A Quantitative Approach to Selecting SUDS for Flood Resilience in Can Tho City, Mekong Delta

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Article Info	Abstract
	This study develops a quantitative framework for selecting Sustainable Urban Drainage Systems (SUDS) to enhance flood resilience in an area formerly under Soc Trang City, now administratively designated as Phu Loi Ward, Soc Trang urban area of Can Tho City, Mekong Delta, a region vulnerable to urban inundation due to low elevations (1.5–1.6 m) and inadequate drainage infrastructure. This is the first framework of its kind applied in Can Tho or in secondary Mekong Delta cities, offering a novel, context-specific approach to flood-risk management. The framework integrates geospatial analysis using QGIS, runoff estimation via the SCS-CN method, and a multi-criteria SUDS Selection Score (SSS) evaluating flood mitigation performance, cost-effectiveness, feasibility, and co-benefits as urban cooling, cultural value. Applied to the Phan Boi Chau Street pilot, the framework assessed SUDS measures, including bio-swales, permeable pavements, and storage tanks. Results demonstrate significant runoff reduction and improved urban aesthetics, validated through stakeholder engagement with Khmer communities through site surveys. The framework's replicability offers a scalable model for flood-prone cities in the Mekong Delta and beyond, supporting evidence-based, community-sensitive flood management planning.

1. Introduction

Urban flooding, intensified by climate change, threatens low-lying cities in Vietnam's Mekong Delta, where heavy rainfall, sea-level rise, and urbanization converge [1]. Soc Trang urban area with over 200,000 residents, faces severe inundation in central streets like Phan Boi Chau, where low elevations (1.5–1.6 m) and undersized drainage systems exacerbate flooding [2]. Climate projections estimate flooding rates of 4.33% to 63.96% under 50–100 cm sea-level rise, with water levels potentially reaching 2.0 m in the city center [3]. These conditions disrupt livelihoods and disproportionately affect vulnerable Khmer communities [4].

Sustainable Urban Drainage Systems (SUDS), such as bio-swales, permeable pavements, and underground storage tanks, mitigate runoff while offering co-benefits like groundwater recharge and urban cooling [5]. However, Vietnam's SUDS adoption lags, with policies historically prioritizing centralized drainage over localized infiltration [6]. A pilot project on Phan Boi Chau Street, featuring bio-swales, permeable sidewalks, and 35.4 m³ storage tanks, highlights the potential for SUDS in Phu Loi Ward but underscores the need for systematic selection criteria [6]. This study addresses the gap by developing a quantitative framework for SUDS selection, leveraging

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QGIS for geospatial mapping, SCS-CN runoff estimation, and a SUDS Selection Score (SSS) to evaluate flood mitigation, cost-effectiveness, feasibility, and co-benefits.

In this research, the framework diverges from prior SUDS selection approaches in two key ways. First, while many previous methods predominantly focus on technical criteria — such as infiltration capacity or cost — this framework explicitly integrates geospatial mapping, runoff estimation, and stakeholder preferences to reflect both physical conditions and community priorities. Second, it combines these components into a unified, quantitative scoring system (SSS) that can be applied to context-specific sites, addressing a methodological gap in guiding decision makers toward tailored, multi-objective solutions. By extending the SUDS selection process beyond purely technical factors and framing it within a participatory, data-informed approach, this framework aims to fill a crucial gap in developing equitable and effective flood resilience strategies for low-lying, rapidly urbanizing area like Phu Loi Ward.

This research seeks to answer: How can a quantitative framework, integrating geospatial mapping, runoff estimation, and stakeholder-driven scoring, optimize the selection of SUDS to enhance flood resilience in Phu Loi Ward? The objectives are to: (1) develop a framework using QGIS, SCS-CN, and SSS; (2) apply it to study area via the Phan Boi Chau pilot; (3) assess its effectiveness against local flooding challenges; (4) engage stakeholders, including local communities, for equitable outcomes; and (5) provide a replicable model for Mekong Delta cities, aligned with Vietnam's Mekong Delta Regional Plan 2021–2030 [7]. This framework aims to empower planners to build resilient, sustainable urban systems.

2. Literature Review

Studies from Vietnam and Southeast Asia underscore Sustainable Urban Drainage Systems (SUDS) as viable approaches to mitigating flood risks under changing climate conditions [5], [8]. SUDS components — including permeable pavements, green roofs, infiltration basins, and underground storage — can be tailored to different land uses and soil conditions [8], [9]. Furthermore, a range of methods, from multi-criteria decision-making to GIS-assisted scoring, has been applied to select and prioritize SUDS techniques based on criteria such as flood mitigation, cost, maintenance, land availability, and co-benefits [10].

Globally, SUDS have successfully been integrated into flood-risk strategies in both developing and developed cities. The "sponge city" initiatives in Ningbo, China, for example, combine permeable materials and infiltration facilities to absorb excess rainwater and reduce flood peaks [8]. European cities have adopted multi-functional SUDS designs to balance flood control, water quality improvement, and green space enhancement [10]. Nonetheless, these solutions face operational issues — clogging, reduced infiltration during heavy rain — and must be maintained and tailored to local conditions [9].

Rapid urbanization, climate change, and policy gaps exacerbate flood risks and challenge existing infrastructure. Urban expansion has led to dramatic increases in impervious land and runoff; for example, in Snohomish, USA, impervious cover grew by 255% over 34 years, while in some Chinese cities it jumped by over 50% within a single decade. SUDS can help absorb excess water, recharge groundwater, and create green spaces, although seasonal conditions and soil characteristics may affect their performance [9].

In Vietnam, policy initiatives and pilot projects have demonstrated the potential of SUDS to control flooding and enhance climate resiliency. The "Flood Proofing and Drainage for Medium-sized Coastal Cities in Viet Nam" (FPP) program supported permeable pavements and infiltration basins in Quang Ngai, Long Xuyen, Rach Gia, and Ca Mau [11]. Furthermore, policy documents — including QCVN 01:2021/BXD and Decision 589/QĐ-TTg — reflect growing recognition of SUDS, although institutional and financial barriers, weak incentives for private implementation, and limited awareness remain.

Case studies from Rach Gia and Ca Mau show measurable benefits from SUDS, ranging from reduced flood depth to improved amenity and water quality [12]. Local perspectives underscore the value of these solutions to communities, aligning with international perspectives on SUDS' ability to provide multiple benefits — not just flood control but also recreation, ecosystem services, and climate adaptability [12].

