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Resident Perceptions of Nature-Based Solutions for Flood Mitigation in Phnom Penh, Cambodia

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ABSTRACT

Nature-based solutions (NBS) involve the sustainable maintenance, management, and restoration of natural or modified ecosystems. Flooding is a major problem in Phnom Penh, Cambodia, and has significant social and economic ramifications. This study tries to suggest creative solutions that support human welfare and biodiversity while simultaneously resolving social problems by adopting NBS. An online survey using convenience and snowball sampling was conducted to assess the openness of Phnom Penh residents to adopting NBS for flood mitigation in their homes or buildings. The survey investigated perceptions of NBS effectiveness based on previous knowledge and flood risk perception. Results revealed a strong correlation between perceived efficacy and willingness to adopt NBS. Specifically, flood risk perception and prior knowledge significantly influenced the perceived effectiveness of NBS. Key findings indicate that high installation and maintenance costs, lack of awareness, limited space, cultural factors, and perceived ineffectiveness are primary barriers to NBS adoption. Additionally, specific regional factors contribute to reluctance in certain areas of Phnom Penh. To overcome these barriers, the study recommends that the Cambodian government and other stakeholders invest in public education campaigns to raise awareness about the benefits of NBS. Financial incentives and subsidies should be provided to reduce the economic burden on residents. Furthermore, integrating NBS into urban planning and infrastructure development is crucial to enhance community resilience against floods.

Keywords: Nature-Based Solutions; Pluvial Flood; Flood Mitigation

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1. Introduction

Developing countries, most notably in Asia, have experienced rapid urbanization that has created a variety of environmental challenges [1]. Phnom Penh, similar to many rapidly growing cities in developing countries, faces a range of urban problems and challenges. These issues can affect the quality of life of the residents and the overall sustainability of the city. One of the most significant challenges to Phnom Penh's urban development is its inadequate infrastructure. City drainage systems are often outdated and insufficient to handle the increasing demand. This has led to urban flooding problems that affect residents' quality of life [2]. Torrential rains have been described as creating an unbearable drainage system. Urban flooding has become a pressing issue in cities worldwide, including Phnom Penh. This stems from both natural and anthropogenic factors. Heavy rainfall, especially during the monsoon season, can overwhelm urban drainage systems. Climate change has exacerbated this problem by increasing the frequency and intensity of rainfall. Anthropogenic activities, such as rapid urbanization, have also worsened the situation. Construction often removes natural drainage systems, such as wetlands, reducing the city's ability to manage water. Additionally, outdated infrastructure and a lack of public education on responsible waste disposal have contributed to flooding. These floodwaters can devastate homes and businesses, disrupt transportation, and contaminate water supplies. Moreover, flooding can result in the spread of disease and the loss of life.

Lower-income neighborhoods may lack the resources to cope with flood impacts, leading to greater hardships for vulnerable populations. Urban environments with limited green space and natural drainage features are less resilient to heavy rainfall, increasing the likelihood of flooding. Efforts to mitigate flooding and reduce urban vulnerability include improved sustainable urban planning, green infrastructure, public awareness, education, and climate-resilient urban design. These measures aim to reduce the risks and impacts of pluvial flooding in urban environments [3]. Nature-based solutions (NBS) are increasingly recognized as effective measures for mitigating urban flooding. NBS are implemented in various countries worldwide. NBS cases in Europe address various issues such as urban heat resilience, pluvial flood prevention, coastal erosion management, and agricultural sustainability [4]. These cases offer sustainable solutions tailored to local conditions. The Sponge City initiative in China, exemplified by Wuhan, aims to address urban waterlogging, enhance water storage and quality, and mitigate heat island effects through a combination of nature-based and gray infrastructure solutions guided by six technical measures [5]. These solutions have the potential to not only reduce the impact of urban flooding but also provide additional benefits, such as improved air quality, biodiversity, and the overall livability of the city. However, research on NBS has predominantly focused on Europe and the United States, with limited application cases in Asian cities, particularly in Phnom Penh and Cambodia.

Implementing NBS would require a combination of policy and infrastructure changes as well as public education and awareness campaigns. The primary objective of this study was to investigate the perceptions and willingness of individuals to adopt NBS for flood mitigation, aiming to inform the development of resilient communities. This research seeks to achieve several specific goals: (1) to gauge the public perception of NBS for flood mitigation, (2) to raise awareness about the potential of NBS in this regard, (3) to identify the key factors influencing individuals' perceptions and willingness to install NBS, and (4) to understand how priorities and incentives influence NBS adoption at the household level. Through the collection of primary data via an online questionnaire survey conducted using Google Forms, this study aimed to provide valuable insights that could support policy recommendations for local authorities and urban planners. These recommendations encompass guidelines for integrating NBS into urban planning and development, incentivizing NBS adoption, and addressing challenges related to public perception and implementation.

2. Theoretical Background

2.1. Nature-Based Solutions for Urban Flood Mitigation

To understand the practical applications of NBS, specific examples are useful. These solutions can effectively mitigate urban flooding by leveraging natural features such as wetlands, forests, and green spaces to absorb water and reduce flood impacts. The International Union for the Conservation of Nature (IUCN) describes NBS as sustainable actions that preserve, manage, and restore ecosystems to address social issues, enhance human well-being, and promote

biodiversity[6]. By supporting societal development, upholding cultural norms, and improving ecosystem resilience and functionality, NBS contribute to long-term ecological health in urban areas[6].

To understand the practical applications of NBS, specific examples from various regions provide valuable insights. NBS include low-impact development (LID), green infrastructure (GI), sustainable urban drainage systems (SUDS), and sponge cities, each tailored to specific contexts. Originating in the USA and Canada, LID minimizes urban development's impact on natural systems. GI, a global term, employs bioswales and green roofs for sustainable flood management[7]. The SUDS, developed in the UK, aim to alleviate pluvial flooding in urban areas while preserving waterways through measures such as swales[8].

