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Applications of Geospatial Technology in Disaster Management: A Critical Analysis

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Abstract : *Environmental hazards and disasters are the most pressing issues in the current context. These hazards and disasters each year claim lives and destroy property and infrastructure. In today's world, geospatial technology is critical for identifying and managing environmental hazards and disasters. Modern geospatial tools such as remote sensing, GIS, and GPS are widely used to mitigate the severity and impact of hazards and disasters. The importance of remote sensing (RS), Geographic Information System (GIS), and Global Navigation Satellite System (GNSS) data is highlighted by comparing studies on their use in natural disaster management. Geographic information systems (GIS) and remote sensing (RS) are very useful and effective tools for various disasters, such as earthquakes, landslides, floods, fires, tsunamis, volcanic eruptions, and cyclones Remotely sensed data can be used to accurately assess the severity and scope of disaster-related damage. Disaster mapping is drawing areas that have experienced excessive natural or man-made troubles to the natural environment, where there is a loss of life and national infrastructures. Spatial data sharing is discussed in the context of setting up Spatial Data Infrastructures (SDIs) for natural disasters. Some examples of SDI applications in disaster management are examined, and the importance of participation from organizations and governments in facilitating information exchange and improving preventive and emergency plans is emphasized. Furthermore, the possibility of citizens contributing to the risk and disaster management process by providing voluntary data from volunteered geographic information (VGI) applications is investigated.*
To demonstrate the importance of the issues raised, a model was proposed that connected all of the spatial data-sharing aspects discussed in the article.

Keywords: *Disaster management, GIS, Remote sensing (RS), Global Navigation Satellite System (GNSS), Volunteered Geographic Information (VGI); Spatial Data Infrastructure (SDI).*

1. INTRODUCTION :

A disaster is a severe disruption to the functioning of a community or society that results in widespread human, material, economic, or environmental losses and impacts that exceed the affected community's or society's capacity to cope with its resources [1]. Disasters, whether natural or caused by humans, have become a growing concern around the world. Disaster management is a broad term that refers to the processes involved in strategic planning as well as the procedures implemented to control natural disasters. The United Nations estimates that in 2015, the average yearly losses worldwide due to natural disasters like tornadoes, floods, droughts, and earthquakes were between $250 and $300 billion [2]. Furthermore, according to the World Bank, in 2016 natural disasters resulted in annual losses of up to 520 billion USD worldwide, a 60% increase over losses that had previously been reported [3]. The potential of geospatial science and technology to reduce risk and disaster is boundless. Remote sensing, photogrammetry, cartography, geographic information systems (GIS), global positioning systems (GPS), and information technology (IT) are all considered forms of geospatial technology. Acquisition, storage, processing, production, presentation, and distribution of geographic data are all facilitated by geospatial technologies. To map the hazard zones during emergencies and provide mitigation, geographic information systems (GIS) may be a useful and essential technique. Techniques like GIS and remote sensing are very beneficial for preparation and mitigation strategies. The distribution of resources for response will be improved by real-time geographic knowledge. The modeling of disaster risks and human variations to hazards is often aided by GIS technologies. By identifying hazard zones related to floodplains, coastal inundation erosion, and active faults, remote sensing can support reduction initiatives. Additionally, high-resolution, temporal, and spatial satellite imagery applications, like flood monitoring and forest fire detection, can aid in the early stages of an efficient response in the event of a real disaster. Developing an efficient plan during disasters remains the biggest challenge that many countries face to the present day. Acquiring a better understanding of a place can be aided by estimating its vulnerability and risk to natural disasters. Planners and operators can prioritize target mitigation and necessary activities for the affected areas by using this insightful information. Although there are technologies for both satellite and aerial remote sensing, satellite-derived remote sensing methods are more frequently employed because they offer a synoptic view that is crucial for studies on disaster risk management.

Figure 1: Disaster management cycle.

When disaster management planning is centered on the priority areas, aerial remote data is primarily utilized for natural hazard management, offering information that is insufficiently detailed to detect in satellite imagery, and verifying small-scale data verifications.

