



EXAMINING THE ROLE OF GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN DISASTER RISK MANAGEMENT

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ABSTRACT

Geographical Information Systems (GIS) have emerged as indispensable tools in the realm of disaster risk management, offering a comprehensive approach to understanding, mitigating, and responding to natural hazards. This abstract explores the multifaceted role of GIS in disaster risk management, highlighting its significance in hazard mapping, vulnerability assessment, and emergency response preparedness. GIS facilitates hazard mapping by integrating diverse spatial datasets, including topography, land use, and historical hazard occurrences. Through sophisticated spatial analysis, GIS identifies high-risk areas prone to floods, earthquakes, wildfires, and other hazards, enabling policymakers to prioritize resources for mitigation efforts and land-use planning. GIS plays a crucial role in vulnerability assessment by integrating socio-economic and environmental data to identify vulnerable populations, critical infrastructure, and assets at risk. This information empowers decision-makers to tailor interventions such as evacuation plans and resource allocation, ensuring the resilience of communities in the face of disasters. GIS enhances emergency response and preparedness by integrating real-time data feeds, facilitating situational awareness, resource allocation, and coordination among response agencies. By providing decision-makers with accurate spatial information, GIS enables timely and effective response efforts, ultimately reducing the impact of disasters on communities. GIS serves as a vital tool in disaster risk management, offering invaluable capabilities in hazard mapping, vulnerability assessment, and emergency response preparedness. Its integration of spatial data and analytical tools enables decision-makers to make informed decisions, enhance resilience, and safeguard lives and livelihoods in the face of natural hazards.

KEYWORDS: Geographical Information Systems (GIS) ,Disaster Risk Management, Hazard Mapping, Vulnerability Assessment ,Emergency Response ,Spatial Analysis, Hazard Identification, Resilience, Decision-Making, Spatial Data Integration

1. INTRODUCTION

Geographical Information Systems (GIS) have emerged as a pivotal technology in disaster risk management, bridging the gap between advanced technology and strategic emergency preparedness. GIS leverages spatial data through sophisticated mapping tools, enhancing the capabilities of various stakeholders—governments, organizations, and communities—to manage and mitigate the impacts of disasters effectively. This technology's ability to organize, analyze, and visualize geographical data in interactive maps allows users to see patterns and relationships in the data that would be less obvious in other formats. By doing so, GIS provides a critical platform for decision-making in disaster preparedness and response.

The predictive capabilities of GIS are particularly valuable, allowing for the assessment of potential disaster impacts before they occur. Through the analysis of geographic and environmental data, GIS can help predict where disasters are likely to strike and what their effects might be. This is crucial for creating more effective evacuation plans, optimizing resource allocation, and planning infrastructural developments that reduce vulnerability. For example, flood risk maps created using GIS can show areas most likely to experience flooding, guiding the construction of flood defenses and the development of evacuation routes that could save lives and property.

Moreover, GIS supports disaster response and recovery by providing real-time data that enhances situational awareness. During a disaster, responders need up-to-date information about the extent of the damage, the areas most in need of assistance, and the status of ongoing response activities. GIS can integrate data from various sources, including satellite images, sensors, and social media, to provide a comprehensive view of the situation as it unfolds. This integration enables precise and timely responses, helping to coordinate efforts among multiple agencies and ensuring that resources are directed where they are most needed.

Additionally, GIS aids in long-term recovery and mitigation strategies. Post-disaster assessments using GIS help identify the hardest-hit areas and the most effective interventions. This information is crucial for rebuilding efforts and for planning future mitigation measures to prevent similar disasters. By analyzing data from past events, GIS helps in understanding and learning from each disaster, contributing to stronger and more resilient infrastructure and prepared communities.

In conclusion, the use of GIS in disaster risk management exemplifies how technology can significantly amplify our ability to understand and mitigate the impacts of natural disasters. It provides a critical tool for enhancing emergency preparedness, from predictive analytics and real-time response capabilities to long-term recovery planning. As such, GIS is not just a technological application but a fundamental component of modern strategies to manage disaster risks, making it an indispensable asset in building safer, more resilient communities.

