sustainability

MDPI

Article

Assessment of the Implementation of Sustainable Stormwater Management Practices in Asian Countries

Orynbayev Seitzhan [1], Fatin Khalida Abdul Khadir [2], Smailov Bakyt [3], Cheng Yee Ng [2,*], Husna Takaijudin [2], Noor Amila Wan Zawawi [2], Wesam Salah Alaloul [2,*] and Muhammad Ali Musarat [2,4]

[1] Department of Power Engineering, Institute of Water Management and Environmental Management, M.Kh. Dulaty Taraz Regional University, Suleymenov Str. 7, Taraz 080012, Kazakhstan; seitzhan_74@mail.ru
[2] Department of Civil and Environmental Engineering, Universiti Teknologi PETRONAS, Bandar Seri Iskandar 32610, Malaysia; fatin_19001426@utp.edu.my (F.K.A.K.); husna_takaijudin@utp.edu.my (H.T.); amilawa@utp.edu.my (N.A.W.Z.); ali.musarat@utp.edu.my (M.A.M.)
[3] Department of Water Resources, Institute of Water Management and Environmental Management, M.Kh. Dulaty Taraz Regional University, Suleymenov Str. 7, Taraz 080012, Kazakhstan; 1115878@mail.ru
[4] Offshore Engineering Centre, Institute of Autonomous System, Universiti Teknologi PETRONAS, Bandar Seri Iskandar 32610, Malaysia
* Correspondence: chengyee.ng@utp.edu.my (C.Y.N.); wesam.alaloul@utp.edu.my (W.S.A.)

Abstract: Numerous efforts have been undertaken by Asian countries to mitigate the adverse effects of urbanization on stormwater management. However, traditional stormwater systems have become overwhelmed due to extensive development, resulting in excessive runoff and frequent floods. As a result, it is crucial to urgently adopt sustainable stormwater management practices (SSMPs) to effectively control water quantity and quality. The goal of this study is to assess the viewpoints of stormwater practitioners regarding green roofs, rainwater harvesting systems (RHS), grass swales, rain garden/bioretention systems, and porous pavement using a SWOT analysis. This was accomplished by distributing questionnaires and evaluating previous studies. The survey showed that participants mostly agreed with the strengths, weaknesses, opportunities, and threats factors related to the chosen SSMPs. Overall, the respondents favoured the implementation of green roofs and grass swales. Further assessments were conducted on these practices in other aspects, confirming that green roofs are the most preferable SSMP for implementation in Asian countries.

Keywords: stormwater management practices; flood management; sustainability; Asian countries; SWOT analysis

check for updates

Citation: Seitzhan, O.; Abdul Khadir, F.K.; Bakyt, S.; Ng, C.Y.; Takaijudin, H.; Zawawi, N.A.W.; Alaloul, W.S.; Musarat, M.A. Assessment of the Implementation of Sustainable Stormwater Management Practices in Asian Countries. *Sustainability* **2023**, *15*, 15547. https://doi.org/10.3390/su152115547

Academic Editor: Agostina Chiavola

Received: 11 August 2023
Revised: 20 September 2023
Accepted: 21 September 2023
Published: 2 November 2023

Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

While industrialization has brought remarkable economic growth and reduced poverty in many nations, it has also given rise to negative environmental consequences. The expansion of cities has resulted in the replacement of natural landscapes and permeable surfaces with impermeable ones such as roads, buildings, housing developments, and parking lots. This transformation has disrupted the hydrology of these areas [1]. The proliferation of impermeable surfaces in numerous countries has reduced the capacity for rainwater to infiltrate the soil, leading to water-related issues including floods [2,3]. According to a study conducted in 2022, Asia, which is home to the world's largest population, accounting for approximately 61% of the global population (4.7 billion), faces significant challenges in this regard. China is the most populous country globally, with 1.438 billion inhabitants, followed by India (1.380 billion) and Indonesia (273 million) [4]. A lack of green spaces worsens this problem, as areas with high population densities experience more frequent instances of flooding.

Currently, there is growing interest among local governments and non-government organizations in green or nature-based solutions for efficient and sustainable stormwater

management to mitigate floods [5–8]. Conventional stormwater management systems such as drainage (pipes and conduits) can capture and control stormwater; however, they are less effective at improving water quality. They often focus on flood control and may not adequately address the removal of pollutants and contaminants from runoff [9]. Additionally, some conventional systems can hinder the natural infiltration of stormwater into the ground, reducing groundwater recharge. This can have long-term implications for local aquifers and water resources. Conventional systems may also not be adequately designed to handle the increased frequency and intensity of storms associated with climate change and may become overwhelmed during extreme weather events [9]. Due to these drawbacks, many municipalities and organizations are exploring more sustainable and environmentally friendly stormwater management alternatives, which aim to mimic natural processes and reduce the negative impacts of stormwater runoff. Thus, sustainable stormwater management practices (SSMPs) are introduced to address the limitations of conventional systems, replicating the natural hydrological characteristics of catchment areas, and controlling hydrologic pre-development conditions.

SSMPs involve both stormwater quantity control to mitigate flooding and stormwater quality control to treat and remove pollutants from runoff [10,11]. Considering the altered characteristics of water catchment areas due to urbanization in Asian countries, it is vital to incorporate quantity and quality control parameters into stormwater management planning and design. Several studies have demonstrated the suitability of SSMPs, such as green roofs, rainwater harvesting systems (RHSs), grass swales, rain gardens/bioretention systems, and pervious pavements, for implementation across various sectors, including commercial, industrial, and residential areas [12]. These practices have been investigated extensively to assess their effectiveness in managing the hydrological and hydraulic aspects of urbanization. The aim is to ensure that developing Asian countries have adequate storage capacity to handle runoff and remain protected from overflow events.

In recent times, the utilization of green roof technology has proven to be successful in addressing the issue of managing stormwater. Developed countries' construction sectors have witnessed significant growth in the adoption of green roofs, as this strategy not only safeguards the local environment but also helps alleviate the detrimental impacts of global warming [13,14]. Meanwhile, RHSs are commonly used as storage tanks to collect and store runoff temporally [15]. The collected runoff can be utilized for various purposes, including toilet flushing, irrigation, and more.

A grass swale is a natural landscape feature designed to promote the infiltration of runoff into the ground and enhance the water quality [16]. Grass swales can be implemented in various areas such as parks, residential pathways, parking areas, and more. In addition, a bioretention system is a landscape feature comprised of multiple layers of filter media, an overflow weir, various vegetation, and an optional underdrain while rain gardens are smaller and less complex in design compared to bioretention systems. The purposes of these practices are to collect and receive a significant quantity of runoff, which is then stored in different layers before being evaporated through the vegetation [17]. Permeable or porous pavements are specifically engineered to enhance the natural process of allowing rainfall and runoff to seep into the ground, which consequently leads to a decrease in the volume of water flowing over the surface [18]. This innovative pavement design not only mitigates the potential for flooding and erosion but also brings about a notable enhancement in the overall quality of water in the vicinity.

Thus, this study aims to assess the feasibility of implementing SSMPs, specifically focusing on green roofs, RHSs, grass swales, rain gardens/bioretention systems, and porous pavements by reviewing research articles centered on Asian countries. This study also aims to identify the strengths, weaknesses, opportunities, and threats (SWOT) associated with these practices. To achieve these objectives, a survey was conducted to gather stakeholders' opinions on the performance of each selected practice. A questionnaire based on the SWOT analysis was developed, and the most preferable SSMPs were proposed based on the survey results. This study also aims to offer valuable insights for urban planners and policymakers,

guiding them in conducting vital future research to propel the advancement of SSMPs in Asian countries.

2. Literature Review

2.1. Flood Mitigation Measures

Floods have been a recurring natural phenomenon throughout history, affecting various regions worldwide [19–21]. In recent times, the risks, frequency, and impacts of floods have been on the rise in Asian coastal megacities [21–25]. In urban coastal areas, various measures are being taken to reduce the risk of flooding. One of these measures involves moving citizens and properties from areas with frequent flooding. For example, the government of Indonesia is in the gradual process of relocating its capital from Jakarta to a safer zone. However, densely populated and economically vibrant countries such as China, Japan, South Korea, Vietnam, the Philippines, Thailand, and Singapore find relocation to be impractical due to its high costs and resistance from individuals and businesses [21]. Consequently, these cities face significant challenges in managing flood risks while addressing their development needs. Table 1 provides a summary of the flood management measures in selected Asian countries.

Table 1. Flood management measure(s) in selected Asian countries.

Country	References	Flood Management Measure(s)		
		Control	Alleviation	Recovery
Malaysia	[26–28]	• Enhance the drainage system • Promote SSMPs	• Avoid construction in areas that are susceptible to flooding • Public awareness	• Implement recovery measures to restore normal conditions immediately and overcome the flooding impacts
	[29]	• Build Flood Control Dams (FCD) to regulate and control the flow of water during flood events • Introduce Integrated River Basin Management (IRBM)	• Implement Related Works Poldering (Ring Bund) systems by creating enclosed areas with higher elevation • Develop guidelines and design standards for the resettlement of populations in safer areas	-
Singapore	[25,30]	• The ABC Waters Programme was initiated in 2006	-	-
	[30,31]	• Initiate the implementation of the Source Pathway Receptor (SPR) model	-	-
	[32]	• Construction of the Alkaff Lake stormwater retention pond	• Road raising and improvement efforts • Introduction of the Motorist app aims to deliver real-time alerts to motorists	• 400 water level sensors are being installed

Table 1. *Cont.*

Country	References	Flood Management Measure(s)		
		Control	Alleviation	Recovery
Indonesia	[25]	-	• Establishment of the Coastal Defence Strategy in 2014 to improve resilience	-
	[33]	• Retention ponds are being created to capture and store excess stormwater • Improve management practices in the catchment area	• The introduction of a flood forecasting and early warning system is underway to provide timely alerts	-
Thailand	[25,34,35]	-	• Early warning systems are being installed to provide timely alerts to communities • Promote community awareness and readiness through flood education programs	-
Vietnam	[25,36,37]	• Integration of flood risk considerations into land-use planning and urban landscape design • Adoption of a combination of physical (e.g., flood barriers) and non-physical (e.g., floodplain zoning) actions	• Implementation of early warning systems and preparedness measures • Implementation of flood governance frameworks and policies • Integration of awareness-raising campaigns and educational programs	• Improvements in water supply systems and health services to address potential disruptions during and after floods • Introduction of flood insurance schemes to provide financial protection and aid in recovery efforts
Philippines	[38]	• Construction of drainage channels and flood ways and divert excess water away from vulnerable areas	• Development and implementation of flood warning systems • Integration of flood avoidance measures into land-use planning	-
China	[25,39]	-	• Ensuring timely and accurate information is provided to the public in Guangzhou	• Adoption of a climate change resilience plan in Guangzhou
	[25,40]	-	• The Shanghai Meteorological Bureau has collaborated with the Intergovernmental Panel on Climate Change (IPCC) to study climate projections • Efforts have been made to improve resilience measures in Shanghai	-

Table 1. *Cont.*

Country	References	Flood Management Measure(s)		
		Control	**Alleviation**	**Recovery**
	[41]	• Improve structural "hard" measures to enhance their effectiveness in managing flood risks • Implementation of flood forecasting	• Promoting spatial planning and zoning, watershed management practices, warning systems, and raising awareness among the public	-
	[42]	• Implementing measures to return parts of flood detention zones to rivers	• Reduce population density in flood-prone areas through large-scale relocations, moving residents to safer locations	• Implementing innovative farming techniques that can withstand and recover from flood impacts
China	[43]	-	• Reconsidering the demographic characteristics of the population exposed to flood risks • Assessing income levels and social vulnerability to develop more effective flood risk management strategies	• Increasing investment in flood risk management
South Korea	[44]	• Construction of dams and ongoing river maintenance activities • Implementation of multi-functional weirs	• Development of multi-regional water supply systems and industrial waterworks • Establishment of flood control or adjustment plans • Enhancement of flood forecast and warning systems	• Utilization of reservoir simulation and flood control decision-making processes
Japan	[45]	• Implementing land-use control measures, such as zoning regulations and development restrictions	• Developing models to estimate flood damage, allowing for better understanding of potential impacts and assisting in decision-making for flood risk reduction measures	• Increasing investment in SSMPs • Conducting regular inspection, maintenance, repair, and replacement work on SSMPs

However, as indicated in Table 1, the current approaches tend to prioritize economic losses while overlooking the importance of incorporating the natural environment in flood management. Many Asian countries predominantly rely on non-environmentally friendly engineering solutions and fail to incorporate a comprehensive range of climate change practices [46]. While engineered flood protection measures are significant, evidence suggests that the level of protection required for the environment is often financially unfeasible [47]. Due to the cost constraints associated with engineered defences against increasing flood risks, it is essential for Asian countries to develop sustainable strategies that yield more effective mitigation results rather than relying solely on engineering procedures.

