INTERNATIONAL JOURNAL OF INTEGRATED ENGINEERING
ISSN: 2229-838X e-ISSN: 2600-7916

IJIE

Vol. 17 No. 7 (2025) 238-246
https://publisher.uthm.edu.my/ojs/index.php/ijie

Green Roofs as a Sustainable Building Practice: A Lab-Scale Evaluation Using Recycled Waste Materials for Stormwater Runoff Control

Noor Suraya Romali[1]*, Shifa' Mawaddah Kamarul Zamani[1], Dayang Arnieza Penni[1], Wan Syuaibah Wan Zaki[1], Sumiliana Sulong[2]

[1] *Faculty of Civil Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, 26300 Kuantan, Pahang, MALAYSIA*
[2] *Drainage and Irrigation Department, 50626, Kuala Lumpur, MALAYSIA*

*Corresponding Author: suraya@umpsa.edu.my
DOI: https://doi.org/10.30880/ijie.2025.17.07.023

Article Info

Received: 19 February 2025
Accepted: 29 August 2025
Available online: 31 December 2025

Keywords

Sustainable building, green roofs, recycled waste, stormwater control

Abstract

Sustainable building in Malaysia is gaining momentum as developers increasingly adopt eco-friendly practices to mitigate environmental impact and promote long-term sustainability in response to rapid urbanisation and climate challenges. Green roofs play a crucial role in the sustainable building movement by enhancing insulation, managing stormwater, and supporting biodiversity. Despite these benefits, green roofs remain rarely adopted in Malaysia. Thus, the objective of this study is to evaluate the performance of green roofs for stormwater control by testing two laboratory-scale models utilising: (i) commercial materials and (ii) recycled waste materials. The findings revealed that green roofs significantly reduced stormwater runoff compared to conventional roofs, with green roofs made from recycled materials achieving up to 72% peak flow reduction, exceeding the performance of those made from commercial materials, which achieved up to 54% reduction. Thus, green roofs can contribute to sustainable development by effectively managing stormwater. The incorporation of recycled materials enhances the performance of a green roof while also lowering construction costs, making sustainable practices more economically viable for developers and builders.

1. Introduction

Nowadays, urbanisation and the increase in population density have resulted in a severe environmental challenge, with the construction sector being one of the key drivers of resource depletion and excessive waste generation. This urban expansion, combined with the impacts of climate change, reduces green spaces, creates more impermeable surfaces, increases stormwater runoff, and heightens the risk of severe flooding, while also exacerbating the urban heat island (UHI) effects [1], [2]. The increasing environmental challenges require innovative approaches to achieve urban sustainability, a concept that aims to balance ecological, economic, and social priorities in the development of cities [3], [4]. Urban sustainability focuses on creating resilient urban environments that can adapt to climate change, conserve resources, and enhance the quality of life for residents. A critical component of this effort is sustainable building, which emphasises constructing and maintaining structures that minimise environmental impacts, optimise resource efficiency, and support long-term resilience. Nowadays, the urgency for sustainable building practices has intensified due to the growing environmental challenges posed by rapid urbanisation and climate change [5]-[7]. Sustainable building practices, including green

This is an open access article under the CC BY-NC-SA 4.0 license.

roofs, green walls, rain gardens, bioswales, and living facades, integrate nature-based solutions (NBS) to tackle pressing environmental challenges. Among these practices, green roofs have gained attention for their ability to address key urban issues. A green roof is a roofing system that supports the growth of vegetation on a building's rooftop. It typically consists of multiple layers, including a vegetation layer, a substrate (or soil layer), a filter layer, a drainage material, a root barrier, and a waterproofing layer [1], [3], [7]. Green roofs contribute to sustainable urban systems by mitigating urban flooding, reducing UHI effects, and promoting eco-friendly construction [1], [4], [8]-[10].

Stormwater management is a pressing concern in Malaysia, where urban areas dominated by impervious surfaces frequently experience flooding due to excessive runoff [11]. In addition to traditional stormwater systems, green roofs are a compelling alternative for mitigating environmental impacts. Green roof systems are effective tools for urban stormwater management, capable of retaining up to 87% annual precipitation, reducing runoff volume by an average of 50% to 82%, and decreasing peak flow by 50% to 93% [12], [13]. However, despite their potential benefits, the implementation of green roofs in Malaysia has been limited and underutilised due to high construction and maintenance costs, limited technical knowledge and skills, and a lack of owner interest [14]-[16]. Overcoming these barriers is crucial to enabling the broader adoption and contribution of these practices to sustainable building in the country.