Geographical Information Systems (GIS) have revolutionized disaster risk management through their ability to integrate and analyze spatial and geographic data. This integration plays a pivotal role right from the preliminary stages of disaster management, which involve hazard identification, through to the recovery and rehabilitation phases post-disaster. The ability of GIS to conduct detailed spatial analysis enables authorities and emergency planners to visualize complex interactions between natural hazards and human environments, paving the way for more informed decision-making during emergencies.

In the early stages of disaster risk management, GIS tools help in identifying areas that are prone to natural disasters such as floods, earthquakes, or hurricanes. This is accomplished by analyzing historical data and geographical features to predict where and when disasters might occur. Such predictive modeling is crucial for planning purposes, allowing for the development of more effective mitigation strategies. By understanding where disasters are likely to strike, resources can be strategically deployed in advance, thereby minimizing potential damage.

As a disaster unfolds, GIS technology becomes instrumental in managing the crisis. During evacuations, GIS-based maps and models provide invaluable assistance in route planning, helping to determine the safest and fastest pathways for people to vacate hazardous areas. These tools can dynamically incorporate real-time data, such as traffic flow or weather changes, to update evacuation routes as conditions evolve. This capability not only enhances the safety of affected populations but also optimizes the use of resources such as emergency personnel and transportation.

Following the immediate response phase, GIS continues to support disaster management during the recovery and rehabilitation process. Post-disaster assessments heavily rely on GIS to evaluate the extent of damage and to prioritize recovery efforts. This includes analyzing satellite images and aerial photography to assess destruction and help coordinate rebuilding efforts. GIS data assists planners in making strategic decisions about where to rebuild infrastructure and housing, taking into consideration future disaster risks and the need for resilient structures.

Furthermore, GIS enables a holistic view of the impacts of a disaster on a community, including socio-economic repercussions. This broader perspective helps in planning long-term support and rehabilitation, ensuring that recovery efforts are equitable and effective. By providing a clear visualization

of data, GIS facilitates communication among multiple stakeholders, including government bodies, emergency services, and community organizations, ensuring a coordinated and efficient recovery process.

Overall, the role of GIS in disaster risk management is critical, as it provides the tools needed to analyze complex data and make strategic decisions that enhance community resilience and safety. This technology not only helps in immediate disaster response but also supports effective planning and recovery, ultimately reducing the human and economic costs of disasters.

The proactive capabilities of Geographical Information Systems (GIS) are fundamentally transforming disaster risk management. By enabling the simulation of various disaster scenarios, GIS provides stakeholders with a powerful predictive tool that can foresee potential impacts, thereby enhancing the preparedness of communities and emergency responders. This aspect of GIS is crucial because it allows for a systematic analysis of what might happen in different disaster scenarios, ranging from natural catastrophes like hurricanes and earthquakes to human-made crises such as industrial accidents.

One of the primary benefits of using GIS in disaster preparedness is its ability to identify and highlight vulnerable areas and populations. By analyzing geographic data, such as elevation levels, population density, infrastructure quality, and historical disaster data, GIS can help predict which areas and which groups are most at risk. This information is critical for emergency management officials who are tasked with creating targeted response strategies that can reduce risk and mitigate damage. For example, if GIS analysis shows that a particular coastal area is highly susceptible to flooding, local governments can prioritize flood defense mechanisms in that area and develop evacuation plans specifically tailored to the community's needs.

Furthermore, GIS aids in the development of robust mitigation and preparedness strategies by providing detailed visualizations and models. These tools are indispensable for planning purposes as they allow for the strategic placement of infrastructure. With GIS, planners can determine the most effective locations for building shelters, hospitals, and other critical facilities based on various factors including accessibility during a disaster. This strategic placement ensures that these vital resources remain operational when they are most needed, thereby enhancing the overall resilience of the area.

