

# Rainwater Harvesting and Sustainable Water Management Strategies for Flood Risk Reduction in the Negombo Urban-Coastal Zone

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## Abstract

Negombo is a rapidly urbanizing coastal city in Western Province, Sri Lanka, faces urban flood risks, particularly during the Southwest monsoon season. Because of these events, we can see disruptions to daily life, infrastructure damage and broader environmental and economic crisis. This paper delves into Rainwater Harvesting (RWH) and sustainable water management strategies as viable solutions to mitigate flood risks in the Negombo urban-coastal zone. A mixed-method approach is adopted, involving hydrological data analysis, case studies and stakeholder interviews to assess current drainage issues and water usage patterns. The study articulates decentralized rainwater harvesting systems and green infrastructure as tools to manage surface runoff and improve water resilience. The findings underscore that integrated water resource planning, when combined with sustainable construction techniques, can significantly reduce the impact of urban flooding. The paper concludes by recommending policy interventions and design strategies that align with climate resilience goals and national sustainable development objectives, with potential applicability to other vulnerable coastal urban areas in Sri Lanka.

**Keywords:** Climate Resilience, Green Infrastructure, Rainwater Harvesting, Urban Flooding, Water Management, Water Resilience.

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## Abbreviations

**RWH:** Rainwater Harvesting

**IWRM:** Integrated Water Resource Management

**GI:** Green Infrastructure

**SDGs:** Sustainable Development Goals

## Introduction

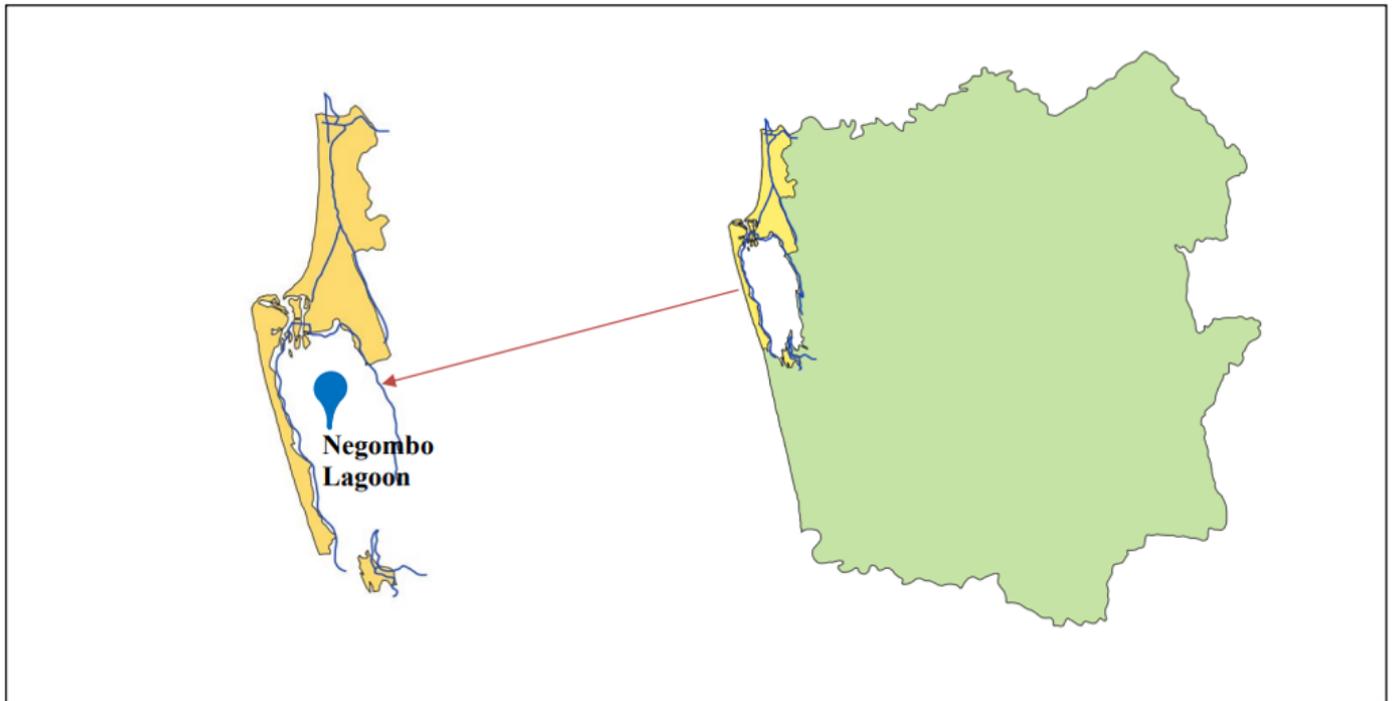
Urban flooding has emerged as a major environmental and socio-economic challenge in many coastal cities worldwide due to rapid urbanization, climate change and inadequate stormwater management systems [1]. Coastal cities in developing countries are particularly vulnerable because of unplanned development, land reclamation and insufficient infrastructure investment. In Sri Lanka, Negombo is one of the most flood-prone coastal urban areas, frequently experiencing inundation during the Southwest monsoon season.

