Wijerathna, W.M.S.D., Dulshan, G.A.K., Wjayasenarathne, K.A.S.H. and Dilini, R.M.A., 2025. Rainwater harvesting systems as a sustainable water management strategy: Addressing water security challenges in Sri Lankan buildings. In Waidyasekara, K.G.A.S., Jayasena, H.S., Wimalaratne, P.L.I. and Tennakoon, G.A. (eds). *Proceedings of the 13th World Construction Symposium*, 15-16 August 2025, Sri Lanka. pp. 1163-1175. DOI: https://doi.org/10.31705/WCS.2025.87. Available from: https://ciobwcs.com/papers/

RAINWATER HARVESTING SYSTEMS AS A SUSTAINABLE WATER MANAGEMENT STRATEGY: ADDRESSING WATER SECURITY CHALLENGES IN SRI LANKAN BUILDINGS

W.M.S.D, Wijerathna[1], G.A.K. Dulshan[2], K.A.S.H. Wjayasenarathne[3] and R.M.A. Dilini[4]

ABSTRACT

Water scarcity has emerged as a critical challenge with wide-ranging implications for economic development, public health, and ecological balance. Despite receiving approximately 2,000 mm of annual rainfall, Sri Lanka struggles with inefficient rainwater capture, resulting in significant runoff losses and growing urban water stress. While rainwater harvesting systems (RWHS) have been recognized for their sustainability potential, existing studies rarely examine the critical gap between policy mandates and their practical implementation in urban buildings. This paper addresses this gap by critically evaluating RWHS as a decentralized water management strategy for Sri Lankan buildings, with a focus on bridging policy–practice disconnects. Drawing on empirical evidence, policy documents, and comparative global practices, the study analyzes RWHS design elements, treatment technologies, performance indicators, and institutional frameworks. Case studies demonstrate that well-designed RWHS can reduce reliance on conventional water supplies by over 70% in institutional and commercial settings, while also contributing to stormwater management and climate resilience. However, widespread adoption remains constrained by inconsistent enforcement, limited incentives, and insufficient public awareness. This paper offers context-specific recommendations for integrating RWHS into urban planning and building codes more effectively. By clarifying these implementation barriers and solutions, the study contributes new insights that can guide policymakers, urban planners, and building professionals to leverage RWHS as a transformative tool for achieving Sustainable Development Goal 6 and long-term water security in Sri Lanka.

Keywords: *Policy Implementation; Rainwater Harvesting Systems; Sri Lanka; Urban Planning; Water Security.*

[1] Undergraduate, Department, Department of Biosystem Engineering, Sri Lanka Technology Campus, Sri Lanka, Sakindu.dulhim@gmail.com

[2] Undergraduate, Department, Department of Biosystem Engineering, Sri Lanka Technology Campus, Sri Lanka, kaveezzadulzan@gmail.com

[3] Lecturer, Department of Environmental Technology, Sri Lanka Technology Campus, Sri Lanka, harshaniwi@sltc.ac.lk

[4] Lecturer, Department of Environmental Technology, Sri Lanka Technology Campus, Sri Lanka, asankar@sltc.ac.lk

1. INTRODUCTION

Freshwater scarcity represents a critical and growing global concern, driven by increasing demand across domestic, agricultural, industrial, and environmental sectors. It is estimated that approximately two-thirds of the global population—equivalent to nearly 4 billion individuals—experience significant water scarcity for at least one month each year (Thebuwena et al., 2024). Water scarcity can be broadly classified into physical scarcity, which occurs when natural hydrological conditions cannot meet demand, and economic scarcity, which results from inadequate infrastructure, poor governance, and inequitable resource allocation. Political and socio-economic factors can exacerbate economic scarcity, further restricting access for vulnerable populations.

Sri Lanka exemplifies the paradox of water abundance coexisting with water insecurity. Despite receiving an average annual rainfall of approximately 2000 mm, over 50% of rainfall is lost to the sea due to inefficient capture and management (Sadushan & Neluwala, 2024). The island's bimodal monsoon system, comprising the Maha (Northeast monsoon) and Yala (Southwest monsoon) seasons, creates pronounced temporal and spatial variability in water availability (Sivakumar, 2021). Per capita renewable water resources are estimated at approximately 2400 m^3; however, only 52% of households have access to piped water, while the remainder depend on local sources such as wells and tanks, which are highly susceptible to seasonal fluctuations (Shamsudduha et al., 2025).

Rapid urbanization further compounds these challenges. By 2030, nearly 70% of Sri Lanka's population is projected to reside in urban areas, with significant expansion of impervious surfaces such as high-rise residential and commercial structures (Ranasinghe & Dissanayake, 2018). This urban growth reduces groundwater recharge and, when combined with more intense rainfall due to climate change, increases the risk of urban flooding. Rainwater harvesting systems (RWHS) have emerged as an effective decentralized approach to enhance urban water security, reduce pressure on centralized supply networks, and improve resilience to climate-induced hydrological extremes (Campisano et al., 2017).

