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DOI: doi.org/10.64780/jeims.v1i1.6

Journal of Engineering Innovation and Management Science Vol 1 No 2. (2025)

Research Article

Comparative Study of Household-Scale Rainwater Harvesting Systems in Indonesia and South Korea: A Case Study of Mojoagung and Jeju

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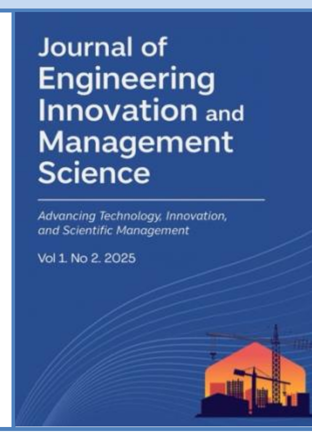
Received : 13 August 2025	Revised : 10 September 2025	Accepted : 05 October 2025	Online : 20 December 2025

Abstract

Rainwater harvesting (RWH) has gained attention as a sustainable alternative to address clean water scarcity in urban and peri-urban settings. This study presents a comparative analysis of household-scale RWH systems implemented in two distinct geographical and climatic contexts: Mojoagung District in Indonesia and Jeju City in South Korea. Both locations experience seasonal water stress but differ significantly in infrastructure development, rainfall distribution, and policy frameworks. A qualitative comparative method was employed using secondary data derived from prior engineering case studies. The Indonesian system incorporates rooftop runoff capture, multi-layer filtration using silica sand, activated carbon, and zeolite, as well as groundwater recharge through infiltration wells. In contrast, the South Korean system is designed for non-potable uses, focusing on storage efficiency and economic return, with a cost-benefit analysis conducted via Net Present Value (NPV) calculation. The findings indicate that the Indonesian RWH system effectively neutralizes acidic rainwater by increasing the pH from 5.37 to 7.50, meeting potable water standards. The system also contributes to local aquifer recharge. Meanwhile, the Korean system achieves a 67.75% efficiency rate in reducing municipal water demand, with a projected monthly cost saving of up to 30,000 KRW and an NPV of 17,190 KRW by month 35. This comparative study highlights the importance of tailoring RWH designs to specific environmental and socio-economic conditions, offering valuable insights for future integrated water resource planning.

Keywords: *Economic Efficiency; Household Scale; Infiltration, Rainwater Harvesting; South Korea*

How to Cite:
Ha, P. E., & Ardianti, I. M. (2025). Comparative Study of Household-Scale Rainwater Harvesting Systems in Indonesia and South Korea: A Case Study of Mojoagung and Jeju. *Journal of Engineering Innovation and Management Science*, *1*(2), 64–77.



INTRODUCTION

The increasing demand for clean water in both urban and rural areas has led to the exploration of alternative water supply strategies that are environmentally sustainable and locally adaptable (Hoffmann et al., 2020; Scanlon et al., 2023; Wong et al., 2020). Rainwater harvesting (RWH) has emerged as one such strategy, providing a decentralized solution to supplement domestic water needs and reduce pressure on centralized water infrastructure (Chen et al., 2025; Lepcha et al., 2024; Zang et al., 2021). Particularly in regions with seasonal rainfall variations, RWH systems offer an opportunity to store surplus rainwater for use during dry periods (Roba et al., 2021; Wartalska et al., 2024). Household-scale RWH systems are relatively simple to implement and can be tailored to fit diverse socio-economic and environmental conditions (Kanno et al., 2021; Parker et al., 2013; Yu et al., 2023). These systems typically involve the collection of rooftop runoff, followed by basic filtration and storage for domestic use. In developing countries, RWH also functions as an adaptive response to infrastructure limitations and climate-induced water insecurity (Magesa & Pauline, 2021; Susilo, 2018; Vanderweyen et al., 2020). Furthermore, by reducing surface runoff, RWH contributes to flood mitigation and groundwater recharge. The promotion of RWH aligns with global water security goals and supports community resilience against water-related vulnerabilities. Strategic planning of urban water supply is crucial in addressing the challenges of rapid urbanization, as it can anticipate the increasing demand for clean water while ensuring sustainable supply through innovation and adaptation of water management systems (Sari & Ismail, 2025).