The expansion of impervious surfaces such as roads, buildings and paved areas has significantly altered the natural hydrological cycle in Negombo, reducing infiltration and increasing surface runoff. Traditional drainage systems are often unable to cope with intense rainfall events, leading to recurrent flooding. Climate change has further exacerbated these conditions by increasing rainfall intensity and variability [2].

Rainwater harvesting (RWH) has gained recognition as a sustainable water management strategy that can reduce runoff volumes, supplement water supply, and enhance urban flood resilience [3]. When combined with green infrastructure and integrated water resource management approaches, RWH can play a vital role in mitigating flood risks while promoting environmental sustainability.

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This study aims to evaluate the potential of rainwater harvesting and sustainable water management strategies for flood risk reduction in the Negombo urban-coastal zone [4].



**Figure 1:** Location Map of Negombo Urban-Coastal Zone



**Figure 2:** Field photograph of the Negombo Lagoon showing the urban-coastal environment and adjacent vegetation

## **Materials and Methods**

### **Study Area**

Negombo is located on the western coast of Sri Lanka within the Western Province. The city lies adjacent to the Negombo Lagoon and is characterized by low-lying terrain, making it highly susceptible to flooding. The region experiences a tropical monsoon climate, with

heavy rainfall occurring mainly during the Southwest monsoon from May to September.

## Research Design

A mixed-method research design was adopted to comprehensively assess flood risk and water management practices in the study area. Both quantitative and qualitative data sources were utilized to capture hydrological, environmental and socio-economic dimensions.

## Data Collection

- **Hydrological Data:** Rainfall records and flood occurrence data were obtained from relevant government agencies and published sources
- **Field Observations:** On-site observations were conducted to identify flood-prone locations, drainage conditions and existing water management practices.
- **Case Studies:** National and international case studies on rainwater harvesting and green infrastructure were reviewed.
- **Stakeholder Interviews:** Semi structured interviews were conducted with local residents, urban planners and municipal officials to understand flood impacts and awareness levels

## Data Analysis

Hydrological data were analysed to identify rainfall patterns and flood frequency. Qualitative data from interviews were analysed thematically to identify key challenges, opportunities and perceptions related to sustainable water management.

## Results and Observations

### Spatial Distribution of Flood-Prone Areas

GIS-based analysis and field observations revealed that flood-prone areas in the Negombo urban-coastal zone are primarily concentrated in low-lying regions adjacent to the Negombo Lagoon and major canal networks. Areas with elevations below 5 m above mean sea level exhibited a higher frequency of water stagnation during intense rainfall events. Approximately 60-70% of reported flood locations were identified within densely built-up zones characterized by high impervious surface coverage and limited drainage capacity. These findings indicate that topography and land-use patterns play a critical role in controlling flood occurrence in the study area.

### Impact of Urbanization on Surface Runoff

The analysis of land-use characteristics showed that rapid urbanization has significantly increased impervious surfaces such as rooftops, paved roads and commercial developments. Field observations and secondary data suggest that impervious cover in central Negombo exceeds 65%, compared to less than 40% in peripheral areas. This increase has resulted in a proportional rise in surface runoff generation during monsoonal rainfall events.

The absence of rainwater harvesting systems in most residential and commercial buildings contributes directly to increased runoff volumes entering drainage networks, overwhelming their design capacity during peak rainfall periods.

### Potential Runoff Reduction Through Rainwater Harvesting

The implementation of decentralized rooftop rainwater harvesting

systems demonstrates substantial potential for runoff reduction. Based on average roof sizes and rainfall intensity in Negombo, rooftop RWH systems could capture approximately 20- 30% of total rainfall runoff at the household level during peak monsoon events. When applied at a neighbourhood scale, this could reduce stormwater inflow to drainage channels by up to 25%, thereby lowering flood peak intensity.

These results highlight that even partial adoption of rainwater harvesting can lead to measurable reductions in urban flood risk.