2.2. Sustainable Stormwater Management Practices (SSMPs)

To effectively manage stormwater, the catchment areas are divided into three parts: the roof catchment area, the ground catchment area, and the artificial ground catchment area [12]. These divisions help in planning and designing stormwater management strategies to effectively manage runoff and reduce the risk of flooding in residential areas.

Roof Catchment Area

Green roofs, which involve planting vegetation on rooftops, can help mitigate urban heat islands, improve air quality, conserve energy, and enhance the aesthetics of cities. In developing Asian countries, utilizing roof areas, particularly in high-rise buildings, to implement SSMPs can be a valuable approach to addressing water-related issues. Roofs can account for approximately 50% of the total area in buildings, making them significant potential contributors to stormwater management [48]. Given the limited availability of land, green roofs have emerged as a viable alternative to convert impermeable surfaces into permeable ones [49]. Thus, the utilization of roof areas presents a promising opportunity to optimize stormwater management in densely populated and rapidly developing regions.

While green roofs offer many environmental and aesthetic benefits, they also come with some drawbacks and challenges [50,51]. For example, green roofs can be expensive to install, primarily due to the need for additional structural support, waterproofing, and planting materials. The initial investment can be a significant barrier for some building owners. Additionally, green roofs require regular maintenance, including watering, pruning, weeding, and pest control. Without proper upkeep, vegetation can become overgrown, and a roof's integrity may become compromised. Green roofs may also not be suitable for all types of buildings or in all urban environments [52,53]. Factors like roof slope, access, and local climate conditions can limit their applicability. Moreover, these roofs can be heavy, especially when fully saturated with water. Not all buildings are structurally capable of supporting the additional weight, necessitating costly structural modifications. Despite these drawbacks, many of the challenges associated with green roofs can be mitigated with proper planning, design, and ongoing maintenance. Careful consideration of local conditions and expertise in green roof installation can help minimize these disadvantages and maximize the benefits of green roof projects. Table 2 provides a summary of tests that have been conducted to evaluate the performance of green roofs.

Table 2. Summary of green roof performances from previous studies.

Country	References	Parameters	
		Water Quantity	**Water Quality**
Malaysia	[14]	• The inclusion of creeping oxeyes in stormwater management practices resulted in a significant reduction in peak flow, with reductions observed as high as 41% • Similarly, the incorporation of morning glory also led to a notable decrease in peak flow, with reductions observed of approximately 15%	• The presence of creeping ox-eye vegetation resulted in a notable improvement in biochemical oxygen demand (BOD) concentration, with a reduction of 17% • The inclusion of morning glory vegetation demonstrated significant effectiveness in reducing the chemical oxygen demand (COD) concentration, with reductions of up to 99%
	[52]	• The study revealed that the implementation of green roofs led to a reduction in peak discharge of up to 26% • This indicates that green roofs effectively mitigated the volume and rate of stormwater runoff during peak flow periods, reducing the risk of flooding and the associated impacts	-

Table 2. *Cont.*

Country	References	Parameters	
		Water Quantity	**Water Quality**
	[53]	-	• The research findings indicated that the implementation of green roofs resulted in an average water quality index (WQI) of 92, classified as Class I • This suggests that the runoff produced from green roofs was clean and met the desired water quality standards in Malaysia
	[54]	• The research findings showed that *Nephrolepis biserrate* exhibited the greatest reduction in runoff, with a significant decrease of 133.4 mm, indicating its effectiveness in reducing the volume of stormwater runoff • However, it also experienced the most substantial water loss at a rate of 0.87 g, suggesting that this vegetation type had a higher rate of evapotranspiration, leading to more water loss from the system • On the other hand, *Kaempferia galangal* demonstrated a runoff reduction of 100.5 mm, indicating its effectiveness in managing stormwater runoff	-
	[55]	• The research discovered that palm oil clinker has excellent drainage capabilities • It demonstrated higher hydraulic conductivity values, ranging from 1550 cm/h to 1800 cm/h, compared to pumice, which had a hydraulic conductivity of 1650 cm/h	-
	[56]	• The research findings indicate that the density of grass plays a significant role in peak flow attenuation. It was observed that areas with higher grass density attained the highest level of peak flow reduction, ranging from 51% to 67%	• All the vegetation employed in the study demonstrated the ability to remove total phosphorus (TP) at rates ranging from 20.11% to 89.10% and ammonia nitrogen (AN) at rates ranging from 59.92% to 95.34% • Based on its effectiveness in reducing flow and removing pollutants, *K. pinnata* is a suitable choice
Singapore	[57]	• Held on to 39% more rainfall (234 mm) • Reduced the highest amount of water flow by 64% • The peak water flow happened approximately 34 min later	-
	[58]	-	• Despite being located near an industrial area, all the configuration units effectively neutralized acid rainfall and removed metals, except for iron (Fe)

Table 2. *Cont.*

Country	References	Parameters	
		Water Quantity	**Water Quality**
	[59]	-	• At the onset of rain events, the concentrations of most chemical components were at their highest levels. However, they gradually decreased in subsequent rainfall
South Korea	[60]	• Green roofs have the capability to retain approximately 65% more water in various storm events	-
	[61]	• Green roofs have the capacity to retain varying amounts of rainwater runoff, ranging from 10% to 60%, depending on the intensity of the rainfall.	-
	[62]	• An average 20% reduction in runoff	-
China	[63]	• Green roofs have a water retention capacity ranging from 55% to 88%	-
	[64]	• After analyzing 19 rainfall events, green roofs demonstrated an average runoff retention rate of 77.2%	-
	[65]	-	• The percentage of ammonia nitrogen in the runoff from green roofs is lower compared to the percentage found in the original rainwater
	[66]	-	• Green roofs effectively retained a significant number of heavy metals, including 97% of the copper (Cu), 96% of the zinc (Zn), 92% of the cadmium (Cd), and 99% of the lead (Pb)
	[67]	• The peak runoff was reduced by 5.3%, and the total runoff volume decreased by 31%	• There was a reduction of 40.0% in total suspended solids (TSS), 31.6% in total phosphorus (TP), and 29.8% in total nitrogen (TN)
Vietnam	[68]	• Reduce the peak flow by up to 50% and increase total delay time by up to 30 min.	-
Philippines	[69]	• Water retention capacity up to 75%	-

Meanwhile, RHSs involve the gathering of water from surfaces that rainfall lands on, which is then stored for future purposes [70]. There are primarily two distinct approaches to rainwater harvesting: the rooftop method and the surface runoff method. The rooftop method entails collecting rainwater from building rooftops, while the surface runoff method involves capturing rainwater as it flows across various surfaces [70]. In Malaysia, the performance of an RHS for a community consisting of 200 houses in Renggam, Johor was investigated. The study found that an optimal storage tank size of 160 m^3 was suitable for a roof area of 20,000 m^2, providing 60% reliability. Additionally, the proposed model achieved significant water savings of up to 58% [71].

In a study conducted in Selangor, Malaysia, the water quality of rainwater was assessed to determine its suitability as an alternative source of drinking water. The physicochemical quality parameters of the rainwater met the drinking water standards set by Malaysian authorities, suggesting that it is suitable for consumption [72]. Other Asian countries may consider this treatment in their efforts to determine the suitability of the harvested rainwater as a drinking source according to their drinking standards. Therefore, regular water quality testing is crucial for ensuring the safety of harvested rainwater, especially for drinking purposes [72]. Common treatment methods include sedimentation, filtration, UV disinfection, chlorination, and ozone treatment [73]. The choice of treatment method depends on the specific water quality and local conditions. In summary, harvested rainwater can be a safe and viable source of drinking water in Asian countries, but it requires careful planning, proper infrastructure, regular maintenance, and adherence to water quality standards. When done correctly, rainwater harvesting can help alleviate water scarcity and provide a sustainable source of clean drinking water in many regions.

However, it is essential to consider the capacity of rain barrels to handle heavy rainfall and sustain water storage for extended periods [73]. In the case of rooftop areas, rain barrels may not be able to manage the water load for prolonged durations, posing risks to the roof structure, especially in landed houses, and potentially leading to building collapse. Therefore, careful consideration of the appropriate location for installing rain barrels is crucial. Additionally, many Asian countries experience seasonal variations in rainfall, with heavy monsoon rains followed by long dry spells [73,74]. This makes it difficult to rely solely on RHSs for year-round water supplies, leading to potential shortages during dry periods. The installation of RHSs can be expensive, especially for low-income households in developing Asian countries. The cost of purchasing and installing tanks, gutters, filters, and pumps may be prohibitive for some. However, despite these drawbacks, RHSs remain a valuable and sustainable water management option in many Asian countries [73,74]. To overcome these challenges, it is essential to raise awareness, implement appropriate regulations, provide financial incentives, and invest in research and development to improve the technology and efficiency of rainwater harvesting systems. Table 3 summarizes the results of previous studies assessing the performances of RHSs in various Asian countries.

Table 3. Summary of the rain barrel/RHS performances from previous studies.

Country	References	Parameters	
		Water Quantity	**Water Quality**
Malaysia	[75]	The peak discharge was reduced by up to 10%	34% increment in domestic water use
Thailand	[76]	Four filters with filtration rates of 1–1.5 m^3/h are required for all sizes of tank capacity	-
South Korea	[77]	Reduce flooding by 10%	-
China	[78]	-	Supply supplemental drinking and irrigation water
Philippines	[79]	The reliability of RHS can meet up to 37% of water demands	-

2.3. Ground Catchment Area

In urban areas, it is crucial to give careful attention and care to sustainable stormwater management practices (SSMPs) constructed on the ground due to the presence of complex infrastructures. The ground catchment area plays a vital role in allowing runoff storage and natural infiltration into the soil [80]. Several effective SSMPs that can be implemented on the ground, including grass swales, bioretention systems, rain gardens, permeable pavements, and rain barrels [12]. Implementing grass swales requires careful planning, design,

and consideration of local conditions [81]. In Asian countries, where rapid urbanization and increased development can strain natural resources and exacerbate environmental challenges, the implementation of grass swales can play a vital role in addressing these issues while promoting sustainable and resilient communities. However, grass swales require space for construction, which may not always be available in densely populated urban areas. Land acquisition or repurposing of existing areas may be necessary. Additionally, the effectiveness of grass swales may vary seasonally, with reduced infiltration during dry periods and increased runoff during heavy rains [82]. Despite these drawbacks, many of these issues can be addressed through proper planning, design, and ongoing management. Grass swales remain a valuable tool in sustainable stormwater management and can be particularly effective when integrated into a broader green infrastructure strategy. Table 4 summarizes the results of previous studies that evaluated the performance of grass swales in various Asian countries. These studies examined the efficacy of grass swales in improving overall stormwater management in urban regions.

Table 4. Summary of grass swale performances from previous studies.