The Sponge City concept, widely adopted in China since 2015, mimics the water storage capacity of natural wetlands and rivers to manage precipitation through infiltration and retention in green spaces[5]. This approach not only reduces the impact of urban flooding but also enhances water quality and urban biodiversity. For example, the city of Wuhan has implemented sponge city principles to mitigate urban waterlogging and improve overall urban resilience[5].

European cities have also embraced NBS for flood mitigation. Copenhagen, Denmark, has developed extensive green infrastructure to manage stormwater, including green roofs, permeable pavements, and urban green spaces[9]. Similarly, Rotterdam in the Netherlands has implemented innovative water plazas that collect and store excess rainwater during heavy rainfall, thus preventing flooding in urban areas[10].

Climate change is expected to exacerbate flood risks globally by increasing the frequency and intensity of extreme weather events, including heavy rainfall and storms[11]. The rising temperatures contribute to more intense and frequent precipitation events, leading to higher risks of urban flooding[12]. These changes highlight the urgent need for adaptive strategies such as NBS to enhance urban resilience to climate-induced flood risks.

2.2. Promoting Public Acceptance of Nature-Based Flood Mitigation Solutions

Despite their proven benefits, NBS are not extensively adopted worldwide, particularly in metropolitan areas. This reluctance may stem from policymakers' lack of awareness and trust in NBS. Generally, those unfamiliar with a concept are hesitant to invest in it. Understanding public perceptions of NBS can help governments promote their adoption and enhance urban planning. Therefore, gauging people's understanding and opinions is the first step toward the successful implementation of NBS[13].

Public perception is one of the fundamental factors influencing the success and effectiveness of NBS for flood mitigation. These sustainable and resilient approaches use or mimic natural processes to manage flood risks and enhance overall urban resilience. Public perception plays a crucial role in several aspects of NBS for flood mitigation, such as acceptance and adoption, community engagement, awareness, education, support, and funding. Engaging communities, conducting effective outreach and education, and addressing public concerns are critical for the long-term sustainability and effectiveness of NBS[14].

Policymakers may modify urban plans to encourage the use of NBS using research insights into the dynamics underlying its application to reduce urban flooding risks. This study aims to address three key questions: gauge the extent of public perception of NBS for flood mitigation, identify the factors shaping individuals' perceptions (e.g., prior knowledge), drive their willingness to install NBS, and discern the incentives prompting NBS adoption at residences while exploring their prioritization.

This research was designed to investigate the receptiveness of Phnom Penh residents toward adopting NBS for flood mitigation in their homes or buildings, focusing on how individuals perceive the effectiveness of such solutions in relation to their prior knowledge and perceptions of flood risk. **Figure 1** is developed under the following three hypotheses

Hypothesis 1 (H1). *Perception of efficacy influences the willingness to adopt NBS; therefore, individuals are more likely to install NBS when they believe in its effectiveness.*

Hypothesis 2 (H2). *Previous knowledge impacts the perception of efficacy, proposing that individuals with greater knowledge of NBS are more likely to perceive them as effective.*

Hypothesis 3 (H3). *Individuals who perceive flood risk as significant are more inclined to believe in the effectiveness of NBS.*

The model shown in **Figure 1** is crucial in community perceptions for practice under the improving flood management paradigm. With this aim, NBS such as Green Roof (GR), Rain Harvesting (RH), Permeable Pavement (PP), and Soakaways (SA) are tested under two main premises: firstly, to define the degree of dwellers' psychology under their experience of flood risk and dwellers' philosophy under their prior knowledge of NBS; and secondly, how willing communities are to adopt NBS through a process of information focused on multiple benefits, costs and effectiveness. Therefore, four main latent variables were selected using the previously cited four types of nature-based solutions.

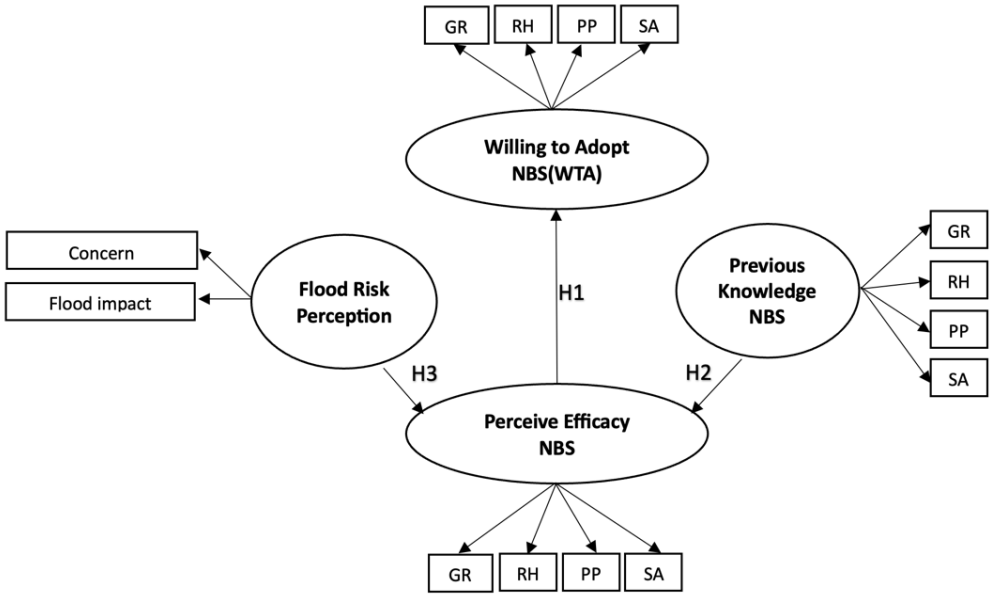


Figure 1. Residence aspects of nature-based solutions; a model to analyze communities perception for practices considering the four types of nature-based solutions.