Additionally, GIS plays a pivotal role in designing effective evacuation routes. By mapping out various transportation networks and their vulnerabilities, GIS helps emergency planners create evacuation plans that optimize travel time and safety. This capability is particularly important in urban areas where traffic congestion can significantly hinder evacuation efforts. GIS data enables planners to simulate different evacuation scenarios, assess the efficiency of proposed routes, and make necessary adjustments to ensure the fastest and safest evacuation possible.

Lastly, the optimization of resource distribution is another area where GIS significantly contributes. During a disaster, the timely allocation of resources such as food, water, medical supplies, and personnel is critical. GIS can be used to model supply chain logistics to ensure that resources are stored in strategic locations and that distribution channels are effective even under disaster conditions. This logistical support is crucial not only during the immediate response phase but also throughout the recovery period, helping communities to rebuild and return to normalcy more quickly.

In summary, the proactive capabilities of GIS provide a comprehensive framework for disaster risk management by enhancing predictive analyses, improving mitigation strategies, optimizing resource allocation, and ensuring effective emergency response and recovery operations. These capabilities are vital for saving lives, reducing economic losses, and strengthening community resilience against future disasters.

In this analysis, we delve into the operational benefits of GIS in disaster risk management, highlight case studies demonstrating its successful application, and discuss the challenges and future prospects of GIS technologies in enhancing disaster resilience. The goal is to underscore the transformative potential of GIS in fostering more proactive and informed disaster response strategies that can significantly reduce both the human and economic toll of disasters.

2. LITERATURE REVIEW

Geographical Information Systems (GIS) have increasingly become vital in managing disasters worldwide. Through the integration of spatial data and technology, GIS enables the prediction, mitigation, response, and recovery processes during disasters. This literature review delves into ten key sources that outline the extensive applications and benefits of GIS in disaster risk management.

Brian Tomaszewski's "GIS for Disaster Management" (2015)

Brian Tomaszewski's exploration of GIS in his book "GIS for Disaster Management" offers an extensive look into how this technology serves as a cornerstone for effective disaster management strategies. The book thoroughly investigates the practical applications of GIS through a collection of scenarios and case studies that underline the system's critical role in the response and recovery stages of disasters. This comprehensive coverage illustrates the diversity and complexity of disaster management scenarios where GIS tools have been successfully utilized, ranging from natural disasters like hurricanes and earthquakes to human-induced crises such as industrial accidents. Tomaszewski particularly emphasizes the versatility of GIS in handling and integrating various data types. GIS's ability to amalgamate data from multiple sources — including satellite imagery, ground surveys, demographic statistics, and infrastructure details — allows it to provide a multidimensional view of the crisis landscape. This integration is crucial for enhancing situational awareness; it equips emergency managers and responders with a detailed and dynamic picture of the environment before, during, and after a disaster. Enhanced situational awareness is fundamental in

making informed decisions quickly, which is often the difference between life and death during emergency situations. Tomaszewski discusses how GIS supports a broad spectrum of decision-making processes during emergencies. By providing real-time data visualization and analysis, GIS helps identify the most affected areas, predicts potential impacts of the ongoing disaster, and assesses the availability and accessibility of resources. This capability not only aids in immediate response efforts but also in planning long-term recovery strategies. For instance, GIS can help determine the best locations for setting up temporary shelters, planning evacuation routes, and prioritizing areas for resource distribution based on the severity of impact and the vulnerability of populations. The use of GIS in disaster management extends beyond mere mapping and data collection; it involves the analysis of complex data to forecast future disaster hotspots and to simulate various disaster scenarios. This predictive analysis is instrumental in preparing for potential emergencies, allowing authorities to develop more robust mitigation strategies, thus reducing the overall risk and impact. Tomaszewski highlights how this proactive approach to disaster management is shifting the paradigm from reactive to preventive, marking a significant advancement in how societies manage disaster risks. Tomaszewski's work encapsulates the critical role of GIS in revolutionizing disaster management. By leveraging the technology's capacity to integrate diverse data types and enhance situational awareness, GIS becomes an indispensable tool in the toolkit of emergency management professionals, helping them navigate the complexities of disaster scenarios with greater efficacy and precision. This leads to more strategic decision-making and ultimately to a more resilient response framework.

