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Revisiting Rainwater Harvesting: A Systematic Review of Management Practices in Malaysia Using PRISMA

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ABSTRACT

This study revisits the development and application of rainwater harvesting (RWH) systems in Malaysia and highlights their role in integrated and sustainable urban water resource management. A systematic literature review based on PRISMA guidelines analyzes research on RWH, storm-water management, and green technologies in Asia, especially Malaysia. The results show that RWH has evolved from a traditional practice to a modern multifunctional solution for water conservation, flood protection, and climate change adaptation. Considering the Malaysian conditions, the unique RWH system is an important tool for reducing flash floods, improving groundwater recharge, and reducing storm-water pollution. The study recommends using green infrastructure, such as rain gardens, as a complementary solution to improve water retention and quality. This highlights the need for local, cost-effective technical and regulatory frameworks to facilitate the widespread adoption of RWH. This study also encourages the integration of RWH into national policies to achieve sustainable water management in line with the Sustainable Development Goals. The novelty of this study lies in its systematic review approach, focusing on the evolution of water resource management strategies in Malaysia and the need for integrated planning and policy support to take full advantage of the potential of the RWH system to address water and environmental issues in Malaysia.

Introduction

Rapid urbanization, population growth, and the effects of climate change are increasing concerns about global water scarcity. As highlighted by Vörösmarty et al. [1], as a result of these factors, the world's water resources are becoming more and more vulnerable, affecting both developed and developing countries. Malaysia, in particular, faces unique challenges, including erratic rainfall patterns, flash floods, and increased water demand, as highlighted by Kabiri et al. [2]. These challenges require innovative and sustainable solutions to ensure water security. Rainwater Harvesting (RWH) has emerged as a solution to deliver a decentralized, eco-friendly and sustainable approach to urban water management. Worldwide, RWH is increasingly being employed as an alternative water source to address water shortages, improve water quality, and manage storm-water [3,4]. As noted by Ercin and Hoekstra [5], the implementation of RWH systems can reduce the pressure on existing water resources, especially in areas prone to drought and water scarcity.

In Malaysia, RWH has emerged as a good strategy to address this problem by reducing dependence on conventional water supply, reducing flash floods, and promoting water conservation [6]. However, despite the potential, implementation of RWH in Malaysia has been relatively slow due to large gaps in policy, infrastructure, and public awareness [7]. Although progress has been made since the first guidelines for using RWH in Malaysia in 1999, its use remains limited [8].

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Regardless of the fact that several studies have examined the environmental and technical benefits of RWH systems [9,10], comprehensive studies on the progress of RWH implementation are still lacking, especially in the Malaysian context. This study is intended to fill this gap by systematically examining the development and implementation of RWH in Malaysia since the introduction of RWH guidelines. In addition, it aims to critically assess barriers to widespread adoption and explore the potential of RWH to become a key component of sustainable urban water management strategies in Malaysia.

This study utilized a systematic literature review to identify and analyze relevant studies published by academics from Malaysia and other Asian institutions using the PRISMA protocol [11,12]. Documents obtained from Scopus, Web of Science, and Google Scholar [13] were used with search terms including "rainwater harvesting," "storm-water management," "green technologies," and "climate change." This review provides valuable insight into the current state of RWH in Malaysia, identifies gaps in current knowledge, and suggests ways to improve RWH implementation in the future.

Materials and Methods

The Selection

This systematic review was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). By following Sharif et al. [11], Liberati et al. [14], and Petticrew and Roberts [15] approaches, this study "clarifies and refines" the list of items reported by PRISMA, followed by a systematic review of social sciences. The review program was formulated based on the purpose of the review. The basic literature search includes information on search offers, search terms, and databases [16,17]. The search was performed on June 13th, 2022, without date restrictions.

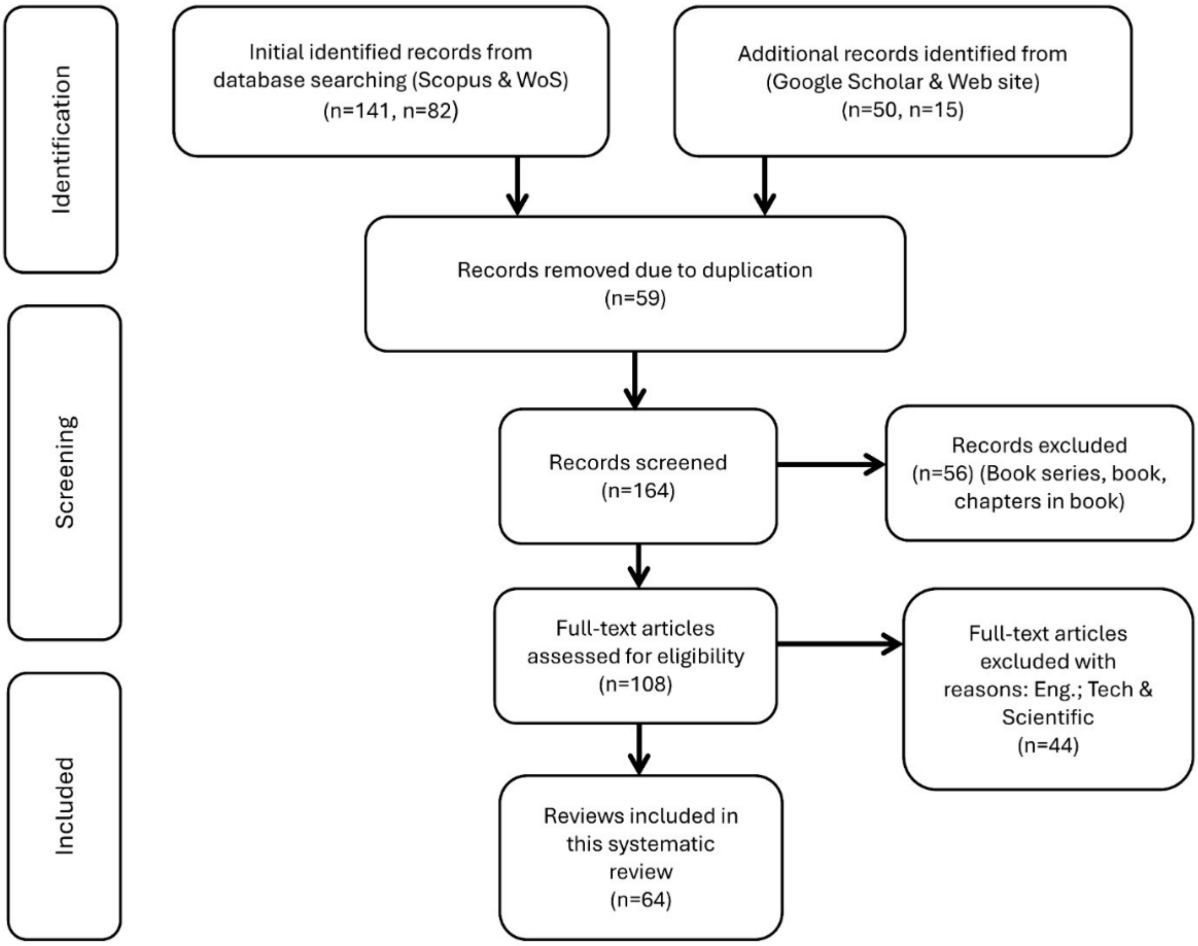

Figure 1. Systematic review process flow following PRISMA guidelines, involving comprehensive literature search, screening, and eligibility assessment to select 64 relevant records.