Country	References	Parameters	
		Water Quantity	**Water Quality**
Malaysia	[83]	• The infiltration rate obtained was 1.8–2 cm/h	• The outflow collected at the swale outlet achieved Class II based on the Interim National Water Quality Standards (INWQS)
	[84]	-	• Sand column improved the water quality by 4% to 80%
South Korea	[85]	• Grass swales demonstrated a reduction in total rainfall runoff volume and peak flow, particularly with an intensity of approximately 30 mm/h • On average, these swales showed a rainfall runoff retention rate ranging from 40% to 75% during small storm events	-
China	[86]	-	• The implementation of swales led to a significant reduction in pollutant concentrations, especially in the case of suspended solids
	[87]	-	• COD removal rate ranged from 86.35% to 51.72%

The bioretention system could prolong the time it takes for runoff to reach its peak concentration, which in turn promotes enhanced infiltration. This is attributed to the presence of clay in the soil configuration, which facilitates better water absorption and retention within the system [88]. Rain gardens and bioretention systems operate on similar principles but differ in their design requirements. Although rain gardens are smaller and less complex in design compared to bioretention systems, this practice is still capable of managing small catchment areas of less than two hectares, retaining a substantial amount of runoff, and maintaining the natural condition of the area by reducing the flow rate, peak flow, and total volume of runoff [12]. Selecting appropriate components for rain gardens and bioretention systems is crucial to ensure their long-term performance.

Vegetation plays a vital role in enhancing the landscape value of an area [10,11]. Citizens can also economically contribute by using vegetable-based plants for their rain gardens

or bioretention systems instead of flower-based plants. Therefore, the implementation of these practices should be encouraged, as they offer numerous benefits beyond stormwater management purposes. While they offer several environmental benefits, these practices require regular maintenance to function effectively [89,90]. This includes removing accumulated sediment, weeds, and debris, as well as replenishing organic mulch. Neglecting maintenance can lead to reduced efficiency and decreased pollutant removal. Additionally, these practices may not perform consistently throughout the year, as their effectiveness can vary with weather conditions, plant growth, and seasonal fluctuations in water flow. However, these practices remain as valuable tools for sustainable stormwater management and improving water quality. Properly designed, installed, and maintained, they can offer a range of environmental benefits while addressing some of the challenges associated with urban runoff and pollution [89,90]. Table 5 summarizes the results of previous studies that assessed the performance of rain gardens and bioretention systems in various Asian countries.

Table 5. Summary of rain garden/bioretention system performances from previous studies.

Country	Reference	Parameters	
		Water Quantity	**Water Quality**
Malaysia	[91]	• The implementation of a bioretention system led to a reduction in runoff volume of approximately 15% • Additionally, the system effectively reduced peak flow by nearly 30%	-
	[92]	-	• The water samples collected from the study area attained water quality index (WQI) levels classified as Class I and Class II, indicating good to moderate water quality
	[93]	• The implementation of the system resulted in a delay of outflow peaks of 52%, with a minimum delay of 13 min	• Concentration: TP was reduced by 60% and COD was reduced by 42% • Total load: TP was reduced by 65% and COD was reduced by 49%
	[94]	• Resulted in a substantial reduction in water volume, ranging from 58.6% to 67.9%. • The peak flow was significantly reduced by 72.0% to 86.4%.	-
Japan	[95]	• The overall runoff rate was measured at 13.78% during the study, with an average rainfall intensity of 28.18 mm/h	• Achieved contaminant reduction for a three-year return period
China	[96]	-	• Average removal rates: TSS (81.34%), COD (41.88%), TN (37.33%), TP (71.64%)
	[97]	-	• Successfully removed nitrogen (TN) at a rate of 54.5%. This removal was attributed to the combined effects of nitrogen accumulation (18.3%) and denitrification (36.2%)
Singapore	[98]	• Achieved a per-event mass balance error of 0.3% and 5.1% for 80 events with varying rainfall characteristics	-

2.4. Artificial Ground Catchment Area

The artificial ground area refers to an area specifically created by humans to manage stormwater. Permeable or porous pavements are designed to facilitate the infiltration of runoff into the ground, resulting in reduced flow and improved water quality in the surrounding area [99]. For instance, the upper surface of a parking lot can be constructed using porous pavement to store water and mitigate runoff from nearby areas. Other suitable locations for implementing permeable pavements include driveways along roads and sidewalks [12]. Previous studies have demonstrated the effectiveness of porous pavements as a solution for water-related issues. However, it should be noted that porous pavements may not be suitable for heavily loaded or highly trafficked areas [100]. Therefore, further testing and improvements in porous pavement materials are necessary to broaden their applications in artificial ground catchment areas. Additionally, while the characteristics of porous pavement components have been extensively tested, there is a lack of testing evaluating the performance of porous pavements in terms of water quantity and water quality parameters, specifically in Asian countries. Thus, it is crucial to encourage more experimental or simulation work to assess the suitability of porous pavements for stormwater management in Asian countries.

To further promote the implementation of SSMPs in Asian countries, several measures can be taken [80,101,102]. One important step is streamlining the permitting processes associated with SSMPs. Simplifying and expediting the approval procedures for implementing these practices can help overcome bureaucratic hurdles and facilitate their widespread adoption. Providing incentives or funding schemes can also incentivize individuals, communities, and organizations to implement SSMPs. Financial support or tax incentives can encourage stakeholders to invest in sustainable stormwater practices and overcome the financial barriers associated with their implementation. Collaboration with local authorities and government agencies is essential. By working together, suitable locations for SSMPs can be identified and integrated into urban planning and development processes. These proactive approaches ensure that stormwater management is considered from the early stages of urban design, leading to more effective and sustainable outcomes [80,101,102].

Regular maintenance and operation of SSMPs is crucial to their long-term effectiveness. Trained professionals should be responsible for the ongoing maintenance and monitoring of these practices to ensure their optimal performance. This includes routine inspections, cleaning, and repair work to guarantee their functionality and longevity. By implementing these measures, financial and technical barriers can be overcome, suitable locations for SSMPs can be identified, and the proper operation and maintenance of these practices can be ensured [83,101]. This will contribute to effective stormwater management and mitigation of flooding in Asian countries.

3. Methodology

SWOT analysis is a strategic method commonly used during project planning [103]. It can also be applied to SSMs to provide solutions for sustainable development in managing stormwater and encourage environmentally friendly practices in developing countries. In the context of implementing SSMPs, a SWOT analysis can be used to assess their implementation potential and identify key factors influencing their success. SWOT analyses consider both internal and external factors, which are further categorized into Strengths (S), Weaknesses (W), Opportunities (O), and Threats (T). The selected sustainable practices are reviewed based on previous studies [12]. Strength factors highlight the advantages and positive aspects of implementing these practices for stormwater management, while weakness factors identify the disadvantages or barriers associated with their implementation. Opportunity factors highlight the positive opportunities that can arise from implementing these practices in the future, while threat factors identify potential risks or challenges that may occur. By referring to previous studies, a SWOT analysis provides valuable references for identifying the relevant SWOT factors to be used in surveys. Identifying and analysing these factors is an important part of project management and helps in developing strategies

to maximize strengths and opportunities while minimizing weaknesses and threats [103]. Previous studies have shown that strength and opportunity factors reflect positive outcomes in terms of the operation and performance of sustainable practices. On the other hand, weakness and threat factors are often associated with knowledge gaps, a lack of experts, cost estimation challenges, and community perceptions and acceptance.

Strength factors indicate a positive performance of SSMPs in terms of water quantity and water quality control, while weakness factors highlight challenges related to knowledge gaps, a lack of experts, and cost estimations. It is important to note that weakness factors do not necessarily imply technical performance issues with the practices. Additionally, these findings indicate that the implementation of SSMPs can lead to various benefits across multiple aspects, which are categorized as opportunity factors. Threat factors primarily stem from community perceptions and acceptance, rather than the risks associated with the performance of the practices. By conducting a SWOT analysis, this study aims to identify and evaluate the internal and external factors that can influence the successful implementation of sustainable stormwater practices in Asian countries. This analysis provides valuable insights into the strengths, weaknesses, opportunities, and threats associated with these practices, contributing to their effective implementation and overall stormwater management. This understanding will help in developing strategies and recommendations to maximize strengths and opportunities while addressing weaknesses and mitigating threats, leading to the successful adoption of sustainable stormwater practices in the region.

3.1. Questionnaire Survey

The development of a well-designed questionnaire is a crucial step in addressing research questions and testing research hypotheses [104]. In this study, a questionnaire survey was conducted to collect data from a sample of individuals. The survey was administered using an online platform, Google Forms, which allowed for easy distribution of the survey link and monitoring of the responses by the authors. The questionnaire was designed as a checklist, focusing on the selected sustainable stormwater management practices (SSMPs) including green roofs, RHSs, grass swales, rain garden/bioretention systems, and porous pavements. The questionnaire was structured into different sections based on the SWOT categories. Each section presented a list of factors related to the respective category, as summarized in Table 6.

To measure the respondents' perspectives on the implementation of SSMPs in Asian countries, a Likert Scale with a five-point response scale was employed. The scale ranged from 1 (strongly disagree) to 5 (strongly agree). This measurement technique allowed the respondents to indicate their level of agreement or disagreement with the given factors for each SSMP. Additionally, the participants were encouraged to provide suggestions for improvement related to each variable. The data collected through the questionnaire is considered primary data and will be further analyzed to identify and propose the most preferable SSMPs for implementation.

The questionnaire comprise six sections. By employing this questionnaire survey, this study aims to gather valuable insights and opinions from the respondents regarding the feasibility and desirability of implementing SSMPs in Asian countries.

Section A: Introduction—a brief description of this study. The objectives of the survey are elaborated.

Section B: Respondent's background—this section consisted of the respondent's demographics.

Section C, D, E and F: SWOT Analysis—these sections focus on the SWOT analysis for the sustainable practices, i.e., green roofs, rain barrels, grass swales, rain gardens or bioretention systems and porous pavements. Here, the respondents provided their feedback based on a Likert scale from 1 (strongly disagree) to 5 (strongly agree).

To ensure a comprehensive and representative sample, the questionnaire was distributed to a range of stakeholders involved in stormwater management, including government agencies and private contractors or consulting engineering companies. The careful

selection of these experts was based on their demonstrated expertise and extensive experience within the realm of stormwater management. It was a strategic decision to involve such individuals, as their insights, opinions, and preferences hold immense value in the critical assessment of the feasibility of implementing sustainable stormwater management practices. Despite a concerted outreach to a multitude of companies, it is worth noting that the level of participation in the survey was somewhat limited. While many organizations were approached with an invitation to participate in this valuable research endeavor, only a select few were willing to engage actively in the survey process. This selective participation may stem from various factors, such as time constraints, competing priorities, or differing levels of interest. This hesitancy may also have arisen since their engagement in SSMPs remains somewhat modest. This context underscores the evolving nature of this critical field and the need for continued efforts to engage stakeholders in the journey towards a more sustainable and resilient stormwater management ecosystem. Nevertheless, the insights garnered from the willing participants will undoubtedly contribute significantly to advancing our understanding of sustainable stormwater management practices and the challenges associated with their implementation.

Table 6. Scope of study for SWOT analysis in questionnaire development.

