THE IMPACT OF FLOODS ON HUMAN AND ENVIRONEMNTAL SYSTEMS IN WET ZONE SRI LANKA

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ABSTRACT

This study explores the complex effects of floods on people and environmental systems in the wet zone of Sri Lanka. The study examines mitigation techniques, examines the contributing elements to flood risk, and emphasizes the vulnerability of ecosystems and human settlements using both qualitative and quantitative data. Flooding has a major effect on both human and natural systems in Sri Lanka's wet zone, especially in places like Colombo, Gampaha, Kalutara, and Kegalle. The frequency of natural disasters has increased tremendously in recent years, among other challenges that have surfaced in both developed and developing nations. In January and February, the northeast monsoon sends a good deal of rain to the eastern side of the central hills, the lowlands that surround them, and to a lesser extent, the northern regions of the island. In the months of June through September, the South West Monsoon brings precipitation to the western and south-western slopes of the central highlands and, to a lesser extent, to neighbouring lowlands in the South, West, and Southwest. Inter-Monsoons – October through November and March through April are the rainiest months on the island. because of frequent weather system formation and convectional activity, particularly in October and November. The first inter-monsoon, which spans March through April, is distinguished from the second inter-monsoon, which spans the final two months. In this research paper, authors have studied impact of floods on the human lives and environment system especially in wet zone of Sri Lanka as there are dominating factors that caused degradation in country overall. Lots of economy and health issues occurred during the floods. Nevertheless, authors have also identified the flood mitigation programs, initiative schemes, challenges towards flood management and environmental issues.

Keywords: Flood impact, human being, environment effect, flood mitigation

1. Introduction

One of the most destructive natural disasters globally, according to rankings [1], is flooding, and Sri Lanka is not an exception. Despite Sri Lanka's tiny size, the impact of natural disasters and risks has not lessened. Natural disasters have always posed a serious threat to the survival and smooth operation of the human environment. Natural catastrophes mostly consist of landslides, cyclones, droughts, and floods. In Sri Lanka, flooding has always been a natural occurrence that has an impact on both infrastructure and people. Sri Lanka can be classified into two main zones: wet and dry, based on its pattern of flooding. The southwest monsoon's arrival increases the likelihood of floods in the wet zone. Significant flooding has occasionally been caused by tropical cyclones and depressions brought on by the south-west monsoon [2]. As a result, exceptionally high rainfall falls throughout the monsoon season. Only a few years have seen such significant rains. Rainwater-soaked soil has a lower absorbency. Even in the presence of forest cover, this is possible. After then, the water runs through the river valley.

It might result in considerable flooding in the river valley's lowlands. It is critical to evaluate susceptibility to climate change and extreme occurrences, such floods, in order to promote risk reduction and long-term adaptation plans [3]. Disaster management places a high priority on crisis response, recovery, and disaster assistance in countries that are susceptible to natural disasters, like Sri Lanka. Studies abound that show how paradigms are shifting from disaster aid to lowering the risk and liability associated with disasters. Vulnerability assessment and mapping would provide a clear picture of the local condition as well as an indication of the extent to which the threat is anticipated to influence the capital, assets, people, and location [4,5]. The Sri Lankan Irrigation Department considers floods that are between five and eight feet in size to be moderate. Major floods are defined as conditions that fall between 8 and 11 feet. Floods up to eleven feet deep can be disastrous. Research has shown that while the wet zone is usually affected by floods most of the time, the dry zone might experience catastrophic flooding during the later-half of the year due to the inter-monsoon rainfall. There have been notable floods reported in the nation within the

past three to four years.