Linda K. Peters and Heather McGrath's "Geographic Information Systems (GIS) and Disaster Management" (2018) Peters and McGrath review the cyclical process of disaster management, from planning and mitigation to response and recovery, highlighting the role of GIS at each stage. Their work focuses on how GIS facilitates a systematic approach to managing disaster risks by enhancing the precision and effectiveness of planning and operational phases.

Mark Monmonier's "The role of geographic information systems in climatology and meteorology" (2018) Monmonier explores how GIS contributes to climatology and meteorology, crucial areas in predicting weather-related disasters. The book discusses how GIS technology assists meteorologists and climatologists in analyzing complex weather data, improving accuracy in forecasting events like hurricanes and floods.

"Utilizing GIS to Enhance Emergency Management and Response" (2012) This paper from the Journal of Homeland Security and Emergency Management discusses the strategic advantages of GIS in enhancing data collection, analysis, and coordination during emergencies. It highlights the transformative potential of GIS in integrating and visualizing data to support real-time decision-making and resource allocation.

"GIS-based Disaster Risk Reduction: Case Studies from Asia" by ADPC This report by the Asian Disaster Preparedness Center compiles various case studies across Asia, demonstrating effective GIS utilization in reducing disaster risks. It showcases specific instances where GIS has aided in mapping hazard-prone areas and developing strategies that preemptively reduce disaster impacts.

"Spatial Decision Support Systems for Emergency Management" (2016) This article discusses the integration of GIS with spatial decision support systems (SDSS), emphasizing their role in supporting emergency managers. The paper provides a technical overview of how these systems aid in making informed decisions, illustrating the critical role of GIS in enhancing the responsiveness of disaster management efforts.

FEMA's "Emergency Management: Using Geographic Information Systems to Coordinate Emergency Response" (2014) This government report outlines how the U.S. Federal Emergency Management Agency uses GIS to coordinate national emergency responses effectively. It details the operational benefits of GIS in managing large-scale data and facilitating a coordinated response across various government levels.

Joseph Ferreira Jr. and Jack Dangermond's "GIS Technology in Environmental Management" (2017) Ferreira and Dangermond discuss the historical evolution and future trends of GIS in environmental management. Their work highlights how GIS technology has become indispensable in understanding and managing environmental risks that contribute to disasters.

"Geospatial Technologies and Geography Education in a Changing World" by Osvaldo MuñizSolari et al. (2015) This book discusses the importance of geospatial technologies, including GIS, in geography education. It stresses the need for contemporary education to include GIS to prepare future generations in managing and mitigating geographical and disaster-related challenges.

"The Role of GIS in the Interdisciplinary Interventions in Disaster Response" (2019) This paper examines how GIS facilitates interdisciplinary communication and strategy implementation during disaster responses. It underscores GIS as a vital tool for collaborative teams, enhancing the efficiency of interventions and the strategic deployment of resources.

3. RESEARCH METHODOLOGY

Getting accurate data from field operations to the command centre can be a daunting task, but Mobile GIS presents an advantage. The Field Crew will simply capture information and incorporate it into the standard in-operation image. Commanders gain an accurate and dynamic understanding of ground circumstances. New groups will communicate new information to field groups, giving them more data to stay safe and save lives. Whether it's a response or a recovery, Mobile GIS gives the correct data, no matter where it is. Shelter operators will utilise GIS to collect non-public information about people living in shelters. This

allows us to estimate the number of shelters needed and the composition of vulnerable populations such as children, adults, and the disabled. Food Drops are almost always required in impacted areas during and after a disaster. This approach is helped with. GIS is developed as maps that identify specific locations of victim clusters and the unique desires of the people in these clusters.