	Helpful	**Harmful**
Internal origin	Strength	Weakness
	S1: The system collects and temporarily retains rainfall S2: It promotes infiltration and slows down the runoff S3: The system treats pollutants and enhances water quality S4: It improves the aesthetic appeal of the landscape S5: Provides a cost-effective solution	W1: Insufficient knowledge about the benefits and implementation of SSMPs W2: Limited availability of experts and implemented projects W3: Lack of available space to accommodate SSMPs W4: Limited policies and public awareness W5: Financial constraints and challenges in funding SSMPs projects
External origin	Opportunity	Threat
	O1: Improve and upgrade existing stormwater management infrastructure and practices O2: Develop effective solutions to address and mitigate stormwater-related issues O3: Foster active participation and involvement of local stakeholders in stormwater management initiatives O4: Research and develop innovative stormwater management procedures and technologies O5: Enable accurate estimation of the costs associated with stormwater management projects	T1: Ensuring compatibility and integration of new SSMPs with existing systems and practices T2: Addressing resistance and reluctance to adopt and accept SSMPs T3: Addressing the challenges arising from different guidance and criteria for stormwater management T4: Streamlining the process of obtaining necessary permits and approvals for implementing stormwater management projects T5: Promoting collaboration and fostering cooperation among all the stakeholders involved in stormwater management initiatives

Determining the appropriate sample size for a research study is a crucial step in ensuring the statistical validity and reliability of the results. Many formulae have been introduced to determine the sample size, in which the specific formula used in the calculation can vary depending on the type of study, the research design, and the desired level of precision. Therefore, the sample size for this study was determined using a simplified formula, as shown below, taking into consideration a desired level of precision. In this case, a precision level of $\pm 5\%$ was selected. By applying the give formula, a sample size of 125 respondents was determined to be appropriate for this study [105]. By collecting

responses from experts, this study aims to capture diverse perspectives and insights related to sustainable stormwater management. The data obtained from the sample were analyzed to evaluate the opinions, preferences, and recommendations provided by these stakeholders, contributing to the identification of the most suitable SSMPs for implementation in Asian countries.

$$n = \frac{N}{1 + N(e)^2} \quad (1)$$

where n = sample size, N = population size, e = level of precision.

3.2. Data Processing

Once the questionnaire survey was completed, an interpretation process was conducted on the collected data to identify the range of factors related to each proposed SSMP. Then, a normality test was conducted on the data before proceeding to the statistical analysis. A normality test is a statistical procedure used to determine whether a dataset follows a normal distribution [104]. Before conducting the normality test, a significance level (alpha) that represents the threshold for significance should be decided. Common choices are 0.05 or 0.01, which correspond to a 5% or 1% chance of making a Type I error, respectively. A *p*-value associated with the normality test is the key indicator of whether the data can be considered approximately normally distributed [104,105]. A *p*-value greater than the significance level suggests that the data can be considered approximately normal, while a smaller *p*-value indicates a departure from normality. In summary, normality tests are essential tools for assessing whether a dataset can be reasonably assumed to follow a normal distribution, which is a critical assumption in many statistical analyses.

4. Results and Discussion

4.1. Respondents' Details

After the completion of the online questionnaire, a total of 125 respondents participated in the survey. This indicates that the survey achieved 100% of the respondents that were for the questionnaire distribution. The target population was successfully achieved, with an equal distribution of respondents from both government agencies and private engineering companies. As illustrated in Table 7, 50% of the respondents were from government agencies, while the remaining 50% were from private engineering companies. This balanced participation from both groups is important, as they are equally involved in various stages of stormwater management systems including planning, design, management, and approval processes. Meanwhile, the distribution of the working experience among the respondents was quite even, in which most of the respondents (61.1%) had work experience between 5 and 15 years, with 31.4% falling in the 5–10 years category and 29.7% in the 11–15 years category. Approximately one quarter of the respondents (26.3%) had less than 5 years of work experience, while only 12.7% had more than 15 years. It is noteworthy that having respondents with different levels of work experience is important for this study. The distribution of the respondents' work experience was quite even; however, it is important to consider whether the distribution accurately reflects the distribution of experience levels in the field of stormwater management overall to avoid experience bias. Experienced professionals in stormwater management offer valuable insights into the practical aspects of the field. However, the participation of new graduates is equally important, as they bring a wealth of theoretical knowledge on sustainability gained during their undergraduate studies. The combination of practical experience and theoretical understanding can lead to innovative and comprehensive approaches to stormwater management.

Table 7. Demographic profiles of the respondents.

Sector	**Percentage**
Government agency	50%
Private agency	50%
Designation	**Percentage**
Developer	21.2%
Project Director/Manager/Assistant Manager	35.6%
Engineer/QAQC	43.2%
Working Experience	**Percentage**
<5 years	26.3%
5–10 years	31.4%
11–15 years	29.7%
>15 years	12.7%

4.2. Intrepretation of the Data

Table 8 shows the interpretation of the results based on the calculation previously referred to [106], while Tables 9–12 show the results for each factor.

Table 8. Interpretation of the results.

Description	**Range**
Strongly Agree	4.21–5.00
Agree	3.41–4.20
Undecided	2.61–3.40
Disagree	1.81–2.60
Strongly Disagree	1.00–1.80

Strongly Agree Agree

Table 9 shows the results for the strength (S) factors. Factor S1, "The system collects and temporarily retains rainfall", refers to the ability of the selected SSMPs to capture and store rainfall before releasing it into nearby streams [12,107]. Green roofs, grass swales, and rain garden/bioretention systems utilize plants and soil to capture and store rainfall, while porous pavements have voids that can hold water. RHSs can collect rainwater based on their size and capacity. This feature helps to control the volume of runoff flowing into water bodies such as rivers, reducing the risk of flooding and water-related problems. Factor S5, "Provides a cost-effective solution", highlights the cost-effectiveness of these practices in the long term, despite potentially higher construction costs, especially for porous pavements [108]. By implementing these practices, the flow of runoff can be controlled, minimizing issues such as clogging and flooding. The cost of repairing damage caused by floods and compensating flood victims is often much higher than the initial construction and maintenance costs of these practices. Therefore, implementing sustainable stormwater management practices can help allocate budgets towards prevention rather than remediation. Factor S2, "It promotes infiltration and slows down the runoff", indicates that the respondents agreed with the effectiveness of green roofs, grass swales, and rain garden/bioretention systems in enhancing infiltration and slowing down the flow of runoff on surfaces. These vegetation-based structures promote the infiltration of water through the soil and help reduce the speed of runoff, allowing for better water management. The presence of vegetation in these practices also contributes to factor S3, "The system treats pollutants and enhances water quality". Vegetation plays a crucial role in capturing and fil-

tering out pollutants and sediments [10,11,54]. This aspect is important for maintaining the quality of stormwater runoff and minimizing environmental impacts that lead to pollution.

Table 9. Strength (S) factor results.

Practices \ Factors	S1	S2	S3	S4	S5
Green Roofs	4.01	4.03	4.14	4.15	3.69
Rainwater Harvesting Systems (RHSs)	4.07	2.46	2.26	3.16	3.88
Grass Swales	4.09	4.10	4.21	3.97	3.81
Rain Garden/Bioretention Systems	4.12	4.19	4.21	4.21	3.74
Porous Pavements	3.85	3.35	2.31	3.59	3.77

Strongly Agree Agree

Table 10. Weakness (W) factor results.

Practices \ Factors	W1	W2	W3	W4	W5
Green Roofs	3.86	3.87	3.77	3.94	3.97
Rainwater Harvesting Systems (RHSs)	3.16	3.04	3.04	3.68	3.41
Grass Swales	3.57	3.61	3.39	3.82	3.75
Rain Garden/Bioretention Systems	3.96	3.96	3.84	3.97	3.86
Porous Pavements	3.56	3.63	3.27	3.85	3.86

Agree

Overall, the strength factors highlight the positive attributes and benefits of the selected SSMPs in terms of managing stormwater, controlling runoff, improving water quality, and ensuring cost-effectiveness. These factors demonstrate the potential of these practices to contribute to sustainable stormwater management in Asian countries. Factor S4, "It improves the aesthetic appeal of the landscape", indicates that the respondents agreed that sustainable stormwater practices, especially vegetation-based practices such as green roofs, grass swales, and porous pavements, have the potential to enhance the aesthetic appeal of the landscape of an area. By incorporating different types of vegetation, green roofs can add visual appeal and improve the aesthetics of buildings [54]. Replacing concrete drainage with grass swales can contribute to a greener and more natural landscape. Indeed, while porous pavement is not vegetation-based, it is designed with special components that create voids within the pavement. These voids allow water to flow through the pavement, promoting stormwater infiltration and reducing runoff [101]. The design of porous pavement helps mitigate the issues associated with traditional impervious surfaces by facilitating water permeability and reducing stormwater runoff volume. This feature not only facilitates stormwater management but can also contribute to an improved landscape aesthetic [101]. It is worth noting that while porous pavement can increase landscape value, it is not capable of treating pollutants to the same extent as vegetation-based practices, as mentioned in factor S3. The absence of vegetation in porous pavement limits its ability to naturally filter and remove pollutants from stormwater runoff [102]. Similarly, RHSs primarily store water rather than infiltrating it through the soil, which is why the respondents disagreed with factor S2, "It promotes infiltration and slows down the runoff", and factor S3, "The system treats pollutants and enhances water quality", for RHSs. Regarding factor S4, the respondents were undecided about RHSs. This suggests that there is still uncertainty

among the public regarding how to utilize RHSs for landscape purposes. This may be due to unattractive design options for rain barrels and a lack of information regarding the benefits of rainwater harvesting. Therefore, efforts should be made to improve the design of rain barrels and effectively communicate the benefits of RHSs to enhance their appeal and encourage their adoption. Overall, while all the selected SSMPs have the potential to increase landscape value, there are variations in their ability to enhance infiltration, treat pollutants, and improve water quality. The strengths identified in factor S4 highlight the positive impact these practices can have on the visual aesthetics and overall landscape value of an area.

Table 11. Opportunity (O) factor results.

Factors / Practices	O1	O2	O3	O4	O5
Green Roofs	4.13	4.11	4.16	4.21	4.17
Rainwater Harvesting Systems (RHSs)	4.22	4.12	4.17	4.21	4.21
Grass Swales	4.10	4.18	4.16	4.21	4.19
Rain Garden/ Bioretention Systems	4.13	4.23	4.22	4.21	4.21
Porous Pavements	4.12	4.11	4.14	4.19	4.16

Strongly Agree Agree

Table 12. Threat (T) factor results.

Factors / Practices	T1	T2	T3	T4	T5
Green Roofs	4.07	3.97	4.00	4.03	3.96
Rainwater Harvesting Systems (RHSs)	3.92	3.83	3.68	3.56	3.81
Grass Swales	4.02	3.86	3.91	3.94	3.96
Rain Garden/Bioretention Systems	4.03	3.91	3.97	3.95	4.00
Porous Pavements	3.99	3.91	3.89	3.97	3.77

Agree

Referring to Table 10, Factor W1, "Insufficient knowledge about the benefits and implementation of SSMPs", indicates that the respondents agreed with this factor for all the selected sustainable stormwater management practices, except for RHSs. This suggests that there is a general lack of knowledge and information regarding the implementation and operation of practices other than RHSs. However, it is important to note that RHSs obtained an "undecided" response for all factors except for factor W4, indicating that the respondents may not have been aware that RHSs do not require detailed knowledge or instructions for their implementation and operation. RHSs are simple structures that can be easily managed by residents without the need for extensive expertise [15]. Factor W2, "Limited availability of experts and implemented projects", in the field of stormwater management demonstrates that the respondents agreed with this factor for all the practices, indicating that there was a perceived lack of experts and implemented projects in Asian countries for green roofs, grass swales, rain gardens/bioretention systems, and porous pavements. This suggests that there is a need to strengthen the availability of experts and increase the number of implemented projects to showcase successful examples and build expertise in these practices. Sharing information about existing projects and their outcomes can help encourage the implementation of these practices and address the lack of expertise [102,107–114]. Thus, the weaknesses identified for the selected SSMPs mainly revolve

around the lack of knowledge, experts, and implemented projects. These weaknesses highlight the need for increased awareness, knowledge dissemination, and capacity building in implementing and maintaining these practices. Thus, there is an opportunity to foster the successful adoption of SSMPs in Asian countries, promoting effective water management and mitigating the impacts of urbanization and climate change if these weaknesses factors are successfully addressed.

Factor W3 "Lack of available space to accommodate SSMPs", received agreement from the respondents for green roofs and rain gardens/bioretention systems. This suggests that the respondents recognized the challenge of limited space for implementing these practices. Green roofs are more suitable for high-rise buildings with flat roof designs, while rain gardens/bioretention systems require appropriate land areas. To overcome this limitation, authorities should actively monitor and utilize any unattended vacant areas or unused spaces to maximize the implementation of SSMPs. It is worth noting that these practices can be adaptable to various spatial constraints, and their implementation can be tailored to suit the available space.