There have been reports of flooding in the river valleys of the Kalu, Kelani, and Gin in 2014. Floods were mostly reported in the Kelani Valley in 2016 and in the Kalu, Gin, and Nilwala Valley in 2017. These occurrences indicate that rainfall intensity is probably increasing in accordance with projections of global climate change [6]. Floods strike several areas of Sri Lanka almost annually. There are 103 river basins in Sri Lanka, the majority of which start in the Central Highlands and run radially toward the Indian Ocean. Heavy seasonal rainfall, illegal deforestation, a lack of flood prevention plans, and haphazard development practices including filling in wetlands are the main causes of Sri Lanka's regular floods. The following list includes some of the key actions in watershed management that help lessen the impact of floods [7].

Numerous investigations have employed geospatial methodologies to cartographically represent flood risk via several methodologies, both domestically and globally. A GIS-integrated MCDA analysis was carried out by Nuwanka and Withanage [8] to identify and analyse the vulnerability of the Nilwala river mouth in Sri Lanka to flooding hazards. Here, the constructed, socioeconomic, and physical environments were the three primary criteria that they also employed. Using the expert judgment approach and AHP, weights were allocated for both the major and minor criteria.

2 Flood impact

1. **Increased Risk of Disease for Human Health:** Because stagnant and contaminated water sources can cause epidemics of waterborne illnesses like cholera and dengue fever, floods can increase the risk of disease. Trauma and Injury: Drowning and debris can result in drowning accidents or fatalities during floods.

2. **Damage to Infrastructure:** Transportation: Damage to roads, bridges, and railroads can impede trade and travel. Housing: A large number of damaged or destroyed dwellings result in displaced people and a lack of place to live.

3. **The Financial Effect:** Agriculture: Flooding can destroy cattle and crops, resulting in a shortage of food and financial loss for farmers. Business Disruption: Damage, inventory loss, and a decline in customer activity could be experienced by nearby businesses.

4. **Migration and Displacement:** Internal Displacement: Communities may be compelled to leave, which could result in the need for makeshift shelters and long-term relocation problems. Urban Migration: Those impacted by flooding may relocate to cities in quest of better prospects, placing a burden on local resources.

5. **Sanitation and Water Management**: Floods have the potential to contaminate sources of drinking water, which might pose a serious threat to public health. Problems with Sanitation: Unsanitary conditions caused by overflowing sewage systems might worsen health hazards.

6. **Psychosocial Consequences:** Mental Health: Long-term psychological problems, such as anxiety and depression, can result from the trauma and stress caused by floods. Community Disruption: When communities are uprooted or impacted differently, social cohesiveness may suffer.

7. **Effect on the Environment:** Ecosystem Disruption: Local ecosystems can be changed by flooding, which has an impact on biodiversity and natural resources. Soil degradation caused by sedimentation and erosion.

8. **Regulation and Administration:** Emergency Response: Floods make it difficult for NGOs and government organizations to conduct relief and recovery efforts quickly, which calls for improved disaster planning and management techniques. Long-term Planning: In order to reduce future hazards, increased flooding episodes require better infrastructure investment and urban planning.

In Sri Lanka, floods have a variety of effects on the country's infrastructure, social institutions, economy, and health. A comprehensive strategy that integrates short-term reaction actions with long-term planning and community resilience building is needed to address these issues.