Quantitative frameworks for SUDS selection are critical to optimizing performance, cost-efficiency, and feasibility. Geospatial tools like QGIS enable spatial analysis of flood risk, land use, and soil permeability, as demonstrated in flood-risk studies in the Mekong Delta [9]. Runoff estimation methods, such as the Soil Conservation Service Curve Number (SCS-CN) approach, quantify SUDS impacts using land use and rainfall data, which is especially useful in data-scarce regions [10]. Multi-criteria decision analysis (MCDA), including scoring systems, integrates flood mitigation, cost, and co-benefits — a process frequently applied in European SUDS projects [10], [13]. The CIRIA Benefits Estimation Tool (2019) further guides practitioners through a structured process to monetize benefits, reflecting context-specific conditions and confidence in the data.

Stakeholder engagement is recognized as a key to designing context-specific solutions, particularly in culturally rich and vulnerable communities. Tran et al. [8] highlight the necessity for frameworks to account for land subsidence and groundwater conditions, which are often neglected in policy and practice. Nevertheless,

existing frameworks frequently omit socio-cultural factors or are ill-adaptation to local conditions [10], indicating a clear gap in developing an integrated, stakeholder-sensitive approach.

While SUDS offer promising solutions, research gaps remain in developing quantitative frameworks tailored to resource-constrained, flood-prone regions like Phu Loi Ward. Currently, many frameworks do not adequately account for the perspectives of stakeholders or for unique local conditions [8]. To fill this gap, this study proposes a Sustainable Urban Drainage System Selection Score (SSS) framework that integrates geospatial mapping (QGIS), runoff estimation (SCS-CN), and stakeholder criteria. By aligning with Vietnam's Mekong Delta Regional Plan 2021–2030 (Decision 589/QĐ-TTg, 2016), this framework aims to provide a scalable, context-specific tool to guide policy makers and practitioners in choosing appropriate SUDS strategies for Phu Loi Ward and other similar urban area, thereby strengthening flood resiliency and sustainable development.
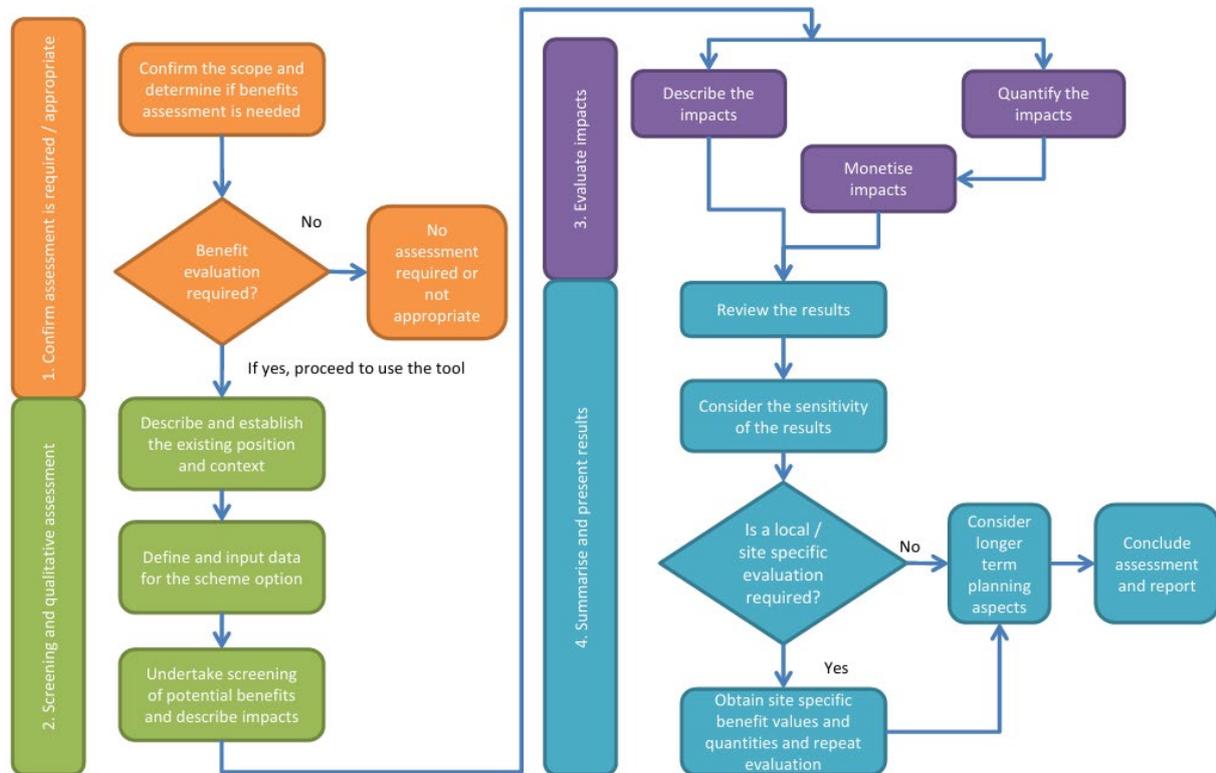

Fig. 1 *Benefits estimation tool – valuing the benefits of blue-green infrastructure (B£ST) [13]*