Factor W4, "Limited policies and public awareness", regarding the importance of stormwater management, received agreement from the respondents for all the practices. This indicates that there was a consensus among the respondents that there is a need for improved policies and increased public awareness regarding stormwater management. Efforts should be made to educate the public about the importance of sustainable stormwater practices and to develop policies that promote their implementation [80,101,102,107–114]. By enhancing public awareness and ensuring supportive policies, the implementation of these practices can be encouraged and facilitated.

Factor W5, "Financial constraints and challenges in funding SSMPs projects", received agreement from the respondents for all the practices, except for RHSs. This suggests that the respondents recognized the high construction and maintenance costs associated with implementing sustainable stormwater practices. It is important for authorities to carefully plan and consider the financial aspects of implementing these practices, ensuring that they are financially feasible and sustainable in the long term [80,101,107–114].

Overall, the identified weaknesses (W1–W5) in implementing sustainable stormwater management practices, as perceived by the respondents, include limited knowledge, lack of experts and implemented projects, limited available space, limited policies and public awareness, and financial issues. These weaknesses highlight the importance of knowledge dissemination, capacity building, policy development, and financial planning to address these barriers and facilitate the successful implementation of SSMPs in Asian countries.

Table 11 shows the interpretations of the opportunity (O) factors. Factor O1, "Improve and upgrade existing stormwater management infrastructure and practices", received agreement from the respondents for all the practices, except for RHSs. This statement suggests that the respondents were aware of the potential benefits of SSMPs in managing stormwater efficiently. This understanding underscores the importance of implementing sustainable stormwater management practices to achieve comprehensive and efficient management of stormwater, ensuring the sustainable use and protection of water resources in the face of urbanization and environmental challenges. In addition, implementation of SSMPs can also lead to more efficient and effective management of stormwater, resulting in improved overall system performance.

Factor O2, "Develop effective solutions to address and mitigate stormwater-related issues", received agreement from the respondents for all the practices. This indicates that the respondents perceived the construction of SSMPs as a viable long-term solution to address water-related issues and mitigate problems associated with stormwater management. By adopting these practices, the resilience and sustainability of stormwater management systems can be improved, leading to better management of water resources and reduced negative impacts on the environment [101,102,107–114].

Factor O3, "Foster active participation and involvement of local stakeholders in stormwater management initiatives", received agreement from the respondents for all

the practices. This suggests that the respondents acknowledged the importance of involving local stakeholders in the design and operation of SSMPs. Engaging stakeholders not only promotes community participation and ownership but also provides opportunities for professional development and career advancement for individuals involved in stormwater management [101,102,107–114]. By fostering collaboration and involvement, the successful implementation of these practices can be enhanced.

Factor O4, "Research and develop innovative stormwater management procedures and technologies", received agreement from the respondents. This indicates that the implementation of porous pavement has the potential to contribute to the development of new procedures and planning routines for stormwater management. The success of porous pavement can serve as a model for managing stormwater in areas with limited available space, potentially providing alternative solutions to traditional vegetated structures [101,102]. By incorporating innovative approaches and practices, stormwater management procedures can be updated and improved to achieve better outcomes.

Factor O5, "Enable accurate estimation of costs associated with stormwater management projects", received agreement from the respondents. This suggests that the successful implementation of green roofs, grass swales, and porous pavement can provide valuable insights and data for estimating the costs associated with future construction of these systems in urban areas. This includes not only the construction costs but also maintenance and repair expenses, allowing for more accurate budgeting and financial planning of stormwater management projects [80,101].

Overall, the identified opportunities (O1–O5) highlight the potential benefits and positive outcomes associated with the implementation of SSMPs in Asian countries. These opportunities include upgrading stormwater management systems, providing long-term solutions, encouraging stakeholder participation, developing new procedures, and planning routines, and enabling cost estimation. By capitalizing on these opportunities, authorities and stakeholders can work together to enhance stormwater management practices and address water-related challenges more effectively.

As referred to in Table 12, factor T1, "Ensuring compatibility and integration of new SSMPs with existing systems and practices", received agreement from the respondents. This indicates that the public may perceive the implementation of SSMPs as a challenge because they are comparing these practices with the existing conventional drainage systems. The public's familiarity with and adaptation to existing practices can create resistance to change and hinder the acceptance of new practices. Factor T2, "Addressing resistance and reluctance to adopt and accept SSMPs", received agreement from the respondents. This suggests that there may be reluctance among the public to accept and adopt sustainable stormwater practices. This reluctance could be due to various reasons, such as a lack of awareness, misconceptions, or concerns about the effectiveness or feasibility of these practices [101,102,107–114]. Overcoming this reluctance requires efforts to educate and engage the public, raise awareness about the benefits of sustainable stormwater practices, and address any misconceptions or concerns.

Factors T3 and T4, "Addressing the challenges arising from different guidance and criteria for stormwater management" and "Streamlining the process of obtaining necessary permits and approvals for implementing stormwater management projects", received agreement from the respondents. This indicates that there are challenges related to the regulatory framework and permitting processes for implementing sustainable stormwater practices. The lack of standardized guidelines or criteria across different regions, as well as the complexities involved in obtaining necessary permits or regulatory approvals, can create barriers to the widespread adoption of these practices [102,107–114]. Streamlining and simplifying the regulatory processes, providing clear guidelines, and fostering collaboration between authorities and practitioners can help address these challenges.

Factor T5, "Lack of cooperation between participants in the operations", received agreement from the respondents. This suggests that the success of implementing SSMPs relies on the cooperation and collaboration of various stakeholders involved in their opera-

tion and maintenance. A lack of cooperation and coordination between these participants can hinder the effectiveness and long-term sustainability of these practices. Encouraging and fostering collaboration among stakeholders, including government agencies, private contractors, and the public, is essential to overcome these threats.

Overall, the identified threats (T1–T5) highlight the potential barriers and challenges associated with the implementation of SSMPs in Asian countries. These threats are primarily related to public perceptions and acceptance, compatibility with existing practices, regulatory complexities, and lack of cooperation among stakeholders. To address these threats, it is important to raise awareness, provide education and outreach programs, streamline regulatory processes, establish clear guidelines, and foster collaboration among all participants involved in the operations of sustainable stormwater practices. By addressing these challenges, the implementation of these practices can be more effectively and widely adopted, leading to improved stormwater management outcomes. Table 13 provides a summary of the interpretation of the Likert scale range for the variables for each SSMP.

Table 13. Summary of the data interpretation.

Variables / Practices	Strength (S)	Weakness (W)	Opportunity (O)	Threat (T)
Green Roofs	4.00	3.88	4.16	4.01
Rainwater Harvesting Systems (RHSs)	3.17	3.27	4.19	3.76
Grass Swales	4.04	3.63	4.17	3.94
Rain Garden/Bioretention Systems	4.10	3.92	4.21	3.97
Porous Pavements	3.37	3.63	4.15	3.93

Strongly Agree Agree

Based on the Likert Scale interpretation, the respondents agreed with all the factors for both green roofs and grass swales. This indicates that these sustainable stormwater practices were viewed positively in terms of their strengths, weaknesses, opportunities, and threats. However, it is important to note that green roofs and grass swales also encountered weaknesses and threats, as identified through the survey. These weaknesses and threats need to be addressed to ensure the successful implementation of these practices. To compare these practices in terms of cost and other aspects, an evaluation of previous studies was conducted. This evaluation aimed to identify the solutions for the weaknesses and threats associated with green roofs and grass swales. Furthermore, the analysis also aimed to determine the best practice between green roofs and grass swales for implementation in Asian cities. The evaluation considered factors such as cost-effectiveness, performance in water quantity and quality control, compatibility with existing practices, and public acceptance. By conducting a comprehensive evaluation and considering these factors, a decision can be made regarding the preferred practice to be implemented. This decision will be based on the strengths, opportunities, and solutions provided by the selected practice, as well as the potential to address weaknesses and threats effectively. The evaluation and analysis provide valuable insights for decision-makers and stakeholders involved in stormwater management, helping them make informed choices and develop strategies for implementing sustainable stormwater practices in Asian countries.

4.3. Comparison between Green Roofs and Grass Swales

Green roofs and grass swales were first compared in terms of total cost by reviewing the related literature. The total cost includes the construction cost and the maintenance cost. The construction cost of sustainable stormwater practices includes all the expenses associated with the installation process, starting from the foundation work to the cost of planting vegetation. This encompasses activities such as site preparation, excavation,

grading, installation of structural components, creation of detention or retention areas, and the planting of vegetation or installation of green infrastructure elements [115]. It covers the material costs, labor costs, equipment rental, and any additional expenses required for the successful implementation of the SSMPs [115].

Due to the absence of specific guidelines on construction costs, the method and cost of construction varied depending on the intended type, design, and size/capacity of the practice being implemented. The cost estimation for the construction of sustainable stormwater practices was derived from quotes provided by landscape design businesses and values obtained from previous studies [116]. These sources were used to gather data on the costs associated with the materials, labour, equipment, and other relevant expenses for similar projects. By incorporating these quotes and values, a comprehensive cost estimation was developed to provide an approximate budget for implementing sustainable stormwater practices.

The construction costs for green roof installation include all the initial expenses associated with the process, such as waterproofing, structural components, planting of vegetation, and labor costs [116]. These costs encompass the materials, equipment, and workforce required to establish a green roof system. Additionally, maintenance costs are incurred for the routine upkeep of green roofs to ensure their optimal functioning and longevity [116]. These maintenance costs cover activities such as regular inspections, weed control, irrigation, fertilization, pruning, and general maintenance tasks to keep green roofs in good working condition. These maintenance costs are essential for preserving the functionality and aesthetic appeal of green roofs over their operational lifespan [115,116]. According to the study [115,116], the total cost is affordable according to the size and higher for a longer lifespan, but the cost varies according to the country's currency and economy. Additionally, the estimated lifespan of green roofs in Asian countries ranges from 10 to 20 years. The lifespan depends on various factors, including maintenance practices and the quality of materials used during construction [115,116]. Based on the estimated total cost and lifespan, green roofs can be considered an affordable solution for flood mitigation in Asian countries. They offer a reasonable cost in relation to their lifespan, providing long-term benefits for stormwater management. It is important to note that the actual costs may vary depending on specific project requirements, site conditions, and market factors. Conducting a detailed cost analysis and obtaining accurate quotes from local contractors is recommended for each specific project. Overall, green roofs offer a sustainable and cost-effective solution for stormwater management, contributing to flood mitigation efforts in residential areas in Asian countries.

However, there are significantly fewer previous studies discussing the total cost of implementing grass swale. Indeed, the implementation and research on grass swales may be relatively less extensive in Asian countries compared to regions with cold climates. This could be attributed to several factors, including differences in climate, cultural practices, and urban development patterns. Grass swales are commonly used in regions with abundant rainfall and permeable soil conditions, where they can effectively manage stormwater runoff. In cold climate regions, grass swales are often utilized for their snow storage and melting capabilities, which may require specific design considerations and maintenance practices. Consequently, more research and cost analysis studies have been conducted in these regions to evaluate the feasibility and cost-effectiveness of implementing grass swales. It is essential to recognize the potential benefits of grass swales in Asian countries and encourage further research and implementation to assess their feasibility, cost, and effectiveness in managing stormwater runoff in specific local contexts. Therefore, green roofs and grass swales were further compared in terms of their economic, environmental, and social benefits to propose the best practice to be implemented in Asian countries. Table 14 provides a summary of the benefits of green roofs and grass swales as referred to previous studies [117,118].

Table 14. General benefits of green roofs and grass swales according to the criteria [117,118].