Note: Green Roof (GR); Rain Harvesting (RH); Permeable Pavement (PP); Soakaway (SA); Hypotheses 1,2,3 (H1, H2, H3).

3. Method

3.1. Research Method

To address the research objectives and questions, this study employed an online questionnaire survey using Google Forms to collect primary data. The survey link was initially disseminated via email and social networks, and participants were encouraged to share the link further within their networks. Participants were recruited through convenience and snowball sampling methods, considering the exploratory nature of the study. This method was deemed most feasible for reaching a broad audience within the available timeframe. Prior to accessing the survey, the respondents were provided with information regarding the research project's objectives and the processing of personal data. Only those who consented to participate completed the survey. The sample size was determined using Cochran's formula for a finite population, taking into account a confidence level of 90%, a margin of error of 5%[15], and a population size of 1,065,771 individuals aged 18 and older in Phnom Penh, according to the National Election Commission of 2023[16]. The calculation resulted in a sample size of approximately 270, which is considered reliable for representing the population in Phnom Penh for this study[15].

3.2. Survey Design and Validation

The survey comprised six sections. Initially, residents were queried about their territorial features, including place of residence and duration of stay. Participants assessed their flood risk perception, gauging concerns, preparedness levels, and the impact of floods on their lives and property using a Likert scale. Subsequently, respondents evaluated their background understanding of NBS such as permeable pavements and green roofs, along with accompanying illustrations for

clarity. In another section, the participants evaluated the perceived effectiveness of the NBS and their willingness to adopt it. Additionally, they prioritized incentives for NBS adoption, including cost-effectiveness, financial support, urban planning modifications, and environmental benefits. Finally, the sociodemographic variables were gathered.

To ensure the reliability and validity of the survey instrument, a pre-test was conducted with ten participants. These participants were selected to represent the broader population of Phnom Penh, including a mix of ages, genders, and educational backgrounds. The pre-test aimed to identify any ambiguities or misunderstandings in the questions, as well as to ensure the overall clarity and flow of the survey. Feedback from the pre-test participants was collected and analyzed, leading to several modifications in the survey instrument, such as rewording complex questions, adjusting the Likert scale options for better clarity, and improving the visual aids accompanying the questions.Furthermore, content validity was ensured by having the survey reviewed by experts in urban planning and environmental studies. Their feedback helped refine the questions to better align with the research objectives and ensure they covered all relevant aspects of NBS and flood mitigation perceptions. The final questionnaire was available for four weeks between August and September 2023, targeting individuals aged 18 years and above residing in Phnom Penh.

3.3. Analysis Method

Data analysis was conducted using the R statistical software, employing ordinal logistic regression to examine the responses. Despite the ordinal nature of the data, the assumption of numerical and normally distributed data was made, allowing for the application of parametric techniques such as normal regression analysis[17, 18]. Descriptive statistics were condensed into graphs to facilitate a more straightforward visualization and were utilized for the preliminary investigation of the sample. These included sociodemographic characteristics, perceptions of flood risk, prior awareness of NBS, perceived effectiveness of NBS, willingness to adopt NBS, and incentives for NBS implementation.

4. Results

4.1. Demographic

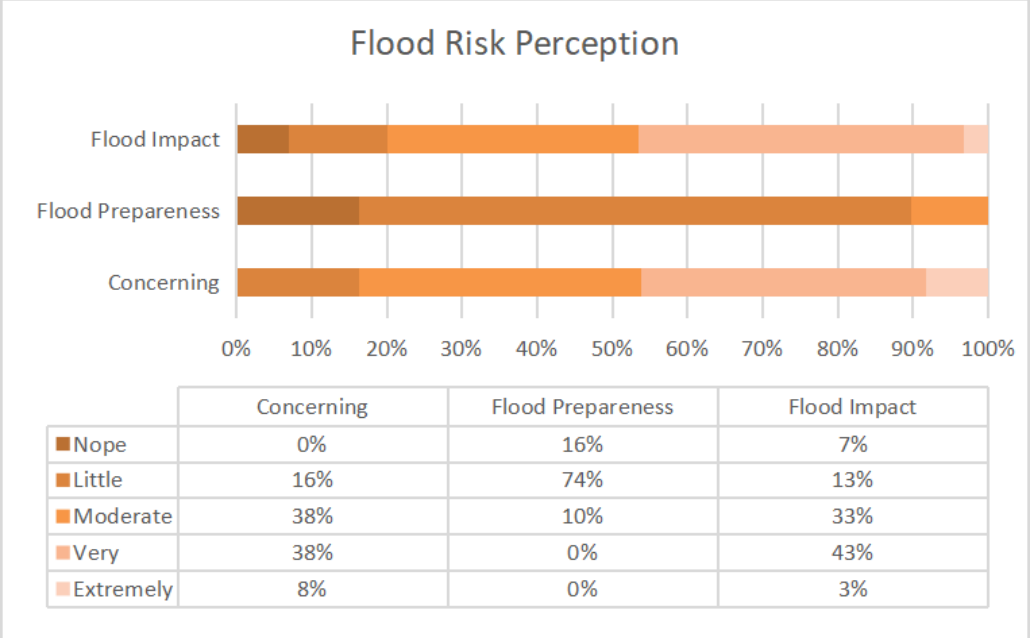
Having established the demographic profile of the respondents, we now turn to their perceptions and attitudes regarding flood risk and NBS adoption. The survey results of 314 respondents living in Phnom Penh with pluvial flood experience show that 67% of respondents were men and 33% were women. Most were between 36 and 46 years old (up to 68%) and 26 and 35 years old (18%), which indicates experiences considerable enough to share their perceptions of NBS. In terms of education level, 44% held a master's degree, 39% a bachelor's degree, and a small number held a PhD and post-doc. This could also be a factor influencing their level of knowledge about NBS. A total of 28% had lived in Phnom Penh for over nine years, 83% owned their house, 11% lived with their parents, and the remaining 6% lived in a rented home. Business owners comprised the largest group (35%), followed by government officers (33%), private company employees (25%), and the remainder (7%). Depending on the living conditions of the occupants, these groups should be able to afford the installation of NBS if they are willing.