3. Methodology

This study develops a practical and systematic approach for selecting appropriate SUDS measures to mitigate urban flooding in Phu Loi Ward, located in the Mekong Delta region of Vietnam. The methodology integrates spatial analysis, hydrological estimation, and community-based input to identify suitable SUDS types and optimal placement within the urban context (Figure 2). The selection process involves the use of geographic information system (GIS) mapping to assess existing land use and topographical conditions. Hydrological calculations, including runoff volume and peak flow estimates, are conducted to evaluate the effectiveness of proposed interventions. Additionally, local stakeholder engagement is incorporated to align technical solutions with community needs and practical implementation constraints.
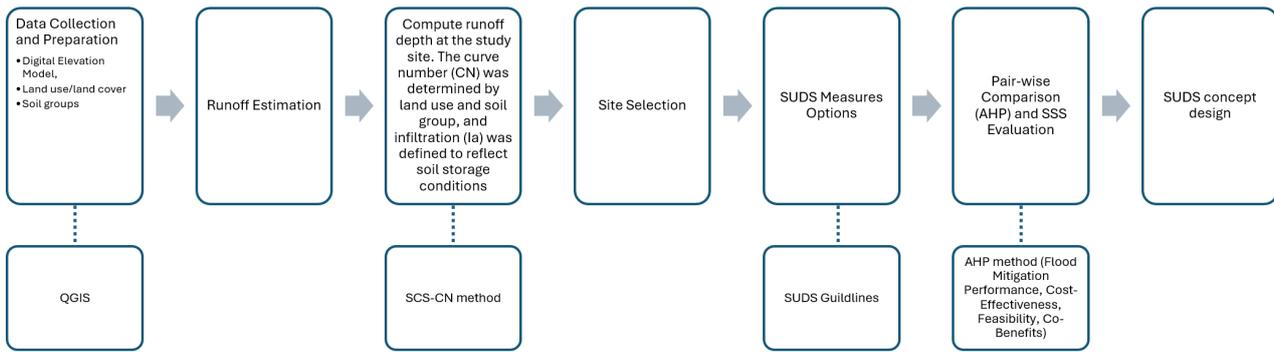
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Fig. 2 *Research process diagram*

Phu Loi Ward formerly under Soc Trang City was selected as the case study for this research based on two key considerations. First, the city is the site of a recently completed pilot SUDS project (Phan Boi Chau street) (Figure 3), implemented under the technical assistance of the German Development Cooperation (GIZ) as part of a broader initiative in the Vietnamese Mekong Delta VMD [6]. Second, Phu Loi Ward has also been identified as one of the focus urban areas for the "Sponge City" study under the Mekong Climate Resilience Programme (MCRP), also supported by GIZ. These factors make Phu Loi Ward a representative and timely case for evaluating the applicability and effectiveness of SUDS in enhancing urban flood resilience in the VMD context. The methodology was applied as a pilot study along Phan Boi Chau Street, a flood-prone urban area. Selected SUDS interventions included vegetated swales, permeable pavements, and underground detention tanks. These solutions were evaluated based on their potential to reduce surface runoff, enhance water infiltration, and improve local drainage performance.
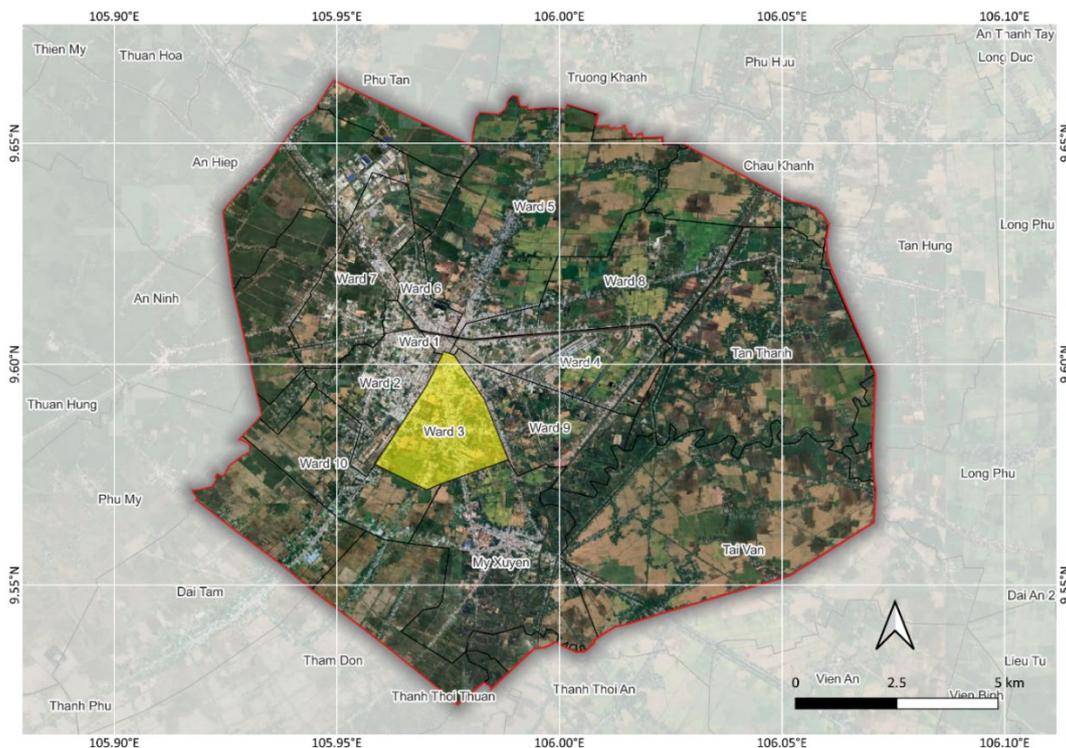

Fig. 3 *Soc Trang urban area map and location of SUDS pilot project (Ward 3)*

3.1 Geospatial Mapping Collection

To perform the geospatial analysis and identify priority areas for Sustainable Urban Drainage Systems (SUDS) implementation in Phu Loi Ward, a range of publicly available geospatial datasets were collected and processed. The main datasets, their sources, resolution, and methods of collection are summarized in Table 1. The 30 m resolution Copernicus GLO-30 DEM was downloaded from the Sentinel Hub and clipped to the boundary of Soc Trang urban area. The DEM was used to generate slope, flow direction, and other topographic attributes relevant

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to infiltration and runoff (Figure 4). Sentinel-2 multispectral satellite imagery with 10 m resolution was accessed and processed through the Google Earth Engine (GEE) platform. A Support Vector Machine (SVM) algorithm was trained with ground control points to classify land cover into classes such as water, vegetation, agricultural land, and built-up areas (Land Use/Land Cover (LULC), Figure 5). The soil raster was sourced from HYSOGs 250m (Harmonized Soil Grids), downloaded from ISRIC's SoilGrids portal. The data were clipped to match the study area's boundary and rescaled to align with other datasets.