Although Sri Lanka's Urban Development Authority mandates RWHS in new buildings, practical implementation remains limited. Existing studies predominantly address the technical feasibility and environmental benefits of RWHS but provide limited analysis of the socio-economic, institutional, and behavioural factors that hinder widespread adoption. The lack of integrated evaluation frameworks to connect design, policy, governance, and stakeholder engagement remains a key research gap.

This study aims to address these gaps by conducting a comprehensive review of RWHS implementation in Sri Lanka's urban context. It critically examines technical performance, institutional barriers, policy effectiveness, and socio-economic drivers influencing adoption. The findings seek to inform evidence-based recommendations to strengthen policy enforcement, stakeholder engagement, and practical integration of RWHS within the built environment, thereby contributing to improved urban water security and climate resilience.

1.1 RESEARCH PROBLEM

Despite Sri Lanka's favourable rainfall and supportive policies promoting rainwater harvesting, practical adoption in urban and built environments remains limited. Many urban developments have yet to integrate RWH systems effectively, leading to missed opportunities for enhancing water security and reducing stress on centralized water supplies. Barriers include technical knowledge gaps, inconsistent design standards, and insufficient incentives, highlighting the need for targeted research and policy measures to optimize RWH implementation in Sri Lanka's unique social and climatic context.

1.2 RESEARCH OBJECTIVES

This paper aims to evaluate the potential of rainwater harvesting systems as a sustainable water management strategy to address water security challenges in Sri Lanka's built environment by examining the underlying causes of water scarcity, reviewing the types, components, and treatment technologies of RWH systems, analysing relevant policy frameworks and implementation challenges, drawing insights from local and global case studies to identify effective strategies, and proposing recommendations to enhance the adoption and optimization of RWH systems for improved urban water resilience and sustainability.

2. METHODOLOGY

This review was conducted using a systematic and targeted literature search to identify, select, and synthesise relevant research on rainwater harvesting (RWH) systems, water scarcity, and urban water security, with a particular focus on Sri Lanka and comparable contexts. Searches were performed across multiple academic and institutional databases, including Google Scholar, ScienceDirect, and ResearchGate, covering publications from 1999 to 2024 to ensure the inclusion of both foundational studies and recent advancements.

A structured keyword strategy was employed to capture technical, environmental, and governance dimensions of RWH, using terms such as "rainwater harvesting," "rainwater harvesting Sri Lanka," "urban water security Sri Lanka," "water scarcity Sri Lanka," "urban rainwater policy," and "global rainwater regulations." Retrieved records were initially screened by title and abstract to determine relevance. Studies were retained if they addressed technical design, system configurations, or performance aspects, environmental or water quality impacts, or policy frameworks, governance challenges, and stakeholder perspectives relevant to Sri Lanka and similar contexts.

A full-text review was then conducted for 50 shortlisted publications, comprising peer-reviewed journal articles, reputable institutional reports, and national or international policy documents. Following detailed assessment, 5 sources were excluded due to limited relevance, resulting in a final dataset of 45 references incorporated into this review. Key data were extracted on system types, components, water treatment methods, policy frameworks, implementation barriers, and relevant case study outcomes. The findings were then thematically analysed to identify prevailing research trends, effective strategies, knowledge gaps, and context-specific recommendations to inform policy enforcement and the practical uptake of RWH systems within Sri Lanka's built environment.

3. RAINWATER HARVESTING SYSTEM (RWHS)

RWHS can be used for both potable (e.g., drinking, cooking, bathing—with appropriate treatment) and non-potable (e.g., irrigation, toilet flushing, washing) purposes, reducing pressure on conventional water supplies. These systems can be adapted to suit a variety of building types depending on factors like roof area, water demand, and usage. For instance, individual houses often use simple rooftop harvesting systems to meet household needs, whereas schools and hospitals require larger systems with greater storage capacity to ensure continuous water availability. Commercial and institutional buildings frequently incorporate RWH as part of sustainable design strategies, aiming to reduce reliance on public water supply and enhance resilience during periods of water scarcity. Recognizing this, Sri Lanka's Urban Development Authority mandates RWH installations for new constructions, underlining their strategic role in urban planning (The Gazette, 2009).

RWHs can be broadly divided into two categories such as rooftop rainwater harvesting systems and surface runoff rainwater harvesting systems.

Rooftop rainwater harvesting (RWH) systems are among the simplest and most widely implemented forms of rainwater harvesting, particularly in domestic and institutional buildings. In these systems, the roof functions as the primary catchment area where rainwater is collected and subsequently directed into a storage facility (Kim et al., 2016).

Permeable and impermeable surfaces, such as asphalt and concrete pavements, have been explored for their potential in rainwater harvesting. Recent designs incorporate features such as infiltration openings along sidewalks and streets that direct runoff into subsurface gravel layers, where water is temporarily stored in underground micro-detention systems before reuse or infiltration (Chen et al., 2022). Such methods are commonly known as surface runoff harvesting systems.

3.1 ROOFTOP RAINWATER HARVESTING: KEY COMPONENTS AND TREATMENT

A. This refers to the surface area where rainfall is captured. Common roofing materials include clay tiles, wood, corrugated steel sheets, cement, galvanized iron, concrete, fibre cement, aluminium, and asbestos. Studies have examined the quality of water collected from roofs made of different materials, along with their runoff coefficients, which ultimately influence the volume of water that can be harvested. It was found that steel roofs produced the highest quality water, followed by asphalt tile roofs, galvanized iron roofs, and concrete tile roofs (Shaheed et al., 2017).