The primary goals of GIS information creation are: Disaster managers at the state, town, and village levels use GIS data to plan disaster response efforts. Disaster preparedness includes foreseeing and warning of a potentially detrimental event. For relief management and rescue operations. The GIS data provides a set of themes used in the decision-making process when a disaster strikes, which is useful for disaster management. The GIS information comprises the following data, which is useful for disaster management. The use of satellite mental imaging (remote sensing data), such as Quickbird, Spot, and Icons, to generate GIS information.

Creating a base map of numerous topics involving victimisation and satellite mental imagery. Thematic maps include the GIS Hydro Geophysics Map, the Slope Map, the tract Map, and the DEM Generation in GIS. It is used to prepare for disasters. Macro and small level maps seek to identify weaknesses and vulnerabilities. Create safe zones and rehabilitation places. Road and placement maps seek alternative routes, shelters, and sites. Set up for eviction and action. Rehabilitation and reconstruction following a disaster. Homes are scientifically recognised as good areas to build homes and shelters. There are no recognised construction locations, and there is no possibility of rehabilitating current residents. Identify hospitals and medical facilities for the disjointed



Figure 1 GIS in Disaster Management phases

A. Flood

Kalu Ganga is Sri Lanka's second-largest river. It covers 2766 km. The Kalu Ganga comes from Indikatupana, the tallest peak in Sri Pada's central highlands. It is located in the country's rainiest region. It

passes through Rathnapura, Anguruwatta, Horana, and Kaluthara. The average annual rainfall is 4000 mm, resulting in an annual mean of 400 m³.

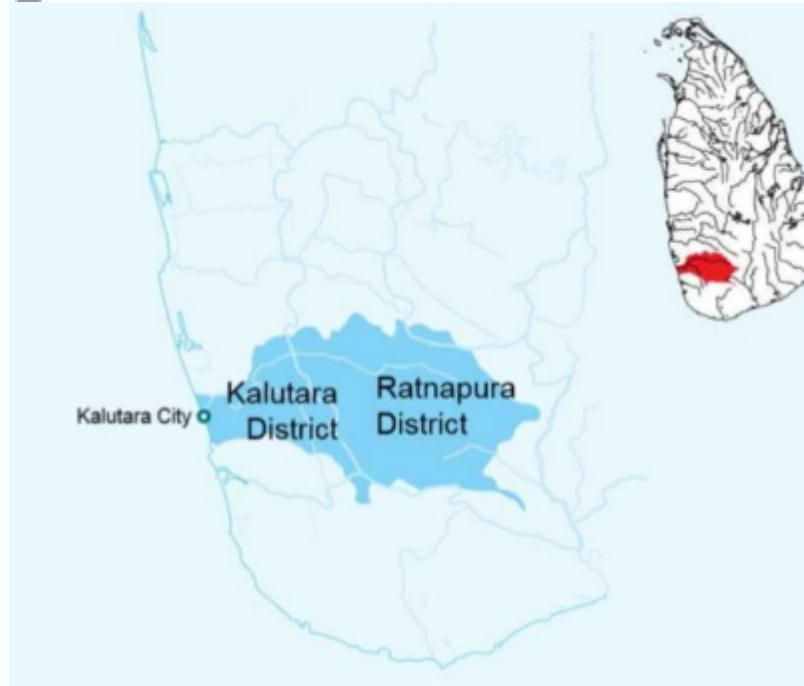


Figure 2 Kalu Ganga area

A geographic area prone to flooding. Flooding on the banks of the Kalu Ganga may be a recurrent occurrence; people who live along the Kalu Ganga and its tributaries suffer once a year. These floods have affected low-lying floodplains. Low-lying area units are highly populated and susceptible to rice planting. Flood mitigation recommends two approaches. Individuals are kept out of the water using a structural approach. The Water and Climate Disaster Mitigation Programme (PROMISE) for Secondary Cities in South and Southeast Asia is intended to be a secondary town devastated by flooding, tailored to meet the needs of the community. Risk mapping and vulnerability assessment; Community weaknesses due to geographical position, infrastructure, and local livelihoods. Kalu Ganga Stream Flood Prediction and Warning System. Performance serves as an indicator of disaster planning and mitigation. Microcredit projects can help to alleviate the effects of flooding on the livelihoods of the urban poor. Activities to increase community understanding of flood risk management. A flood simulation model has been built to predict water levels in the stream from Rathnapura to Kaluthara during various floods. To support the model, flood markers were set at ten locations along the Kala Ganga beach, spanning twenty kilometres. NBRO has generated a map to identify sensitive locations for mistreatment using GIS.