Table 1 *Geospatial mapping collection summary*

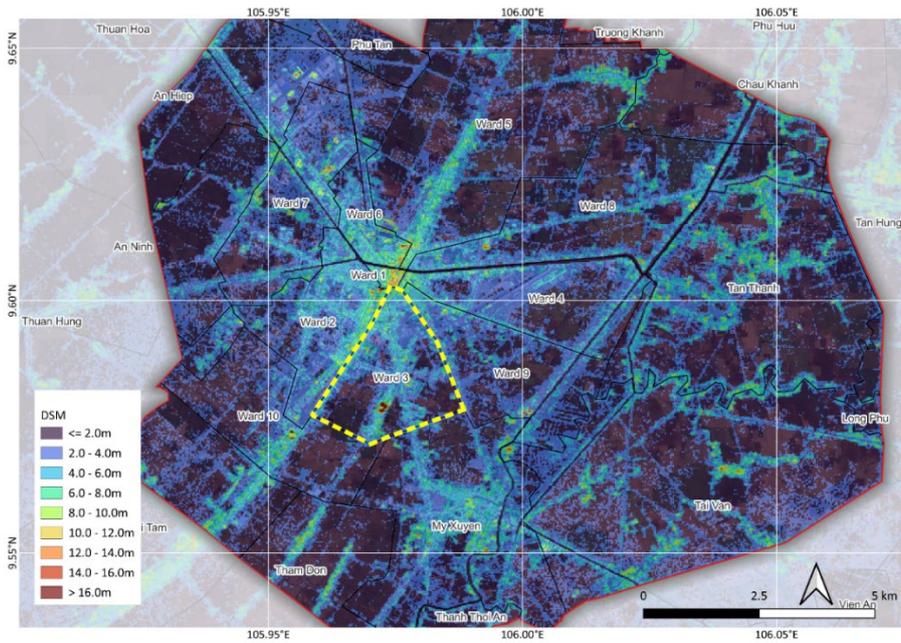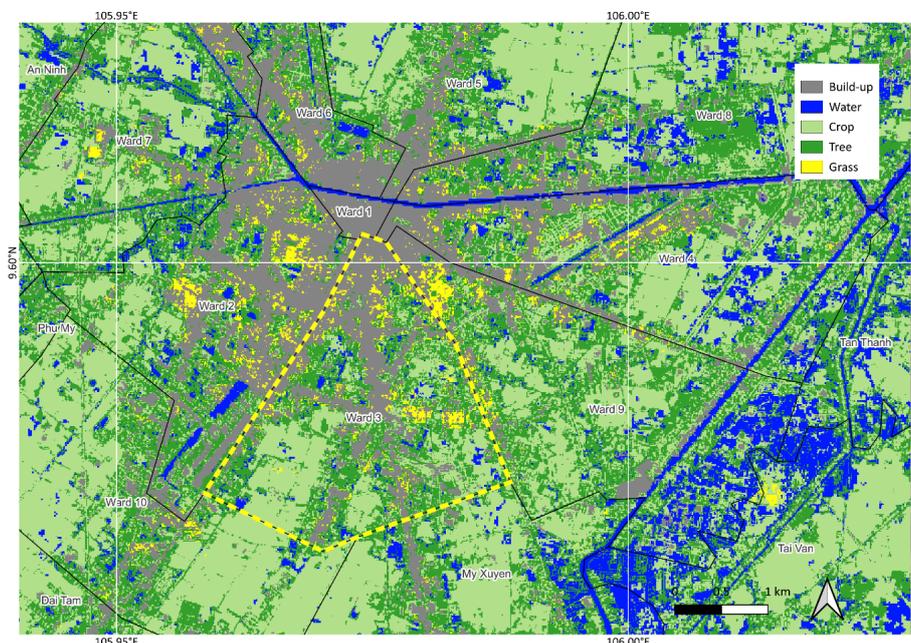|	Source	Resolution	Method
DEM	Copernicus GLO-30	30 m	Sample and clipped to study area
LULC	Sentinel-2	10 m	SVM classified with GEE platform
Soil Type	HYSOGs 250m	250 m	Sample and clipped to study area

Fig. 4 *Soc Trang urban area DEM map*

Fig. 5 *Soc Trang urban area LULC map*

Penerbit
UTHM

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3.2 Runoff Estimation

To quantify direct runoff under both pre- and post-SUDS scenarios, the Soil Conservation Service Curve Number (SCS-CN) method was applied. This approach assesses flood mitigation potential by estimating excess runoff from a given rainfall event, considering land use, soil characteristics, and antecedent soil conditions [14]. SCS-CN formula (1) with parameters below:

- Q is direct runoff (mm).
- P is total Rainfall depth (mm).
- I_a is Initial abstraction (typically $I_a = 0.2S$)
- S is soil storage

$$Q = \frac{(P - I_a)^2}{P - I_a + S}, S = \frac{25400}{\text{CN}} - 254 \tag{1}$$

In the Runoff Estimation process (Figure 6), Curve Number values were assigned based on land use/land cover. Built-up areas typically exhibit higher curve numbers due to low infiltration, while vegetation and agricultural land have lower curve numbers reflecting greater infiltration. Soil groups were classified into Hydrologic Soil Groups A–D according to infiltration characteristics. HYSOGs 250m soil data and local soil reports [15] were used to determine HSG for the study area. Design rainfall depth was sourced from Vietnam's Meteorological Administration [2]. A 110 mm/hr rain event was used to reflect a heavy rain scenario for flood-risk analysis.

Table 2 *Curve number values based on USDA TR-55*

LULC	Soil HSG-C	Soil HSG-D
Build-up	92	94
Crop	78	83
Water	100	100
Grass	61	69
Tree	55	60

Classify land use and soil groups from LULC and HYSOGs 250m data → Assign curve numbers (CN) for each combination of land use and soil group → Calculate storage (S) and initial abstraction (I_a) for each pixel → Apply SCS formula to compute direct runoff depth across the study area
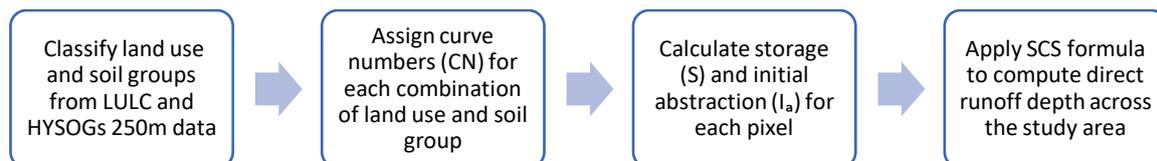
Fig. 6 *Runoff estimation process*

3.3 SUDS Selection Score (SSS)

The SSS is a multi-criteria decision-making tool that evaluates SUDS measures based on technical performance and local priorities, incorporating stakeholder input. Criteria:

- Flood Mitigation Performance (FMP): A composite indicator that integrates both the baseline runoff conditions (derived from SCS-CN) and the specific mitigation capacity of each SUDS measure.
- Cost-Effectiveness (CE): Cost per unit runoff reduced (VND/m^3), based on local construction costs (Soc Trang City People's Committee, 2023).
- Feasibility (F): Assessed via land availability, zoning compatibility scored on a 0–1 scale.
- Co-Benefits (CB): Includes urban cooling, biodiversity, and cultural value, weighted by community preferences (0–1 scale).