B. This is the primary component for storing water in a rainwater harvesting (RWH) system. Storage tanks can be constructed either underground or above ground. The size and design of the tank are determined by factors such as the catchment area, rainfall intensity, duration of dry periods, and daily water demand (Vijitha et al., 2022). Materials commonly used for constructing cisterns include concrete, plastic, galvanized sheet metal, and ferro cement (Kihila, 2014). Ferro cement tanks are often selected due to their cost-effectiveness, durability under extreme weather conditions, and low maintenance requirements (Kihila, 2014). Plastic tanks, on the other hand, are preferred for their ease of cleaning and simple integration with piping systems (Khoury-Nolde, n.d.). To prevent algal growth and mosquito breeding, the tank should be fitted with a tightly sealed cover (Pradhan & Sahoo, 2019). Filter for inlet - a screen filter to remove large contaminants such as debris, branches, and vegetation.

C. First flush diverters - the roofs of the buildings can easily get contaminated with dust, debris, bird and rodent droppings, and vegetation. This mechanism ensures that the first incoming stream of water from the rooftop is sent away from the storage tank.

D. Conveyance system - consists of a set of pipes that direct water from the catchment area to the storage tank. A drain is provided along the edge of the roof and is fixed with a slope to ensure the flow of water to the storage tank.

E. Filtering System – The collected rainwater must be safe and free from contaminants to be suitable for use. Well-designed water filters—such as charcoal filters, sand and gravel filters, and PVC sponge or pipe filters—can be used to achieve this objective (Pradhan & Sahoo, 2019).

F. Outlet pipe and the distribution system - This pipe is installed above the storage tank and is responsible for drawing water from the tank to the point of use. A pump may also be attached to facilitate smooth water extraction and distribution.

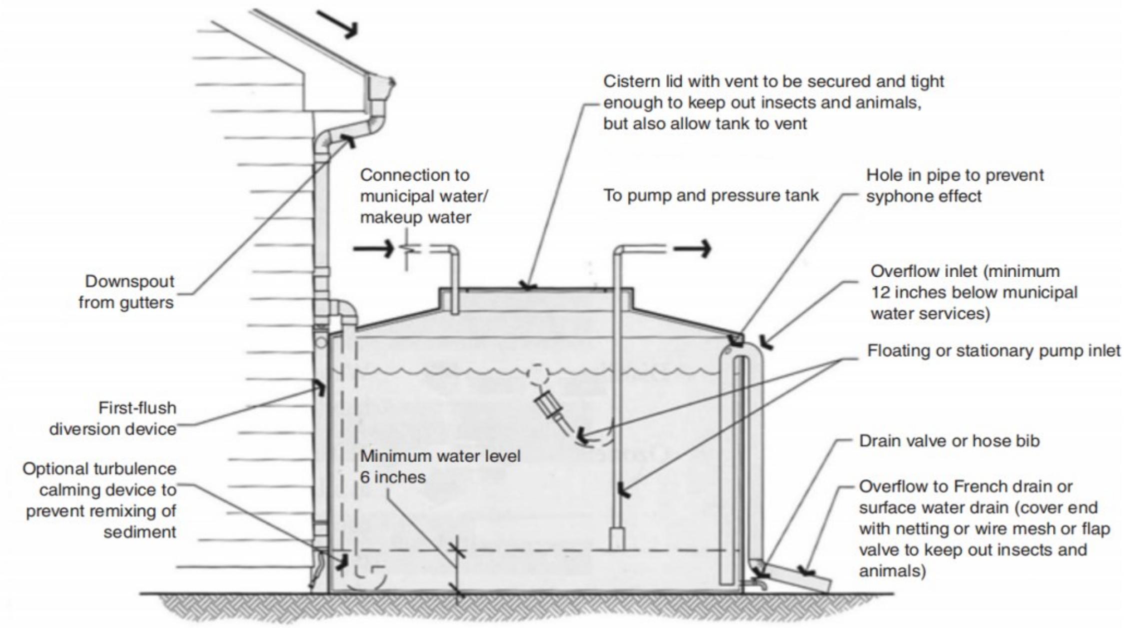

Figure 1: Visual representation of a rooftop rainwater harvesting system
Source: (Kinkade-Levario, 2004)

After the collection of rainwater, the physicochemical and microbiological parameters are assessed to decide how to use the collected rainwater, and they must fall within the range of national and international criteria. Research shows that in Sri Lanka, 68% consume rainwater after boiling without any further treatment. 27% of that population practiced boiling, whereas only 5% of the population practiced filtering (Karthiga & Inoka, 2014).

It has been reported that the first millilitres of precipitation have a significant number of contaminants (Nunes et al., 2020). Higher concentrations of the primary metals discovered include Ca, K, and Na, which might be suspended as both aerosols and fine particulate matter. Escherichia coli, total coliforms, and faecal coliforms are the primary bacteria detected in rainwater (Kim et al., 2016). Microorganisms such as Salmonella spp., Legionella spp., and Pseudomonas spp have been newly discovered to be present in water (Struk-Sokołowska et al., 2020). Disinfection and appropriate treatment are therefore crucial to be used for potable purposes.