4.2. Survey Result

The survey shed light on the attitudes and perceptions of the population regarding flood risk and the adoption of NBS (**Figure 2**). Concerning flood risk, a significant portion of respondents expressed varying degrees of concern, with 38% reporting very concerned and moderate levels, while 8% indicated extreme concern. This highlights the prevailing unease within the community regarding flooding. Moreover, the majority of respondents (74%) felt inadequately prepared to deal with floods in their vicinity, indicating a perceived lack of solutions to mitigate such occurrences. However, a substantial proportion (43%) acknowledged the significant impact of floods on their daily lives, underscoring the importance of the issue.

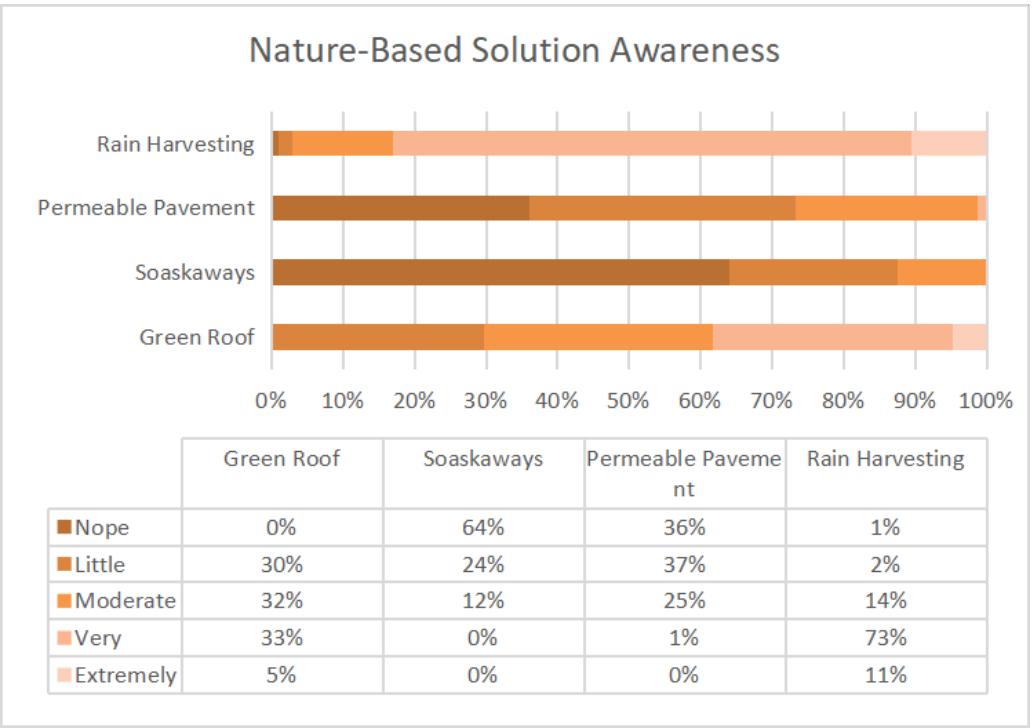
Regarding knowledge of NBS (**Figure 3**), rain harvesting emerged as the most recognized solution, with 73% of the respondents indicating high familiarity, followed by green roofs (33%). However, soakaways were the least known, with 64% reporting no knowledge, followed by permeable pavements (36%). Perceptions of efficacy varied among the proposed NBS (**Figure 4**), with green roofs and rain

harvesting being perceived as the most effective. A noteworthy 38% deemed green roofs to be very effective, closely followed by rain harvesting, with 7% considering them extremely effective. By contrast, soakaways and permeable pavements were regarded as less effective, with the majority expressing little confidence in their efficacy. Regarding the willingness to adopt NBS (**Figure 5**), respondents showed a general inclination toward green roofs and rain harvesting, albeit with varying degrees of willingness. In contrast, there was resistance to the adoption of soakaways and permeable pavements, with a significant proportion expressing reluctance.