Criteria are normalized to a 0–1 scale and weighted using the Analytic Hierarchy Process (AHP) [16]. According to survey results with local authority (Department of Construction and the City Urban Management Division), the pair-wise matrix as Table 3 below.

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Table 3 *AHP pair-wise matrix by survey results*

	FMP	CE	F	CB
FMP	1	3	2	4
CE	1/3	1	1/2	2
F	1/2	2	1	3
CB	1/4	1/2	1/3	1

Therefore, the criteria weights are calculated as Table 4:

Table 4 *The weights of SSS criteria*

	FMP	CE	F	CB	Average
FMP	0.47	0.46	0.52	0.4	0.47
CE	0.16	0.15	0.13	0.2	0.18
F	0.24	0.31	0.26	0.3	0.24
CB	0.12	0.08	0.09	0.1	0.11

As the calculated weights above, SSS is computed as:

$$SSS = 0.47 \cdot FMP + 0.18 \cdot CE + 0.24 \cdot F + 0.11 \cdot CB \tag{2}$$

3.4 Application to Case Studies of Phu Loi Ward

As part of Can Tho City after the administrative merger, the area formerly known as Phu Loi Ward, Soc Trang urban area—was classified as a Type II urban area, with a population exceeding 200,000 and an urban density of about 2,672 people/km² [2]. Despite ongoing infrastructure development, the city remains vulnerable to flooding. In 2022, many roads in the city center experienced severe flooding, particularly toward the end of the year, due to heavy rainfall combined with high tides [6]. For implementation of the pilot SUDS project, the Local People's Committee proposed 3 locations: (1) the intersection of Nguyen Dinh Chieu, (2) the intersection of Phan Boi Chau and Nguyen Thi Minh Khai, and (3) the intersection of Le Duan and Le Hong Phong (Figure 7). The study will apply the above method to assess and prioritize these locations for SUDS implementation.
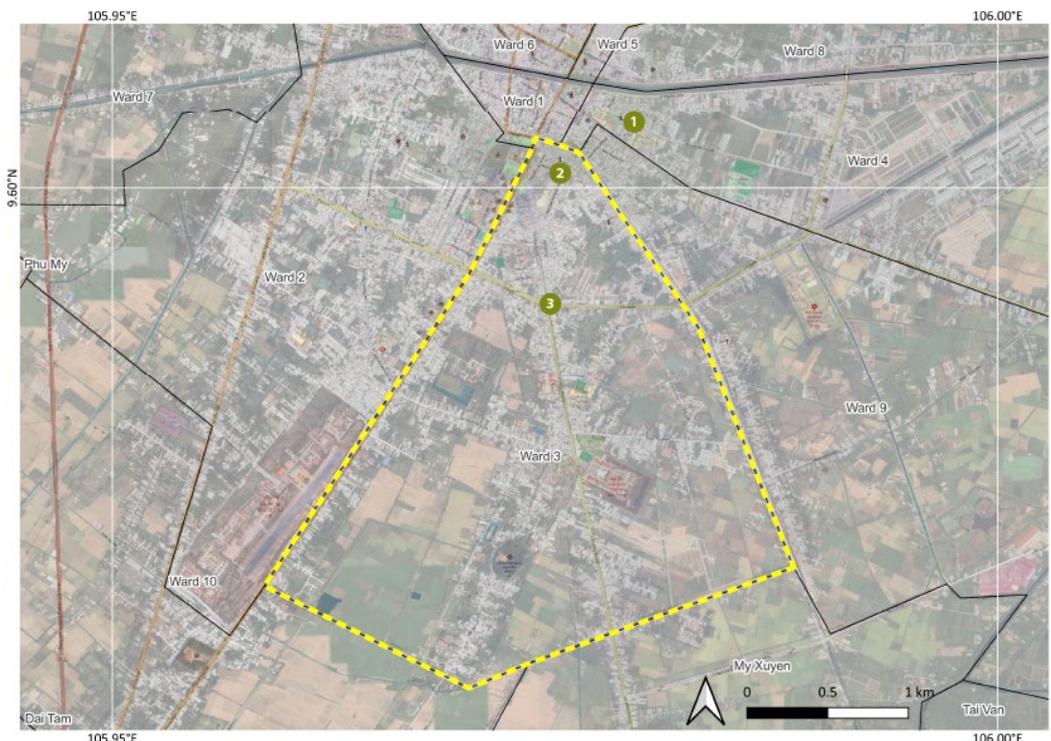
Fig. 7 *Proposed location for SUDS pilot project in Phu Loi Ward*

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The framework is applied to the SUDS pilot project based on the funding of approximately €55,000. According to the National SUDS Guidelines [17], these measures are proposed:

- Bio-Swales: Vegetated channels with perforated pipes for infiltration and conveyance.
- Permeable Pavements: Self-interlocking pavers with gravel sub-base to reduce runoff.
- Soakaway: Excavated, gravel-filled structures that allow rainwater to permeate directly into the soil.
- Storage Tanks: Underground modules for detention and infiltration.
- Rain garden: Shallow, landscaped depressions that capture and absorb rainwater from nearby impervious areas.

Once the SUDS location has been selected through runoff estimation and mapping, the appropriate SUDS measures will be chosen using the SSS method.

4. Results

The curve number calculator result is show in Table 5 and Figure 8. Location 1 has a lower CN, indicating higher infiltration and lower runoff potential. Location 2 and 3 higher curve numbers, reflecting predominantly built-up land cover on clay soil (D). This means infiltration is poor and runoff is expected to be much greater.