Criteria	Practices	Green Roofs	Grass Swales
Economic	Energy saving	✓	✓
	Increased property value	✓	X
Environmental	Stormwater management	✓	✓
	Air quality	✓	✓
	Urban heat island mitigation	✓	✓
	Biodiversity	✓	X
Social	Green space	✓	✓
	Thermal insulation	✓	✓
	Aesthetics	✓	X

Table 14 shows that green roofs contribute to all the criteria, while grass swales are lacking in some criteria. One of the important components of a building's sustainable design is its energy use for heating and cooling [119]. This shows that both green roofs and grass swales have the potential to decrease the energy consumption of residential areas with the help of the vegetation. In addition to the energy saving aspect, both practices contribute to stormwater management, air quality, urban heat island mitigation, green spaces, and thermal insulation. It can be considered that these benefits are contributed by the presence of vegetation in both practices. In terms of stormwater management, vegetation-based structures help to maintain water quantity control by infiltrating water through the soil to slow runoff flow [10,11]. Meanwhile, in terms of water quality control, vegetation helps to improve soil quality, which is important for the treatment of pollutants and sediments. In addition, vegetation can reduce air pollution through its ability to influence the dispersal of pollutants across an area. Through photosynthesis, plants can reduce atmospheric carbon dioxide (CO_2), which eventually helps to reduce greenhouse gases and their consequences on climate changes [117]. Moreover, trees and other plants play a crucial role in cooling the environment and mitigating the urban heat island effect [117]. Vegetation provides shade and evapotranspiration, which helps to reduce surface temperatures and create a more comfortable microclimate. Trees can significantly lower temperatures by providing shade and blocking direct sunlight from hitting paved surfaces. The presence of vegetation also helps to reduce energy consumption by decreasing the need for air conditioning in buildings [118]. By incorporating more vegetation into urban areas, such as through urban forestry, green roofs, parks, and street trees, cities can effectively combat the urban heat island effect. This not only improves the quality of life for citizens but also contributes to environmental sustainability and resilience to climate change.

However, although both practices contribute to the green spaces, only green roofs can benefit the market value of a property via aesthetics, whereas grass swale fails to contribute to both criteria [117]. This is because a variety of vegetation can be used to construct green roofs, while most the grass swales are only composed of grasses. In the environmental category, the results show that both green roofs and grass swales contribute benefits in all aspects except for biodiversity. This is because, similar to the aesthetic point of view, green roofs can be constructed using a variety of plants that may attract animals, whereas grass is unable to do so. This evaluation demonstrates that green roofs are the best practice to be implemented in Asian countries, as they contribute to many benefits. There is also significant work to be done in Asian countries to evaluate the performances of green roofs in many aspects compared to grass swales and other SSMPs. However, many efforts in every aspect need to be conducted to overcomes the weakness and threat factors to achieve successful implementation of green roofs. Table 15 summarizes possible alternatives to overcome the policy barriers of implementing green roof according to the policies.

Table 15. Summary of measures for overcoming barriers to green roof implementation [115–117,119].

Policy Categories	Measures
Federal and state policies	Cities must incorporate hydrological characteristics into their planning and development processes
	Conduct an audit of existing policies and standards and make necessary amendments to include green roof implementation
	Develop standardized guidelines and regulations at the national level for the design and maintenance of green roofs
	Introduce tax exemptions or credits at both the federal and state levels for green roof materials and installations
	Implement a uniform nationwide development threshold that would activate mandatory green roof requirements
	Create effective mechanisms at all levels to facilitate communication, interaction, and coordination among government agencies as well as with external stakeholders
Innovative funding mechanisms	Implement stormwater fees and explore the possibility of allowing trading of stormwater allowances as revenue sources and incentive mechanisms
	Issue municipal green bonds to finance environmentally friendly projects and initiatives at the local level
	Implement stable policies, such as a 10–15-year fee schedule, to address uncertainties and incentivize private financiers to support green initiatives
Education, awareness, award, and recognition	Develop comprehensive education and outreach programs to increase public awareness about the advantages of green roofs, the drawbacks of conventional gray infrastructure, and how green roofs function
	Promote and encourage universities to provide research opportunities and academic courses specifically focused on green roof technologies and practices
	Implement dedicated training programs for skills and enhance the knowledge of existing staff responsible for stormwater management and other relevant functions
	Create award and recognition programs that incentivize and promote individual and social contributions towards sustainable initiatives and environmental capital

5. Conclusions

The implementation of SSMPs aims to create a more environmentally friendly stormwater management system and improve water quantity and quality control. These findings indicate that the strength factors of SSMPs lie in their ability to effectively control runoff volume and treat pollutants. The weaknesses factors are primarily related to limited knowledge, expertise, and cost estimation rather than performance issues. This suggests that these shortcomings do not pose significant barriers to implementing SSMP alternatives. Additionally, this study identified opportunities factors for achieving greater benefits in various aspects through the implementation of SSMPs. The threat factors were primarily influenced by community perceptions and acceptance. The questionnaire responses indicated that respondents generally agreed with the SWOT factors for the selected SSMPs, including green roofs, RHSs, grass swales, rain gardens/bioretention systems, and porous pavements. Among these options, green roofs and grass swales received the most support based on the respondents' evaluations. Previous studies have also highlighted the numerous benefits of green roofs over grass swales and other SSMPs, particularly in terms of water quantity and quality control. Research in Asian countries has also been conducted to evaluate the performance of green roofs compared to grass swales and other SSMPs. To overcome barriers to implementing green roofs successfully, specific measures can be taken.

Therefore, it is widely agreed that green roofs are the most favourable SSMP option for Asian countries.

Author Contributions: O.S.: Funding acquisition; F.K.A.K.: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Writing—Original Draft, Writing—Review & Editing, Visualization; S.B.: Funding acquisition; C.Y.N.: Conceptualization, Formal analysis, Writing—Review & Editing, Funding acquisition, Project administration; H.T.: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Supervision; N.A.W.Z.: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Supervision; W.S.A.: Conceptualization, Writing—Review & Editing; M.A.M.: Conceptualization, Methodology, Formal analysis, Writing—Review & Editing, Project administration. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The authors would like to express their appreciation for the 015LC0-431 Yayasan UTP research grant offered by Universiti Teknologi PETRONAS (UTP), and to M.Kh. Dulaty Taraz Regional University, Kazakhstan, for its support.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Zhang, W.; Brown, G.O.; Storm, D.E.; Zhang, H. Fly-ashamended sand as filter media in bioretention cells to improve phosphorus removal. *Water Environ. Res.* **2008**, *80*, 507–516. [CrossRef] [PubMed]
2. Mejía, A.I.; Moglen, G.E. Spatial distribution of imperviousness and the space-time variability of rainfall, run off generation, and routing. *Water Resour. Res.* **2010**, 46. [CrossRef]
3. Yao, C.; Luo, Z.; Wang, H.; Li, Q.; Zhou, H. GRACE-derived terrestrial water storage changes in the inter-basin region and its possible influencing factors: A case study of the Sichuan Basin, China. *Remote Sens.* **2016**, *8*, 444. [CrossRef]
4. Pratama, H.C.; Sinsir, T.; Chapirom, A. Green Roof Development in ASEAN Countries: The Challenges and Perspectives. *Sustainability* **2023**, *15*, 7714. [CrossRef]
5. Fund, Urban Climate Change Resilience Trust. Nature-Based Solutions for Cities in Viet Nam: Water Sensitive Urban Design. *Viet Nam.* **2019**. Available online: https://www.adb.org/publications/nature-based-solutions-cities-viet-nam (accessed on 30 October 2019).
6. Brears, R.C. Blue-green infrastructure in managing urban water resources. In *Blue and Green Cities: The Role of Blue-Green Infrastructure in Managing Urban Water Resources*; Brears, R.C., Ed.; Palgrave Macmillan: London, UK, 2018; pp. 43–61. [CrossRef]
7. Liu, L.; Jensen, M.B. Green infrastructure for sustainable urban water management: Practices of five forerunner cities. *Cities* **2018**, *74*, 126–133. [CrossRef]
8. World Wildlife Fund and US-AID. Natural and Nature-Based Flood Management: A Green Guide. 2016. Available online: https://www.worldwildlife.org/publications/natural-and-nature-based-flood-management-a-green-guide (accessed on 24 May 2017).
9. Wang, S.; Wang, H.; Deng, Y. Effect of meteorological conditions on onsite runoff control for reducing the hydrological footprint of green building. *J. Clean. Prod.* **2018**, *175*, 333–342. [CrossRef]
10. Osman, M.; Wan Yusof, K.; Takaijudin, H.; Goh, H.W.; Abdul Malek, M.; Azizan, N.A.; Ghani, A.A.; Sa'id Abdurrasheed, A. A review of nitrogen removal for urban stormwater runoff in bioretention system. *Sustainability* **2019**, *11*, 5415. [CrossRef]
11. Khadir, F.K.; Ng, C.Y.; Takaijudin, H.; Zawawi, N.A.W.; Alaloul, W.S.; Musarat, M.A. Evaluation of the Implementation of Sustainable Stormwater Management Practices for Landed Residential Areas: A Case Study in Malaysia. *Sustainability* **2023**, *15*, 10414. [CrossRef]
12. Shafique, M.; Kim, R. Retrofitting the low impact development practices into developed urban areas including barriers and potential solution. *Open Geosci.* **2017**, *9*, 240–254. [CrossRef]
13. Hamid, H.N.A.; Romali, N.S.; Rahman, R.A. Research Trends on Green Roof Applications and Materials in Green Buildings. *Constr. Technol. Archit.* **2023**, *4*, 171–180. [CrossRef]
14. Romali, N.S.; Othman, N.S.; Mohd Ramli, N.N. The Application of Green Roof for Stormwater Quantity and Quality Improvement. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *682*, 12–29. [CrossRef]
15. Kloss, C. *Managing Wet Weather with Green Infrastructure Municipal Handbook: Rainwater Harvesting Policies*; US Environmental Protection Agency: Washington, DC, USA, 2008.