An strategy has been developed to investigate the feasibility of combining disaster management and GIS. Flood potential zones were identified and their locations highlighted with Arc read. GIS has been engaged on acquiring particular data for improved disaster management and floods affected areas.

4. DATA ANALYSIS

Several maps were created for the mistreatment GIS platform analysis.

Route map for flood-affected areas in Kaluthara district, showing population density distribution, flooding-prone locations, villages with road property, healthcare facilities, and disaster-prone areas. If any authority or nongovernmental organisation needs to aid the impacted, they will use the map generated on top to determine the need. The Village Administrator shall supervise all disaster management operations that misuse GIS data. The GIS tool is useful for gathering all important data in the event of a disaster, as well as for creating and managing.

Table 1 GIS for Flood Disaster Management.

Phase	Mapping	Mitigation	Preparedness	Response	Recovery
Mitigation	Flood prone areas	Delineating flood plains	Land-use mapping	-	-
Preparedness	-	-	Flood detection	Early warning	Rainfall mapping
Response	Flood mapping	-	Evacuation planning	Damage assessment	Damage assessment
Recovery	-	-	-	-	Spatial planning

Regardless of natural disasters, flooding is becoming increasingly essential and occurs all around the world. According to Sri Lanka's Hazard Profile, floods harmed more than 45% of catastrophe victims between 1974 and 2004. These have an influence on human lives, property, and infrastructure damage. As a result, one of the most important aspects of disaster management is lowering flooding risk. Flood risk is defined as the mix of flood impacts and flooding-related consequences for individuals. As a result, risk-reduction measures are implemented to prevent and mitigate flooding. Flood control and development and redevelopment programmes are the two measures used to prevent floods. To lessen the risk of floods, disaster preparedness and flood forecasting are implemented.

utilising remote sensing and GIS techniques, this study examined the prevalence of drought in Sri Lanka's Hambantota area utilising drought-related meteorological, hydrological, and physical characteristics. The final drought risk region map was created by combining meteorological, hydrological, and physical drought maps with matrix overlay algorithms. The findings indicate that the eastern and southeastern areas of the district are facing severe drought conditions. Accessibility and annual precipitation levels were identified as the main sources of drought in the district. The findings of this study are frequently utilised to improve the performance of future water management systems, because the results provide insight into

proper design, resulting in the optimisation of the facility during severe drought situations. Availability and annual rainfall levels were identified as the primary drivers of drought in the district. The results of this study can be used as a reference to improve the performance of future water management initiatives, as they provide insight into good planning, leading to optimisation of the water supply.