Selected titles, abstracts, keywords, authors, journal names, and publication years were exported to an MS Excel spreadsheet for sorting. The researcher used two additional reviewers to assist him in selecting the most appropriate papers through the screening and eligibility process. All reviewers read each article individually to select the appropriate paper that should be included; any disagreements about this matter were classified, negotiated, and discussed until an agreement was reached. An initial Scopus and WoS search yielded 141 records and 82 records, respectively, Google Scholar yielded 50 records, and another web-site with 15 records (based on searches for 'Rainwater' and 'Harvesting' or 'Management' and 'Asia'), but if the record was book series, book and chapters in the book, they were excluded in the screening. The remaining 108 records were assessed in more detail based on the full text, where the eligibility, such as purely engineering perspective, technologies point of view, or highly scientifically focused, must be excluded. Of these, only 64 records met the review eligibility criteria. The selection process is given in Figure 1.

The Information Collection Process and Syntheses of Results

The reviewers then read the full selected articles and performed content analysis. In this process, reviewers carefully consider all articles concerning information about researching topics/areas of focus, methods, and authors. This information was then submitted to an Ms. Excel sheet [17,18]. All disputes were settled by negotiation and discussion among the reviewers until a consensus was reached. The main results of the review are presented (subject to articles related to this paper).

Results and Discussion

Results

The results of this systematic literature review (SLR) are reflected in three tables. Table 1 shows the 34 articles selected from the original 64 articles. This serves as a basis for identifying key themes in rainwater harvesting (RWH) research. Table 2 summarizes 10 emerging themes highlighting the role of RWH in sustainable water management. Key themes include "Water Supplies," focusing on the RWH’s potential to clean water to address water shortages, and "Flooding Control," concentrating on reducing flood risk through storm surge control. Other themes, such as “Sediment and Pollution” and “Storm-water Runoff Mitigation”, focus on RWH's ability to improve water quality and reduce stress on waterways or drainage.

At the same time, themes such as "Sustainable Development" and "Green Infrastructure and Technology" acknowledge the broader environmental benefits of RWH systems, especially sustainable urban growth, and climate resilience, whereas “Policy, Legal, Social and Economic” theme recognizes the need to create a legal framework and incentives to improve adoption of RWH. This theme highlights the importance of public policy and community involvement in promoting more sustainable water management practices. Finally, Table 3 shows the relationships between these emerging themes and the topics discussed in the next section of this paper. The following paragraphs describe the results, drawing on the data from Tables 1 and 2 to provide a coherent narrative of the findings.

Table 1 shows the 34 articles selected from an initial pool of 64 articles based on the proposed search criteria. These articles form the basis for identifying key themes in RWH research. The selection process included studies from various databases, including Scopus, Web of Science, and Google Scholar, focusing on various aspects related to RWH, such as water supply, storm-water runoff, and sustainable development. The selected studies highlight the growing global interest in RWH systems, especially as urbanization and climate change exacerbate water scarcity and flooding risk.

Table 1. Review findings based on the proposed search criteria.

No.	Author(s)	Year	Title	Database	References
1.	Malek	2007	Pelan Penjimatan Air kebangsaan: Tanggungjawab Kerajaan	Web site	[44]
2.	Al-Batsh et al.	2019	Assessment of Rainwater Harvesting Systems in Poor Rural Communities: A Case Study from Yatta Area, Palestine	Scopus	[4]
3.	Buntat et al.	2015	Development of an Integrated System for Ozone Treated Harvested Rainwater in Perspective of Green Building Scenario of Malaysia	Scopus	[33]
4.	Che-Ani et al.	2009	Rainwater Harvesting as an Alternative Water Supply in the Future	Scopus	[3]

No.	Author(s)	Year	Title	Database	References
5.	Crouch et al.	2021	Defining Domestic Water Consumption Based on Personal Water Use Activities. *Aqua-Water Infrastructure*	WoS	[20]
6.	Du and Li	2019	Towards a Green World: How do Green Technology Innovations Affect Total-Factor Carbon Productivity	WoS	[24]
7.	Ercin and Hoekstra	2014	Water Footprint Scenarios for 2050: A Global Analysis	Web site	[5]
8.	Fletcher et al.	2008	Reuse of Urban Runoff in Australia: A Review of Recent	Scopus	[21]
9.	Hajani and Rahman	2014	Reliability and Cost Analysis of a Rainwater Harvesting System in Peri-Urban Regions of Greater Sydney, Australia	Scopus	[31]
10.	Kyahan et al.	2019	Rainwater as a Source of Drinking Water: Health Impacts and Rainwater Treatment	Scopus	[19]
11.	Johor et al.	2017	Filtration of Rainwater Harvesting System in Rural Area	Scopus	[29]
12.	Jimenez et al.	2020	Unpacking Water Governance: A Framework for Practitioners	Scopus	[25]
13.	Kabiri et al.	2015	Assessment of Hydrologic Impacts of Climate Change on The Runoff Trend in Klang Watershed, Malaysia	Scopus	[2]
14.	Kim et al.	2005	Application of A Metal Membrance for Rainwater Utilization: Filtration Characteristics and Membrance Fouling	Scopus	[30]
15.	Kuok and Chiu	2020	Optimal Rainwater Harvesting Tank Sizing for Different Types of Residential Houses: Pilot Study in Kuching, Sarawak	WoS	[9]
16.	Lee et al.	2016	Rainwater Harvesting as an Alternative Water Resource in Malaysia: Potential, Policies and Development	Scopus	[6]
17.	Leong et al.	2017	Longitudinal of Rainwater Quality Under Tropical Climatic Conditions in Enabling Effective Rainwater Harvesting and Reuse Schemes	Scopus	[34]
18.	Rashid et al.	2022	A Comparison of Environmental Impacts between Rainwater Harvesting and Rain Garden Scenarios	Scopus	[26]
19.	Amin et al.	2019	Impacts of Climate Change on the Hydrolic-Climate of Peninsular Malaysia	Scopus	[42]
20.	Lani et al.	2018	A Review of Rainwater Harvesting in Malaysia: Prospects and Challenges	Scopus	[7]
21.	Mohamad	2020	Research on Rainwater Harvesting for Drinking Water	Google Scholar	[56]
22.	Shaari	2020	An Overview of Rainwater Harvesting for Sustainable Future in Malaysia	Google Scholar	[22]
23.	Mohammad et al.	2014	The Awareness Among Developers on Rainwater Harvesting System	Google Scholar	[57]
24.	Muhammad et al.	2020	Characteristics of Rainfall in Peninsular Malaysia	Scopus	[32]
25.	Munna et al.	2020	Rainwater Harvesting Potentialities to Reduce Over Extraction of Groundwater in Sylhet	Google Scholar	[47]
26.	Nikmatin et al.	2017	Physical, Thermal, and Mechanical Properties of Polypropylene Composities Filled with Rattan Nanoparticles	Scopus	[28]
27.	Nizam et al.	2021	Water Quality of Rooftop Rainwater Harvesting System (MyRAWAS)	Google Scholar	[10]
28.	Palla et al.	2017	The Impact of Domestics Rainwater Harvesting Systems in Storm Water Runoff Mitigation at the Urban Block Scale	Scopus	[38]
29.	Tayouga and Gagne	2016	The Socio-Ecological Factors that Influence the Adoption of Green Infrastructure	WoS, Scopus	[23]
30.	Vörösmarthy et al.	2000	Globalwater Resources: Vulnerability from Climate Change and Population Growth	Google Scholar	[1]
31.	Wang et al.	2019	Green Technology Innovation Development in China in 1990-2015	Scopus	[36]
32.	Ying et al.	2022	Green Infrastructure: Systematic Literature Review	Google Scolar	[27]
33.	Zaid et al.	2022	Green Roof Maintenance for Non-residential Buildings in Tropical Climate: Case Study of Kuala Lumpur	Scopus	[35]
34.	Zakaria	2019	Transforming the Water Sector: Working in an Integrated Manner	Google Scholar	[8]