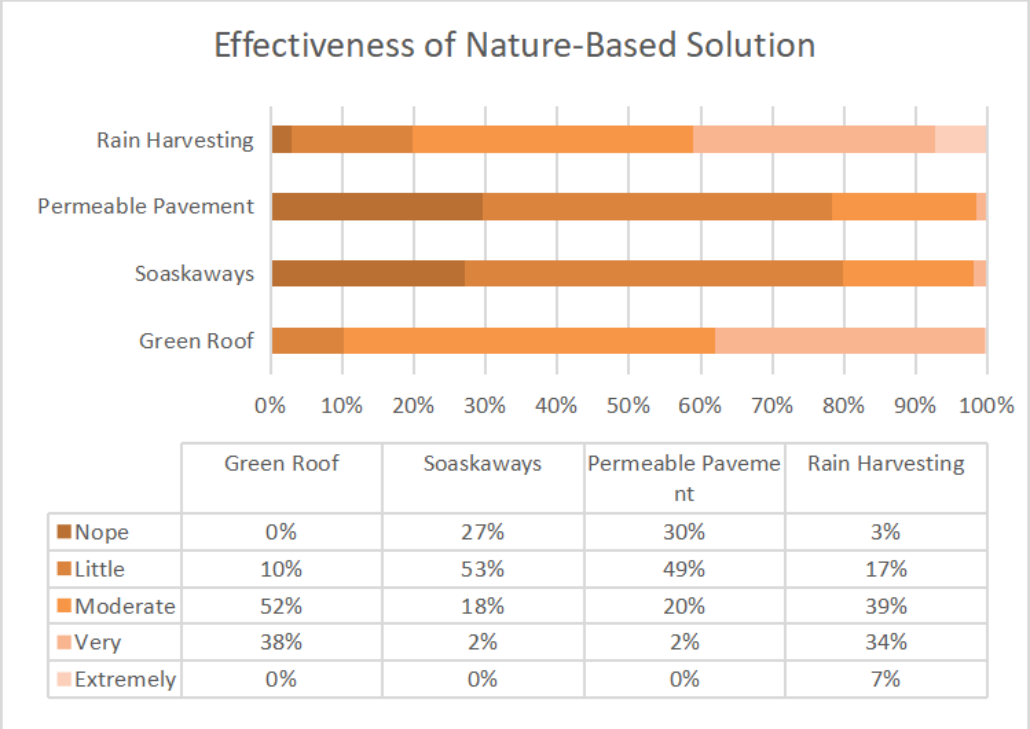
	Concerning	Flood Prepareness	Flood Impact
Nope	0%	16%	7%
Little	16%	74%	13%
Moderate	38%	10%	33%
Very	38%	0%	43%
Extremely	8%	0%	3%

Figure 2. Percentage of the people's flood risk perception.



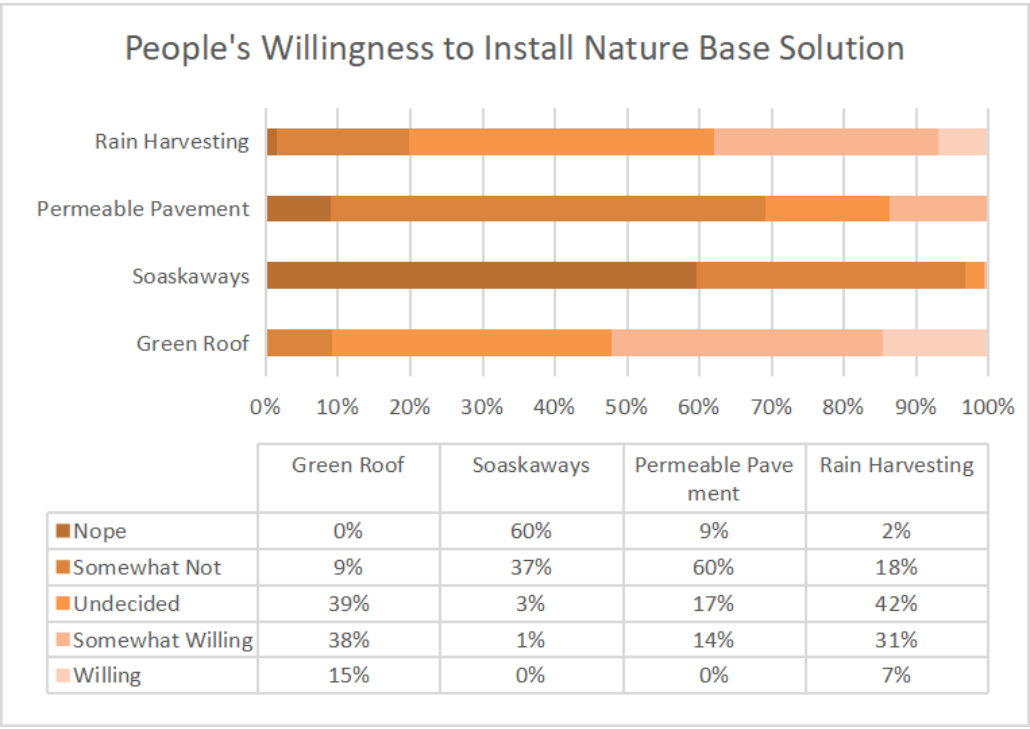
	Green Roof	Soaskaways	Permeable Pavement	Rain Harvesting
Nope	0%	64%	36%	1%
Little	30%	24%	37%	2%
Moderate	32%	12%	25%	14%
Very	33%	0%	1%	73%
Extremely	5%	0%	0%	11%

Figure 3. Percentage of the peoples' awareness of the nature-based solutions.



	Green Roof	Soaskaways	Permeable Pavement	Rain Harvesting
Nope	0%	27%	30%	3%
Little	10%	53%	49%	17%
Moderate	52%	18%	20%	39%
Very	38%	2%	2%	34%
Extremely	0%	0%	0%	7%

Figure 4. The effectiveness of the nature-based solutions.