Previous studies have demonstrated the effectiveness of green roofs in reducing stormwater runoff and peak flows in various contexts [7], [10]-[13]. However, most research has relied on commercially available materials, which may not be economically practical for widespread use in developing countries like Malaysia. There is limited exploration of alternative, cost-effective solutions such as recycled materials, which could make green roof systems more accessible and sustainable. In fact, exploring innovative materials is essential in advancing sustainable construction practices, with recycled waste materials emerging as a remarkable, eco-friendly option with significant untapped potential [6], [17]-[19]. Asman et al. [17] highlighted the suitability of rubber crumbs as a green roof drainage layer, emphasising their ability to retain water during rainfall, facilitate filtration, and ensure proper drainage and aeration for the substrate and roots. The incorporation of rubber crumbs into green roof layers has proven effective for stormwater management, reducing the volume of water directed to storm drains. Similarly, Romali et al. [18] and Santos et al. [19] investigated coconut and construction waste, respectively and demonstrated their potential to enhance the performance of commercial materials in controlling runoff. The use of recycled materials in modular layers holds significant potential for reducing costs, particularly in economical housing projects. Incorporating recycled materials offers a cost-effective solution while also promoting environmentally responsible waste management [20]. Addressing this gap can help identify practical and affordable methods for integrating green roofs into Malaysia's urban landscape.

This study aims to evaluate the performance of green roofs in controlling stormwater runoff, focusing on lab-scale experiments using both commercial and recycled materials. By analysing peak flow reduction and the integration of recycled waste materials, this study highlights the potential of green roofs to advance sustainable building practices in Malaysia, promoting environmental resilience and resource efficiency. The findings aim to assist policymakers, developers, and stakeholders with practical strategies for implementing green roofs, advancing the country's efforts toward achieving urban sustainability.

2. Materials and Methods

2.1 Experimental Set-up

The present study aims to evaluate the hydrological performance of green roofs through lab-scale experiments comparing two models using: (i) commercial materials and (ii) recycled waste materials. Three green roof models have been constructed for evaluation: two vegetated models that employed commercial materials and recycled waste materials, which are later referred to as the Commercial Green Roof (CGR) and the Recycled Waste Green Roof (RWGR), respectively, along with a non-vegetated conventional roof model serving as the control. The experiment was conducted in the Hydraulics and Hydrology Laboratory at Universiti Malaysia Pahang Al-Sultan Abdullah (UMPSA). Fig. 1 illustrates the setup of the green roof model. The system is equipped with a designed tank to store stormwater samples, which was connected to the 1m x 1m green roof models through a pipe network system. A rainfall simulator was constructed from a plastic container under the storage tank. The base of the simulator featured a grid of 2 mm diameter holes to generate rainfall. Flow rates were collected at the outlet of the green roof model using a flow-over-weir apparatus.

2.2 Materials and Components

The experiments were conducted using two green roof models: The Commercial Green Roof (CGR) and the Recycled Waste Green Roof (RWGR). The CGR was constructed using commercial materials, while the RWGR utilised recycled coconut waste as its primary material. The green roof models of CGR and RWGR consist of vegetation, substrate, filter, drainage, and waterproofing layers (from top to bottom) as shown in Fig. 2.

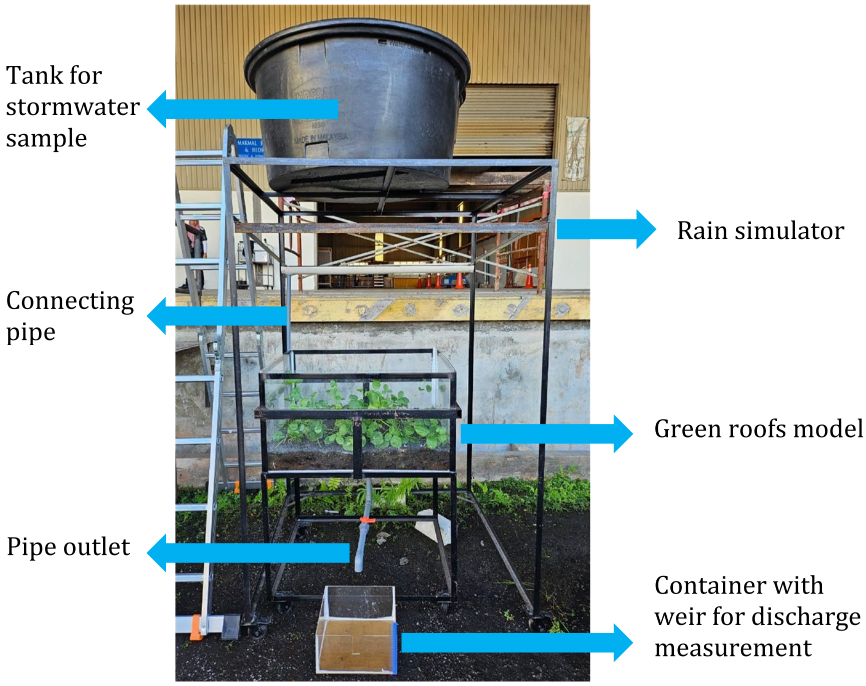

Fig. 1 *Experimental green roof set-up*

Fig. 2 *Arrangement of green roof layers: (a) Vegetation; (b) Substrate; (c) Filter; (d) Drainage; and (e) Waterproofing*