In tropical countries such as Indonesia, the contrast between high-intensity rainfall during the wet season and extended dry spells creates acute challenges in water availability (Dharmawati et al., 2025; Iwansyah et al., 2023). Many areas face flooding during periods of heavy rainfall and experience clean water shortages during prolonged droughts (Cook et al., 2020; Herrera-Franco et al., 2024). The quality of water in tropical regions of Indonesia is greatly influenced by environmental conditions and human activities, thereby necessitating adaptive and context-specific water management strategies to ensure the availability of clean water (Navia et al., 2024). To address this, RWH systems are designed not only to collect and store rainwater but also to treat it for basic household use through multi-stage filtration. The application of simple filtration technology, such as the slow sand filter, has proven effective in reducing pollutant levels in wastewater, making it a potential adaptation for household-scale rainwater harvesting systems to ensure safe and usable water quality (Rizki et al., 2025). In addition, excess rainwater is often diverted into infiltration wells to enhance local groundwater recharge (Hijrawadi & Setiacahyandari, 2025; Keithley et al., 2018; Segal et al., 2024). This integrated approach simultaneously addresses short-term water supply and long-term aquifer sustainability. Local innovations in filtration media and system configuration have increased the practicality of RWH in household settings (Adeosun & Omonona, 2021; Tiwari et al., 2021). Community-based programs in Indonesia have demonstrated the feasibility of such systems even in low income neighborhoods. Community-based sanitation facility assistance programs have made a significant contribution to improving access to clean water and environmental health, aligning with the objectives of developing sustainable rainwater harvesting systems (Ismail et al., 2024). These interventions show promise in strengthening local water autonomy in the absence of reliable municipal services.

In contrast, South Korea despite being an industrialized country with advanced infrastructure has adopted rainwater harvesting as part of its broader sustainability agenda. The country faces uneven rainfall distribution, with most precipitation concentrated in a few months, making seasonal water management critical (Jung et al., 2012; H.-H. Kwon et al., 2016; M. Kwon et al., 2019). Household-scale RWH in Korea is commonly applied for non-potable purposes such as flushing toilets and doing laundry, with an emphasis on water use efficiency. Financial models and policy incentives have supported the adoption of RWH, particularly in urban areas where space and regulatory frameworks permit integration (Khan et al., 2023; Ranasingha & Wattage, 2024). Studies from Korea have highlighted the potential for RWH systems to reduce household utility costs and lower urban stormwater runoff. Unlike the Indonesian context, Korean systems often do not include groundwater recharge components, focusing instead on reusing water within closed-loop domestic systems. This reflects a prioritization of cost-efficiency and infrastructure load reduction (Pari et al., 2021; Schuster-Wallace et al., 2022). Nevertheless, both countries recognize the value of RWH in enhancing water resilience and addressing local water management concerns.

Although numerous studies have explored RWH from technical, economic, and environmental perspectives, most have focused on single-country contexts or specific components of the system. For instance, financial feasibility assessments in Poland (Musz-Pomorska et al., 2020), life cycle analyses in the UK and US (Maskwa et al., 2021; Rashid et al., 2021), and first-flush filtration studies in Europe (Charlebois et al., 2023) have provided insights relevant to temperate, high-income settings. Further studies have reviewed optimization approaches and communal versus individual system performance (Quinn et al., 2020; Sharma & Trivedi, 2023), yet few have attempted systematic comparisons between countries with differing socio-environmental contexts. Existing literature also tends to overlook the role of RWH in tropical climates where rainfall patterns, water needs, and socio-economic conditions differ considerably from those in developed regions. This lack of cross-national comparative research limits our understanding of how RWH designs adapt to contextual challenges. Moreover, the absence of studies comparing Southeast Asian and East Asian implementations leaves a gap in practical knowledge transfer. Evaluating systems across contrasting geographies can reveal underlying principles for designing more adaptable and scalable RWH strategies. A natural resource management approach that integrates local wisdom has proven capable of enhancing the effectiveness of environmental technology implementation, including the application of rainwater harvesting systems adapted to the local socio-economic and cultural context (Ardianti et al., 2023). Therefore, a comparative study between Indonesia and South Korea can offer valuable lessons for the broader adoption of sustainable water practices.

This study aims to examine and compare household-scale rainwater harvesting systems in Mojoagung District, Indonesia, and Jeju City, South Korea. Specifically, it evaluates the technical configurations, water treatment approaches, and economic feasibility of each system. The study utilizes a qualitative comparative methodology, drawing on design documents, secondary data, and published case studies. Through this analysis, the research highlights how climate, infrastructure, and water policy influence system performance. The goal is to identify best practices and context-sensitive adaptations that can inform future implementations in similar regions. The findings are expected to contribute to the literature on sustainable water management and urban climate adaptation. Moreover, the study offers a framework for assessing RWH suitability across different environmental and economic settings. Ultimately, this research supports the development of integrative solutions that bridge engineering design with localized needs.