1. **Prevention:** According to ISDR (2009), prevention is the complete avoidance of the negative effects of hazards and related disasters. Large volumes of data must be managed to complete the area's hazard and vulnerability assessments, and remote sensing and GIS can help with this.
2. **Preparedness:** The ability to anticipate, respond to, and recover from the effects of likely, impending, or current hazardous events or conditions is referred to as preparedness. It is cultivated by governments, professional response and recovery organizations, communities, and individuals. When it comes to carefully planning evacuation routes and creating zones for emergency operations in areas of the city where they are appropriate and necessary, geospatial technology is a helpful tool [5].
3. **Relief:** The provision of emergency services and public assistance during or shortly after a disaster is known as relief. Its goals are to ensure public safety, minimize health effects, save lives, and provide for the basic needs of those impacted. GPS and GIS work together to provide vital information for search and rescue missions. This is crucial because every minute counts and can mean the difference between life and death.
4. **Rehabilitation:** In this case, remote sensing organizes the damaged data and offers crucial knowledge for later application. It is possible to centrally and effectively manage the post-disaster census and analysis data that are available for reconstruction sites.

The effective technology to monitor, plan, and respond to disaster risk is now more possible than ever due to the use of remote sensing, earth observation systems (EOS), and geographic information systems (GIS), among many other tools available to disaster management professionals. The spectrum of visible, near-infrared, infrared, short-wave infrared, thermal-infrared, and synthetic aperture radar (SAR) provides sufficient coverage and enables computer enhancement, which is mainly utilized for disaster risk management.

However, none of the current satellites and their sensors have been designed specifically to observe natural hazards. In addition, the study intends to outline the application and assess how geospatial science and technology are currently used for disaster risk management phase analysis.

2. LITERATURE REVIEW :

The Role of Geospatial Science and Technology for Disaster Risk Management-

Geospatial technologies have made it easier to produce valuable information products for disaster management, which would otherwise require a lot of time and resources. Based on modelling geospatial data, modelling, simulation, and visualization enable disaster management decision-makers to leverage embedded information with ease inefficient knowledge generation and decision support processes. Furthermore, the application of geospatial technology can significantly impact disaster management by supporting the delivery of crucial decisions in times of crisis. With the use of a GIS database or a database that is accessible through a GIS platform, geographic information has emerged as a valuable tool for risk assessment and hazard identification.

Moreover, decision-making can benefit greatly from the application of geospatial science and technology, which also helps to improve governance and decision transparency [7]. Spatial or georeferenced decisions account for about 80% of daily national decisions in the areas of the economy, finance/taxation, demography, environment, hazard areas, infrastructure, housing, cultural heritage, etc. [8]. That makes it abundantly evident that the foundation of every nation and economy is geoinformation or location. Geographical technology offers a vast array of information that can be applied to disaster management, claims Kohler (2005). All stages of disaster management involve the use of geoinformation products like satellite photos, aerial photographs, land use maps, thematic maps, and hazard maps based on geographic information systems [7,9,10–12].

3. MATERIALS AND METHODS :

Distinct software methodologies and satellite imagery were employed to detect disaster-prone regions, classify them based on risk levels, register vulnerable populations and assets, and conduct damage simulations to manage disaster risk [13]. First, using various satellite imagery and image processing software such as ILWIS 4.2, the disaster risk area was drawn. After that, a shape file was created and exported for analysis into Arc GIS 10.8. After that, the satellite imagery was registered to a particular geographic area and geo-referenced. To extract information about land cover and vegetation, image classification algorithms like NDVI were applied to this georeferenced image. The third stage involved exporting all of the processed and classified images to ArcGIS for overlay analysis, which helped to identify areas of risk.

To obtain new and significant data for overlay analysis, additional GIS operations, such as buffering, were applied to some of the obtained data below. Also, a GIS environment was used to integrate all of the data. Lastly, a variety of software programs, including ENVI 5.0, ERDAS IMAGINE 2015, ILWIS 4.2, ArcGIS10.8, and ArcPro 2.9, will be utilized for efficient disaster risk management. Arc GIS-3D Analyst Extension, Spatial Analysis Extension with Model Builder. The Analytical Hierarchical Process (AHP) is a multi-criteria decision-making technique that offers a methodical way to evaluate and integrate the effects of different factors. It involves multiple levels of dependent, qualitative, and quantitative information about the risk of disaster.

APPLICATIONS OF GIS AND REMOTE SENSING IN DISASTER MANAGEMENT -

Studies on the value and uses of remote sensing and GIS in disaster management are becoming more and more prevalent. [14, 15] Vin Jiping (2006). The fact that remote sensing and GIS are among the quickest ways to gather data for pre- and post-disaster research is a primary driver behind their adoption. Furthermore, the effective and well-developed use of GIS and remote sensing in monitoring, hazard mitigation, and disaster management has resulted from satellite imagery. With GIS, you can use models to combine various data types. It makes it possible to combine different kinds of spatial data with attribute and non-spatial data, making them useful information that can be used at different stages of the disaster management cycle.