Table 1 *Green roof materials for each layer*

Green roof layers	Materials	
	CGR	RWGR
Vegetation	Beach Morning Glory	
Substrate	Topsoil	
Filter	Non-woven geotextile	Coconut fibre
Drainage	Drainage plate	Burnt-crushed coconut shell
Water-proofing	Bitumen layer	

Table 1 details the materials used in the various layers of both models. Both CGR and RWGR models were utilised with Beach Morning Glory (*Ipomoea pes-caprae*) as the vegetation. This perennial vine, typically found in coastal areas, creates a dense mat that effectively controls erosion and enhances water retention. This coastal vegetation was selected for this study due to its ability to withstand harsh environmental conditions, such as the Malaysia hot climate, and its proven effectiveness in reducing runoff, as suggested by Chen et al. [21]. Additionally, its extensive root system enhances its ability to retain moisture on green roofs [21]. From a cost-effectiveness perspective, Beach Morning Glory requires minimal maintenance, making it a suitable choice for sustainable building practices. Furthermore, the plants used in this study were freely obtained from Teluk Cempedak beach.

Both CGR and RWGR models were utilised with similar materials, including topsoil as the substrate and a bitumen layer for waterproofing. For the filter and drainage layers, CGR used non-woven geotextile as the filter layer and a drainage plate for the drainage layer. In contrast, RWGR utilised coconut fibre for the filter layer and burnt-crushed coconut shells for the drainage layer. The process of producing the burnt-crushed coconut shells was described earlier in Romali et al. [18].

2.3 Data Collection and Analysis

Observations on the performance of the green roof models were made during two simulated rainfall events: Event 1, corresponding to a 10-minute design storm, and Event 2, corresponding to a 20-minute design storm. The rainfall intensities applied in this study are shown in Table 2. The performance of the green roof models was evaluated based on their ability to reduce the flow hydrograph and achieve peak flow reduction. The flow rate was measured using a rectangular weir and calculated using Eq. (1), while the percentage of flow reduction was determined using Eq. (2):

$$Q = \frac{2}{3} b \sqrt{2g} H^{\frac{3}{2}} \tag{1}$$

where Q is the flow rate over the weir in m^3/s, b is the width of the weir crest, and H is the distance between the water surface and the crest.

$$\text{Peak flow reduction } (\%) = \frac{Q_p^{\text{Control}} - Q_p^{\text{Green Roof}}}{Q_p^{\text{Control}}} \times 100 \tag{2}$$

where Q_p represents the peak flow, and the term "green roof" refers to either the CGR or the RWGR model.

Table 2 *Simulated rainfall events for data collection*

Event	Rainfall intensities (mm/hr)
1	100
	200
	300
2	150
	250

3. Results and Discussion

3.1 Hydrological Performance of Green Roofs

Fig. 3(a) to Fig. 3(c) present the hydrographs obtained from the experimental observations during Event 1 for the control, CGR and RWGR models under rainfall intensities of 100 mm/hr, 200 mm/hr, and 300 mm/hr, respectively. The hydrographs clearly show that the peak discharge is highest for the control model, indicating no mitigation of runoff, followed by the CGR, and lowest for the RWGR. This trend is observed across all rainfall intensities, highlighting the effectiveness of both green roof models in mitigating runoff, with the RWGR demonstrating a better performance in reducing and delaying peak discharge compared to the CGR. The delayed peaks suggest both systems reduce and slow down runoff effectively. A similar trend is observed in the hydrographs for Event 2, as shown in Fig. 4(a) and Fig. 4(b). The vegetated models, CGR and RWGR, effectively reduce the peak discharge compared to the non-vegetated control model. The CGR and RWGR effectively reduce and delay the peak discharge, with the RWGR continuing to show better performance. This suggests that incorporating recycled waste materials can substantially improve the hydrological performance of green roofs, as demonstrated by the findings of Asman et al. [17], Romali et al. [18], and Santos et al. [19]. Recycled waste materials offer enhanced water retention and absorption properties, contributing to the overall hydrological performance of green roofs. The porous structure enables them to absorb and retain substantial amounts of water, similar to commercial materials such as perlite or vermiculite. This ability to hold moisture helps reduce runoff by slowing the release of water, improving the water retention capacity of the green roof [17].