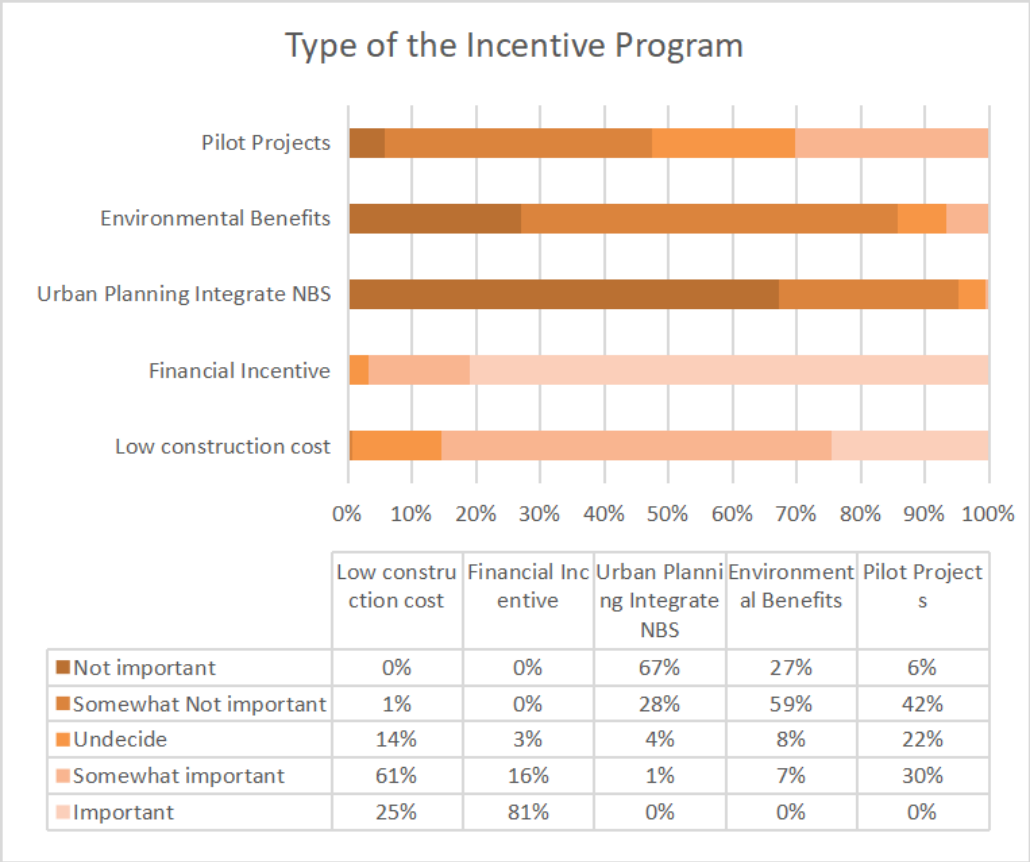


	Green Roof	Soaskaways	Permeable Pavement	Rain Harvesting
Nope	0%	60%	9%	2%
Somewhat Not	9%	37%	60%	18%
Undecided	39%	3%	17%	42%
Somewhat Willing	38%	1%	14%	31%
Willing	15%	0%	0%	7%

Figure 5. Peoples' willingness to install type of nature-based solutions.

Regarding incentives for NBS adoption (**Figure 6**), financial incentives emerged as the most influential factor, with 97% of the respondents considering them important or somewhat important. This was followed by low construction costs, highlighting the significance of economic factors in decision-making. Conversely, factors such as

urban planning modifications, environmental benefits, and pilot projects are deemed less important in motivating adoption. These findings underscore the urgent need to address flood risks and promote NBS adoption in Phnom Penh. Efforts should be focused on raising awareness, providing financial incentives, and overcoming barriers to adoption to build resilience and mitigate the impact of floods in urban areas.



	Low construction cost	Financial Incentive	Urban Planning Integrate NBS	Environmental Benefits	Pilot Projects
Not important	0%	0%	67%	27%	6%
Somewhat Not important	1%	0%	28%	59%	42%
Undecide	14%	3%	4%	8%	22%
Somewhat important	61%	16%	1%	7%	30%
Important	25%	81%	0%	0%	0%

Figure 6. Perspective of people for incentive program.

4.3. Regression by Influence Factor

This research encompasses two sections of regression analysis. First, the relationship between variables was examined, with willingness to adopt NBS as the dependent variable and perceived efficacy as the independent predictor. Second, it explored the factors influencing the perceived effectiveness of NBS, with perceived efficacy as the dependent variable and previous knowledge of NBS and flood risk perception (including concerns about flood risk, flood impact, and flood preparedness) as independent variables. As depicted in **Figure 7**, this study elucidates the directional linkages between the variables. According to hypotheses 1 (H1) and hypotheses 2 (H2), previous knowledge and flood risk perception influence perceived efficacy, with perceived efficacy subsequently impacting willingness to adopt NBS in hypotheses 1 (H1).

The initial investigation revealed a significant influence of perceived efficacy on willingness to adopt NBS. Respondents exhibiting higher perceived efficacy regarding rain harvesting and green roofs were more inclined to adopt these practices at home (p-value for rain harvesting = 0.00994 < 0.05; p-value for green roofs = 0.0225 < 0.05), whereas no such significance was observed for permeable pavements and soakaways as shown in **Table 1**. This suggests that for individual purposes, green roofs and rain harvesting are more readily adopted in households than permeable pavements and soakaways, which might be more suitable for public projects because of space requirements.