Table 2 presents 10 emerging themes derived from the reviewed literature. These themes capture the diverse ways RWH systems contribute to sustainable water management, urban resilience, and climate adaptation. Each theme in Table 2 is described, outlining its significance and the articles supporting it, as listed below.

Table 2. The 10 emerging themes.

No.	Emerging themes	Description	References
1.	Water supplies	Rainwater harvesting (RHW) provides a reliable source of supplemental water to reduce dependence on reclaimed water systems and provide a sustainable water supply for urban and residential properties, especially in water-stressed areas	[3], [4], [9], [19], [20], [44], [56]
2.	Flooding control	RWH systems reduce the impact of urban flooding by reducing the risk of flooding by collecting excess storm-water, reducing peak flows, and preventing sewer system overload	[5], [7], [21], [22], [47]
3.	Sediment and pollution	The use of rain gardens and other RWH technologies can improve water quality and reduce environmental pollution by removing pollutants such as sediment, nutrients and pathogens from storm-water runoff	[1], [2], [23], [27], [57]
4.	Storm water runoff mitigation	RWH and low-impact development strategies such as permeable pavement, and green roofs effectively manage storm-water runoff by reducing and slowing flow into drainage systems	[2], [24], [25], [26], [38], [47]
5.	Sustainable development	RWH supports sustainable urban development by implementing green infrastructure practices that conserve water, reduce environmental impact, and balance environmental, social and economic needs	[8], [23], [27], [28]
6.	Hydrological cycle	RWH systems restore the natural hydrological cycle by capturing rainwater and gradually seeping into the soil, replenishing groundwater levels and mitigating changes in water flow patterns caused by urbanization	[2], [22], [29], [30], [31]
7.	Climate change	As heavy rainfall is expected to increase due to climate change, RWH provides proactive solutions to manage excess water reduce flood risk and mitigate the effects of drought through decentralized water management	[32], [33], [34], [42]
8.	Green infrastructure and technology	Green infrastructure, including RWH systems, contributes to sustainable urban planning by promoting effective storm-water management, enhancing ecosystem services, improving water quality, reducing flood risk, and promoting environmental cooling	[23], [27], [35], [36]
9.	Mitigating water loss through evaporation	Compared to large reservoirs, small RWH systems that collect and store rainwater on site are a more efficient solution for local water management by reducing water loss through evaporation	[7], [10], [22]
10.	Policy, legal, social and economic	Mandatory implementation of RWH systems will require legal reforms and public incentives to encourage the adoption of efficient rainwater harvesting and promote sustainable water management practices	[6], [7], [31]

Water Supplies

RWH systems are increasingly recognized as a reliable source of supplemental water, particularly in water-stressed areas. RWH contributes to sustainable water supply management in urban and residential settings by reducing reliance on conventional water sources. Studies such as those by Al-Batsh et al. [4], Kyahan et al. [19], and Crouch et al. [20] emphasize RWH's potential to mitigate water shortages by capturing and storing rainwater, which can be used for non-potable applications or, with treatment, for potable use. This emerging theme underscores the importance of RWH in ensuring water security, particularly in arid and semi-arid regions.

Flooding Control

One of the key benefits of RWH systems is their ability to alleviate urban flooding by capturing excess storm-water. By reducing peak flows and preventing sewer system overload, RWH systems help mitigate the risk of flooding during heavy rainfall events. This is particularly crucial in rapidly urbanizing areas where impermeable surfaces exacerbate flooding. Studies, including those by Lani et al. [7], Fletcher et al. [21], and Shaari [22], highlight the effectiveness of RWH in controlling storm-water and reducing urban flooding risks.

Sediment and Pollution Control

RWH technologies, such as rain gardens and filtration systems, significantly improve water quality by removing pollutants, including sediment, nutrients, and pathogens from stormwater runoff. As highlighted by Vörösmarty et al. [1], Kabiri et al. [2], and Tayouga and Gagne [23], RWH can act as a pre-treatment system, filtering contaminants before they enter natural water bodies, thereby enhancing the quality of water in urban environments. This theme is critical for urban areas where water pollution from runoff is a significant environmental concern.

Storm-water Runoff Mitigation

RWH systems, particularly when integrated with green infrastructure solutions such as permeable pavements and green roofs, are effective in mitigating storm-water runoff. These systems help slow down the flow of storm-water, reduce the burden on drainage systems, and promote groundwater recharge. Du and Li [24], Jimenez et al. [25], and Rashid et al. [26] supports the idea that RWH, as part of a broader green infrastructure strategy, can significantly reduce the environmental impact of urban runoff.

Sustainable Development

The integration of RWH systems aligns with the principles of sustainable development by conserving water resources, reducing environmental impacts, and supporting climate resilience. Tayouga and Gagne [23], Ying et al. [27], and Nikmatin et al. [28] emphasize how RWH systems contribute to green urban development by promoting sustainable water management practices that balance environmental, social, and economic needs.

Hydrological Cycle Restoration

RWH systems help restore the natural hydrological cycle by capturing rainwater and allowing it to infiltrate the soil, thus replenishing groundwater levels. This is particularly important in urban areas, where changes to the natural water cycle caused by urbanization can lead to altered water flow patterns and reduced groundwater recharge. Johor et al. [29], Kim et al. [30], and Hajani and Rahman [31] show that RWH can mitigate these negative effects by promoting more natural water management processes.

Climate Change Adaptation

As climate change increases the frequency and intensity of both flooding and drought events, RWH offers a proactive solution for managing these risks. RWH systems help manage excess rainfall during storms and provide an alternative water source during droughts. Muhammad et al. [32], Buntat et al. [33], and Leong et al. [34] underscore the potential of RWH to enhance resilience to climate change by providing decentralized water management solutions.

Green Infrastructure and Technology

Integrating RWH systems into urban planning is an essential component of green infrastructure. These systems help manage water resources efficiently and contribute to environmental cooling, biodiversity, and the overall aesthetic and functional quality of urban spaces. According to Tayouga and Gagne [23], Zaid et al. [35], and Wang et al. [36], RWH systems are an integral part of green infrastructure solutions that support sustainable urban planning and help mitigate the environmental impacts of urbanization.