3.2 GROUNDWATER AND SURFACE WATER HARVESTING

Runoff harvesting involves collecting rainwater from surfaces like gardens, driveways, landscapes, open fields, parks, roads, and pavements. This approach is particularly effective in low-rainfall regions and is especially suitable for agricultural applications. In urban settings, it is used to conserve water and facilitate groundwater recharge by directing runoff into infiltration pits. In Sri Lanka, traditional "Pathaha" (unlined runoff ponds) and "Pokuna" (lined runoff tanks) remain prevalent forms of surface runoff harvesting, widely used especially in dry zone agricultural regions (Bandara et al., 2010).

Groundwater recharge is a key method in rainwater harvesting where collected rainwater or treated surface runoff is directed into aquifers through mechanisms such as recharge wells, percolation pits, or infiltration basins (Ariyananda, 2010). This process plays a vital role in replenishing depleted groundwater tables, enhancing water quality through natural filtration, and maintaining the viability of wells during dry periods (De Silva & Ariyananda, 2020). In urban environments, managed aquifer recharge (MAR) techniques are increasingly employed to mitigate the effects of over-extraction and reduce the risk of saline intrusion, offering a sustainable solution to growing water demands (Campisano et al., 2017).

Surface runoff rainwater harvesting involves several key methods tailored for effective groundwater recharge and water storage, particularly in urban and agricultural settings. Traditional surface storage techniques include the use of underground tanks, ponds, and check dams to retain rainwater for later use or gradual infiltration (Radhika & Prasoona, 2021). Recharge structures such as pits, trenches, dug wells, and recharge wells are commonly constructed to direct runoff into shallow or deep aquifers; these are typically backfilled with filter materials like boulders, gravel, and coarse sand to facilitate percolation and reduce clogging. Spreading methods such as check dams, nala bunds, cement plugs, gabion structures, and percolation ponds aid in channelling runoff over permeable ground, encouraging widespread infiltration (Radhika & Prasoona, 2021). Finally, diversion of storm runoff into natural or artificial surface water bodies further assists in augmenting both groundwater and surface water reserves, underscoring the diversity and utility of these approaches in managing water scarcity (Radhika & Prasoona, 2021).

4. GROWTH AND DEVELOPMENT OF RAINWATER HARVESTING

While ancient Sri Lankan civilizations, such as that of King Parakramabahu, pioneered sophisticated water management systems, the country's long-standing heritage of sustainable water use is often underutilized in modern urban planning. The existence of ancient tanks and the intricate distribution systems of sites like the Sigiriya fortress provide concrete evidence of the historical importance and technical ingenuity behind rainwater harvesting (Sayanthan et al., 2017). These ancient tank cascade systems-comprising over 15,000 small tanks supported agriculture, biodiversity, and community drought resilience for centuries (World Bank Group, 2023).

However, despite this rich legacy, contemporary practices often fail to integrate traditional knowledge with modern rainwater harvesting technologies. This disconnect suggests a missed opportunity to leverage time-tested community-based systems to strengthen current policy frameworks and public engagement.

Modern interest in rainwater harvesting re-emerged in the early 1990s, driven largely by severe droughts, declining groundwater quality, and increased salinity in the dry zone. The Community Water Supply and Sanitation Project (CWSSP) provided the initial impetus for institutional support by introducing standardized subsurface brick tanks and above-ground ferrocement tanks for domestic use (Ariyananda, 2010). The establishment of the Lanka Rainwater Harvesting Forum (LRWHF) in 1996 further institutionalized RWH promotion across the island, with support from the National Water Supply and Drainage Board (NWSDB), Sarvodaya, and the Southern Development Authority, along with international partners such as UNICEF and WHO.

While these initiatives helped expand decentralized water access in rural and underserved areas, the literature suggests that their impact in urban contexts remains inconsistent. For example, although policy support has grown — with the Urban Development Authority mandating RWH installations in certain urban developments since 2009 — practical enforcement and monitoring have been notably weak (The Gazette, 2009; Dissanayake & Ranasinghe, 2018). Case studies such as Dematawelihinna in Badulla District and Killinochchi District show that pilot community projects can be highly adaptable and effective in household and institutional settings (De Silva & Ariyananda, 2020; Ariyananda & Aheeyer, 2011). Yet these successes have not translated into widespread replication or scaling, highlighting a persistent implementation gap that previous descriptive studies often overlook.

Despite well-documented benefits of rainwater harvesting systems (RWHS)—such as enhanced drought resilience, reduced labor burden on women and children, and improved public health outcomes (Ariyananda, 2010; Elias, 2015)—their integration into formal urban water management frameworks remains limited. This disparity highlights a critical gap in institutional mechanisms necessary for scaling localized successes into enforceable policies, regulatory standards, or incentive structures that promote broader adoption by urban developers.