The longer duration of rainfall in Event 2, which is 20 minutes, leads to lower and broader peaks, compared to the hydrographs in Fig. 3. The shorter storm duration of 10 minutes in Event 1 results in higher and sharper peak discharges for all models. This is because the intensity of rainfall is concentrated over a shorter time, leading to rapid runoff accumulation. For instance, at 250 mm/hr in Fig. 4(b), the control model shows a peak discharge of approximately 18×10^{-5} m^3/s, significantly lower than the 300 mm/hr case in Fig. 3(c) (39×10^{-5} m^3/s), despite the similar rainfall intensity. The time to peak is also shorter in Fig. 3 due to the rapid response of runoff to the concentrated rainfall. The peaks typically occur around 300–400 seconds, indicating a fast runoff process. In contrast, Fig. 4 shows longer times to peak, typically around 500–700 seconds, because the extended storm duration allows more water to infiltrate and be retained by the system, reducing the immediacy of runoff. This is particularly evident in the CGR and RWGR models, where delayed peaks are observed compared to the control model. The results align with the findings of Dong et al. [12] and Chen et al. [13], who demonstrated that incorporating green roofs significantly enhances water retention, delays runoff, and attenuates peak flow.

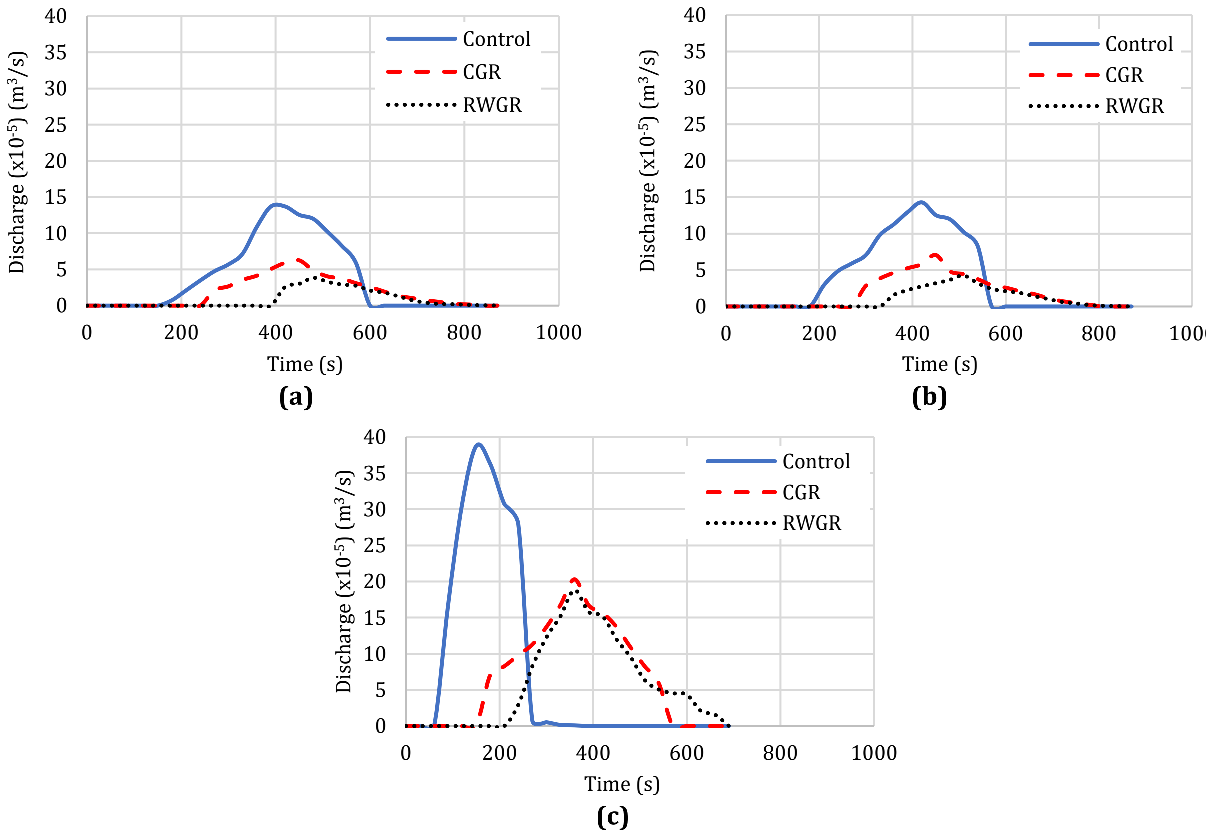

Fig. 3 *Hydrographs for control, CGR, and RWGR models during Event 1 at rainfall intensities of (a) 100 mm/hr, (b) 200 mm/hr; and (c) 300 mm/hr*

