise to integrate and analyze complex geospatial data, thus preventing the effective utilization of these technologies for disaster risk management. These technical challenges require a comprehensive effort to build the necessary infrastructure and provide adequate resources for geospatial technology deployment.

o Policy and Institutional Framework Challenges

The effective application of geospatial technologies in disaster risk management also faces significant policy and institutional framework challenges. In Pakistan, there is a lack of coordinated policies that promote the use of geospatial

technologies across various sectors involved in disaster management, such as emergency services, urban planning, and environmental protection. This fragmented approach results in the underutilization of geospatial technologies and hinders collaboration between different government agencies and stakeholders. Additionally, disaster management policies often fail to incorporate geospatial technologies as part of the national disaster management plans, and there is a lack of clear guidelines on how these technologies should be integrated into disaster response and recovery efforts. Institutional frameworks are often weak in terms of coordination and capacity, with a limited number of agencies having access to or expertise in geospatial tools. These challenges can be attributed to insufficient awareness among policymakers about the potential benefits of geospatial technologies and the lack of legal and institutional mechanisms to facilitate their widespread use.

5. Recommendations for Enhancing the Use of Geospatial Technologies in DRM

o Capacity Building and Training

To overcome the challenges related to data quality, technical expertise, and infrastructure, capacity building and training are crucial. Building the skills of individuals involved in disaster risk management, from government officials to local community leaders, is vital for the successful application of geospatial technologies. This can be achieved through dedicated training programs that focus on GIS, remote sensing, and GPS technologies, tailored to the needs of disaster management professionals. These programs should include both theoretical and practical components, allowing participants to gain hands-on experience with geospatial software, satellite imagery, and field data collection. Moreover, training should not only be limited to urban areas but should also extend to rural and disaster-prone regions, ensuring that personnel in all regions are capable of utilizing geospatial tools in disaster risk management. In addition to government staff, training should also target universities and private sector entities, encouraging collaboration and knowledge-sharing across different sectors. Enhancing the overall capacity of human resources will result in more effective and efficient use of geospatial technologies for disaster preparedness, response, and recovery.

o Infrastructure Development

To fully integrate geospatial technologies into disaster risk management in Pakistan, significant infrastructure development is necessary. First and foremost, there is a need for reliable and robust data collection systems. Establishing national databases of geospatial data on natural hazards, vulnerable populations, and infrastructure will support more accurate and comprehensive hazard mapping and risk assessments. Moreover, enhancing internet connectivity and energy infrastructure in remote and rural areas will enable real-time data transmission, which is essential for timely disaster response. Investment in modern geospatial equipment, such as GPS devices, remote sensing technologies, and GIS software, is also necessary to enable government agencies, NGOs, and local authorities to effectively monitor, assess, and respond to disasters. Additionally, improvements in the telecommunication network and cloud-based systems will help to ensure the timely sharing and dissemination of disaster-related information, providing a collaborative platform for all stakeholders involved in disaster management.

o Strengthening Institutional Frameworks

A key recommendation for improving the use of geospatial technologies in disaster risk management is the strengthening of institutional frameworks. This includes establishing clear national policies that promote the integration of geospatial technologies into disaster management plans and strategies. The government should work towards creating a unified disaster management framework that encourages collaboration between various stakeholders, including federal and provincial disaster management authorities, local governments, non-governmental organizations, and the private sector. Additionally, a dedicated agency or task force should be established to oversee the implementation and coordination of geospatial technologies in disaster management. This agency would be responsible for setting standards, developing training programs, facilitating data sharing, and ensuring the effective use of geospatial tools across all stages of disaster risk management. Strengthening legal frameworks to protect and regulate the use of geospatial data is necessary to ensure data security, privacy, and accuracy. While there are significant challenges in the application of geospatial technologies in disaster risk management in Pakistan, there are also clear opportunities for improvement. By focusing on capacity building, infrastructure development, and strengthening institutional frameworks, Pakistan

can harness the full potential of geospatial technologies to enhance its disaster preparedness, response, and recovery efforts. These measures will not only improve disaster management but also build resilience in vulnerable communities across the country.

Naveed Rafaqat Ahmad's (2025a) study on State-Owned Enterprise (SOE) reform in Pakistan presents a comprehensive evaluation of governance, financial performance, and accountability challenges across eight major public-sector organizations from 2019 to 2024. Employing both quantitative and qualitative methods, the research reveals chronic inefficiencies, excessive subsidy dependence, and structural weaknesses, particularly within PIA and Pakistan Steel Mills, which together accounted for more than 92% of total subsidies. Ahmad emphasizes that political interference, weak institutional controls, and poor governance frameworks have significantly eroded public trust. He advocates for urgent reforms including privatization, public–private partnerships, governance professionalization, and citizen-focused accountability mechanisms to restore transparency, fiscal sustainability, and institutional credibility.

Ahmad (2025b) investigates the implications of human–AI collaboration in professional knowledge work, focusing on productivity gains, error patterns, and ethical risks. Using a mixed-methods approach, the study demonstrates that AI assistance can enhance task completion speed by 32–39%, particularly for novice users, while simultaneously increasing error rates in complex tasks. Ahmad categorizes AI-related errors into hallucinations, logical inconsistencies, fabricated citations, omissions, and biased assumptions, highlighting the critical need for human oversight. His findings underscore the importance of ethical awareness, verification practices, and trust calibration to ensure responsible and accountable integration of AI into professional workflows.

Summary:
Geospatial technologies have demonstrated considerable potential in improving disaster risk management in Pakistan. This paper has provided an overview of how GIS, Remote Sensing, and GPS technologies are employed in hazard mapping, risk assessment, preparedness, response, and recovery. Through

examples and case studies, the paper highlighted the significant role of these technologies in creating early warning systems, assessing vulnerabilities, and coordinating disaster responses. The study also addressed the challenges faced by Pakistan in fully utilizing these technologies, including the lack of data, limited technical expertise, and institutional barriers. Finally, the paper provided several recommendations, including the need for capacity-building programs, improved data-sharing mechanisms, and strengthened policy frameworks to support the effective integration of geospatial technologies into Pakistan's disaster risk management system.

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