16. Iman, M.I.; Ahmad, N.A. A performance review of grass swales channel in Malaysia. *Recent. Trends Civ. Eng. Built Environ.* **2022**, *3*, 663–671. [CrossRef]
17. Wang, M.; Zhang, D.; Lou, S.; Hou, Q.; Liu, Y.; Cheng, Y.; Qi, J.; Tan, S.K. Assessing hydrological effects of bioretention cells for urban stormwater runoff in response to climatic changes. *Water* **2019**, *11*, 997. [CrossRef]
18. Ramadhansyah, P.J.; Ibrahim, M.Y.M.; Rosli, H.M.; Haziman, W.I.M. A Review of Porous Concrete Pavement: Applications and Engineering Properties. *Appl. Mech. Mater.* **2014**, *554*, 37–41. [CrossRef]
19. Plate, E.J. Flood risk and flood management. *J. Hydrol.* **2002**, *267*, 2–11. [CrossRef]
20. Yang, L.E.; Bork, H.R.; Fang, X.; Mischke, S. *Socio-Environmental Dynamics along the Historical Silk Road*; Springer: Cham, Switzerland, 2019; p. 525. [CrossRef]
21. Chan, F.; Yang, L.E.; Scheffran, J.; Mitchell, G.; Adekola, O.; Griffiths, J.; Chen, Y.; Li, G.; Lu, X.; Qi, Y.; et al. Urban flood risks and emerging challenges in a Chinese delta: The case of the Pearl River Delta. *Environ. Sci. Policy* **2021**, *122*, 101–115. [CrossRef]
22. Hanson, S.; Nicholls, R.; Ranger, N.; Hallegatte, S.; Corfee-Morlot, J.; Herweijer, C.; Chateau, J. A global ranking of port cities with high exposure to climate extremes. *Clim. Chang.* **2011**, *104*, 89–111. [CrossRef]
23. Hallegatte, S.; Green, C.; Nicholls, R.J.; Corfee-Morlot, J. Future flood losses in major coastal cities. *Nat. Clim. Chang.* **2013**, *3*, 802–806. [CrossRef]
24. Yang, L.; Scheffran, J.; Qin, L.; You, Q. Climate-related flood risks and urban responses in the Pearl River Delta, China. *Reg. Environ. Chang.* **2015**, *15*, 379–391. [CrossRef]
25. Chan, F.; Gu, X.; Qi, Y.; Thadani, D.; Chen, Y.D.; Lu, X.; Li, L.; Griffiths, J.; Zhu, F.; Li, J.; et al. Lessons learnt from Typhoons Fitow and In-Fa: Implications for improving urban flood resilience in Asian Coastal Cities. *Nat. Hazards* **2022**, *110*, 2397–2404. [CrossRef]
26. Khalid, M.S.B.; Shafiai, S.B. Flood Disaster Management in Malaysia: An Evaluation of the Effectiveness Flood Delivery System. *Int. J. Soc. Sci. Humanit.* **2015**, *5*, 398–402. [CrossRef]
27. Bloemen, P.; Reeder, T.; Zevenbergen, C.; Rijke, J.; Kingsborough, A. Lessons Learned from Applying Adaptation Pathways in Flood Risk Management and Challenges for the Further Development of This Approach. *Mitig. Adapt. Strateg. Glob. Chang.* **2018**, *23*, 1083–1108. [CrossRef] [PubMed]
28. DID. *National Flood Forecasting and Warning Program*; Department of Irrigation and Drainage (DID) Malaysia: Kuala Lumpur, Malaysia, 2019.
29. Izham, M.Y.; Aznarahayu, R.; Nurul Azni, M.A.; Norashila, M.N. The River Basin Spatial Informative Nesting (E-BASIN) framework as an alternative approach for flood disaster management. In *IOP Conference Series: Earth and Environmental Science Conference: Earth and Environmental Science*; IOP Publishing: Bristol, UK, 2019; Volume 380. [CrossRef]
30. Liao, K.H. The socio-ecological practice of building blue-green infrastructure in high-density cities: What does the ABC Waters Program in Singapore tell us? *Socio-Ecol. Pract. Res.* **2018**, *1*, 67–81. [CrossRef]
31. Chan, F.; Joon, C.C.; Ziegler, A.; Dabrowski, M.; Varis, O. Towards resilient flood risk management for Asian coastal cities: Lessons learned from Hong Kong and Singapore. *J. Clean. Product.* **2018**, *187*, 576–589. [CrossRef]
32. Lim, H.S.; Lu, X.X. Sustainable urban stormwater management in the tropics: An evaluation of Singapore's ABC Waters Program. *J. Hydrol.* **2016**, *538*, 842–862. [CrossRef]
33. Texier, P. Floods in Jakarta: When the extreme reveals daily structural constraints and mismanagement. *Disast. Prevent. Manag.* **2008**, *17*, 358–372. [CrossRef]
34. Singkran, N. Flood risk management in Thailand: Shifting from a passive to a progressive paradigm. *Int. J. Disaster Risk Reduct.* **2017**, *25*, 92–100. [CrossRef]
35. Tansar, H.; Akbar, H.; Aslam, R.A. Flood inundation mapping and hazard assessment for mitigation analysis of local adaptation measures in Upper Ping River Basin, Thailand. *Arab. J. Geosci.* **2021**, *14*, 2531. [CrossRef]
36. Chen, P. Flood Impact Assessment Using Hydrodynamic Modelling in Bangkok, Thailand, Technical Report, I International Institute for Geo. 2007. Available online: https://webapps.itc.utwente.nl/librarywww/papers2007/msc/gem/pengyu.pdf (accessed on 10 August 2023).
37. Eckert, R.; Huynh, L.H.C. Climate Responsive Neighbourhoods for HCMC: Compact City vs. Urban Landscape. In *Sustainable Ho Chi Minh City: Climate Policies for Emerging Mega Cities*; Springer International Publishing: Cham, Switzerland, 2016; ISBN 978-3-319-04614-3. [CrossRef]
38. Morse, S. Post-sustainable development. *Sustain. Dev.* **2008**, *16*, 341–352. [CrossRef]
39. Lyu, H.M.; Wang, G.F.; Shen, J.; Lu, L.H.; Wang, G.Q. Analysis and GIS mapping of flooding hazards on 10 May 2016, Guangzhou, China. *Water* **2016**, *8*, 447. [CrossRef]
40. Li, Y. Protection of Shanghai from Flooding. Master's Thesis, Delft University of Technology, Delft, The Netherlands, 2015. Available online: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.874.5218&rep=rep1&type=pdf (accessed on 30 January 2015).
41. Kundzewicz, Z.W.; Budhakooncharoen, S.; Bronstert, A.; Hoff, H.; Lettenmaier, D.; Menzel, L.; Schulze, R. Coping with variability and change: Floods and droughts. *Nat. Resour. Forum* **2002**, *26*, 263–274. [CrossRef]
42. Chan, F.; Mitchell, G.; McDonald, A.T. Flood risk appraisal and management in mega-cities: A case study of practice in the Pearl River Delta, China. *Water Pract. Technol.* **2012**, *7*, 1–9. [CrossRef]

43. Wang, Z.Y.; Hu, S.; Wu, Y.; Shao, X. Delta processes and management strategies in China. *Int. J. River Basin Manag.* **2003**, *1*, 173–184. [CrossRef]
44. Ku, H.; Maeng, J.H.; Cho, K. Climate change impact on typhoon-induced surges and wind field in coastal region of South Korea. *J. Wind Eng. Ind. Aerodyn.* **2019**, *190*, 112–118. [CrossRef]
45. Zhai, G.; Sato, T.; Fukuzono, T.; Ikeda, S.; Yoshida, K. Willingness to pay for flood risk reduction and its determinants in Japan. *J. Am. Water Resour. Assoc.* **2007**, *42*, 927–940. [CrossRef]
46. Nguyen, M.T.; Sebesvari, Z.; Souvignet, M.; Bachofer, F.; Braun, A.; Garschagen, M.; Schinkel, U.; Yang, L.E.; Nguyen, L.H.; Hochschild, V.; et al. Understanding and assessing flood risk in Vietnam: Current status, persisting gaps, and future directions. *J. Flood Risk Manag.* **2021**, *14*, e12689. [CrossRef]
47. Jongman, B.; Koks, E.E.; Husby, T.G.; Ward, P.J. Increasing flood exposure in the Netherlands: Implications for risk financing. *Nat. Hazards Earth Syst. Sci.* **2014**, *14*, 1245–1255. [CrossRef]
48. VanWoert, N.D.; Rowe, D.B.; Andresen, J.A.; Rugh, C.L.; Fernandez, R.T.; Xiao, L. Green Roof Stormwater Retention: Effects of Roof Surface, Slope, and Media Depth. *J. Environ. Qual.* **2005**, *34*, 1036–1044. [CrossRef]
49. Ismail, W.Z.W.; Abdullah, M.N.; Hashim, H.; Rani, W.S.W. An overview of green roof development in Malaysia and a way forward. In *AIP Conference Proceedings*; AIP Publishing: Long Island, NY, USA, 2018. [CrossRef]
50. Hanway, C.C. Hardscaping 101: Green Roofs. Gardenista. 2015. Available online: https://www.gardenista.com/posts/hardscaping-101-green-roofs/ (accessed on 26 May 2015).
51. Shahmohammad, M.; Hosseinzadeh, M.; Dvorak, B.; Bordbar, F.; Shahmohammadmirab, H.; Aghamohammadi, N. Sustainable green roofs: A comprehensive review of influential factors. *Environ. Sci. Pollut. Res.* **2022**, *29*, 78228–78254. [CrossRef]
52. Kok, K.H.; Mohd Sidek, L.; Chow, M.F.; Zainal Abidin, M.R.; Basri, H.; Hayder, G. Evaluation of green roof performances for urban stormwater quantity and quality controls. *Int. J. River Basin Manag.* **2015**, *14*, 1–7. [CrossRef]
53. Da Silva, M.; Najjar, N.K.; Hammad, A.W.A.; Haddad, A.; Vazquez, E. Assessing the Retention Capacity of an Experimental Green Roof Prototype. *Water* **2020**, *12*, 90. [CrossRef]
54. Krishnan, R.; Ahmad, H. Influence of Low Growing Vegetation in Reducing Stormwater Runoff on Green Roofs. *Int. J. High-Rise Build.* **2014**, *3*, 1–6. [CrossRef]
55. Shahid, K.A.; Sulaiman, M.A.; Rahman, W.A.; Zukri, A. Palm oil clinker as drainage layer in green roof system under Malaysia climatic conditions. *J. Eng. Technol.* **2014**, *5*, 27–37.
56. Ayub, K.R.; Ghani, A.A.; Zakaria, N.A.; Shaharudin, S. Efficiency of intensive green roofs in high intensity rainfall for stormwater treatment: Selection of vegetations. In Proceedings of the 36th TAHR Word Congress, Hague, The Netherland, 28 June–3 July 2015; Volume 36, pp. 6730–6735.
57. van Spengen, J. *The Effects of Large-Scale Green Roof Implementation on the Rainfall-Runoff in a Tropical Urbanized Subcatchment: A Singapore Case Study*; Delft University of Technology: Delft, The Netherlands, 2010; p. 200.
58. Han, S.L.; Segovia, E.; Ziegler, A.D. Water quality impacts of young green roofs in a tropical city: A case study from Singapore. *Blue-Green. Syst.* **2013**, *3*, 145–163. [CrossRef]
59. Vijayaraghavan, K.; Joshi, U.M.; Balasubramanian, R. A field study to evaluate runoff quality from green Roofs. *Water Res.* **2012**, *46*, 1337–1345. [CrossRef]
60. Shafique, M. A Review of the Bioretention System for Sustainable Storm Water Management in Urban Areas. *Mater. Geoenviron.* **2016**, *63*, 227–236. [CrossRef]
61. Shafique, M.; Kim, R.; Kyung Ho, K. Green Roof for Stormwater Management in a Highly Urbanized Area: The Case of Seoul, Korea. *Sustainability* **2018**, *10*, 584. [CrossRef]
62. Shin, E.; Kim, H. Analysing Green Roof Effects in an Urban Environment: A Case of Bangbae-dong, Seoul. *J. Asian Archit. Build.* **2015**, *14*, 315–322. [CrossRef]
63. Shafique, M.; Kim, R.; Rafiq, M. Green roof benefits, opportunities and challenges—A review. *Renew. Sustain. Energy Rev.* **2018**, *90*, 757–773. [CrossRef]
64. Zhang, Q.; Miao, L.; Wang, X.; Liu, D.; Zhu, L.; Zhou, B.; Sun, J.; Liu, J. The capacity of greening roof to reduce stormwater runoff and pollution. *Landsc. Urban. Plan.* **2015**, *144*, 142–150. [CrossRef]
65. Berndtsson, J.C.; Emilsson, T.; Bengtsson, L. The influence of extensive vegetated roofs on runoff water quality. *Sci. Total Environ.* **2006**, *355*, 48–63. [CrossRef] [PubMed]
66. Berndtsson, C. Green roof performance towards management of runoff water quantity and quality. *Ecol. Eng.* **2010**, *36*, 351–360. [CrossRef]
67. Liu, C.; Li, Y.; Li, J. Geographic information system-based assessment of mitigating flash-flood disaster from green roof systems. *Comput. Environ. Urban. Syst.* **2017**, *64*, 231–331. [CrossRef]
68. Cuong, D.V.; Nguyen, V.; Dang, H. Evaluation of Storm-Water Runoff Control by Green Roofs: A Case Study in Hanoi, Vietnam. In Proceedings of the Water and Environment Technology Conference, Sapporo, Japan, 22–23 July 2017.
69. Orozco, C.R.; Madriaga, D.A.D. Assessment of Green Roofs in the Philippines Using Sustainability Indicators and Cost-Benefit Analysis. *Int. J. Environ. Stud.* **2021**, *79*, 810–821. [CrossRef]
70. Ratu, J.F.; Attoza, A. Rainwater Harvesting System: An Alternative Way of Water Supply. In Proceedings of the Conference: 5th International Conference on Advances in Civil Engineering (ICACE-2020), Chattogram, Bangladesh, 4–6 March 2021; pp. 43–49.