Mitigating Water Loss through Evaporation

Compared to large-scale water storage systems such as reservoirs, small-scale RWH systems are more efficient in reducing water loss through evaporation. By collecting and storing rainwater on-site, these systems minimize water loss and ensure that more water remains available for use. Lani et al. [7], Nizam et al. [10], and Shaari [22] highlights the efficiency of small-scale RWH systems in local water management, particularly in areas with high evaporation rates.

Policy, Legal, Social, and Economic Consideration

Successfully implementing RWH systems requires supportive policies, legal frameworks, and incentives that encourage adoption and integration into urban water management strategies. As noted in studies by Lee et al. [6], Lani et al. [7], and Hajani and Rahman [31], effective regulation and public policies, including financial incentives and public education, are crucial for the widespread adoption of RWH systems. This theme highlights the importance of addressing social, economic, and legal factors to promote sustainable water management practices.

Discussion

Table 3 shows the relationship between the discussion topics and emerging themes identified in the rainwater harvesting (RWH) literature. Each topic covers critical aspects of flood protection, water supply and sustainability related to the role of RWH in environmental management. This section examines how the themes contribute to the integration of RWH systems into urban planning, climate adaptation and water conservation strategies.

Table 3. Connection of emerging themes with discussion topic.

No.	Discussion topic	Related themes	Justification
1.	Rainwater management	Flooding control Storm water runoff mitigation Hydrological cycle Climate change	Rainwater management focuses on flood control and storm-water management solutions. It also addresses impacts on the hydrological cycle and adapt to climate change by promoting sustainable water management practices
2.	Re-position the altered hydrologic characteristics	Flooding control Hydrological cycle	This topic is about how urban development changes water flow and hydrology. RWH can help manage these impacts by reducing runoff and improving hydrological cycle management, especially in flood-prone areas
3.	Coping with climate change	Climate change Flooding control Water supplies	RWH can help cope with the growing risks of floods and droughts associated with climate change, providing alternative sources of water during extreme weather events and reducing pressure on existing infrastructure
4.	Translating the green infrastructure and technology	Sustainable development Green infrastructure and technology Flooding control	This topic discusses the integration of green infrastructure such as RWH systems to create a sustainable urban environment. It supports sustainable development by saving water and helps reduce flooding by promoting infiltration and water storage
5.	Rainwater utilisation	Water supplies Sustainable development	RWH provides an alternative source of water to replenish drinking water supplies, especially in water-stressed areas. Support sustainable water management and reduce dependence on central water supplies
6.	Supplement to the supply of treated water	Water supplies Sustainable development	RWH systems provide an additional source of water, reducing dependence on reclaimed water, maintaining water supply sustainability and helping to improve water system resilience
7.	Tool for solving environmental problems	Flooding control Sediment and pollution Storm water runoff mitigation	RWH addresses environmental issues by reducing storm-water runoff, preventing flooding, filtering pollutants before they reach waterways, improving water quality and reducing environmental damage
8.	Approach to sediment and pollutant trap	Sediment and pollution Storm water runoff mitigation	RWH, especially through rain gardens and infiltration systems, can serve as a tool to capture sediment and pollutants, improve water quality, and reduce the harmful effects of runoff
9.	Rainwater utilisation and management: Research needed	Water supplies Storm water runoff mitigation	Research is important to improve the efficiency of RWH systems and improve water supply and storm-water management. Researching the right systems for local region can help improving water conservation strategies
10.	The needs of regulation and policy	Policy, legal, social and economic Sustainable development	Effective regulations and policies, including incentives for RWH systems, are needed to promote sustainable water management, including legal, social and economic aspects, and to ensure widespread adoption and integration of RWH

Rainwater Management

Rainwater management focuses on providing appropriate storm-water solutions. A variety of new technologies enable rainwater management to deliver solutions to various needs. A good rainwater management system can be a cost-effective solution for current and future water conservation and management challenges [37]. However, there has been a shift from the traditional view of "storm-water management' to an integrated and holistic view that encompasses the term' rainwater management.' Storm-water suggests that there is a problem, but rainwater suggests a resource. Traditional storm-water management is reactive in nature. It is applicable only to the consequences of rare and extreme events. Rainwater management actively manages all rainfall events that occur throughout the year. Rainwater management integrates drainage infrastructure planning with related planning processes to address the impact of rainwater on community values [5,38,39].

During the rainwater management planning process, a design approach naturally aligns rainwater management with the value and benefits to the community. The desired outcome is to improve the natural and built environments in urban areas. This means integrating rainwater management goals with land development processes and tools to determine how to reduce the cumulative effects of landscape change and generate cumulative benefits for watersheds [35,40]. Generally, rainwater management aims to solve existing problems and protect environmental resources, as both are associated with previous or proposed land-use changes. Rainwater management will serve as a tool for repositioning altered hydrological characteristics, coping with climate change, and translating green infrastructure and technology.

Re-position The Altered Hydrologic Characteristics

Urban development can fundamentally modify the quantity and pattern of water flow and local hydrology. Paved roads and buildings quickly carry water and pollutants into waterways, and pollutants from commercial, industrial, and residential activities can easily enter rivers, lakes, or oceans. Sustainable urban development must include a balanced plan that considers environmental safety and economic efficiency. Sustainable development must also strive to achieve water balance throughout the hydrological cycle [2,22].

Waterproof surfaces, such as roads, highways, residential areas, and parking lots, prevent rainwater from entering the soil naturally and in a timely manner. Runoff that remains on the surface, called storm-water, ends up in streams and rivers and is released into bodies of water, such as lakes and oceans. When storm-water passes through the soil, it not only causes erosion, but untreated pollutants, such as sediment, nutrients, and pesticides, can migrate and accumulate in water bodies, creating pollution problems [1,39]. Precipitation in urban areas inevitably leads to storm-water runoff in watersheds. Implementing an RWH system that can cover a large area is a way to reduce storm-water runoff and related problems [7,22]. Rainwater harvesting and management can be used as a tool to restore altered hydrological properties to their original state or to mitigate the impact associated with it.

Coping with Climate Change

The impact of climate change on people's livelihoods, and how these changes will ultimately affect our determination to manage water resources, are key questions. In the next 40 years, Kelantan, Terengganu, and Pahang are expected to experience a 10% increase in average annual rainfall, whereas Selangor and Johor are expected to experience a 5% decrease, according to the Malaysian Hydro-climate Forecast Study [2,32,41]. There is a consistent relationship between changes in monthly maximum and minimum rainfall and changes in flux or river flow. Flood flow changes varied from +11% to +43%, and low flow changes range from –31% to –93%. This means more floods and droughts will occur in the future [32,42].

With higher extreme rainfall in the future, how should excess water be dealt with during heavy rain? RWH can be used to combat this extreme climate change and prevent its decline. For example, South Korea's Star-City's "No Regret Approach" to RWH systems is a great climate change adaptation strategy. With the existing central water infrastructure vulnerable to climate change and urbanization, the system shows that adding a decentralized storm-water management system can make the existing centralized water system safer and more sustainable [43,44]. The multipurpose rainwater management concept implemented by Star-City is beneficial for effective flood mitigation and drought management. Notably, using the same facilities to manage floods and droughts is more efficient. The multi-purpose rainwater management concept works well, as shown in the star-city case [22,40,45].