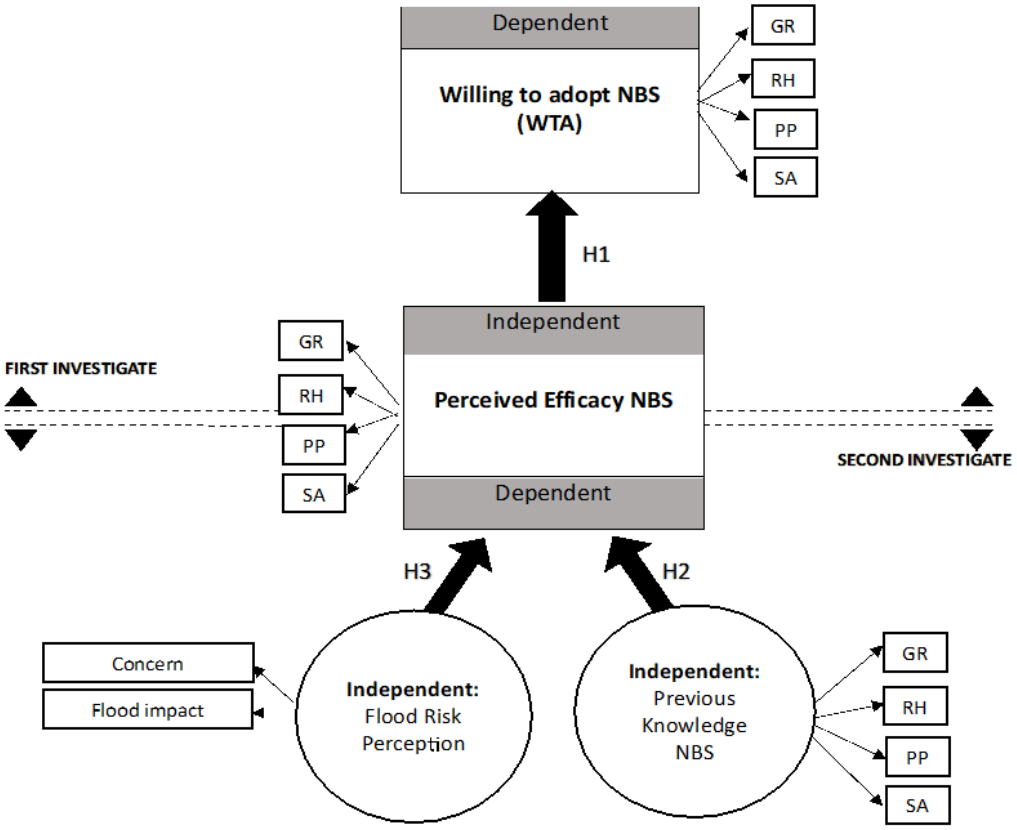


Figure 7. Regression analysis approach.

Note: Green Roof (GF); Rain Harvesting (RH); Permeable Pavement (PP); Soak-Away (SA); Hypotheses 1,2,3 (H1, H2, H3).

Table 1. Analysis result of factors influencing willingness to adopt nature-based solutions.

Dependent: Willing to Adopt NBS Independent: Perceive Efficacy NBS	**Estimate**	**Std. Error**	**t-Value**	**P-Value**
Green Roof	1.2626	0.2903	4.349	**0.0225**
Rain Harvesting	1.04262	12.95	0.08051	**0.000994**
Permeable Pavement	0.944	0.3778	2.499	0.0878
Soakways	0.8757	0.521	1.681	0.191

The study endeavored to unravel the reasons behind the lower willingness to adopt permeable pavements and soakaways, hypothesizing that this may stem from a lack of knowledge. Subsequently, a second investigation revealed the influence of previous knowledge on perceived efficacy, particularly for soakaways ($p = 0.0145 < 0.05$) as illustrated in **Table 2**. Conversely, no significant effect of previous knowledge was observed for permeable pavements, indicating their popularity in public projects.

Moreover, flood risk perception was found to affect perceived efficacy, with respondents who expressed greater concerns about flood risk being more likely to believe in the effectiveness of green roofs and rain harvesting (p-value for green roofs = $0.00888 < 0.05$; p-value for rain harvesting = $0.00758 < 0.05$) as indicated in **Table 2**. Similarly, those who perceived floods as affecting their daily lives or property were more inclined to believe in the effectiveness of green roofs ($p = 0.0401 < 0.05$). This underscores the psychological aspect in which individuals driven by fear and concern may compel themselves to believe in the effectiveness of certain NBS. In **Table 3**, a simpler comparison shows how preceived effectiveness affects willingness by comparing the number of respondents through a scale from 1 to 5 (nope – extremely). For instance, green roof scale 1 shows that if no people believe in the effectiveness (0 respondents), there are also no people (0 respondents) willing to install it.

Table 2. Analysis result of factors influencing perceived efficacy of nature-based solutions.

Flood impact	SA	–0.4334	0.2668	–1.624	0.2028
	GR	0.9051	0.2602	3.478	**0.0401**
	RH	0.9073	0.2945	3.081	0.0541
	PP	0.007601	0.431998	0.018	0.987
	SA	–0.3343	0.3185	–1.05	0.371

Table 3. Comparing serial number of respondents on perceived effectiveness and willingness of nature-based solutions regarding the scale from 1 to 5.

SCALE	Independent(x)				Dependent(y)			
	Percieved Effectiveness of NBS(Respondents)				Willing to Install NBS(Respondents)			
	Green Roof	Rain Harvesting	Permeable Pavement	Soakaways	Green Roof	Rain Harvesting	Permeable Pavement	Soakaways
1	0	5	28	187	0	9	93	85
2	29	57	189	117	32	53	153	166
3	121	133	54	8	163	123	63	57
4	118	97	43	2	118	106	5	6
5	46	22	0	0	1	23	0	0

In conclusion, these findings provide valuable insights for policymakers, highlighting the need to address concerns about flood risk and promote awareness and understanding of NBS to enhance its perceived efficacy and encourage its adoption, ultimately fostering resilience in communities.

5. Discussion

The results of our survey on the awareness and implementation of NBS in Phnom Penh revealed a critical lack of awareness and general skepticism regarding the efficacy of these solutions among the city's residents. This skepticism translates into a low willingness to adopt NBS, although there are exceptions, such as green roofs and rainwater harvesting systems. The familiarity and direct benefits of green roofs, such as energy savings and aesthetic improvements, make them more acceptable, while the relatively lower cost and traditional familiarity with rainwater harvesting promote their acceptance despite overall reservations. Moreover, the perception of high flood risk significantly correlated with the belief in the effectiveness of NBS, such as green roofs and rainwater harvesting, in mitigating such risks.