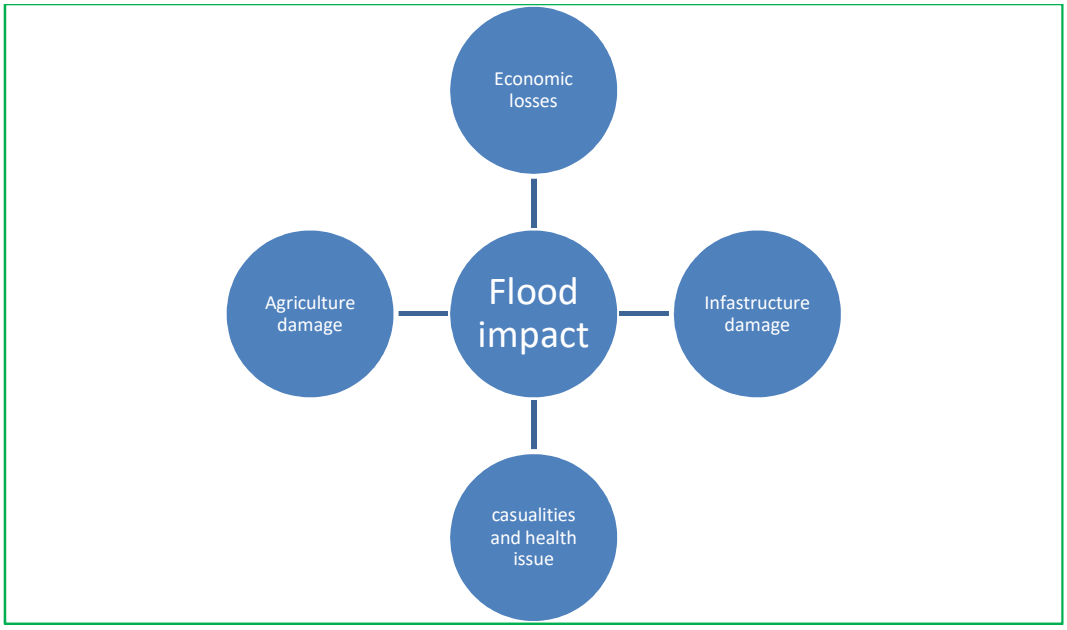

Fig. 1 Flood impact on country

3. Strategy of flood mitigation and adaptation

Strategies for flood mitigation and adaptation are essential for controlling the effects of floods, particularly in high-risk areas like Sri Lanka. Here's a complete approach Combining these tactics can dramatically lower Sri Lanka's vulnerability to the effects from flooding. Effective flood mitigation and adaptation measures require cooperation between government agencies, communities, non-governmental organizations, and the corporate sector.

1. **The management of integrated watersheds:**
River Basin Planning: Implement holistic management of river basins to control water flow and limit flood hazards.
Reforestation: To improve water retention and lower runoff, plant trees and restore vegetation in catchment regions.

2. Development of Infrastructure:
Flood Control Structures: To keep farms and settlements safe from flooding, construct levees, flood walls, and dams.
Urban drainage systems should be improved to guarantee effective water flow and lessen surface runoff after heavy rains.

3. Systems of Early Warning:
Meteorological Services: Improve weather forecasts and set up real-time tools to detect early warnings of flooding.
Community Alerts: Put communication mechanisms in place to quickly alert local populations to the possibility of flooding.

4.Community Engagement and Education Awareness Programs:
Inform local populations about the dangers of flooding, how to be prepared, and what to do in an emergency.

5. Planning Land Use:
Implement land use regulations known as zoning regulations to limit growth in areas at high risk of flooding.
Sustainable Agriculture: Encourage methods like crop rotation and agroforestry that reduce soil erosion and improve water absorption.

6.Methods Based on Ecosystems:
Wetland Restoration: Protect and restore wetlands, which operate as natural buffers against floods by

absorbing excess water.
Conservation of Mangroves: Maintain coastal mangroves to lessen storm surges and shield interior regions from flooding.

7.Developing and Putting into Practice Adaptation solutions for Climate Resilience:
Create and put into action solutions that increase ecosystems' and communities' resistance to the effects of climate change.
Designing infrastructure to survive severe weather conditions and flooding situations is known as infrastructure resilience.

8.Financial and Technical Support insurance Schemes:
Promote crop and property insurance to help communities recover from flood losses.

9.Investigation and Information Gathering evaluations of Flood Risk:
To determine susceptible locations and provide information for planning and development decisions, conduct studies.
Long-term Monitoring: Set up data gathering mechanisms to keep an eye on how flood patterns and environmental effects evolve over-time.

A number of initiatives have been launched by the Sri Lankan government and foreign organizations to lessen the effects of floods in the wet zone.