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Additionally, low-impact development strategies, such as permeable pavements, detention and retention tanks or reservoirs, green roofs, and rain gardens, can reduce flooding without requiring costly upgrades to the existing drainage infrastructure. This concept is a "no regrets" way to prepare for possible flooding. Even if climate change does not bring as much rain as expected, detention and retention reservoirs, rain gardens, green roofs, and permeable pavements will make our environment and urban watersheds greener and friendlier while improving the health of the population and providing storage facilities for a conjunctive water supply.

Translating The Green Infrastructure and Technology

Green infrastructure is defined as any type of infrastructure designed to ease the burden of environmental development or provide ecosystem services such as runoff management, environmental cooling management, carbon sequestration, and habitat provision. Green infrastructure can effectively coordinate environmental, social, and economic development and has been one of the key strategies for achieving sustainable development [23,27]. Adequate green infrastructure (GI) is a way to adapt to the impacts of climate change related to floods, biodiversity, urban cooling, renewable energy, noise, and light pollution. The main benefits of green infrastructure related to hydrology are rainfall interception, increased soil infiltration, water absorption, water storage, and slowing and reducing peak flows, all of which increase the amount of water that must be managed.

Meanwhile, the term ‘green technology’ includes evolving methods and materials, from power generation technologies to non-toxic cleaners and many other strategies [24,35,36]. Green technology topics include energy, green buildings, green procurement, green chemistry, and green nanotechnology. With or without other water sources, RWH is a technical approach to green infrastructure technologies that has important implications for the sustainable development of future cities. RWH has become an important part of the Green Building Index (GBI) for water efficiency. It has great potential to reduce the amount of storm-water that needs to be managed at all levels [46].

Rainwater Utilisation

RWH is essentially an ancient technology used to collect or capture rainwater before it reaches the ground and store it to irrigate human settlements and, more recently, urban buildings. Rainwater has long been gathered and used in Malaysia, especially in villages. In 2003, the National Hydraulic Research Institute of Malaysia (NAHRIM) carried out a study at Taman Wangsa Melawati in Kuala Lumpur, and the results showed that household use of rainwater for non-potable purposes accounts for 34% of the total monthly household water use [7,40]. Rainwater is a reliable and locally managed water resource that can be implemented quickly and modularly. Unlike large dams that collect and store water over considerable areas, small RWH projects can collect rainwater in situ and store it in various ways, thereby reducing water loss through evaporation. The advantage of RWH is that it acts as a supplement to the supply of treated water [3,9,19], a tool for solving environmental problems [2,22,33], and an approach to sediment and pollutant traps [2,42,47].

Supplement to The Supply of Treated Water

In some countries, rainwater reservoirs are the main source of water-supply infrastructure. RWH has become one of the options available to address water scarcity in developing countries such as India, Sri Lanka, Kenya, and Tanzania, where millions of people depend on rainwater for their domestic water needs, and rain is not a regular phenomenon that occurs throughout the year [4,48]. Perhaps the most classic example of RWH can be found in the Sumida district in east-central Tokyo, Japan. Sumida City Hall began implementing the innovative Sky-Water project in 1982, and the success of the project influenced City Hall to be at the forefront of promoting the Sky-Water project, not only in Japan, but in other parts of Asia [49,50].

Tokyo’s annual average rainfall as a water resource is 25 billion cubic meters, while the annual city water consumption is 2 billion cubic meters [49]. If Tokyo were used this rainwater, it would achieve much greater water independence. Based on the report, Tokyo relies entirely on a large, centralized water supply pipeline known as life-line, which is very vulnerable in the face of a large-scale natural disaster, and a shift from this life-line to decentralized life-points is needed and should be encouraged. Harvested rainwater can be used as an alternative source of water for community facilities. Alternative water is a sustainable source of water that is not available from freshwater or groundwater and compensates for freshwater needs. A RWH system collects, diverts, and stores rainwater from rooftops for subsequent use. Common uses of rainwater include irrigation for landscaping, washing, filling decorative ponds and fountains, and being accountable for water in cooling towers, toilets, and urinals. Rainwater collected through additional filtration and disinfection can be invoked as a drinking water standard to supplement municipal drinking water supply to the facility [19]. As drawn from the Star City Rainwater Project in Korea, this approach is equally a buffer against drought [43].

Tool for Solving Environmental Problems

RWH solves many social and economic problems and improves the community's ability to manage or reduce the risk of disasters such as floods and droughts. RWH can prevent flooding and erosion [9,21]. NAHRIM's research at Taman Wangsa Melawati Kuala Lumpur found that by incorporating an RWH system, it is possible to achieve a 20% reduction in peak discharge in this housing area, ensuring that all terrace houses have been installed with the same system [51]. By installing these systems in commercial facilities and other public facilities in the same residential areas, the peak emissions can be reduced by up to 50%.

In addition, the effects of climate change, which have become a hot topic in recent years, will change the country’s spatial and temporal rainfall patterns, triggering water-related problems such as floods and droughts. Flash floods are more frequent, and dry conditions can lead to drought due to this phenomenon. The implementation of RWH could be an important mitigation measure in this case. Flooding can also cause serious problems linked to the quality and quantity of groundwater. Short-term intense rainfall that falls on the surface tends to flow rapidly, leaving a very small amount of water to percolate as the groundwater recharges. Collecting rainwater and slowly releasing it into the aquifer has become an ideal solution for maintaining or improving groundwater quality [2,25,34,42]. Therefore, it cannot be denied that RWH is a very sustainable and efficient method in the long run.

Approach to Sediment and Pollutant Trap

Pollutants from commercial, industrial, and residential activities may seem insignificant at their source, but rainfall can carry them into storm drains, dumping waste into rivers, lakes, and seawater. Contaminants typically include nutrients, sediments, pathogens and litter [1,39]. Owing to the high concentration of pollutants in the "first stream," the disposal of the first rainfall may be the most dangerous. Spills can also increase when rain falls on hard surfaces, such as rooftops, roads, and parking lots. These storm water surges flow into waterways with great energy, clearing important habitats such as shelters and fish refuges, and eroding riverbanks [52].

The rain garden concept, also known as vegetated infiltration basins, bioretention gardens or facilities, and infiltration rain gardens, are landscape features designed to address storm-water runoff from hard surfaces such as rooftops, driveways, and parking lots. The rain garden concept deals with sunken garden spaces where runoff becomes a pond that seeps deep into the accumulated soil and then into the native soil below. This concept has been proven to replenish local groundwater [22,26,53,54].