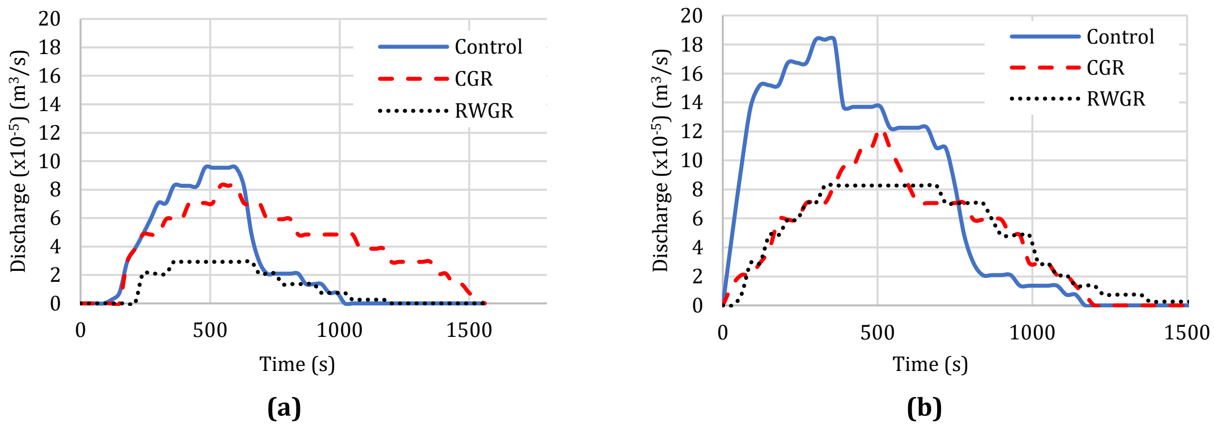

Fig. 4 *Hydrographs for control, CGR, and RWGR models during Event 2 at rainfall intensities of (a) 150 mm/hr; and (b) 250 mm/hr*

3.2 Peak Flow Reduction

Table 3 presents the performance of the green roof models, CGR and RWGR, in terms of peak flow reduction. Both systems effectively reduce stormwater runoff, with RWGR demonstrating better performance compared to CGR. In Event 1, RWGR achieves a peak flow reduction of up to 72%, while CGR's reduction ranges from 48% to 54%. Similarly, in Event 2, the performance of RWGR continues to exceed that of CGR, with reductions ranging from

55% to 69%, whereas CGR achieves a maximum reduction of only 33%. These results highlight the potential of using recycled waste materials in green roof systems, as green roofs incorporating recycled materials demonstrate significantly better performance in managing stormwater runoff [17]-[19]. The inclusion of recycled waste in the green roof substrate composition resulted in rainfall water retention and runoff control [19]. The higher percentages of peak flow reduction achieved by the RWGR compared to the CGR in the current study are consistent with the findings of Romali et al. [18], who reported similar results, with peak flow reductions reaching as high as 86% using coconut waste as green roof material, compared to 24–67% for the commercial green roofs.

Table 3 *Peak flow reduction*

Event	Rainfall intensities (mm/hr)	Peak flow reduction (%)	
		CGR	RWGR
1	100	54	72
	200	51	70
	300	48	51
2	150	13	69
	250	33	55

In Event 1, where the storm duration is shorter (10 minutes), both CGR and RWGR show significant peak flow reductions, with RWGR consistently exceeding CGR across all rainfall intensities. For a rainfall intensity of 100 mm/hr, CGR achieves a 54% reduction, while RWGR demonstrates a higher reduction of 72%. As rainfall intensity increases to 200 mm/hr and 300 mm/hr, the reduction percentages for both systems slightly decrease, reflecting the diminishing efficiency of green roof systems under higher rainfall intensities, as shown in Fig. 5. This finding aligns with the study by Ge & Zhang [22], which indicates a significant negative correlation between runoff reduction rates and rainfall volume. Similar observations have been reported in other studies, such as those by Fang [23], Krishnan & Ahmad [24], and Kok et al. [25], which found that rainwater retention rates decrease as rainfall intensity increases. For instance, Fang [23] noted that retention rates can reach as high as 100% during light rainfall but drop to 26-33% during heavy rainfall. However, the current study demonstrates that RWGR still performs better, with reductions of 51-70% compared to CGR's 48-54%. This highlights the capability of RWGR to manage runoff effectively, especially at lower intensities.