Overall, the literature reveals a trend of sporadic adoption driven by donor-funded projects rather than sustained, policy-backed expansion. This inconsistency justifies the need for a more critical synthesis, such as the present study, which examines not only technical aspects but also the governance, institutional, and socio-cultural factors that shape the success or failure of RWHS implementation in Sri Lanka's evolving urban landscape.

4.1 IMPLEMENTATION IN SRI LANKAN BUILDINGS

Several Sri Lankan industries have successfully adopted rainwater harvesting (RWH) systems tailored to their specific operational demands, reducing reliance on municipal water and ensuring continuity during dry periods. For example, Finlays Tea Estate in Haldummulla has implemented a large-scale RWH system to support tea processing activities (Finlays, n.d.). Cargills Quality Dairies harvests over 3,000 cubic meters of rainwater annually, mainly used for cooling processes (Cargills, n.d.). Hayleys Quality Seeds meets approximately 30% of its annual water demand through a system with 7.4

million litres of storage capacity, sufficient to support operations for 7–8 months after the monsoon. MAS Intimates in Thulhiriya, Sri Lanka's first LEED Platinum-certified building, integrates an advanced RWH system used for toilet flushing, landscaping, and cooling, significantly reducing potable water consumption (Aheeyar & Bandara, 2010). The Heritance Kandalama Hotel uses harvested rainwater primarily for irrigation as part of its eco-friendly operations (Aitken Spence Hotels, 2013).

According to Aheeyar and Bandara (2010), projects at David Peiris Motor Company, MillenniumIT Campus, and Brandix Casual Wear met between 15% and 100% of daily non-potable water demands such as cleaning, sanitation, and landscaping. Economic evaluations revealed that the RWH systems at MillenniumIT Campus and David Peiris Motor Company had positive net present values and internal rates of return of 18% and 11% respectively, with acceptable payback periods, confirming their financial viability.

Ranasinghe and Dissanayake (2018) found that residential properties with asbestos, concrete, or tile roofs have adopted RWH systems utilizing roughly half of their rainfall collection potential, retaining about 5% of total rainfall. This contributes meaningfully to stormwater runoff management and reduces urban flash flood risks. If RWH adoption were mandated through effective regulations, over 20% of rainwater could be harvested from residential properties alone, potentially lowering urban flood volumes by a similar margin. Using rainfall data, mass curves were developed to estimate potential storage requirements, revealing that approximately 130 m^3 of rainwater per household per year—equivalent to 53.06% of annual potable water consumption—could be harvested under optimal conditions (Nimalka et al.,2021).

4.2 RWH AS A SUSTAINABLE WATER MANAGEMENT STRATEGY

According to a case study conducted by Thebuwena et al.,2024, connecting rainwater storage to flushing system in an office building has reduced the municipal water usage from 946,444 gallons/year to 574,669 gallons/year. Consequently, establishment of a rainwater harvesting system has improved the overall water efficiency of the building by 72.92%. This case emphasizes the value of rainwater harvesting as a viable strategy for reducing potable water demand in non-potable applications, contributing to resource conservation, cost savings, and climate-resilient infrastructure (Eslamian et al., 2023).

The rainwater harvesting tank served as the community's only supply of clean water during the 2018 floods in the Kilinochchi district, when well water and surface water supplies were contaminated (Ariyananda,2020). People can get water from RWHS constructed in schools, which serve as flood shelters, until government assistance arrives (Ariyananda,2020). Therefore, the implementation of rainwater harvesting systems in flood-prone urban areas is vital, as they offer a reliable alternative water source when conventional potable water supplies are compromised due to contamination or disruption. Furthermore, the widespread adoption of rainwater harvesting in vulnerable urban centres can enhance community resilience, ensure emergency water supply continuity, and support public health during climate-induced disasters.

Rainwater harvesting (RWH) offers crucial environmental benefits, especially in urbanized and water-stressed regions. By reducing demand on groundwater and surface water, RWH helps maintain ecological flows and prevents degradation of wetlands and aquatic ecosystems (Barron, 2009). Urban stormwater pollution has become a major factor contributing to the deterioration of municipal water quality and the environmental degradation of drinking water catchment areas (Soltaninia et al.,2025). Thereby RWHs decrease the treatment of stream flows in wastewater treatment plants, erosion, and non-point source of pollution of water bodies (Angrill et al.,2017; Campisano et al., 2017).

Moreover, RWH enhances ecosystem services by improving soil moisture, vegetation cover, and groundwater recharge. These effects support biodiversity and reduce landscape degradation, especially in semi-arid zones (Barron, 2009). RWH also strengthens climate resilience by providing a decentralized water source during droughts and floods, mitigating the impact of rainfall variability (Barron, 2009).

Commercial buildings benefit more from RWHS than do homes with small installations since they have larger roof areas, higher water use, and higher water tariffs (Lani et al.,2019). Installing RWHS during the early design and construction phases can significantly reduce retrofitting costs in later stages (Lani et al., 2018).