Table 5 *Curve number sampling result*

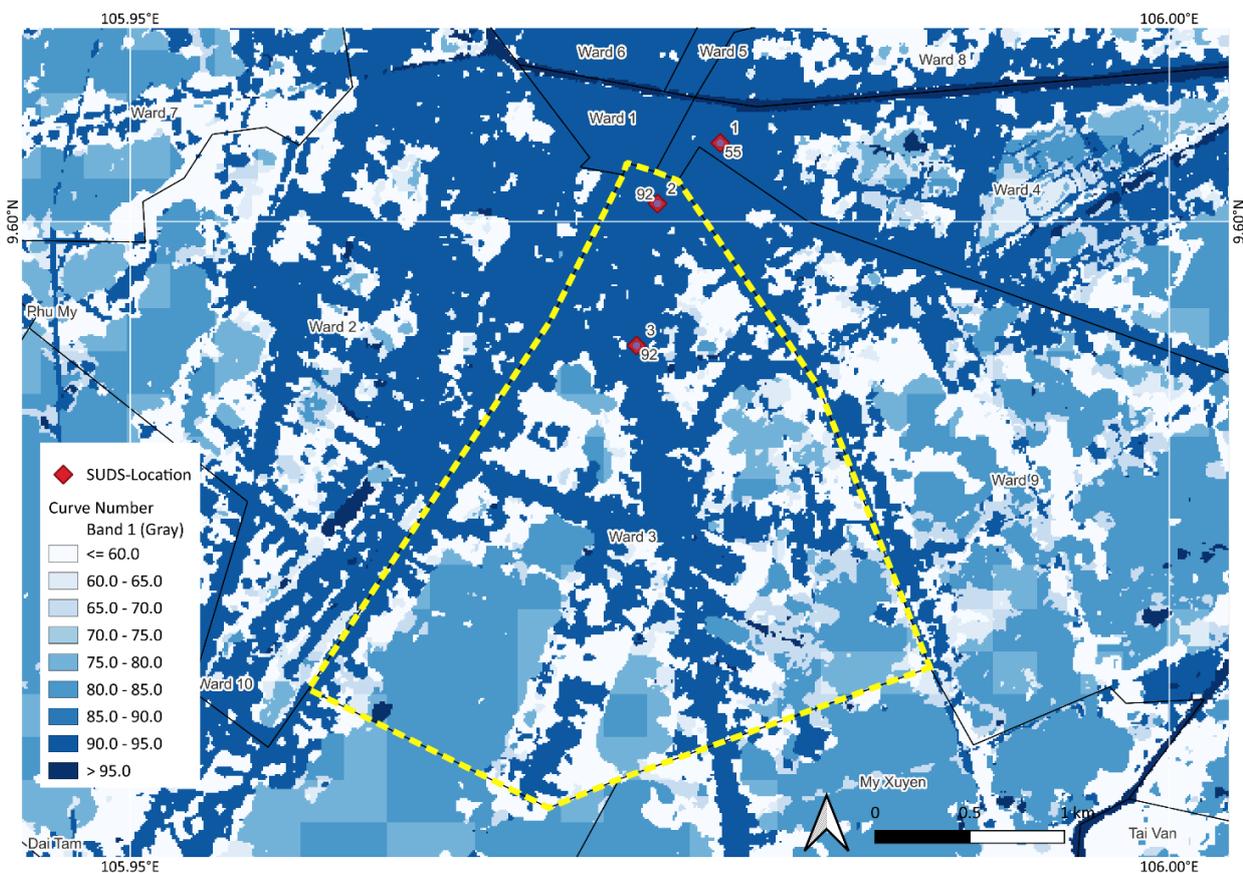| Location	Curve Number (CN)
(1) Intersection of Nguyen Dinh Chieu	55
(2) Intersection of Phan Boi Chau and Nguyen Thi Minh Khai	92
(3) Intersection of Le Duan and Le Hong Phong	92

Fig. 8 *Curve number map of Phu Loi Ward and SUDS location result*

According to Formular (1), the direct runoff (Q, mm) of 3 location are calculated as:

- Location 1: Q = 16.92mm
- Location 2: Q = 87.2mm
- Location 3: Q = 86.2mm

With the highest direct runoff value (87.2mm), Location (2) – Phan Boi Chau street is selected for SUDS pilot project. On Phan Boi Chau Street, flooding occurs primarily due to the road's lower elevation — about 1.50–1.60 m — in comparison to adjacent road levels. Additionally, the water collection pits on both sidewalks are relatively small, and the existing drainage network, which comprises 400x500 mm box drains and 600 mm-diameter pipes, has limited dimensions and is prone to clogging. This restricts its ability to convey runoff efficiently during heavy rain. The pilot SUDS site is located on Phan Boi Chau Street, between Thu Khoa Huan and Nguyen Thi Minh Khai in Phu Loi Ward. The total length of this road segment is 60 m. The left side pavement has a width of 2.5 m, while the right side is 3.5 m wide, and the road itself spans 11 m in width. These dimensions provide enough space to implement a combination of Sustainable Urban Drainage System measures — including bioswale, permeable pavement, and underground storage — alongside the existing road and sidewalk infrastructure.

Table 6 *SUDS measures options for selected location*

Option	SUDS Measure Combination	Rationale
1	Permeable Pavement + Soakway	Permeable pavement to reduce surface runoff and a soakway to promote infiltration in clay soil.
2	Bioswale + Storage Tank + Permeable Pavement	Bioswale assists in conveyance and infiltration; storage tank temporarily holds excess flow during heavy rain.
3	Rain Garden + Soakway + Permeable Pavement	Rain garden adds infiltration and ecological benefits, permeable pavement reduces flow at the source, and soakway provides additional infiltration.

Bases on Table 6, the SSS framework will be use to calculate the potential option.
Flood Mitigation Performance (FMP):
- Option 1 (Permeable Pavement + Soakway): Score 0.6 — permeable pavement and soakway together allow infiltration and temporary storage, reducing flood peaks to a medium degree.
- Option 2 (Bioswale + Storage Tank + Permeable): Score 0.9 — this combination provides multi-layered storage and infiltration, yielding a strong reduction in flood peaks.
- Option 3 (Rain Garden + Soakway + Permeable): Score 0.7 — rain garden adds infiltration and retention, although it is slightly less effective than bioswale plus storage.

Cost-Effectiveness (CE):
- Option 1: Score 0.7 — permeable pavement and soakway are cheaper and fairly effective, yielding a good cost-benefit.
- Option 2: Score 0.5 — adding a storage tank and bioswale increases total cost, reducing cost-efficiency.
- Option 3: Score 0.6 — rain garden is less expensive than storage but not as cost-effective as permeable pavement + soakway.