METHODS

This research was conducted in two selected locationsMojoagung District in East Java, Indonesia, and Jeju City in South Korea. These sites were deliberately chosen due to their contrasting climatic conditions and differing approaches to household-scale rainwater harvesting (RWH) implementation. Mojoagung represents a tropical setting with high rainfall intensity concentrated in short periods, while Jeju City experiences more evenly distributed precipitation within a temperate climate. Both areas have documented RWH practices that make them suitable for comparative evaluation. Data collection was conducted through a combination of structured field observations, document review, and semi-structured interviews. In each location, households that had installed RWH systems for a minimum of one year were visited to observe system configuration, filtration components, and storage mechanisms. Interviews were conducted with household owners, local technicians, and relevant stakeholders to understand the operational context and user perspectives. Additionally, supporting technical documentation such as design schematics, rainfall records, and water use logs were reviewed to supplement primary data.

Data analysis was carried out using a comparative-descriptive approach. Key variables—including system layout, filtration method, water application purpose, and cost-related data—were coded thematically and organized into comparative matrices. Environmental indicators such as rainfall intensity, catchment area, and daily water demand were also considered to contextualize the performance of each system. Qualitative insights were interpreted through the lens of adaptive water management theory, emphasizing context-based functionality. To ensure the validity and representativeness of findings, ten households from each location were purposively selected based on criteria such as operational status, documentation availability, and system diversity. These cases reflect a range of socio-economic backgrounds and architectural layouts, allowing for nuanced interpretation of how RWH systems function under different physical and social constraints. While the sample size is limited, the depth of inquiry provides rich insights suitable for comparative analysis across diverse environmental settings.

RESULT AND DISCUSSIONS

Water Demand Utilization

In Jeju City, RWH is primarily used for non-potable applications such as toilet flushing and laundry. Table 1 shows that daily water demand varies seasonally, with the highest consumption during the cold season (0.260 m³/day), followed by spring/fall (0.235 m³/day), and the lowest during the hot season (0.201 m³/day). The increase in winter reflects greater domestic activity and water heating needs. In contrast, in Mojoagung, daily water demand ranges from 100 to 150 liters, covering broader uses including bathing, cleaning, and when properly filtered drinking. This wider usage pattern illustrates the system's role in supplementing unreliable centralized water supplies in rural settings.

Table 1. Daily Non Potable Water Demant in Jeju City by Season

Season	Flush Water (m3/day)	Washing Machine (m3/day)	Total Demand (m3/day)
Hot	0,146	0,065	0,201
Spring/Fall	0,170	0,065	0,235
Cold	0,195	0,065	0,260

System Design and Technical Components

The technical configuration of RWH systems reflects distinct operational objectives. Table 2 highlights the system components in both study areas. In Jeju, systems are integrated with buildings and use reinforced concrete tanks, mesh filters, and gravity-fed distribution. In Mojoagung, systems employ PVC tanks, multi-stage filtration units (gravel, sand, charcoal, ceramic), and overflow management via infiltration wells for groundwater recharge. The Indonesian model exhibits higher ecological integration, while the Korean model is optimized for space efficiency and water reuse.

Table 2. Summary of Household RWH System Components and Functions

Component	Mojoagung, Indonesia	Jeju City, South Korea
Catchment Area	Rooftop	Rooftop
Storage Tank	PVC Tank (≥ 1000 L)	Reinforced Concrete or Plastic Tank
Filtration	Gravel, sand, charcoal, ceramic filter	Sedimentation + mesh filter
Water Use	Bathing, cleaning, filtered drinking	Toilet flushing, laundry
Overflow Management	Infiltration well (biopori)	Overflow pipe to drainage
Water Treatment Goal	Potable or semi potable	Non potable
Community Role	Community based initiative	Policy supported urban initiative
Enviromental Role	Groundwater recharge, flood control	Stormwater control

Environmental Conditions and Water Potential

Table 3 compares rainfall characteristics. Mojoagung receives 2,000–2,500 mm/year with high seasonal variability, which supports rainwater harvesting but complicates storage consistency. Jeju receives 1,300–1,600 mm/year with historically more uniform distribution, although recent studies indicate increasing variability in seasonal rainfall patterns, which allows better predictability in RWH performance for routine non-potable use. These differences influence tank sizing, overflow design, and water use planning.