4.3 IMPLEMENTATION CHALLENGES OF RAINWATER HARVESTING SYSTEMS IN SRI LANKA

Despite progressive policy frameworks promoting the adoption of Rainwater Harvesting Systems (RWHS) in Sri Lanka, several implementation challenges continue to impede widespread uptake, particularly in urban and institutional contexts. According to the Gazette of the Democratic Socialist Republic of Sri Lanka (2009), all industrial and commercial buildings—including car parks—within Municipal and Urban Council jurisdictions are required to submit RWHS plans and obtain prior approval before construction. However, in practice, enforcement remains weak. For instance, in 2017, neither the Dehiwala-Mount Lavinia nor the Kesbewa Municipal Councils approved or rejected any building applications based on RWHS compliance, indicating a disconnect between policy intent and regulatory enforcement (Dissanayake & Ranasinghe, 2018).

Institutional commitment also remains limited. Although the Urban Development Authority (UDA) regulations mandate the inclusion of RWHS in all buildings, including government facilities, no central, provincial, or local authority has independently constructed such systems despite having the financial capacity to do so. Existing installations are largely restricted to a few government offices, particularly schools, and have primarily been funded through donor-driven or NGO-supported initiatives (Dissanayake & Ranasinghe, 2018).

Public awareness constitutes another major barrier to implementation. While national policies highlight awareness-raising as a strategic priority, no formal campaigns or funding allocations have been undertaken by any government institution at the national, provincial, or local level. Consequently, non-governmental organizations (NGOs) have assumed the primary role in conducting outreach efforts, resulting in fragmented and un-sustained public engagement (Dissanayake & Ranasinghe, 2018).

Design optimization and cost considerations further complicate RWHS implementation. A study by Nimalka et al. (2021) identified cylindrical ferro cement tanks as the most structurally efficient and cost-effective option when compared to cuboid and doubly curved alternatives. Life cycle cost analysis confirmed the long-term economic viability of these systems. However, under the current tariff structure provided by the National Water Supply and Drainage Board (NWS&DB), the capital cost recovery period exceeds the typical design life of the system. Notably, when assessed against the actual production cost of potable water, RWHS becomes significantly more cost-effective, underscoring the need for more realistic valuation methods in economic assessments.

5. WAY FORWAD

While rainwater harvesting (RWH) is acknowledged in Sri Lanka's national building code, its implementation is hindered by vague legal definitions, weak enforcement, and a lack of post-installation oversight. Strengthening regulatory clarity—particularly regarding urban classifications—and introducing standardized verification mechanisms are essential to ensure the consistent application of RWH requirements. Incorporating routine inspections, maintenance standards, and mosquito control measures, as practiced in countries such as Singapore and India, would enhance system reliability and public health safety. Additionally, the absence of financial incentives and government-led installations underscores the need for dedicated funding, subsidies, and policy-backed support to drive adoption, particularly in urban settings. Capacity-building programs for municipal authorities and technical professionals are vital to ensure effective planning and design. Moreover, Sri Lanka must expand research efforts to include system performance, scalability, and urban integration, drawing from global innovations such as smart sensors, infiltration storage, and green infrastructure. A more integrated national approach—combining legal reform, financial incentives, technical training, and innovation—will be essential to establish RWH as a viable tool for sustainable water management and climate resilience in Sri Lankan buildings.

6. CONCLUSION

This review examined rainwater harvesting systems (RWHS) as a sustainable water management strategy to address Sri Lanka's water security challenges. Despite substantial rainfall and historical water management traditions, modern RWHS adoption in urban areas remains sporadic and poorly enforced. Although policies mandate RWHS for new buildings, compliance and monitoring are often weak and symbolic. Technical feasibility alone does not ensure uptake; the gap between policy intentions and enforcement is a major barrier. Most evidence comes from small pilot projects with limited scaling, and few studies assess long-term performance, costs, or social acceptance. While RWHS can reduce municipal water demand and enhance climate resilience, institutional, socio-economic, and behavioural barriers remain underexplored. Limitations include reliance on secondary data with variable methodologies and underrepresentation of grey literature and informal practices. To improve urban water security, an integrated governance approach is needed—combining compliance monitoring, capacity building, financial incentives, and clear guidelines for users and developers. Regular maintenance and health safeguards are critical for system reliability. Future research should focus on multi-disciplinary, long-term studies of RWHS performance in diverse settings and draw lessons from countries with successful implementation. Exploring smart systems and integration with urban green infrastructure can enhance RWHS benefits like flood control and heat reduction. By closing these gaps and strengthening enforcement, RWHS can become a key element of Sri Lanka's resilient, decentralized urban water management.

7. REFERENCES

Aheeyar, M. M., & Ariyananda, T. (2014, September). *Domestic rainwater harvesting interventions in Sri Lanka: Some lessons learnt* [Conference Presentation]. Symposium on Mainstreaming Rainwater Harvesting as a Water Supply Option, Colombo, Sri Lanka. https://doi.org/10.13140/2.1.1364.8645

Aheeyar, M. M. M., & Bandara, M. A. C. S. (2010). *Impact of rainwater harvesting on household food security in dry zone of Sri Lanka*. Hector Kobbekaduwa Agrarian Research and Training Institute.