- **Enhancement of Drainage Systems:** To lessen urban flooding, urban drainage systems, especially in Colombo, should be upgraded.
- **Programs for Reforestation:** To lessen runoff and enhance water absorption, reforestation and sustainable land use techniques are encouraged in flood-prone areas.
- **Early Warning Systems:** Creating and putting into place systems that are designed to notify local communities before floods occur.
- **Wetland conservation:** it is the preservation and restoration of wetlands, which act as organic buffers to lessen the intensity of floods by absorbing floodwaters.

4. Impact of flood on environmental systems in Sri Lanka

In Sri Lanka, flooding has a major effect on environmental systems, influencing both human communities and the natural ecology. The following are some major effect areas.

1.Erosion and Degradation of Soil: Topsoil loss can result in long-term agricultural issues as nutrient-rich topsoil is washed away by heavy rains and flooding. Extended flooding can lead to land degradation, which lowers agricultural production and makes the land less fertile.

2. Pollution of Water Quality: Waste, chemicals, and pollutants from cities can be carried into rivers and lakes by floodwaters, which lowers the quality of the water. Water Supplies **Contaminated:** Flooding can contaminate sources of drinking water, which increases the risk of waterborne illnesses and other health hazards.

3. Loss of Biodiversity:
Destruction of Habitat: Various species' habitats can be destroyed by floods, which lowers biodiversity.
Ecosystem disruption: A sudden influx of water has the potential to upset aquatic ecosystems, which could have an impact on fish populations and other wildlife.

4. Forests and Vegetation:
Floodwaters have the power to uproot trees and harm forest ecosystems, which in turn affects the local flora and wildlife.
Invasive Species: Invasive species have the potential to displace native plants due to the ease with which they can spread.

5. Marine and Coastal Systems:
Flooding has the potential to hasten coastal erosion, which could have an effect on mangroves and

other coastal ecosystems.
Saltwater Intrusion: Flooding in certain places can cause saltwater to seep into freshwater systems, which can have an impact on drinking water supplies and agriculture.

6. Feedback Loops for Climate Change:
Increased Frequency: Floods may become more frequent and intense as a result of climate change, further taxing natural systems.
Carbon Sequestration: Wetlands' capacity to store carbon can be impacted by flooding, which may have an impact on patterns of the world's climate.

7. Social and Economic Effects:
Livelihoods: Local economics and food security may be impacted by the devastation of agricultural and fishery areas.
Resilience: Communities may find it difficult to recover, which could affect their capacity to withstand flooding in the future.