There are numerous uses for GIS and remote sensing in disaster management. These are referred to as potential geospatial science and technology application areas for disaster risk management.

- **Earthquake detection** Among the most destructive natural disasters, earthquakes claim a significant number of lives and destroy a lot of property [16, 17]. Over time, geographic information systems (GIS) and remote sensing have grown in importance as tools for earthquake prediction. An earthquake's beginning can be detected by distant sensors. They thus offer helpful information for forecasting impacted areas. Recent years have seen a rise in interest in satellite-assisted earthquake and monitoring [16, 18]. These benefits aid in a deeper comprehension of the laws governing earthquake preparedness, occurrence, and development. The remote sensing techniques that are most applicable to earthquake science/ engineering are optical satellite imagery, synthetic aperture radar (SAR), and light detection and ranging (LIDAR). These remote sensing techniques generate imagery using different sensing approaches and as such, provide different information about the area being investigated.
- **Relief operations** The fields of space technology and disaster mitigation collaborate to create precise and successful strategies for preparedness, relief, and prevention. Lack of information to inform planning frequently causes problems in the coordination of humanitarian relief, for instance, during a natural disaster or in a conflict situation. In emergency response and humanitarian relief, satellite maps and Geographic Information Systems are now routinely used for logistics, staff security, distribution, transportation, and the establishment of telecommunication networks and refugee camps. Satellite or unmanned aerial vehicle (UAV) remote sensing imagery can provide valuable information about ground conditions, even in hard-to-reach places [19].
- **Wildfires-** One of the most significant and frequent natural disasters in many nations, wildfires can seriously affect both human health and property. Like other calamities, wildfires pose a threat to people and property while simultaneously raising carbon emissions. To map burned areas, modeling, monitoring, and detecting of fires, geospatial technology, and data are helpful. Specifically, visible and infrared sensors on high-resolution earth observation satellites, optical remote sensing, and GIS tools are used for managing the risk of wildfire disasters [20]. Temperature, mid-infrared, and near-infrared radiation are all sensitive to variations in the health of the vegetation. They are widely employed to support forest management initiatives by accurately assessing burn severity and areas affected by fires. Green, healthy vegetation reflects radiation in the near-infrared (NIR) spectrum. It absorbs red light in the visible range of the electromagnetic spectrum. Meanwhile, burn-affected areas emit more energy in the visible and shortwave infrared (SWIR) region while absorbing energy in the NIR region.
- **Flood Management** Natural disasters are inevitable and it is almost impossible to fully recoup the damage caused by disasters. However, it is possible to minimize the potential risk by early warning strategies and preparing and implementing developmental plans. A suitable framework to reduce flood risk can be developed by using RS images and analyzing the data obtained from them in GIS. Providers of Earth observation satellites needed a database for pre- and post-disaster readiness initiatives. They offer real-time, extensive, synoptic, and multitemporal coverage of sizable areas. Even though floods have dramatically increased in size and frequency over the past few decades, it is evident from these patterns that technical capabilities to lessen their effects have dramatically improved. Two stages make up disaster management. The first is disaster preparedness and prevention, which is happening before the flood. The second one, disaster relief, rehabilitation, and reconstruction, takes place following the flood. GIS is used to manage a lot of data during the flood prevention phase, including RS images needed for risk and hazard assessment.
  - In the flood relief phase, GIS, when combined with a Global Positioning System (GPS), is extremely useful in search and rescue operations in devastated areas where finding one's bearings is difficult.
  - In the flood preparedness phase, it is a tool for planning evacuation routes, designing centers for emergency operations, and integrating satellite data with other relevant data in the design of disaster warning systems.
  - During the flood rehabilitation stage, GIS is used to assess potential reconstruction sites and arrange data on damage and post-disaster censuses.
- **Drought prediction** -The multifaceted phenomenon of drought is brought on by a lack of precipitation as a result of hydrological and climatic changes. Rising global temperatures may lead to drought and other defects associated with high temperatures. On the other hand, temperature rise predictions could be made using sensors. They can measure the temperature of the reflected radiation from the earth's surface because they are based in the sky, and the results can be compared to those from earlier missions. When there is a temperature increase, the vulnerable group is alerted and appropriate action is taken to stop the temperature rise. Divides drought into four categories: hydrological, agricultural, socioeconomic, and meteorological/climatological [22}. A "meteorological drought" is a condition in which there is less rainfall than usual. Through the use of derivatives such as crop failure, evapotranspiration, soil moisture deficit, and precipitation shortfall, agricultural drought relates the various features of meteorological drought to agricultural impacts. A socioeconomic drought affects the supply and demand for specific economic goods by combining hydrological, agricultural, and meteorological droughts. Over the past ten

years, data from various satellite-based platforms have become more significant in drought studies and analysis due to the spatial and temporal advantages that remote sensing and GIS can provide.