Amarasinghe, U. A., Mutuwatta, L., & Sakthivadivel, R. (1999). *Water scarcity variations within a country: A case study of Sri Lanka* (IWMI Research Report 32). International Water Management Institute. https://hdl.handle.net/10568/39819

Angrill, S., Segura-Castillo, L., Petit-Boix, A., Rieradevall, J., Gabarrell, X., & Josa, A. (2017). Environmental performance of rainwater harvesting strategies in Mediterranean buildings. *The International Journal of Life Cycle Assessment*, *22*(3), 398–409. https://doi.org/10.1007/s11367-016-1174-x

Ariyananda, T. (2004, September). *Rainwater harvesting in Sri Lanka: Lessons learned* [Conference presentation]. IWA World Water Congress, Marrakech, Morocco. https://citeseerx.ist.psu.edu/document?doi=6a1a11d21197a0da143f3953d0f4e037e4fc58c8

Ariyananda, T. (2010). Domestic rainwater harvesting as a water supply option in Sri Lanka. *Hydro Nepal: Journal of Water, Energy and Environment, 6,* 27-30. https://doi.org/10.3126/hn.v6i0.4189

Ariyananda, T., & Aheeyar, M. M. M. (2011, October 1). *Effectiveness of rain water harvesting (RWH) systems as a domestic water supply option* [Conference presentation]. National Workshop on Rainwater Harvesting, Colombo, Sri Lanka. https://doi.org/10.13140/RG.2.2.10817.66403

Ariyananda, T. (2018). *Rainwater harvesting in Sri Lanka: Lessons from two decades* [PowerPoint slides]. Lanka Rainwater Harvesting-Forum. https://cdn.cseindia.org/userfiles/tanuja- Lanka.pdf

Aitken Spence Hotels. (2013, September 27). *Heritance Kandalama goes the extra mile to conserve water.* Aitken Spence Hotels. Retrieved August 10, 2025 from https://aitkenspencehotels.typepad.com/blog/2013/09/heritance-kandalama-goes-the-extra-mile-to-conserve-water.html

Barron, J. (2009). Rainwater harvesting: *A lifeline for human well-being*. Stockholm Environment Institute. https://www.sei.org/publications/rainwater-harvesting-lifeline-human-well/

Bandara, M. A. C. S., De Silva, R. P., & Dayawansa, N. D. K. (2010). Household water security through stored rainwater and consumer acceptability: A case study of the Anuradhapura District. In A. Evans, & K. Jinapala (Eds.), *Proceedings of national conference on water, food security and climate change in Sri Lanka, Colombo, Sri Lanka,* 9–11 June 2009. (pp. 87-97). International Water Management Institute. https://agris.fao.org/search/es/records/67235f878aa2fad1ce46fd47

Campisano, A., Butler, D., Ward, S., Burns, M. J., Friedler, E., DeBusK, K., Fisher-Jeffes, L. N., Ghisi, E., Rahman, A., Furuma, H.,& Han, M. (2017). Urban rainwater harvesting systems: Research, implementation and future perspectives. *Water Research, 115*, 195–209. https://doi.org/10.1016/j.watres.2017.02.056

Cargills Ceylon. (n.d.). *Cargills quality dairies: Case studies*. Retrieved August 10, 2025, from https://www.cargillsceylon.com/case-studies/

Chen, C., Lin, J., & Lin, J. (2022). Hydrological cycle performance at a permeable pavement site and a Raingarden site in a subtropical region. *Land, 11*(6), 951. https://doi.org/10.3390/land11060951

De Silva, C. S., & Ariyananda, T. (2020). Groundwater responses to artificial recharge of rainwater in Badulla District in Sri Lanka. *Journal of Dry Zone Agriculture, 6*(2), 15–23. https://doi.org/10.4038/jdza.v6i2.40

Dissanayake, D. M. S. B., & Ranasinghe, P. (2018). Effectiveness of national rainwater policy and strategy in Sri Lanka. In *Proceedings of International Conference on Water Security through Rainwater Harvesting, Colombo, Sri Lanka,* 27–29 November 2018. Lanka Rainwater Harvesting Forum. https://www.lankarainwater.org/symposium-proceedings/

Dodangoda, A., Hapuarachchi, H. A. S. V., Dilshan, M. G. M., & Steinwall, F. P. (2021). *Implementation of a sustainable rainwater harvesting system for Sri Lanka Ex-Servicemen's Institute building* [Unpublished master's thesis]. General Sir John Kotelawala Defence University.

Elias, F. (2015). *Women's roles in integrated water resource management: A case study of the Mutale water user association* [Unpublished master's thesis]. University of Pretoria.

Eslamian, S., Roknizadeh, H., Maleki, M., & Abedi-Koupai, J. (2023). Surface runoff water harvesting for irrigation. In S. Eslamian, & F. Eslamian (Eds.), *Handbook of water harvesting and conservation for sustainable agriculture* (pp. 323–334). CRC Press. https://doi.org/10.1201/9780429290114-22

Finlays. (n.d.). *Finlays Colombo sustainability*. Finlays. Retrieved August 10, 2025 from https://www.finlays.net/our-businesses/finlays-colombo/

Kihila, J. (2014). Rainwater harvesting using ferrocement tanks: An appropriate and affordable technology for small rural institutions in Tanzania. *International Journal for Computational Civil and Structural Engineering, 3*(3), 332–341. https://www.researchgate.net/publication/285009281

Kim, Y., Dao, A. D., Kim, M., Nguyen, V. A., & Han, M. (2016). Design and management of rainwater harvesting systems to control water quality for potable purposes in Cu Khe, Vietnam. *Water Science and Technology: Water Supply, 17*(2), 452–460. https://doi.org/10.2166/ws.2016.154

Kinkade-Levario, H. (2004). *Forgotten rain: Rediscovering rainwater harvesting*. Granite Canyon Publications.