Feasibility (F):
- Option 1: Score 0.9 — permeable pavement and soakway are relatively simple to construct and maintain in the available space.
- Option 2: Score 0.7 — bioswale and storage will require more space, specialized components, and maintenance, reducing feasibility.
- Option 3: Score 0.8 — rain garden is fairly simple to implement and maintain, although it needs soil infiltration conditions and some green space.

Co-Benefits (CB)
- Option 1: Score 0.5 — permeable pavement and soakway provide infiltration, but their co-benefits (such as beautification or habitat) are limited.
- Option 2: Score 0.7 — bioswale adds green space, storage provides hidden benefits, and permeable pavement contributes to infiltration; together yielding higher co-benefit.
- Option 3: Score 0.6 — rain garden adds green space and beautification, while permeable pavement assists infiltration — yielding a medium co-benefit.

Table 7 *SUDS measures options scoring by SSS method*

Option	SUDS Measure Combination	FMP	CE	F	CB	SSS
1	Permeable Pavement + Soakway	0.6	0.7	0.9	0.5	0.68
2	Bioswale + Storage Tank + Permeable Pavement	0.9	0.5	0.7	0.7	0.76
3	Rain Garden + Soakway + Permeable Pavement	0.7	0.6	0.8	0.6	0.70

To test the robustness of the results, we performed a brief sensitivity analysis by increasing the weight of cost by 20%. The results show a slight reshuffling in the SUDS ranking — permeable pavement scored higher due to its lower implementation cost, while storage tanks fell in priority. Nevertheless, the overall preferred options remained broadly consistent, suggesting that the framework is reasonably robust to reasonable fluctuations in criteria weights. Nonetheless, this highlights the influence subjective preferences can have on final decisions and underscores the importance of stakeholders' input in choosing appropriate weights.

5. Discussion

This study developed a simple and practical framework to choose the best Sustainable Urban Drainage Systems (SUDS) for Phu Loi Ward to fight flooding. Using maps with QGIS, water runoff calculations with SCS-CN, and a scoring system called SUDS Selection Score (SSS), we tested the method on Phan Boi Chau Street. The framework helped pick SUDS like bio-swales, permeable pavements, and underground tanks for Phan Boi Chau Street, a place with bad flooding because of low land and small drains.

According to Table 7, Option 2 scored highest with 0.76, outperforming the other options. This combination effectively integrates infiltration, temporary storage, and permeable surfacing to maximize flood mitigation while offering additional co-benefits. The main advantages of this option lie in its ability to absorb and retain a large volume of stormwater, reducing flood peaks and pressure on the existing drainage system. The bioswale adds green space and helps filter sediments and nutrients, the storage tank provides underground retention for excess runoff, and permeable pavement further assists infiltration. However, there are drawbacks to consider: the solution is more complex and costly to implement, requiring careful design, specialized components, and maintenance to keep the bioswale, storage, and permeable pavement fully functional. Nonetheless, given its strong overall performance and adaptability to the site conditions, Option 2 emerges as the most appropriate SUDS combination for the pilot area on Phan Boi Chau Street in Phu Loi Ward, Can Tho City.
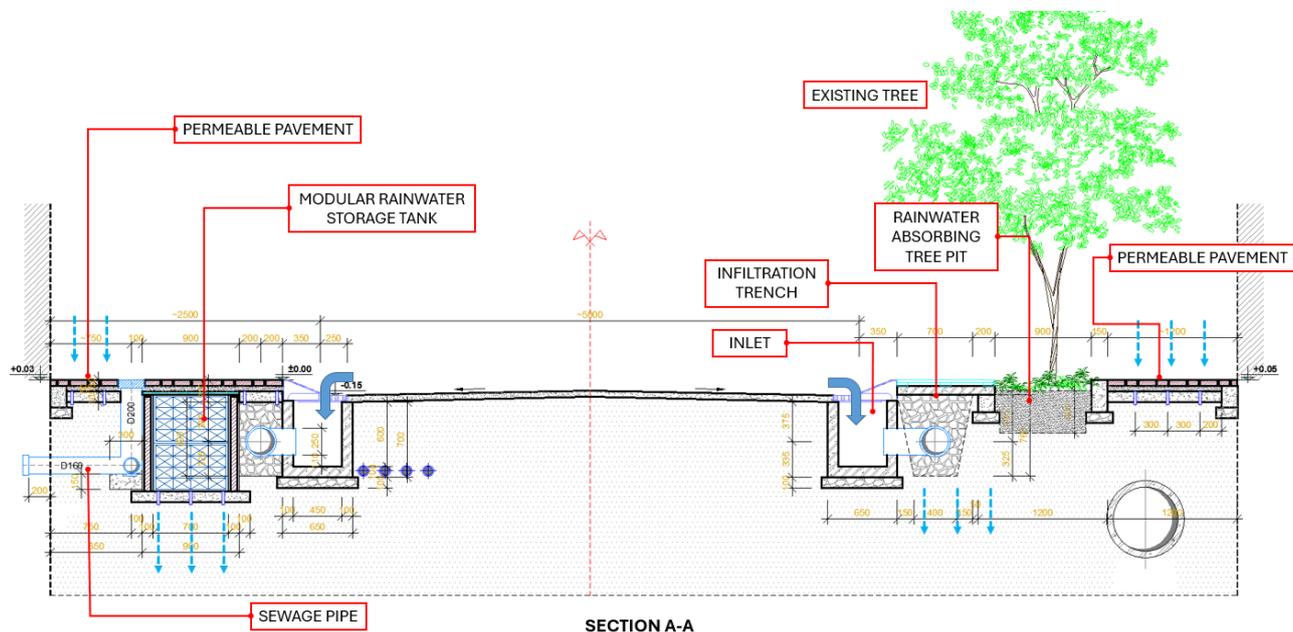

Fig. 9 *SUDS pilot project in Phan Boi Chau Street –Concept design with option 2*

Figure 9 illustrates the pilot project design concept, showing how these SUDS can cut water runoff, hold extra rain, and make the street nicer. The tanks store water during big storms, and the bio-swales let water sink into the ground slowly. Local people, including Khmer families, like how these solutions keep streets dry and add green spaces. This method fits local's needs, where floods can cover 4.33% to 63.96% of the city if sea levels rise. It also matches Vietnam's plan to make the Mekong Delta stronger against climate change. By scoring SUDS for flood control, cost, ease of building, and extra benefits like cooling or beauty, the framework helps city leaders make smart choices. It shows how small projects like Phan Boi Chau can grow to help the whole city.