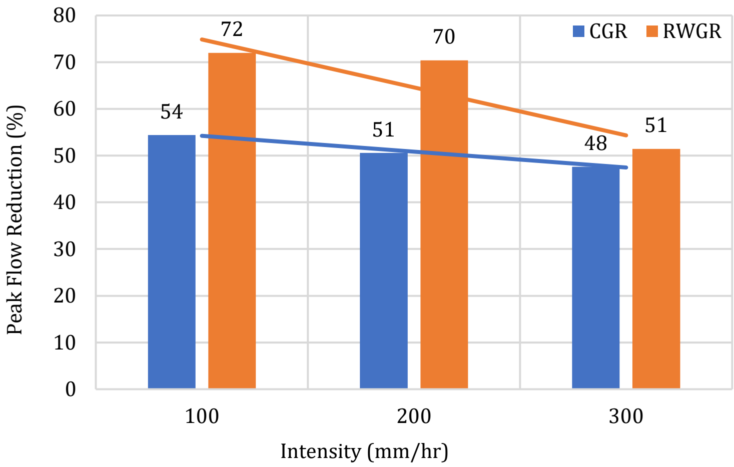

Fig. 5 *Peak flow reduction for event 1*

Similarly, in Event 2, with a longer storm duration (20 minutes), the peak flow reduction percentages decrease for both vegetated models compared to Event 1, especially for CGR, as illustrated in Table 3. At a rainfall intensity of 150 mm/hr, CGR achieves only a 13% reduction, while RWGR still manages a significant reduction of 69%. For the higher intensity of 250 mm/hr, the reduction percentages improve slightly for CGR (33%) and RWGR (55%), but they remain lower than the reductions observed in Event 1. The reduced effectiveness in Event 2 can be attributed to the extended storm duration, which likely leads to saturation of the green roof systems, reducing their ability to retain additional runoff.

Overall, the performance of RWGR is consistently better than that of CGR in terms of peak flow reduction across both Event 1 and Event 2. The enhanced performance of RWGR can be attributed to several factors, particularly the potential benefits of using recycled waste materials in its construction. These materials may contribute to increased water retention capacity and enhanced structural efficiency, enabling RWGR to manage and slow down runoff more effectively than CGR [19]. On the other hand, CGR, which relies primarily on vegetation to mitigate stormwater runoff, has limitations when it comes to handling large amounts of water, especially in intense or prolonged rainfall events. While vegetation in CGR can absorb and infiltrate water, it may not provide the same level of runoff control as RWGR, particularly in extreme storm conditions. In contrast, the use of recycled materials in RWGR is likely to enhance overall water retention, facilitating better runoff management and reduced peak discharge [17]-[19].

3.3 Implications for Sustainable Building and Stormwater Management

The findings of this study highlight the significant role of green roofs in managing urban stormwater, particularly as cities face increasing challenges from climate change. By reducing peak flow by up to 54%, green roofs make a significant contribution to sustainable building practices. The performance of green roofs improves when recycled waste materials are incorporated into green roof designs, resulting in up to a 72% reduction in peak flow. This approach not only enhances resource conservation and waste reduction but also promotes a more sustainable and efficient use of resources.

The findings on the reuse of coconut waste, particularly coconut shells, carry significant implications for sustainable building and stormwater management. Coconut shells, being biodegradable and naturally insulating, provide an eco-friendly material for green roofs. Recycled materials can capture and store more water during rainfall events, significantly reducing runoff and alleviating pressure on traditional stormwater systems. Moreover, recycled materials improve the structural integrity of green roofs, allowing them to better support vegetation and enhance overall system performance, resulting in greater reductions in peak flow. Furthermore, by incorporating coconut shells into green roof designs, Malaysia leverages a locally abundant and cost-effective resource [26], [27], aligning with sustainable building practices. This approach reduces reliance on non-renewable materials, minimises landfill waste, and lowers carbon emissions. Additionally, green roofs integrated with recycled coconut shells contribute to the potential of transforming agricultural waste into valuable resources, setting a precedent for innovative solutions in green building and environmental management.

The application of green roofs to construction industries, together with the utilisation of recycled materials, supports the Sustainable Development Goals (SDGs), particularly SDG 6 (Clean Water and Sanitation), SDG 11 (Sustainable Cities and Communities), and SDG 12 (Responsible Consumption and Production). RWGR contributes to improved water management by mitigating runoff and protecting water quality, while also promoting sustainable urban infrastructure and minimising environmental harm through waste reuse. This innovative approach enables cities to build eco-friendly, resilient urban environments, addressing immediate challenges while aligning with global sustainability objectives to ensure the well-being of both current and future generations.