The use of rain gardens has several advantages, such as: 1) rain gardens are areas where depressions, accumulated soil, and reservoirs are built to temporarily store runoff during small to moderate storm events; 2) pollutant removal: Vegetated soil removes more pollutants from rainwater than non-vegetated soil through processes such as absorption, filtration, sedimentation, infiltration, plant recovery, volatilization, and surface resistance; 3) rain gardens that use bioretention systems have been shown to be very effective in removing heavy metals, with some studies showing that most uptake occurs in the mulch layer (the layer of material applied to the surface of the soil). Hydrocarbons are removed by sorption during storms and biodegrade in the mulch layer by a combination of microorganism activity; 4) pollutant load-bioretention areas can be used to treat polluted runoff from land use that has a concentration of pollutants greater than that found in normal storm water; 5) groundwater recharge–For rain gardens, rainwater is detained for a period of time, creating slow infiltration, replenishing soil, and replicating natural hydrology. Bioretention areas are used for almost any soil or terrain, and are designed to allow runoff to penetrate the engineered soil layer and return excess flow to the storm-water system.

Rainwater Utilisation and Management: Research Needed

The development of low-cost and efficient technologies to support RWH is critical for promoting rainwater utilization [7,9]. Finding and exploring locally made RWH system components, such as the first flash chamber and rainwater tank, which are cheaper and suitable for local weather conditions, will help with the installation of the system and ensure the quality of rainwater storage [7,22].

The production of high-quality potable rainwater requires a natural treatment chain that treats rainwater collected in rainwater tanks to reduce the presence of bacterial and mineral contamination [19,29,55]. Optimal conditions such as optimal temperature and pH must be determined for a successful process [10,28,30,56]. In addition, the use of rainwater to supplement public water and groundwater is also important for water-stressed/high-water-consumption industries, such as food and electronics manufacturers. To convince all factory/manufacturer owners to adopt RWH systems, more research is needed on how rainwater can be used as a non-potable water source to replace or supplement existing water supplies [20,22,34,57].

Reducing peaks in storm runoff can help mitigate urban flash flooding problems. Studies on rainwater management to assist in the reduction of flash floods in large watersheds should be conducted in order to assess the impact of RWH on large-scale flood control projects [22,31,42]. The use of rain gardens in conjunction with other low-impact development practices to reduce the amount of storm-water entering drainage systems is yet to be widely practiced in Malaysia [26,54]. Research is needed on the effectiveness of rain gardens as an alternative to traditional storm-water management and their specific functions as sediment and pollutant traps and as sources of local groundwater drainage.

The Needs of Regulation and Policy

The mandatory use of rainwater in Malaysia has implications for the legal, social, and economic sectors. Legally, the mandatory use of rainwater involves special legislative amendments, as it adds to development, planning, environmental, and health concerns [6,19,25,35]. The Malaysian government should consider offering incentives in the form of tax rebates or raw water supply tax rebates to those owners who add RWH systems to their existing or new buildings as implemented in countries such as Japan, Australia, and the United States [7,22,31,40]. Various implementation policies can be developed and designed to harvest rainwater and use it in the social system. Implementation agencies can learn about initiatives to improve RWH practices by supporting RWH facilities and providing incentives for RWH.

At the international level, water resource management has emerged as a key factor in achieving adequate and sustainable progress towards Sustainable Development Goals (SDGs) [25]. Malaysia is currently facing a dynamic and rapidly changing situation from political, legal, and economic points of view. Prudent management and control of water resources are essential. Effective water management practices in Malaysia promote the participation of various stakeholders and practitioners and public interest in the issue [22]. To ensure that this agenda has been implemented, the Malaysian government has issued eight guidelines and rainwater distribution policies since 1999, to assure water management through relevant agencies [7,22]. In addition, the Malaysian government implemented several strategic plans and sustainable water management actions for the well-being of the community.

Recommendations for Further Research

Research should focus on key areas to improve RWH and address water resource management problems. First, there is a requirement to develop cost-effective and locally appropriate RWH technologies, especially those suitable for Malaysia's urban climate and environment. These include innovations in rainwater storage, filtration systems, and the first flush mechanism to ensure the quality of the collected rainwater. Further research is needed to evaluate the impact of RWH systems on large-scale flood control, especially in large watersheds, and to evaluate the ability of RWH systems to mitigate the effects of urban flash floods and heavy rainfall events.

Another important area of research is the integration of rain gardens, bioretention systems, and other low-impact development (LID) practices into urban landscapes. Conducting this study specifically in Malaysia will help explore the possibilities of this system to reduce storm-water runoff and increase local aquifers or groundwater recharge. Finally, research on improving the treatment of collected rainwater to meet drinking water standards will be essential for expanding the use of RWH systems in broader communities. Such efforts will promote sustainable water management and increase the resilience of urban areas to climate change.

Policy and Practical Recommendations for Malaysia

The Malaysian government should consider introducing policies and regulations to promote the use of RWH in new and existing settlements. This could include providing tax breaks and other incentives to homeowners who install RWH systems, similar to the policies in countries such as Japan and Australia.

Additionally, policies that increase access to RWH systems in urban and rural areas, including financial incentives, can facilitate large-scale implementation. An awareness campaign should also be undertaken to educate the public about the benefits of RWH, especially in terms of water conservation and environmental protection.

In addition, RWH strategies and green infrastructure must be integrated with Malaysia's urban planning policies to ensure that future development is climate-resilient and promotes sustainable water management. Finally, RWH projects should be encouraged at the local level, especially in water-stressed areas, to reduce the pressure on existing water supply networks and increase water self-sufficiency. These recommendations will help strengthen Malaysia's water management strategy, enhance climate resilience, and achieve development goals related to protecting water and the environment.

Conclusions

This review stresses the importance of Rainwater Management (RWM) as a sustainable solution for urban water problems. This highlights a shift from traditional storm-water management to a more integrated approach that views rainwater as a valuable resource rather than a problem. RWM systems, such as rainwater harvesting (RWH), can improve water supply security and reduce environmental problems, such as flooding, erosion, and pollution, especially in the face of climate change. This review shows that RWH plays a major role in addressing urban hydrology, supporting water conservation efforts, and promoting adaptation to climate change by reducing storm-water runoff and improving water management. These results highlight the importance of the RWM in addressing Malaysia's unique water challenges, especially given the expected increase in rainfall and the potential for more extreme weather events due to climate change. Implementing RWH systems in urban and rural areas can improve resilience to floods and droughts by decreasing dependence on central water supplies and providing reliable alternative water sources. Combining RWH with green infrastructure, such as storm drainage parks and permeable pavements, offers opportunities for sustainable urban development in Malaysia, contributing to a healthier environment and improved water quality.

Author Contributions

MSS: Conceptualization, Methodology, LR, Writing - Review & Editing, Supervision; **MNY**: LR, Writing – Review & Editing; **ZH**: LR, Writing - Review & Editing.