- **Emergency mapping-** Over the past few decades, there has been a significant increase in the need for RS and GIS in the field of emergency management. This technology is being used more and more by researchers and decision-makers to collect clear and understandable data about disaster scenes. The framework of emergency mapping can take into account a variety of GIS and remote sensing sensor types, platforms, and techniques; the choice is primarily based on activation details and end-user requirements, such as the type of disaster to be mapped, the approximate extent of the affected areas, the required level of detail of the analysis, and the necessity of event monitoring [29]. Emergency mapping relies heavily on remote sensing techniques to facilitate rapid and simple disaster response. The sensors provide large, wide, and timely data used by the emergency team to plan how they will carry out the rescue mission.

CHALLENGES FOR THE APPLICATION OF GEOSPATIAL SCIENCE AND TECHNOLOGIES FOR DISASTER RISK MANAGEMENT

Significant obstacles stand in the way of the efficient use of geospatial technologies for disaster risk reduction. The majority of these difficulties are related to operations, policies, and applications. To meet the ever-increasing demand for effective solutions daily, the disaster and management community is driven by challenges to conduct more advanced geospatial technology research. High degrees of operational and system interoperability as well as successful capacity building are also necessary to improve or enhance current capacities, particularly for vulnerable communities. Lower interoperability levels, weaker data integration capacities, and divergent stakeholder demands and expectations are operational challenges. These are just a few of the many obstacles that prevent geospatial data from being fully utilized for emergency and disaster management. Specifically, it makes it challenging to share, analyse, or obtain particular datasets for particular applications. Last but not least, ensuring consistent access to geospatial data from various regions of the world is the biggest policy challenge. The International Charter "Space and Major Disasters," which establishes a uniform procedure for exchanging worldwide data during disasters, is being spearheaded by the United Nations Office for Outer Space (UNOOSA). In addition, there are the competing interests of those involved in disaster management in dire circumstances, when effective models become extremely important.

On the applications side, challenges are in the limited geospatial data modelling and processing capabilities in different parts of the world, and constraints of internet bandwidth as well as the availability of trained human resources all have led to ineffective disaster and emergency management processes in many parts of the world.

The Future of Geospatial Science and Technologies for Disaster Management

The field of disaster management will persist in investigating novel approaches to data integration, modelling, and simulation, given the ongoing progress in geospatial technologies. Significant advancements are anticipated in spatially enabled integrated incident management and response systems, which can provide multi-tier modelling, simulation, processing, and visualization in handheld devices, on computer screens, and on large displays in Emergency Operation Centres (EOCs). This includes virtual reality modelling and simulation. This can be achieved through various multi-modalities of spatial information systems. Data visualization and human factors are combined in geospatial information technologies for disaster and emergency management to offer efficient analytical and decision support. This application area is growing quickly, offering near-real-time simulations for displaying and analysing large and diverse datasets to the disaster and emergency management community. Recognizing efficient methods for gathering field data, improving data and system integration, analysing most emerging 3D data quickly, including LIDAR, and offering quick and workable disaster management solutions Addressing multi-tier vulnerability analysis and assessment falls under the category of location-based issues. Expanding the application of public participation GIS (PPGIS) for emergency and disaster management is necessary. This will facilitate the collection, processing, and analysis of geospatial data [30, 31].

4. CONCLUSION:

Finding and recognizing emergency problems and their connections to the existing environment is the first step in disaster management. In disaster management, geospatial science and technology are crucial, particularly in the phases of monitoring, preparedness, and response. The majority of disaster management is carried out using local knowledge, therefore the application of geospatial science and technology in disaster management is currently very limited. This divides the potential and actual applications of geographic science and technology. Therefore, to accurately, precisely, and timely manage and mitigate disaster risk, an integrated approach utilizing scientific and technological advances must be adopted. Lastly, technology should be used to create a path toward resilient communities and sustainable development as well as to assist our society during times of crisis.

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