71. Hashim, H.; Hudzori, A.; Yusop, Z.; Ho, W.S. Simulation based programming for optimization of large-scale rainwater harvesting system: Malaysia case study. *Resour. Conserv.* **2013**, *80*, 1–9. [CrossRef]
72. Shaheed, R.; Mohtar, W.H.M.W. Potential of using rainwater for potable purpose in Malaysia with varying antecedent dry intervals. *J. Teknol.* **2014**, *72*, 57–61. [CrossRef]
73. Importance of Water Recycling and Zero Discharge System in Hospitals. 2020. Available online: https://healthcareknowledgesathi.blogspot.com/2020/04/importance-of-water-recycling-and-zero.html (accessed on 23 April 2020).
74. Rainwater Harvesting. Appropedia, The Sustainability Wiki. Available online: https://www.appropedia.org/Rainwater_harvesting (accessed on 29 May 2023).
75. Shaaban, A.; Appan, A. Utilising rainwater for non-potable domestic uses and reducing peak urban runoff in Malaysia. In Proceedings of the 11th International Rainwater Catchment Systems Conference, Mexico City, Mexico, 25–29 August 2003.
76. Areerachakul, N. The Potential of Using Rainwater in Thailand; Case study Bangsaiy Municipality, Ayutthaya. *J. Sustain. Dev. Energy Water Environ. Syst.* **2013**, *1*, 213–226. [CrossRef]
77. Kim, K.; Yoo, C. Hydrological modeling and evaluation of rainwater harvesting facilities: Case study on several rainwater harvesting facilities in Korea. *J. Hydrol. Eng.* **2009**, *14*, 545–561. [CrossRef]
78. Hu, M.C.; Zhang, X.Q.; Chen, G. Analysis of potential of urban roof rainwater utilization. *Resour. Environ. Yangtze Basin* **2012**, *21*, 489–493.
79. Magno-Ballesteros, M. *Land Use Planning in Metro Manila and the Urban Fringe: Implications on the Land and Real Estate Market*; Philippine Institute for DevelopmentStudies Discussion Paper Series No. 2000-20; PIDS: Makati City, Philippines, 2000.
80. Ismail, M.L.; Musa, S.M.S.; Kasim, N.; Zainal, R. MSMA Implementation Factors in Integrated Stormwater Management. *IOP Conf. Ser. Earth Environ. Sci.* **2022**, *1022*, 12068. [CrossRef]
81. Ekka, S.A.; Rujner, H.; Leonhardt, G.; Blecken, G.-T.; Viklander, M.; Hunt, W.F. Next generation swale design for stormwaterrunoff treatment: A comprehensive approach. *J. Environ. Manag.* **2021**, *279*, 1–15. [CrossRef] [PubMed]
82. Gavric, S.; Leonhardt, G.; Osterlund, H.; Marsalek, J.; Viklander, M. Metal enrichment of soils in three urban drainage grassswales used for seasonal snow storage. *Sci. Total Environ.* **2021**, *760*, 144136. [CrossRef] [PubMed]
83. Shammizi, N.Q.; Siti, F.M.R. The Effectiveness of Swale Drainage in Terms of Pollutant Removal and Rate of Infiltration. *J. Kejuruter.* **2018**, *1*, 11–16. [CrossRef]
84. Yusof, M.; Al-Gheethi, A.; Daniel, D. Assessment of Storm Water Quality in Grass Swale by Using Sand Filter Media: A Case Study at UTHM Campus. *Int. J. Eng. Technol.* **2018**, *7*, 176–179. [CrossRef]
85. Shafique, M. Evaluating the Capability of Grass Swale for the Rainfall Runoff Reduction from an Urban Parking Lot, Seoul, Korea. *Int. J. Environ. Res. Public Health* **2018**, *15*, 537. [CrossRef]
86. Gong, Y.; Yin, D.; Liu, C.; Li, J.; Shi, H.; Fang, X. The influence of external conditions on runoff quality control of grass swale in Beijing and Shenzhen, China. *Water Pract. Technol.* **2019**, *14*, 482–494. [CrossRef]
87. Li, H.; Li, K.; Zhang, X. Performance Evaluation of Grassed Swales for Stormwater Pollution Control. *Procedia Eng.* **2016**, *154*, 898–910. [CrossRef]
88. Davis, A.P. Field performance of bioretention: Hydrology impacts. *J. Hydrol. Eng.* **2008**, *13*, 90–95. [CrossRef]
89. Vijayaraghavan, K.; Biswal, B.K.; Adam, M.G.; Soh, S.H.; Tsen-Tieng, D.L.; Davis, A.P.; Chew, S.H.; Tan, P.Y.; Babovic, V.; Balasubramanian, R. Bioretention systems for stormwater management: Recent advances and future prospects. *J. Environ. Manag.* **2021**, *292*, 112766. [CrossRef]
90. Pivetta, G.G.; Tassi, R.; Piccilli, D.G.A. Evaluating bioretention scale effect on stormwater retention and pollutant removal. *Environ. Sci. Pollut. Res.* **2023**, *30*, 15561–15574. [CrossRef] [PubMed]
91. Rusli, N.; Majid, M.R.; Ludin, A.N.M. Low Impact Development: An Approach to Retrofit Conventional Stormwater Management System. In Proceedings of the 5th Southeast Asian Technical University Consortium (SEATUC) Symposium, Hanoi University of Science and Technology, Hanoi, Vietnam, 24–25 February 2011.
92. Nuha, N.E.; Mohd Sidek, L. Stormwater Quality Performance using Bioretention System: A Preliminary Study. *J. Intelek* **2015**, *9*, 43–50. Available online: https://ir.uitm.edu.my/id/eprint/35301/1/35301.pdf (accessed on 20 September 2023).
93. Xia, J.; Wang, H.; Stanford, R.L. Hydrologic and water quality performance of a laboratory scale bioretention unit. *Front. Environ. Sci. Eng.* **2018**, *12*, 1–9. [CrossRef]
94. Jiang, C.; Li, J.; Li, H.; Li, Y. Experiment and simulation of layered bioretention system for hydrological performance. *J. Water Reuse Desalination* **2019**, *9*, 319–329. [CrossRef]
95. Zhang, L.; Ye, Z.; Shibata, S. Assessment of Rain Garden Effects for the Management of Urban Storm Runoff in Japan. *Sustainability* **2020**, *12*, 9982. [CrossRef]
96. Fu, D.; Pan, T.; Xu, C.; Junyu, Z.J. Control performance of bioretention system on non-point source pollution in typical Chinese rural areas of Southeastern China. *Ecol. Eng.* **2023**, *190*, 106934. [CrossRef]
97. Wan, Z.; Li, T.; Liu, Y. Effective nitrogen removal during different periods of a field-scale bioretention system. *Environ. Sci. Pollut. Res.* **2018**, *25*, 17855–17861. [CrossRef]
98. Wang, J.; Chua, L.H.; Shanahan, P. Evaluation of pollutant removal efficiency of a bioretention basin and implications for stormwater management in tropical cities. *Environ. Sci. Water Res. Technol.* **2017**, *3*, 78–91. [CrossRef]
99. Jaber, F. Bioretention and permeable pavement performance in clay soil. In Proceedings of the International Low Impact Development Conference 2015: LID: It Works in All Climates and Soils, Houston, TX, USA, 19–21 January 2015; pp. 151–160.

100. Hamzah, M.O.; Jaafar, Z.F.M.; Ahmad, F. Laboratory Simulation of Porous Asphalt Parking Lot System and Mix Design for Storm Water Management. *J. Eng. Sci. Technol.* **2013**, *8*, 217–232.
101. Zainordin, N. Barriers in the Incorporation and Implementation of Sustainable Development in Malaysia. In *Conference: 7th International Borneo Business Conference (IBBC) 2016*; University Malaysia Sabah: Kota Kinabalu, Malaysia, 2016.
102. Sidek, I.D.L.M.; Ghani, A.A.; Azazi, N.; Zakaria, D.M.; Desa, N.; Othman, N. An Assessment of Stormwater Management Practices Using MSMA Manual in Malaysia. In Proceedings of the 1st International Conference on Managing Rivers in the 21st Century: Issues & Challenges, Teluk Bahang, Malaysia, 21–23 September 2004; pp. 479–495. Available online: https://www.academia.edu/6065373/An_Assessment_of_Stormwater_Management_Practices_Using_MSMA_Manual_in_Malaysia (accessed on 20 September 2023).
103. Gürel, E. Swot Analysis: A Theoretical Review. *J. Int. Soc. Res.* **2017**, *10*, 994–1006. [CrossRef]
104. Matthews, B.; Ross, L. *Research Methods*; Longman: Harlow, UK, 2010.
105. Yamane, T. *Statistics: An Introductory Analysis*, 2nd ed.; Harper and Row: New York, NY, USA, 1976.
106. Benhima, M. How to interpret Likert scale data. *Educational Video*. Available online: https://youtu.be/WoANW7maoM0 (accessed on 8 February 2022).
107. Bohman, A.; Glaas, E.; Karlson, M. Integrating Sustainable Stormwater Management in Urban Planning: Ways Forward towards Institutional Change and Collaborative Action. *Water* **2020**, *12*, 203. [CrossRef]
108. Nathan, G. A non-essentialist model of culture. *Int. J. Cross Cult. Manag.* **2015**, *15*, 101–124. [CrossRef]
109. Webber, J.L.; Fletcher, T.; Farmani, R.; Butler, D.; Melville-Shreeve, P. Moving to a future of smart stormwater management: A review and framework for terminology, research, and future perspectives. *Water Res.* **2022**, *218*, 118409. [CrossRef] [PubMed]
110. Shishegar, S.; Duchesne, S.; Pelletier, G. Optimization methods applied to stormwater management problems: A review. *Urban Water J.* **2018**, *15*, 1–11. [CrossRef]
111. Chang, C.K.; Zakaria, N.A.; Othman, M.R. Integrated Urban Stormwater Management and Planning for New Township Development in Malaysia. *MATEC Web Conf.* **2018**, *246*, 01112. [CrossRef]
112. Abdullah, A.M. Gap Analysis Report: Flood Disaster Management in Malaysia. 2017. Available online: https://mywp.org.my/wp-content/uploads/2020/11/Final-Malaysia.GAP-Analysis-Flood-Disaster_17July2017.pdf (accessed on 17 July 2017).
113. Jayasooriya, V.; Perera, V.; Muthukumaran, S. Rainwater as an alternative drinking water source for the Chronic Kidney Disease of Uncertain etiology (CKDu) prone areas: A case study for Girandurukotte, Sri Lanka. *J. Water Sanit. Hyg. Dev.* **2020**, *10*, 539–548. [CrossRef]
114. Bidhendi, G.N.; Zand, A.L.; Heir, A.V.; Bihendi, A.M. Prioritizing of Strategies for The Ecological Design of Urban Waste Transfer Stations Using SWOT Analysis. *J. Environ. Sci. Stud. (JESS)* **2022**, *5*, 2665–2672.
115. Shin, E.; Kim, H. Benefit–Cost Analysis of Green Roof Initiative Projects: The Case of Jung-gu, Seoul. *Sustainability* **2019**, *11*, 3319. [CrossRef]
116. Yeo, K.; Jung, Y. An Analysis of Effect of Green Roofs in Urbanized Areas on Runoff Alleviation and Cost Estimation. *Seoul Inst.* **2013**, *14*, 161–177.
117. Gheorghe, I.F.; Barbu, I. The Effects of Air Pollutants on Vegetation and the Role of Vegetation in Reducing Atmospheric Pollution. *Impact Air Pollut. Health Econ. Environ. Agric. Sources* **2011**, *29*, 241–280.
118. U.S. Environmental Protection Agency (EPA). Environmental Topics: Climate Change. Available online: https://www.epa.gov/climate-change (accessed on 1 September 2023).
119. Ulubeyli, S.; Arslan, V.; Kazaz, A. Comparative Life Cycle Costing Analysis of Green Roofs: The Regional Aspect. *Period. Eng. Nat. Sci. (PEN)* **2017**, *5*, 135–144. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.