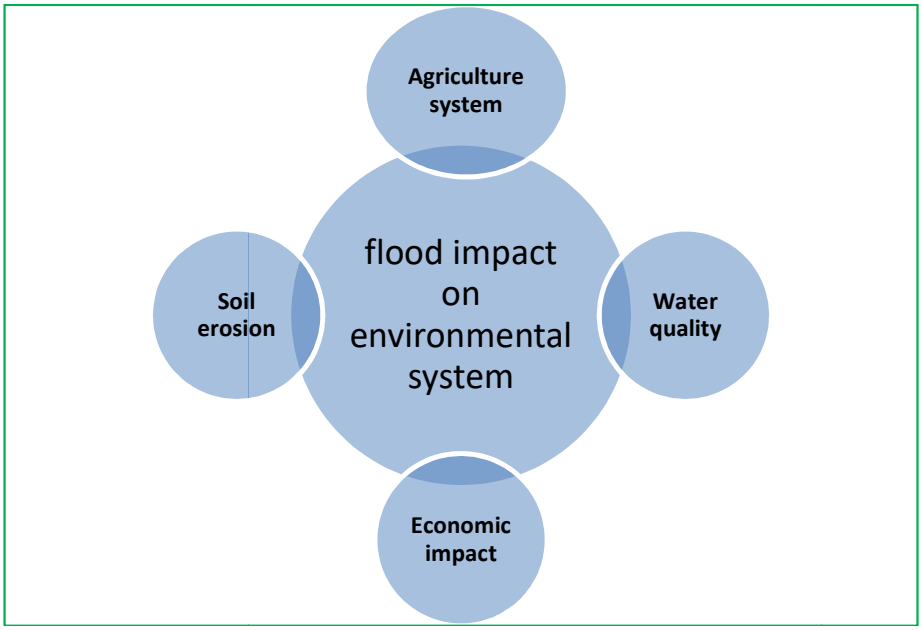

Fig.2 Impact of flood on environment

5. METHODS AND TOOLS

However, there hasn't been any prior research done in the study region on the use of Geographic Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA) with the Analytic Hierarchy Process (AHP) approach for flood modelling. Consequently, these technological approaches have been examined in the current study, with the primary distinction being the first-ever use of the MCDA–AHP method for the Neluwa region along the Gin River. Flood risk has been discovered in several zones by the proposed technique and methodology, which enables a comparison between parameters because flood circumstances are more common in the examined location [9]. For many years, one of the most widely used and recognized approaches in the field of research has been the combination of MCDA methodologies with AHP. Saaty has introduced the AHP approach to better comprehend the specified factors and criteria in the study in a hierarchical fashion [10]. Following suitable methods, the variables are ranked after a comparative investigation suitable values are then assigned to the parameters [11].

The AHP and MCDA approaches have been effectively applied in several research in the past few years, and they have been recognized as noteworthy technical instruments in the areas of problem analysis, criterion selection, and complicated decision-making. By successfully integrating a wide range of technical, environmental, and socioeconomic elements into holistic decision-making, MCDA will improve study

efficacy. Areas vulnerable to flooding were mapped using geospatial tools and the MCDA method. Undoubtedly, the utilization of Remote Sensing and Geographic Information System-based spatial data plays a crucial role [12,13,14] in enabling a more precise portrayal and illustration of findings in the research employing MCDA [15].

Flood risk reduction and management strategies are critical to the long-term viability and advancement of the nation's or region's environmental and socioeconomic environment. In order to lessen the effects of floods on the neighbourhood, properties, and environment, risk assessment is very beneficial.

The combination of climate change, monsoonal patterns, and deforestation is responsible for the escalation of floods in Sri Lanka's wet zone. The frequency, intensity, and unpredictability of floods have all increased due to these variables, both separately and in combination. One of the main causes of the floods' increasing intensity in Sri Lanka's rainy zone is climate change. Because of its tropical monsoon climate, which can result in abrupt increases in rainfall and catastrophic weather events from small changes in weather patterns, the region is particularly vulnerable to the effects of global warming.

- **Variable rainfall pattern:** The timing, length, and intensity of rainfall have all changed as a result of climate change. There has been a discernible trend in the wet zone toward shorter, more intense rainfall events that cause flash floods because they are greater than the land's and drainage systems' capacity for absorption.
- **Frequent Extreme Weather Events:** Climate models predict that Sri Lanka would have more extreme rainfall events as a result of rising atmospheric moisture content, which intensifies monsoons and prolongs periods of heavy rainfall. These catastrophic events, such as the floods in 2016 and 2017, cause significant damage due to the inability of current infrastructure and ecosystems to cope with rapid spikes in water volume.
- **Sea-level:** While rainfall is the primary cause of floods in the wet zone, coastal communities are more vulnerable to the effects of increasing sea levels brought on by global warming. Rivers and drainage systems have less ability to release floodwaters into the ocean as sea levels rise. Flood dangers are exacerbated during monsoon seasons when coastal flooding is coupled with excessive rainfall, particularly in low-lying locations close to the coast.
- **Monsoon pattern:** The Southwest Monsoon, which delivers most of the rains to the wet zone, is becoming less predictable in terms of when it will start and how strong it will be. Unpredictable monsoonal rains make it more difficult to predict and control floods, which results in inadequate planning for both floods and droughts.