Table 3. Rainfall Characteristics and Rainwater Potential

Location	Average Annual Rainfall (mm.year)	Rainfall Pattern	RWH Potential Use
Mojoangung, Indonesia	2.000-2.500	High intensity, seasonal	Potable and non potable
Jeju, South Korea	1.300-1.600	Evenly distributed	Non potable only

Cost Structure and Feasibility

Initial setup costs differ significantly, as seen in Table 4. Mojoagung's systems average IDR 4.5 million (~USD 280), higher due to multi-stage filters and infiltration wells. Jeju systems average KRW 1.25 million (~USD 950), aided by policy subsidies and simpler configurations. Despite the higher nominal cost in Korea, installation is supported through municipal programs and cost-sharing models.

Table 4. Cost Estimation of RWH Systems (Initial Setup Only)

Item	Mojoagung, Indonesia (IDR)	Jeju, South Korea (KRW)
Storage Tank (1.000 L)	1.200.000	450.000
Filtration System	800.000	300.000
Plumbing + Installation	1.000.000	500.000
Infiltration Well (optinal)	1.500.000	-
Total Estimated Coast	4.500.000	1.250.000

Institutional and Policy Support

Institutional differences are summarized in Table 5. Jeju's RWH systems, as observed in the reviewed documents and past literature, have been integrated into urban sustainability policies with structured incentives, technical guidance, and monitoring mechanisms. In contrast, Mojoagung relies on community mobilization and NGO partnerships, with limited formal evaluation or long-term support from local government. This affects system standardization and scalability.

Table 5. Institutional and Policy Support

Indicator	Mojoagung (Indonesia)	Jeju (South Korea)
Government Support	Minimal, community driven	Strong, policy backed subsidies
Integration with urban Planning	Limited	Integrated into green infrastructure planning
Technical Guidance Available	NGO driven or self built	Available through local government initiatives
Monitoring and Evaluation	Not standardized	Periodic evaluation by municipal authority

Water Quality and Public Health

Water quality post-filtration differs due to treatment intensity. Table 6 shows that water in Mojoagung often requires further disinfection for drinking due to occasional E. coli presence. In Jeju, harvested water consistently meets non-potable reuse standards. This reflects the difference in target application and expected safety levels.

Table 6. Water Quality Parameters (Post Filtration)

Parameter	Mojoagung (Indonesia)	Jeju (South Korea)	WHO Standard
pH	6,5-7,2	6,8-7,5	6,5-8,5
Turbidity (NTU)	2-5	<1	≤5
E. coli (cfu/100ml)	Detected occasionally	Not detected	0
TDS (mg/L)	100-250	50-100	≤500

Community Engagement and User Perception

Public acceptance and maintenance practices are critical. As shown in Table 7, both communities show high satisfaction, but in Jeju, stronger technical literacy and government outreach foster more consistent maintenance behavior. In Mojoagung, community involvement is vital, but limited training and resources may affect long-term functionality.

Table 7. Community Participation and Perception

Indicator	Mojoagung, Indonesia	Jeju, South Korea
User Satisfaction	High	High
Willingness to Maintain	Medium to High	High
Awareness of Water Issues	High due to scarcity	High due to sustainability
Technical Literacy	Medium	High

Comparative Insights

The comparison reveals that while both regions benefit from RWH systems, the underlying motivations and implementation models differ. Jeju's systems are policy-driven and efficiency-oriented, while Mojoagung's systems are locally adapted, ecologically integrated, and grassroots-led. Both models offer valuable lessons for designing flexible, context-responsive RWH strategies.

An integrated approach that combines Jeju's regulatory strengths with Mojoagung's community-based innovations could enhance water resilience across varied global contexts.

Discussion

The comparative analysis between household-scale rainwater harvesting (RWH) systems in Mojoagung, Indonesia, and Jeju City, South Korea, demonstrates that the effectiveness of such systems is highly influenced by local environmental conditions, institutional structures, and socio-cultural dynamics. In Jeju, the systems are characterized by government-led implementation, standardized design for non-potable uses, and strong policy integration that promotes efficiency and reduces pressure on centralized water infrastructure. Conversely, the Mojoagung systems exhibit a more community-driven and ecologically integrated model, with multifunctional purposes including potable use and groundwater recharge, albeit with limited technical support and funding. The seasonal variability and higher rainfall intensity in Mojoagung necessitate larger storage and infiltration features, while Jeju benefits from stable rainfall distribution, enabling compact system configurations. User engagement also differs significantly technical literacy and maintenance consistency are higher in Jeju due to structured oversight, while Mojoagung relies on local innovation and shared responsibility. These contrasting cases reveal that successful RWH implementation requires not only appropriate technological adaptation but also alignment with local governance capacity and community participation. A context-sensitive strategy that synthesizes the institutional strengths of Korea with the adaptive practices observed in Indonesia may offer a replicable framework for enhancing domestic water security across diverse geographical settings.