References

1. Vörösmarty, C.; Green, P.; Salisbury, J.; Lammers, R.B. Globalwater resources: Vulnerability from climate change and population growth. *Science* **2000**, *289*, 284–288, doi:10.1126/science.289.5477.284.
2. Kabiri, R.; Bai, V.R.; Chan, A. Assessment of hydrologic impacts of climate change on the runoff trend in Klang Watershed, Malaysia. *Environmental Earth Sciences* **2015**, *73*, 27–37, doi:10.1007/s12665-014-3392-5.
3. Che-Ani, A.I.; Shaari, N.; Sairi, A.; Zain, M.F.M.; Tahir, M.M. Rainwater harvesting as an alternative water supply in the future. *European Journal of Scientific Research* **2009**, *34*, 132–140.
4. Al-Batsh, N.; Al-Khatib, I.; Ghannam, S.; Anayah, F.; Jodeh, S.; Hanbali, G.; Khalaf, B.; van der Valk, M. Assessment of rainwater harvesting systems in poor rural communities: A case study from Yatta Area, Palestine. *Water* **2019**, *11*, *585*, 1–15, doi:10.3390/w11030585.
5. Ercin, A.E.; Hoekstra, A.Y. Water footprint scenarios for 2050: A global analysis. *Environment International* **2014**, *64*, 71–82, 2014, doi:10.1016/j.envint.2013.11.019.
6. Lee, K.E.; Mokhtar, M.; Hanafiah, M.M.; Halim, A.A.; Badusah, J. Rainwater harvesting as an alternative water resource in Malaysia: Potential, policies and development. *Journal of Cleaner Production* **2016**, *126*, 218–222, doi:10.1016/j.jclepro.2016.03.060.
7. Lani, N.H.M.; Yusop, Z.; Syafiuddin, A. A review of rainwater harvesting in Malaysia: Prospects and challenges. *Water* **2018**, *10,* 1–21, doi:10.3390/w10040506.

8. Zakaria, S. Transforming the Water Sector: Working in an Integrated Manner. Kick off Conference 12th Malaysia Plan, Ministry of Economic Affairs, Malaysia. 2019. Available online: https://rmke12.ekonomi.gov.my/storage/fileUpload/2021/08/2021082930_dr_salmah_zakaria.pdf (accessed on 20 April 2022).
9. Kuok, K.K.; Chiu, P.C. Optimal rainwater harvesting tank sizing for different types of residential houses: Pilot study in Kuching, Sarawak. *Journal of Engineering Science and Technology* **2020**, *15*, 541–544.
10. Nizam, N.U.M; Hanafiah, M.M.; Mokhtar, M.B.; Jalal, N.A. Water quality of rooftop rainwater harvesting system (MyRAWAS). *IOP Conf. Series: Earth and Environmental Sciences* **2021**, *880*, 1–11, doi:10.1088/1755-1315/880/1/012039
11. Sharif, S.P.; Mura, P.; Wijesinghe, S.N.R. Systematic reviews in Asia: Introducing the "PRISMA" protocol to tourism and hospitality scholars. In *Quantitative Tourism Research in Asia: Current Status and Future Directions*; Rezaei, S., Eds.; Springer Nature Singapore: Singapore, 2019; pp. 24–33.
12. PRISMA. PRISMA, Transparent Reporting or Systematic Reviews and Meta-Analyses*.* 2020. Available online: https://www.prisma-statement.org/protocols (accessed on 24 June 2022).
13. Haddaway, N.R.; Collins, A.M.; Coughlin, D.; Kirk, S. The role of google scholar in evidence reviews and its applicability to grey literature searching. *PLoS ONE* **2015**, 10(9), 1-17. doi:10.1371/journal.pone.0138237
14. Liberati, A.; Altman, D.G.; Tetzlaff, J.; Mulrow, C.; Gøtzsche, P.C.; Ioannidis, J.P.A.; Clarke, M.; Deveraux, P.J.; Kleijnen, J.; Moher, D. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: Explanation and elaboration. *PLoS Medicine* **2009**, *6*, 354–391*,* doi:10.1016/j.jclinepi.2009.06.006.
15. Petticrew, M.; Roberts, H. *Systematic Reviews in the Social Sciences: A Practical Guide*; Blackwell Publishing: Malden, MA, USA, 2006.
16. Yang, E.C.L.; Khoo-Lattimore, C.; Arcodia, C. A systematic literature review of risk and gender research in tourism. *Tourism Management* **2017***, 58,* 89–100, doi:10.1016/j.tourman.2016.10.011.
17. Shaffril, H.A.M.; Ahmad, N.; Samsuddin, S.F.; Samah, A.A.; Hamdan, M.E. Systematic literature review on adaptation towards climate change impacts among indigenous people in the Asia Pasific Regions. *Journal of Cleaner Production* **2020***, 258*, 1–29, doi:10.1016.jclepro.2020.120595.
18. Musinguzi, D. Trends in tourism research on Qatar: A review of journal publications. *Tourism Management Perspectives* **2016***, 20,* 265–268, doi:10.1016/j.tmp.2016.10.002.
19. Kyahan; Husodo, A.H.; Astuti, I.; Sudarmadji; Djohan, T.S. Rainwater as a source of drinking water: Health impacts and rainwater treatment. *Journal of Environmental and Public Health* **2019**, *5*, 1–10, doi:10.1155/2019/1760950.
20. Crouch, M.L.; Jacobs, H.E.; Speight, V.L. Defining domestic water consumption based on personal water use activities. *Aqua-Water Infrastructure, Ecosystems and Society* **2021***, 70,* 1002–1011, doi:10.2166/aqua.2021.056.
21. Fletcher, T.; Deletic, A.; Mitchell, V.G.; Hatt, B.E. Reuse of urban runoff in Australia: A review of recent. *Journal of Environmental Quality* **2008***, 37*, 116–127, doi:10.2134/jeq2007.0411.
22. Shaari, S.M. An overview of rainwater harvesting for sustainable future in Malaysia. *Environment-Behaviour Proceeding Journal* **2020***, 5*, 255–261, doi:10.21834/ebpj.v5i14.2232.
23. Tayouga, S.J.; Gagne, S.A. The socio-ecological factors that influence the adoption of green infrastructure. *Journals of Sustainability* **2016***, 8*, 1–17*,* doi:10.3390/su8121277.
24. Du, K.; Li, J. Towards a green world: How do green technology innovations affect total-factor carbon productivity. *Energy Policy* **2019***, 131*, 240–250, doi:10.1016/j.enpol.2019.04.033.
25. Jimenez, A.; Saikia, P.; Gine, R.; Avello, P.; Leten, J.; Lymer, B.L.; Schneider, K.; Ward, R. Unpacking water governance: A framework for practitioners. *Water* **2020**, *12*, 227–238, doi:10.3390/w12030827.

26. Rashid, A.R.M.; A. Bhuiyan, M.A.; Pramanik, B.; Jayasuriya, N. A comparison of environmental impacts between rainwater harvesting and rain garden scenarios. *Process Safety and Environmental Protection* **2022***, 159*, 198–212, doi:10.1016/j.psep.2021.12.047.

27. Ying, J.; Zhang, X.; Zhang, Y.; Bilan, S. Green infrastructure: Systematic literature review. *Economic Research* **2021***, 35*, 343–366, doi:10.1080/1331677X.2021.1893202.

28. Nikmatin, S.; Syafiuddin, A.; Kueh, A.B.H.; Maddu, A. Physical, thermal, and mechanical properties of polypropylene composities filled with rattan nanoparticles. *Journal of Applied Research and Technology* **2017**, *15*, 386–395, doi:10.1016/j.jart.2017.03.008.