In Sri Lanka's wet zone, the combination of changing monsoonal patterns, deforestation, and climate change has increased the frequency and intensity of floods. Extreme weather events have become more frequent and unpredictable due to climate change. The natural resilience of ecosystems has been diminished by deforestation, and the wet zone's already high flood risks are made worse by changes in the monsoon. These variables not only cause floods to occur more frequently, but they also exacerbate the socioeconomic and environmental effects of these natural disasters, making mitigation and disaster management more challenging. Reforestation, wetland restoration, improved urban planning, and climate adaption techniques to reduce the danger of future flooding are some of the integrated approaches needed to address these problems.

6. Data analysis methods

To assess the effects of floods on human and environmental systems in Sri Lanka's wet zone, a multidisciplinary approach is essential. This methodology can integrate both qualitative and quantitative techniques to elucidate the intricate relationships among flood episodes, human habitation, and the natural ecosystem. Below are several analytical approaches that may be utilized:

1. Hydrological Modelling Objective: To model and forecast flood behaviour, including their magnitude, duration, and recurrence, utilizing historical data and geographical information.

- **Instruments and Methods:** Geographic Information Systems (GIS) can delineate flood-prone regions, hydrological flow, terrain, and land utilization. GIS can show flood extents by merging satellite images with elevation data. Hydrological models (e.g., HEC-RAS, SWAT) can forecast flood flows utilizing rainfall data, soil composition, and land cover. They assist in evaluating the extent of rainfall that will lead to runoff, so contributing to flooding.
- **Analysis of Climate Data:** Historical rainfall and flood data may be examined to identify changes in flood frequency and intensity attributable to climate change, especially in Sri Lanka's wet zone.

- **Utilization:** Identifying flood hazards and evaluating susceptible regions. Examining the alterations in river catchment dynamics resulting from deforestation, land use modifications, or urban development.

2. Social Impact Assessment (SIA) Objective: To evaluate the effects of floods on human populations, encompassing their livelihoods, health, displacement, and economic stability.

- **Instruments and Methods:** Utilize household surveys and focus group talks to collect data on the effects of floods on communities. This includes the loss of property, income, infrastructure, and displacement.
- **Susceptibility Mapping:** Assess the socioeconomic susceptibility of various populations according to income levels, housing conditions, access to services, and geographical position (e.g., flood basins).
- **Livelihood Analysis:** Examine the impact of floods on local economies, including agriculture, fishing, and tourism, which are vital for many in Sri Lanka's wet zone.
- **Utilization:** Identifying the most impacted communities and at-risk populations (e.g., economically disadvantaged households, agricultural workers). Comprehending the enduring social and economic consequences of periodic flooding.

3. Environmental Impact Assessment (EIA) Objective: To assess the impact of floods on ecosystems, biodiversity, and natural resources in the wet zone.

- **Instruments and Methods:** Evaluate the effects of flooding on local biodiversity, focusing on endangered species and ecosystems such as wetlands and forests. Assessing variations in species populations pre- and post-floods can reveal ecological disturbances.
- **Water Quality Assessment:** Examine for pollutants (e.g., pesticides, fertilizers, heavy metals) that floods may introduce into rivers, lakes, and groundwater. Floodwaters frequently induce contamination from runoff originating in agricultural and urban regions. Examine soil erosion, landslides, and sediment deposition resulting from flooding in land degradation studies. This is especially pertinent in the steep rainy zone of Sri Lanka, where floods frequently induce landslides. **Utilization:** Evaluating the impact of flood events on ecosystems, encompassing aquatic environments, woodlands, and agricultural areas. Comprehending the aggregate effects of repeated flooding on ecosystems and biodiversity.

4. Analysis of Disaster Risk and Vulnerability Objective: To evaluate the flood risk to human settlements and infrastructure in Sri Lanka's wet zone and identify the most vulnerable regions.