Lani, N. H. M., Syafiuddin, A., & Yusop, Z. (2019). Comparison of cost benefits of new installation and retrofitted rainwater harvesting systems for commercial buildings. In G. Mannina (Ed.), *New Trends in Urban Drainage Modelling. UDM 2018. Green Energy and Technology. Springer, Cham.* (pp. 169–174). https://doi.org/10.1007/978-3-319-99867-1_30

Nimalka, K. D. C., Rathnasena, B. B. L. R., & Suraweera, D. D. D. (2021). Rain water harvesting system to supplement non-potable water requirements: Designing domestic dwelling in Colombo suburbs. In H. M. L. Kumari, K. Bnadara, M. Vithanapathirana, C. Wannigama, S. Neranjani, L. Wedikkarage, K. Senevirathna, S. Senarath, J. Herath, & R. D. C. Nirashinie (Eds.), *Proceedings of the university of vocational technology (UoVT) international research symposium* [Online], 26 November 2021. (pp. 278–284). University of Vocational Technology. https://d1wqtxts1xzle7.cloudfront.net/89285585/Full_Paper_Volume_2021_UoVT_International_Symposium_Proceedings-libre.pdf#page=278

Nunes, G., Alves, L. D., Escobar, I., Bila, D. M., Akira, A., & Corrêa, S. M. (2020). An assessment of atmospheric deposition of metals and the physico-chemical parameters of a rainwater harvesting system in Rio de Janeiro, Brazil, by means of statistical multivariate analysis. Ambiente e Água - An *Interdisciplinary Journal of Applied Science, 15*(4), e2522. https://doi.org/10.4136/ambi-agua.2522

Pradhan, R., & Sahoo, J. (2019). Smart rainwater management: New technologies and innovation. In J. Sahoo (Ed.), *Smart urban development* (pp. 225–240). IntechOpen. https://doi.org/10.5772/intechopen.86336

Ranasinghe, R., & Dissanayake, P. (2018). Urbanization and rainwater harvesting potential in Colombo DS Division. *Sri Lanka Journal of Environmental Professionals, 7*(1), 55–68.

Radhika, V., & Prasoona, J. (2021). Rain water harvesting techniques and methods. *International Journal of Research and Analytical Reviews, 8*(3), 284–289. https://www.researchgate.net/publication/373194725

Sadushan, S., & Neluwala, N. G. P. B. (2024). Application of GIS & RS in rainwater harvesting for an arid region. *Engineer: Journal of the Institution of Engineers, Sri Lanka, 57*(2), 23–32. https://doi.org/10.4038/engineer.v57i2.7650

Sayanthan, S., Mikunthan, T., Thaneswaran, N., Prabhaharan, M., & Thaneswaran,N (2017). Needs and trends of rain water harvesting in Sri Lanka. *International Journal of Research Studies in Agricultural Sciences, 3*(12), 42–52. https://doi.org/10.20431/2454-6224.0312005

Shamsudduha, M., Lee, J., Joseph, G., Bahuguna, A., Wijesundera, S., Nair, Hoo, Y.R.., Wang, Q., & Ayling, S. C. (2025). Assessing the water quality hazard and challenges to achieving the freshwater goal in Sri Lanka. *Scientific Reports, 15*(1), 10187. https://doi.org/10.1038/s41598-025-93845-1

Soltaninia, S., Eskandaripour, M., Golmohammadi, M. H., Taghavi, L., & Mehboodi, A. (2025). Nitrate pollution in urban runoff: A comprehensive risk assessment for human and ecological health. *Science of The Total Environment, 974*, 179184. https://doi.org/10.1016/j.scitotenv.2025.179184

Thebuwena, A. C. H. J., Samarakoon, S. S. M., & Ratnayake, R. C. (2024). On the necessity for improving water efficiency in commercial buildings: A green design approach in hot humid climates. *Water, 16*(17), 2396. https://doi.org/10.3390/w16172396

U.S. Green Building Council. (2012). *MAS Intimates Thurulie: LEED platinum certified factory*. U.S. Green Building Council. Retrieved August 10, 2025 from https://www.usgbc.org/projects/mas-intimates-thurulie

Vijitha, V., Sayanthan, S., &Mikunthan, T. (2022). A review on rainwater harvesting in Sri Lanka. *Vavuniya Journal of Science, 1*(1), 31–37. https://doi.org/10.4038/vjs.v1i1.5

World Bank Group. (2023). *What the future has in store: A new paradigm for water storage*. The World Bank. https://documents1.worldbank.org/curated/en/099454002022397507/pdf/IDU031e759b40be950485909796045bca5d8e378.pdf