4. Conclusion and Recommendations

In conclusion, the findings of this study demonstrate that green roofs are a promising alternative for sustainable stormwater management. The materials used in the five main layers of the green roof models are especially well-suited for recycled waste green roofs, which align with sustainable building practices. The conclusions highlighted are as follows:

- Overall, the stormwater runoff management can be significantly enhanced using green roofs, with the vegetated roof achieving a lower peak flow compared to conventional roofs (unvegetated roofs).
- The application of recycled waste materials in green roofs (RWGR) demonstrated a higher peak flow reduction compared to commercial materials (CGR) across both Event 1 and Event 2, with reductions ranging from 51% to 72% for RWGR, as compared to 48% to 54% for CGR in Event 1, and 55% to 69% for RWGR, versus 13% to 33% for CGR in Event 2.
- The peak flow reduction percentages for the green roof decreased with higher levels of rainfall intensity applied.

The incorporation of recycled material not only provides effective stormwater control but also supports environmental sustainability by reducing waste and minimizing the need for new resources. Therefore, the following recommendations are suggested for future studies:

- It is recommended to explore a wider variety of recycled waste materials with high potential for application and significant generation rates. Examples include agro-industrial waste such as rubber crumbs, empty fruit bunches (EFB), rice husks, and bagasse, as well as construction waste like bricks, glass, and cement waste.
- Sustainable building designs must consider varying storm conditions and intensities to ensure effective runoff management across diverse scenarios. Therefore, long-term studies are recommended to assess the durability, efficiency, and environmental impacts of the proposed applications under different conditions, including extreme weather events or high-intensity scenarios.

- Additionally, future research should include cost-benefit analyses to evaluate the economic feasibility of incorporating recycled materials, considering factors such as production costs, maintenance, and potential subsidies or incentives.

Acknowledgement

The authors are grateful to Universiti Malaysia Pahang Al-Sultan Abdullah for the financial support through UMPSA International Publication Grant RDU223312 and UMPSA Fundamental Research Grant RDU210323. The technical support from the laboratory staff of the Faculty of Civil Engineering Technology, UMPSA and the Drainage and Irrigation Department of Malaysia was equally acknowledged and appreciated.

Conflict of Interest

The authors declare that they have no conflict of interest regarding the publication of this paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***Study conception and design:*** *Noor Suraya Romali, Sumiliana Sulong;* ***Data collection:*** *Shifa' Mawaddah Kamarul Zamani, Dayang Arnieza Penni, Wan Syuaibah Wan Zaki;* ***Analysis and interpretation of results:*** *Noor Suraya Romali, Shifa' Mawaddah Kamarul Zamani, Dayang Arnieza Penni, Wan Syuaibah Wan Zaki;* ***Draft manuscript preparation:*** *Noor Suraya Romali. All authors reviewed the results and approved the final version of the manuscript.*

References

[1] Tang, Y. Y., Slimani, Y., Al-Ghazali M. A., Talukdar, G., & Maharjan, A. K. (2023). Sustainable urban development in Malaysia: enhancing green roofs with integrated technologies. Civil and Sustainable Urban Engineering, 3, 148-162.

[2] IPCC (2022). Climate Change 2022: Impacts, adaptation, and vulnerability. Contribution of working group II to the sixth assessment report of the intergovernmental panel on climate change. In Pörtner, H.-O., Roberts, D. C., Tignor, M., Poloczanska, E. S., Mintenbeck, K., … , Rama, B. (Eds.), Climate Change 2022 – Impacts, Adaptation and Vulnerability. Cambridge University Press. https://doi.org/10.1017/9781009325844

[3] Mihalakakou, G., Souliotis, M., Papadaki, M., Menounou, P., Dimopoulos, P., Kolokotsa, D., Paravantis, J. A., Tsangrassoulis, A., Panaras, G., Giannakopoulos, E., & Papaefthimiou, S. (2023). Green roofs as a nature-based solution for improving urban sustainability: Progress and perspectives. Renewable and Sustainable Energy Reviews, 180, 113306.

[4] Li, Y., Beeton, R.J.S., Zhao, X., Fan, Y., Yang, Q., Li, J., & Ding, L. (2024). Advancing urban sustainability transitions: A framework for understanding urban complexity and enhancing integrative transformations. Humanities and Social Sciences Communications. https://doi.org/10.1057/s41599-024-03598-x

[5] Masoumi-Hajiagha, A., Heravi, G., & Khosravi, H. (2024. Development of a framework for optimal selection of sustainable building envelope using BIM. Iranian Journal of Science and Technology, Transactions of Civil Engineering. https://doi.org/10.1007/s40996-024-01644-x

[6] Yadav, M., & Singhal, I. (2024). Sustainable construction: The use of cork material in the building industry. Materials for Renewable and Sustainable Energy. https://doi.org/10.1007/s40243-024-00270-x

[7] Liu, W., Feng, Q., Chen, W., & Wei, W. (2020). Assessing the runoff retention of extensive green roofs using runoff coefficients and curve numbers and the impacts of substrate moisture. Hydrology Research. https://doi.org/10.2166/nh.2020.167

[8] Wu, Q., Huang, Y., Irga, P., Kumar, P., Li, W., Wei, W., Shon, H. K., Lei, C., & Zhou, J. L. (2024). Synergistic control of urban heat island and urban pollution island effects using green infrastructure. Journal of Environmental Management. https://doi.org/10.1016/j.jenvman.2024.122985

[9] Romali N. S., Othman N. S., & Mhd Ramli N. N. (2021). The application of green roof for stormwater quantity and quality improvement. IOP Conference Series: Earth and Environmental Science, 682, 012029.