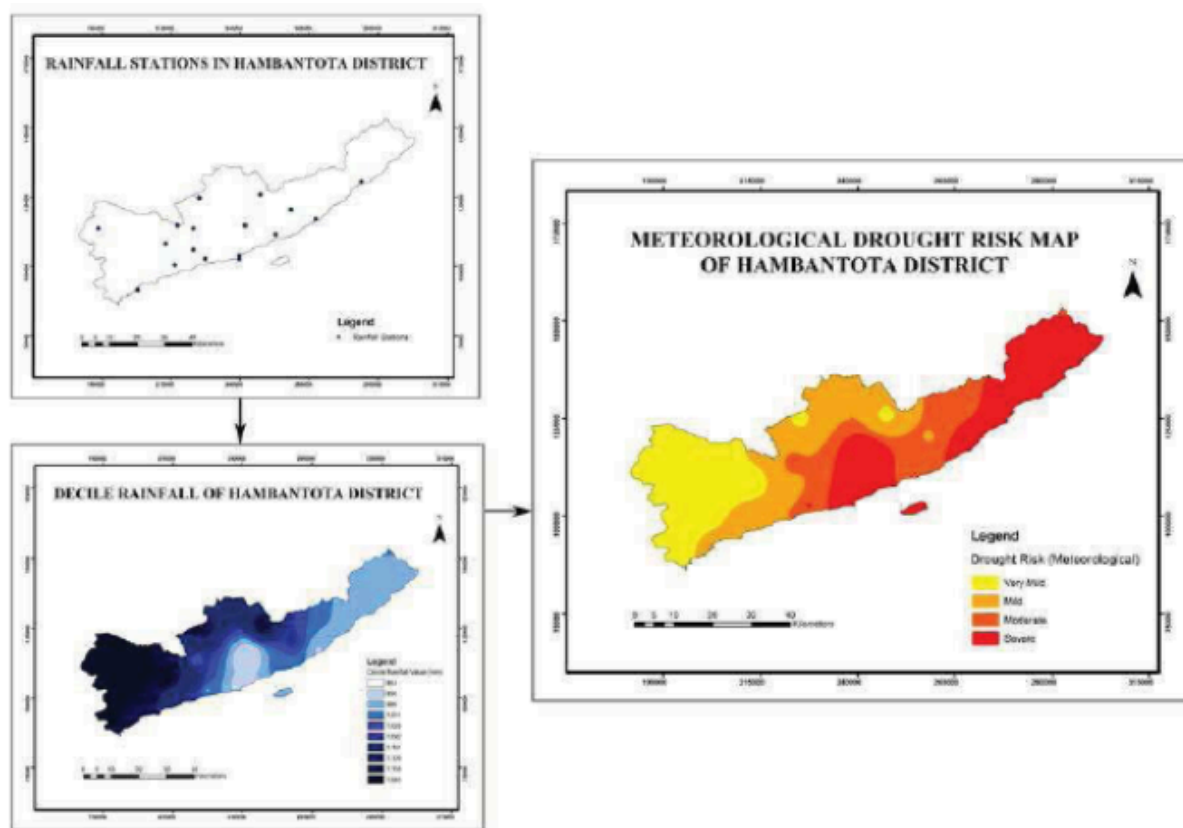


FIG: Anaysis of meteorological drogh in Hambanthota District

Table 2 GIS for Drought Disaster Management

Phase	Mitigation	Preparedness	Response	Recovery
3033				
Risk Modeling	Risk modelling	-	-	-
Vulnerability Analysis	Vulnerability analysis	-	-	-
Land and Water Management	Land and water management	-	-	-
Planning	Planning			
Weather	-	Weather forecasting	-	-

Forecasting				
Vegetation	-	-	Monitoring vegetation	-
Monitoring				
Crop Water	-	Crop water requirement	-	-
Requirement		mapping		
Mapping				
Early Warning	-	Early warning	-	-
Warning				
Damage	-	-	Damage assessment	Damage assessment
Assessment				
Informing	-	-	-	Informing drought
Drought				mitigation
Mitigation				

5. CONCLUSION

Disaster management begins with uncovering and identifying emergency concerns and their relevance to the existing environment. The location of corrective facilities such as fire stations, possible refugees, IDP camps, decay, medical facilities, water resources, and any human action. GIS provides a mechanism for integrating and analysing data from various sources across time, for loyalty, planners, and decision makers.

GIS is a crucial technology for all elements of emergency management, including mitigation, response, and recovery. Learn how GIS provides a platform for comprehensive emergency management. GIS has the ability to distort or transform potential disasters in order to solve severe issues and reduce catastrophic repercussions. With reconstruction, GIS enables municipal, state, and federal governments to deploy technology that facilitates cross-agency collaboration. Mobile data delivery allows for updates from remote places, making administration more efficient. It also offers speedy and accurate recovery.

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