A notable disparity in the levels of prior knowledge regarding different NBS was identified; rainwater harvesting is relatively well understood due to its historical and traditional presence in the region, whereas other solutions, such as soakaways, are not as well known, likely due to their lesser visibility and reputation within the community. When considering the willingness to implement NBS, economic incentives and low construction costs emerged as critical factors that could enhance the adoption of these practices. It appears that a detailed understanding of how NBS works in terms of urban planning, environmental benefits, and pilot projects is less significant to the community than the direct economic benefits it might bring.

5.1. Comparison with Other Studies

Our findings align with those of other studies that highlight the importance of public awareness and economic incentives in the adoption of NBS. For instance, a study in the Veneto Region of Italy found that economic factors and awareness significantly influenced public willingness to implement NBS for flood mitigation[13]. Similarly, research conducted in Rotterdam emphasized the role of economic incentives and public education in promoting green infrastructure[10]. However, unlike our study, which identified green roofs and rainwater harvesting as more accepted solutions, these studies reported a broader acceptance of various NBS due to extensive public education campaigns and government incentives.

5.2. Implications for Policy and Practice

Our study highlights the substantial impact flooding has on the lives of Phnom Penh citizens. Floods interrupt everyday life, especially during the rainy season, inflict property damage, affect the local economy, and put the health of poor

communities at risk. While locals have devised numerous coping methods, these are frequently temporary approaches that do not address the underlying causes of floods. The diverse assessments of public perception underscore the importance of a more consistent and robust strategy for flood control. Improving infrastructure, particularly drainage systems, and developing comprehensive flood control plans are key tasks that must be undertaken.

Moreover, the rapid urbanization of Phnom Penh over the last decade has exacerbated the city's flooding issues. The inadequate infrastructure has struggled to keep pace with the city's growth, resulting in severe pluvial floods during the rainy season. These floods not only disrupt daily life but also cause significant property damage and pose health risks to vulnerable populations. Despite the community's efforts to manage these challenges, their strategies often fall short of addressing the root causes of flooding. Meanwhile, the low-income population faces a barrier to access and for nature-based solutions; nonetheless, these groups may not own land or even have secure tenure, making it challenging to implement projects such as green spaces.

Another critical finding is the lack of awareness and engagement among local practitioners and communities regarding nature-based solutions (NBS) for flood prevention. The involvement of these actors is crucial in ensuring that communities are prepared and resilient in the event of floods. Therefore, it is essential to enhance public education and professional training on the benefits and implementation of NBS.

5.3. Policy Recommendations

The incorporation of NBS into urban development strategies in Phnom Penh is currently insufficient because the city's master plan lacks specific provisions for integrating NBS into land-use planning, infrastructure design, and urbanization regulations. This oversight leads to fragmented efforts and inconsistencies that could be streamlined with better coordination among the Ministry of Land Management, Urban Planning and Construction, the Ministry of the Interior, and other relevant government departments. Clear communication channels and collaborative frameworks involving local authorities and stakeholders are necessary to establish a cohesive NBS implementation strategy.

5.3.1. Specific and Actionable Recommendations

Financial Incentives: Establish government grants and subsidies for homeowners and businesses that implement NBS.

Public Education Campaigns: Launch extensive education campaigns to raise awareness about the benefits and implementation of NBS. This can include workshops, seminars, and informational materials.

Integration into Urban Planning: Mandate the inclusion of NBS in new urban development projects through updated building codes and zoning regulations.

Pilot Projects: Implement pilot projects in flood-prone areas to demonstrate the effectiveness of NBS and gather data for further planning.

5.3.2. Challenges and Solutions

Economic Barriers: High initial costs may deter adoption. To overcome this, provide low-interest loans and financial assistance programs.

Lack of Awareness: Address this through targeted educational initiatives and community engagement programs.

Technical Expertise: The limited local expertise in NBS can be mitigated by partnering with international experts and organizations to provide training and support.

5.4. Limitations

Our study has several limitations that should be acknowledged. The use of convenience and snowball sampling methods may limit the generalizability of the findings. Additionally, the reliance on self-reported data may introduce bias. Future research should consider employing more robust sampling techniques and incorporating objective measures to validate self-reported data.

6. Conclusions

In conclusion, this study provides valuable insights into the awareness and adoption of nature-based solutions (NBS) for flood mitigation in Phnom Penh. The survey revealed a critical lack of awareness and skepticism towards NBS among residents, significantly impacting their willingness to adopt these solutions. Exceptions like green roofs and rainwater harvesting systems show promise due to their rec-

ognized benefits and cost-effectiveness. The findings highlight that economic incentives and low construction costs are crucial factors in promoting NBS adoption.

This study contributes to the existing body of knowledge by identifying the key barriers to NBS adoption in Phnom Penh, including lack of awareness, perceived inefficacy, and economic constraints. It also underscores the importance of public perception in the successful implementation of NBS. For urban planners and policymakers, this research provides a basis for developing targeted strategies to promote NBS, emphasizing the need for economic incentives, public education, and integration into urban planning.

Future research should focus on evaluating the long-term effectiveness of various NBS in mitigating flood risks in urban environments similar to Phnom Penh. Investigating the socioeconomic factors influencing NBS adoption and identifying best practices for community engagement and education will be crucial. Additionally, pilot projects should be established to demonstrate the practical benefits of NBS and provide real-world data to inform policy and planning.By addressing these implications, Phnom Penh can significantly enhance its urban resilience and set a precedent for sustainable urban development in Cambodia and other similar urban contexts globally.

Author Contributions

SO: data collection, analysis, and drafting; R.R.: designing survey pool and result presentation; H.P.: conceptualization, editing, and revising.

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Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

The data used in this study is a survey and is not publicly available because it contains personal information.

Conflicts of Interest

The authors declares no conflict of interest.

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