[10] Schultz, I., Sailor, D. J., & Starry, O. (2018). Effects of substrate depth and precipitation characteristics on stormwater retention by two green roofs in Portland OR. Journal of Hydrology: Regional Studies, 18, 110-118.

[11] Romali N. S., Suzany M. N., & Shahid K. A. (2023). Green roof for stormwater runoff control: A review. AIP Conference Proceedings, 2688, 040001.

[12] Dong, Z., Bain, D. J., Buck, J. K., & Ng, C. (2024). Assessment of the long-term hydrological performance of a green roof system in stormwater control. Journal of Environmental Management, 370, 122831.

[13] Chen, P. Y., Hong, X. F., & Lo, W. H. (2024). Evaluating the stormwater reduction of a green roof under different rainfall events and antecedent water contents with a modified hydrological model. Ecohydrology & Hydrobiology, 24, 112-127.

[14] Hamid, H. N. A., Romali, N. S., & Rahman, R. A. (2023). Key barriers and feasibility of implementing green roofs on buildings in Malaysia. Buildings, 13, 2233.

[15] Mustaffa, N. K., Mat Isa, C. M., & Che Ibrahim, C. K. I. (2021). Top-down bottom-up strategic green building development framework: Case studies in Malaysia. Building and Environment, 203, 108052.

[16] Zahir, M. H. M., Raman, S. N., Mohamed, M. F., Jamiland, M., & Nopiah, Z. M. (2014). The perception of Malaysian architects towards the implementation of green roofs: A review of practices, methodologies and future research. E3S Web of Conferences, 3, 01022.

[17] Asman, N. S. A., Dullah, S., Ayog, J. L., Mirasa, A. K., & Djamila, H. (2017). The hydrological performance of lightweight green roofs made from recycled waste materials as the drainage layer. MATEC Web of Conference, 103, 04011.

[18] Romali N. S., Ardzu F. A., & Suzany M. N. (2023). The potential of coconut waste as green roof materials to improve stormwater runoff. Water Science & Technology. https://doi.org/10.2166/wst.2023.060

[19] Santos, M. L., Silva, C. M., Ferreira, F., & Matos, J. S. (2023). Hydrological analysis of green roofs performance under a Mediterranean climate: A case study in Lisbon, Portugal. Sustainability, 15, 1064.

[20] Leite, F. R., & Antunes, M. L. P. (2023). Green roof recent designs to runoff control: A review of building materials and plant species used in studies. Ecological Engineering, 189, 106924.

[21] Chen, Y., Pei, L., & Shiau, Y. (2015). Application of coastal vegetation to green roofs of residential buildings in Taiwan. Artificial Life Robotics, 20, 86-91.

[22] Ge, D., & Zhang, S. H. (2018). Impacts of vegetation on hydrological performances of green roofs under different rainfall conditions. Huanjing Kexue/Environmental Science, 39, 5015-5023.

[23] Fang, C. F. (2010). Rainwater retention capacity of green roofs in subtropical monsoonal climatic regions: A case study of Taiwan. WIT Transactions on Ecology and the Environment, 138, 239-249.

[24] Krishnan, R., & Ahmad, H. (2014). Influence of low growing vegetation in reducing stormwater runoff on green roofs. International Journal of High Rise Buildings, 3, 1-6.

[25] Kok, K. H., Mohd Sidek, L., Chow, M. F., Zainal Abidin, M. R., Basri, H. & Hayder, G. (2015). Evaluation of green roof performances for urban stormwater quantity and quality controls. International Journal of River Basin Management, 14, 1-7.

[26] Rosli, T. M., & Jumali, S. S. (2022). Mycoremediation of coconut shell (cocos nucifera) with ganoderma lucidum. IOP Conference Series of Earth Environmental Science, 1059, 012025.

[27] Sulaiman, S., Abdul Raman, A. A., & Aroua, M. K. (2010). Coconut waste as a source for biodiesel production. (2010). Proceeding of the 2nd International Conference on Chemical, Biological and Environmental Engineering, Cairo, Egypt.