29. Johor, S.F.W.; Ibrahim, S.H.; Yaman, K.; Wahab, R.A.; Nasrun, M.N.M. Filtration of rainwater harvesting system in rural Area. *Journal of Engineering Science and Technology* **2017**, *4*, 181–191.

30. Kim, R.; Lee, S.; Kim, J. Application of a metal membrance for rainwater utilization: Filtration characteristics and membrance fouling. *Desalination* **2005**, *177*, 121–132, doi:10.1016/j.desal. 2004.12.004.

31. Hajani, E.; Rahman, A. Reliability and cost analysis of a rainwater harvesting system in peri-urban regions of Greater Sydney, Australia. *Water* **2014**, *6*, 945–960, doi:10.3390/w6040945.

32. Muhammad, N.S.; Abdullah, J.; Julien, P.Y. Characteristics of rainfall in peninsular Malaysia. *Journal of Physics: Conference Series* **2020**, *1529*, 1–12, doi:10.1088/1742-6596/1529/5/052014.

33. Buntat, Z.; Iqbal, S.M.Z.;, Saburi, W.M.F.A.; Adzis, Z.; Sohaili, J.; Smith, I.R. Development of an integrated system for ozone treated harvested rainwater in perspective of green building scenario of Malaysia. *Journal Environmental Earth Sciences* **2015**, *5*, 51–60.

34. Leong, J.Y.C.; Chong, M.N.; Poh, P.E.; Hermawan, A.; Talei, A. Longitudinal assessment of rainwater quality under tropical climatic conditions in enabling effective rainwater harvesting and reuse schemes. *Journal of Cleaner Production* **2016**, *143*, 64–75, doi:10.1016/j.jclepro.2016.12.149.

35. Zaid, S.; Zaid, L.; Esfandiari, M.; Hasan, Z.F.A. Green roof maintenance for non-residential buildings in tropical climate: Case study of Kuala Lumpur. *Environment, Development and Sustainability* **2022**, *24*, 2471–2496.

36. Wang, Q.; Qu, J.; Wang, B.; Wang, P.; Yang, T. Green technology innovation development in China in 1990–2015. *Science of The Total Environment* **2019***, 696*, 1–8, doi:10.1016/j.scitotenv.2019. 134008.

37. UNEP-DTIE-IETC/Sumida City Government/People for Promoting Rainwater Utilisation. *Rainwater Harvesting and Utilisation - An Environmentally Sound Approach for Sustainable Urban Water Management: An Introductory Guide for Decision Makers*; IETC UNEP: Osaka, Japan.

38. Palla, A.; Gnecco, I.; Barbeca, P.L. The impact of domestics rainwater harvesting systems in storm water runoff mitigation at the urban block scale. *Journal of Environmental Management* **2017***, 191*, 297–305, doi:10.1016/j.jenvman.2017.01.025.

39. Piarapakaran, S. Decontaminating Water Issues in 12th Malaysia Plan. Available online: http://www.awer.org.my/?pgid=home&cid=485 (accessed on 25 May 2022).

40. Shaaban, A.J.; Amin, M.; Feng, H.Y. Rainwater management and utilisation system. *The Ingenieur* **2010**, *45*, 28–38.

41. Department of Irrigation and Drainage Malaysia, Ministry of Energy Transition and Water Transformation. The Official Web of Public InfoBanjir. Rainfall. 2022. Available online: https://publicinfobanjir.water.gov.my/hujan/?lang=en (accessed on 9 July 2022).

42. Amin, I.M.Z.M.; Ercan, A.; Ishida, K.; Kavvas, M.L.; Chen, Z.Q.; Jang, S. Impacts of climate change on the hydrolic-climate of peninsular Malaysia. *Water* **2019**, *11*, 1–18, doi:10.3390/w11091798.

43. Han, M; Mun, J. Operational data of the Star City rainwater harvesting system and its role as a climate change adaptation and a social influence. *Water Science & Technology* **2011***, 63*, 2796–2801, doi:10.2166/wst.2011.597.

44. Malek, B.A. Pelan Penjimatan Air Kebangsaan: Tanggungjawab Kerajaan. Presented at The National Seminar on Water Saving Awareness in Malaysia, Kuala Lumpur, Malaysia, 22 March 2007.

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45. UNICEF. Water scarcity. Available online: https://www.unicef.org/wash/water-scarcity (accessed on 18 June 2022).
46. Greenbuildingindex. FAQ. Available online: https://www.greenbuildingindex.org/faq-green/#1582099513659-6bdc153c-f59b (accessed on 6 September 2022).
47. Munna, G.M.; Alam, J.B.; Uddin, M.M.; Islam, M.A.; Tonmoy, K.T.R.; Hridoy, I.A. Rainwater harvesting potentialities to reduce over extraction of groundwater in Sylhet. *Scholars Journal of Engineering and Technology* **2020**, *8*, 48–58, doi:10.36347/sjet.2020.v08i03.003.
48. Population Matters. Resources & Comsumption. 14 March 2022. Available online: https://populationmatters.org/resources-consumption (accessed on 25 June 2022).
49. Tokyo Metropolitan Foundation for History and Culture. Topping East. Available online: https://ttf-koubo.jp/en/project/topping-east/index.html (accessed on 24 July 2022
50. Nafisah, A.R.; Matsushita, J. Comparative study on rainwater harvesting practice between two metropolises: Tokyo (Sumida-Ku) & Selangor, Malaysia. *Society for Social Management Systems Internet Journal* **2010**, *6*, 1–8.
51. NAHRIM Research Centre. NAHRIM Strategic Plan 2016–2020. 2020. Available online: https://digital.nahrim.gov.my/portal-main/publication-details?id=4 (accessed on 25 May 2022).
52. Patrick, A.E.S. Influence of rainfall and water level on inland fisheries production a review. *Archives of Applied Science Research* **2016**, *8*, 44–51.
53. State of Rhode Island Department of Environmental Management. Create A Rain Garden: Preventing Water Pollution in Your Community. 2018. Available online: https://dem.ri.gov/sites/g/files/xkgbur861/files/ri-stormwater-solutions/documents/Abridged_ServiceManual.pdf (accessed on 12 May 2022).
54. Sidek, L.M.; Muha, N.E. Constructed rain garden for Water Sensitive Urban Design (WSUD) as stormwater management in Malaysia: A literature review. In National Graduate Conference (Natgrad 2012) Universiti Tenaga Nasional (UNITEN), Selangor, Malaysia, November 2012.
55. Muhammad, M. A.; Abidin, M.Z. Water quality assessment of rainwater collected from rooftop at UTM. 2016. Available online: https://engineering.utm.my/civil/wp-content/uploads/sites/29/2016/12/Water-Quality-Assessment-of-Rainwater-Collected-from-Rooftop-at-UTM.pdf (accessed on 8 June 2022).
56. Mohamad, N. Research on Rainwater Harvesting for Drinking Water. Presented at National Colloquium on Research and Water Development 2020, Malaysia, 2020.
57. Mohammad, S.; Mohammad, M.F.; Yusof, M.R.; Musa, M.F. The Awareness among Developers on Rainwater Harvesting System (RWHS). Presented at International Colloquium on Science and Technology, Penang, Malaysia, 7–8 March 2014.