The framework presented in this study offers a practical and adaptable approach for selecting Sustainable Urban Drainage Systems (SUDS) in a context like Phu Loi Ward. It utilizes QGIS and the SCS-CN method — both easily accessible and cost-effective — to estimate runoff and identify priority locations. The scoring process (SSS) successfully integrates technical criteria, cost-efficiency, and community preferences by adding weight to flood mitigation while considering financial and social factors. Besides, the survey results from the Department of

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Construction and the Local Urban Management Division played a key role in shaping the AHP criteria weights. During a workshop, representatives from these authorities were asked to compare criteria in pairs — flood mitigation performance, cost-efficiency, feasibility, and co-benefits — reflecting their expert judgment and policy priorities for flood management in Phu Loi Ward. The aggregated responses revealed a strong emphasis on flood mitigation performance and feasibility, while cost-efficiency and co-benefits were rated slightly lower. The survey process provided valuable insight into local priorities and preferences, helping to produce a set of criteria weights that are well aligned with the city's strategic goals and implementation capabilities. The Phan Boi Chau pilot project demonstrated the framework's applicability: permeable pavement, bioswale, and storage components collectively reduced runoff and improved flood resilience. The results are in line with experiences from other Mekong Delta cities, suggesting this framework can be a valuable tool for flood-risk management across the region.

Despite these achievements, the framework has several limitations that should be addressed in future applications. The accuracy of runoff estimates depends largely on the resolution and completeness of soil and land cover data. The case study relied on a 30 m Digital Elevation Model (DEM) and 250 m soil maps, which may omit small-scale depressions and infiltration patterns that affect flow paths and storage. Furthermore, soil characteristics were derived from global datasets at 250 m resolution, which may not fully reflect local variability. To account for these uncertainties, a sensitivity analysis was performed by resampling the DEM to 10 m and validating infiltration coefficients against in situ soil samples. Although finer resolution and more detailed soil data slightly influenced runoff estimates, the overall ranking of SUDS options remained robust.

Another limitation is the lack of validation against observed runoff. Due to the absence of flow measurements or flood depth recordings for the Phan Boi Chau pilot area, it was not possible to directly compare the model's results with actual conditions. Consequently, while the framework provides a useful comparative tool for evaluating SUDS options, these results should be interpreted with some caution. Future studies could be strengthened by collecting field data to calibrate and validate the model's predictions, thereby improving confidence in its applicability.

Additionally, future applications would benefit from higher-resolution data and field-verified infiltration measurements to produce more accurate, site-specific scores. Furthermore, while scoring criteria reflect a range of priorities, stakeholders may weigh these factors differently, adding subjective dimensions to the decision process. Although community workshops were held to align perspectives, further engagement may be required to reconcile conflicting preferences. The framework also focuses primarily on present conditions and does not account for future stressors — such as land subsidence or climate change — that may undermine its long-term performance. To enhance robustness and applicability, future research should incorporate forward-looking scenarios, finer-resolution data, and trial applications in a range of contexts.

Compared to other approaches, such as Ningbo's "Sponge City" initiatives in China [10], this framework offers a more tailored and flexible tool for flood-risk mitigation in small and medium-sized cities within the Mekong Delta context. The Ningbo model primarily focuses on large-scale infrastructure and policy regimes to absorb and reuse rainwater across a whole city, reflecting its resources, scale, and administrative capabilities. In contrast, our framework integrates geospatial mapping, runoff estimation, and stakeholder scoring to identify and prioritize site-specific SUDS interventions in a more granular, cost-effective, and participatory way. Importantly, this approach is designed to be adaptable to local conditions — soil characteristics, land use, flood-risk profile, and community preferences — and can be applied in different contexts with varying data availability and financial resources. Furthermore, by employing a multi-criteria scoring system alongside QGIS and SCS-CN, the framework not only quantifies flood mitigation but also considers co-benefits and stakeholder priorities, which is often missing in more top-down models. Consequently, this framework is well-suited for small to medium-sized Southeast Asian cities that face unique climate risks and policy constraints, offering a scalable, adaptable, and community-informed tool for flood-risk reduction.

6. Conclusion

This research demonstrates how a quantitative framework, integrating geospatial mapping (QGIS), runoff estimation (SCS-CN), and stakeholder-driven scoring (SSS), can effectively guide the selection of Sustainable Urban Drainage Systems (SUDS) to enhance flood resilience in Phu Loi Ward, Can Tho City. Applying this framework to the Phu Loi Ward SUDS pilot area, the study successfully (1) identified appropriate SUDS components based on local conditions and criteria; (2) evaluated their flood mitigation potential, cost-efficiency, and maintenance requirements; (3) incorporated stakeholder perspectives to reflect community preferences; and (4) provided a systematic, adaptable approach for choosing SUDS in a medium-sized, flood-prone urban area. Importantly, this framework aligns with the goals of Vietnam's Mekong Delta Regional Plan 2021–2030, offering a scalable tool that can help planners respond to climate impacts while optimizing resources and strengthening resiliency.

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However, the framework has some limitations. The accuracy of its results depends on the completeness and resolution of soil, land use, and rainfall data. Furthermore, subjective judgments in scoring criteria and weightings may affect the final selections. To enhance its robustness and applicability, future studies should incorporate forward-looking scenarios, finer-resolution data, and a more participatory approach that involves a broader range of stakeholders in the decision-making process.

Overall, this framework provides a valuable, adaptable, and context-specific tool for flood-risk management and for designing Sustainable Urban Drainage Systems in Phu Loi Ward, Can Tho City and other coastal cities in the Mekong Delta. It underscores the potential of a systematic, multi-criteria approach to help practitioners, planners, and policy makers move toward more resilient and sustainable flood management solutions.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design and data collection:** *Trong Nhan Huynh;* **draft manuscript preparation:** *Ho Tuyet Ngan Le;* **analysis and interpretation of results:** *Trong Nhan Huynh, Hong Tien Nguyen. All authors reviewed the results and approved the final version of the manuscript.*

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