Implication

The results of this comparative study carry meaningful implications for the development of context-appropriate rainwater harvesting (RWH) strategies at the household level. The contrasting approaches observed in Indonesia and South Korea demonstrate that a one-size-fits-all model is insufficient to address the complexity of water accessibility challenges across diverse regions. In developed urban settings, such as Jeju, structured policy incentives and regulatory frameworks have proven effective in facilitating the adoption and maintenance of RWH systems for non-potable use. In contrast, the experience in Mojoagung highlights the critical role of community engagement, locally sourced materials, and multifunctional system designs in compensating for limited institutional support. This suggests that empowering communities through participatory processes and affordable technologies can enhance water resilience in resource-constrained areas. Moreover, integrating environmental functions—such as flood control and aquifer recharge—into household-scale RWH systems may offer additional long-term ecological benefits. For planners and policymakers, these insights call for the formulation of adaptive guidelines that consider local rainfall patterns, socio-economic conditions, and technical capacities. The study further supports the idea that cross-regional learning and the exchange of best practices can inform the creation of hybrid models that combine the strengths of top-down policy with bottom-up innovation. Such an integrated approach is essential for advancing sustainable water management and strengthening community-level water security in an era of increasing climatic uncertainty.

Limitation and Suggestion for Further Research

Despite offering valuable comparative insights, this study acknowledges several limitations that may affect the breadth and depth of its findings. The selection of only two case locations—Mojoagung in Indonesia and Jeju City in South Korea—limits the representativeness of the results, as these areas may not capture the full spectrum of environmental, socio-economic, and institutional variations present in both countries. Moreover, the study primarily utilized secondary data and literature-based analysis, which, while informative, restricts the ability to evaluate real-time performance metrics such as water yield efficiency, seasonal storage dynamics, and long-term system reliability. Additionally, the study did not explore behavioral, cultural, or gender-related factors that may significantly influence user adoption and maintenance practices at the household level. These aspects are crucial for understanding the social sustainability of RWH systems, particularly in community-driven contexts. Future research is therefore encouraged to employ mixed-methods approaches that combine quantitative field measurements with qualitative investigations, including stakeholder interviews and participatory assessments. Expanding the geographical scope to include rural, peri-urban, and coastal areas would further enrich the analysis and improve the applicability of recommendations. Longitudinal studies tracking system performance over multiple seasons could also provide deeper insights into resilience under variable climatic conditions. Ultimately, interdisciplinary collaboration and context-sensitive inquiry will be essential to refine and scale rainwater harvesting strategies tailored to diverse environmental and societal needs.

CONCLUSION

This study has demonstrated that household scale rainwater harvesting (RWH) systems, while conceptually similar, are implemented with distinct approaches in Indonesia and South Korea due to differences in environmental conditions, governance structures, and community capacities. In Jeju, RWH is systematically integrated into urban water management through policy incentives and infrastructure planning, primarily serving non-potable needs with high operational efficiency. Meanwhile, in Mojoagung, RWH serves multiple functions—including potable use and groundwater recharge driven largely by community initiative and local adaptation in the absence of formal institutional support. These contrasting models highlight the necessity of context-sensitive RWH strategies that align technical design with climatic patterns, resource availability, and social structures. The findings suggest that a hybrid framework combining policy-driven standardization with grassroots innovation may offer a scalable and resilient solution for enhancing domestic water security. As climate variability intensifies and urbanization accelerates, the role of decentralized water systems like RWH will become increasingly vital in both developed and developing contexts. Therefore, fostering supportive policies, community engagement, and cross-regional knowledge exchange is essential to ensure the long-term sustainability and adaptability of RWH systems across diverse socio-ecological landscapes.

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AUTHORS CONTIBUTIONS STATEMENT

Park Eun Ha was responsible for the conceptual framework, development of the research design, and analysis of the rainwater harvesting system in South Korea, including the integration of relevant policy and technical literature. Indah Marlina Ardianti contributed to the examination and interpretation of the Indonesian case study, led the comparative discussion, and coordinated the structure and refinement of the manuscript. Both authors were actively involved in writing, reviewing, and revising the manuscript to ensure academic rigor and coherence. All authors have read and approved the final version of the article and agree to be accountable for the accuracy and integrity of the work.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript. All contributions were conducted independently and without any financial, commercial, or institutional influence that could be perceived as a potential conflict. The research was carried out solely for academic and professional purposes.

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