### Role of Green Infrastructure in Flood Mitigation

The integration of green infrastructure measures, including permeable pavements, rain gardens and wetland conservation, further enhances flood mitigation capacity. Areas with existing vegetated surfaces and open drainage showed faster water recession times compared to highly built-up zones. Table 4 demonstrates that green infrastructure elements improve infiltration rates and delay runoff discharge, reducing pressure on drainage systems during intense rainfall events.

This combined approach provides both immediate flood reduction benefits and long-term climate resilience.

### Stakeholder Perspectives and Practical Implications

Stakeholder interviews revealed that while over 70% of local residents expressed willingness to adopt rainwater harvesting systems, implementation remains limited due to financial constraints and lack of technical guidance. Municipal officials acknowledged the effectiveness of RWH but identified policy gaps and enforcement challenges as major barriers.

These findings emphasize the need for policy incentives, technical support and awareness programs to translate theoretical benefits into practical outcomes.

### A. Summarizes the Environmental Conditions Contributing to Flood Vulnerability

**Table 1: Climatic and Hydrological Characteristics of Negombo Urban-Coastal Zone**

Parameter	Description
Geographic Location	Westren Province, Sri Lanka
Climate Type	Tropical monsoon climate
Average Annual Rainfall	2400-2600 mm
Peak Rainfall Period	May - September (Southwest Monsoon)
Average Elevation	0-5m above mean sea level
Major Water Bodies	Negombo Lagoon, Hamilton Canal
Flood Frequency	Seasonal urban flooding

### B. Identifies Key Flood Drivers Supporting the Problem Statement

**Table 2: Major Causes of Urban Flooding Identified in Negombo**

Flood Contributing Factor	Impact Level	Description
Rapid Urbanization	High	Increased Impervious Surfaces
Inadequate Drainage	High	Limited Drainage Capacity
Wetland Encroachment	Medium	Reduced natural water storage
Intense Rainfall Events	High	Climate variability
Poor Drainage Maintenance	Medium	Blocked canals and drains

### C. Shows Feasible RWH Options for Coastal Urban Areas

**Table 3: Types of Rainwater Harvesting Systems Suitable for Negombo**

RWH System Type	Applications	Flood Reduction Benefits
Rooftop RWH	Residential buildings	Reduces Surface runoff
Surface Storage Tanks	Commercial buildings	Peak flow reduction
Recharge Pits	Urban open spaces	Enhances groundwater recharge
Rain Barrels	Small households	Temporary runoff storage

### D. Supports Integrated Water Management Discussion

**Table 4: Green Infrastructure Measures for Flood Risk Reduction**

Green Infrastructure Type	Functions	Flood Reduction Benefits
Permeable Pavements	Infiltration	Reduces runoff
Green Roofs	Rainwater retention	Delayed peak discharge
Rain Gardens	Local Drainage	Improved infiltration
Urban Wetlands	Storage & filtration	Flood buffering

### Discussion

The findings of this study highlight the critical role of rainwater harvesting and sustainable water management strategies in reducing urban flood risks in coastal cities like Negombo. The lack of RWH systems contributes directly to increased runoff and drainage overload. Integrating rainwater harvesting with green infrastructure enhances infiltration and delays runoff, thereby reducing flood peaks.

Similar studies in other coastal cities have reported comparable benefits, reinforcing the effectiveness of integrated approaches. However, institutional constraints, lack of policy enforcement and limited public awareness hinder widespread adoption. Addressing these challenges requires coordinated efforts between policymakers, urban planners and local communities [5].

### Conclusion

This study evaluated the role of rainwater harvesting and sustainable water management strategies in reducing urban flood risks in the Negombo urban-coastal zone, Sri Lanka. The findings confirm that rapid urbanization, increased impervious surfaces and inadequate drainage systems have intensified flooding, particularly during the Southwest monsoon. Conventional stormwater management approaches alone are insufficient to address these challenges [6].

The results demonstrate that decentralized rainwater harvesting systems significantly reduce surface runoff and relieve pressure on urban drainage networks. When integrated with green infrastructure measures such as permeable pavements, green roofs, rain gardens and wetland conservation, rainwater harvesting enhances infiltration capacity and strengthens urban water resilience. These integrated approaches also provide co-benefits including groundwater recharge, improved water quality and climate adaptation. The study emphasizes the importance of integrated water resource management supported by appropriate policies, land-use planning and community participation [7]. Overall, rainwater harvesting combined with sustainable water management practices offers a practical, cost-effective and scalable solution for flood risk reduction in Negombo and other flood-prone coastal cities in Sri Lanka.

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