- **Instruments and Methods:** Utilize historical flood data, topographical information, and infrastructure maps to develop risk maps that identify flood-prone regions and assess potential damage to human settlements, roadways, bridges, and other infrastructure.
- **Household Vulnerability Surveys:** Gather data on households' flood readiness, awareness, and adaptive capability to manage flood events. This encompasses access to early warning systems, evacuation protocols, and emergency resources.
- **Resilience Evaluation:** Assess the resilience of various communities based on their availability to financial resources, social networks, emergency services, and governmental assistance during and following floods.
- **Utilization:** Emphasizing flood control and disaster preparedness initiatives in the most susceptible regions. Formulating specific flood relief and recovery measures.

5. Remote Sensing and Satellite Imagery Objective: To evaluate and analyse the magnitude and effects of flood occurrences, along with temporal alterations in land cover and land use.

- **Instruments and Methods:** Utilize satellite imagery (e.g., Landsat, Sentinel) to monitor flood extents in real time, observe water levels, and evaluate damage to agricultural fields, forests, and infrastructure.
- **Change Detection Analysis:** Evaluate satellite imagery pre- and post-flood events to determine the impact of floods on the terrain, encompassing forest cover, water bodies, and urban development. **Unmanned Aerial Vehicles (UAVs) and Drones:** In regions where satellite data is inadequate, drones may be utilized for comprehensive aerial assessments of flood-impacted zones. **Utilization:** Immediate surveillance of flood occurrences and swift evaluation of damage. Recognizing enduring alterations in land cover that intensify flood hazards, including deforestation or urban development.

6. Analysis of Policy and Governance Objective: To evaluate the efficacy of policies and governance frameworks pertaining to flood management, disaster response, and climate adaption.

- **Instruments and Methods:** Examine governmental policies, land-use strategies, flood management protocols, and legal frameworks to assess their efficacy in mitigating flood threats.
- **Interviews with Stakeholders:** Interview important government agencies, NGOs, and local leaders to evaluate the efficacy of flood mitigation techniques and the execution of disaster risk reduction programs.
- **Institutional Analysis:** Assess the function and collaboration of entities tasked with flood management and catastrophe response, pinpointing deficiencies or redundancies in responsibilities.
- **Utilization:** Assessing deficiencies in flood preparedness and response strategies. Advocating for policy reforms to enhance flood control, land-use planning, and climate adaption in Sri Lanka's wet zone.

Assessing the effects of floods on people and environmental systems in Sri Lanka's wet zone necessitates a holistic approach that incorporates hydrological, social, environmental, and economic analyses. The integration of GIS mapping, hydrological modelling, social vulnerability assessments, and economic analysis offers a comprehensive understanding of flood consequences, facilitating the development of more effective flood prevention and adaptation methods.

7. Conclusion

When determining the overall spatial flood risk assessment for the area, the three primary criteria—the built environment, the physical environment, and the socioeconomic environment were highly helpful. By combining multiple criteria and applying geospatial methodologies at the local level, this study offered a useful approach for spatial risk assessment of flood damages. Based on firsthand observations from the field, community input, disaster management officers, meteorologists, and land-use planners, a qualitative validation approach was employed to validate the created risk maps. Prioritizing community-level flood awareness and information sharing is important. A guide for managing potential flood scenarios in the future will be the appropriate application of such guidelines and proposals. Four scenarios were used to conduct flood simulations for the future and historical climates: historical land use and climate; historical land use and climate; historical land use and future climate; and future climate and future land use. It is difficult to determine which phenomenon—land-use transformation or climate change—is primarily responsible for variations in river flow and flood extremes. This challenge stems from a variety of elements pertaining to the processes under investigation as well as the approaches used in their evaluation. River valley human civilizations are regarded as unique because of the affluent agricultural cultures that sprang from the nutrient-rich sediments carried by floods.

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