

Greening the Flood: Sustainable Urban Solutions for Barangay Lorega, Cebu City

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ABSTRACT

Urban flooding has become an urgent environmental issue in rapidly developing cities like Cebu City, Philippines, where accelerated urbanization has led to increased impervious surfaces and limited natural water absorption. Traditional flood management approaches, such as concrete drainage systems, are proving insufficient amid the growing impacts of climate change. This study investigates the effectiveness of green infrastructure (GI) in urban flood control, with a focus on Barangay Lorega. GI includes sustainable, nature-based solutions such as permeable pavements, green roofs, rain gardens, and constructed wetlands that offer both ecological and social benefits. Employing a descriptive-quantitative research design, the study combined survey data and stakeholder interviews to evaluate GI's flood mitigation capacity, cost-effectiveness, and social relevance. Statistical results revealed no significant differences in flood control effectiveness based on demographic factors such as sex, age, civil status, or education. However, regression analysis showed that community engagement and awareness significantly influenced perceived effectiveness, while GI implementation demonstrated a modest yet meaningful impact. These findings suggest that while GI alone may not drastically transform urban flood resilience, it plays a valuable role when combined with public participation and informed governance. This study contributes to the growing body of knowledge on urban resilience and sustainable flood management, particularly in tropical, high-density settings. It offers insights for local policymakers, urban planners, and community stakeholders seeking to integrate green infrastructure into comprehensive climate-adaptive urban planning.

Keywords: *Green Infrastructure, Urban Flooding, Community Engagement, Sustainability, Cebu City*

INTRODUCTION

Urban flooding has emerged as a critical environmental challenge, particularly in rapidly urbanizing and densely populated cities such as Cebu City, Philippines. Accelerated urban growth has led to the proliferation of impervious surfaces, significantly reducing natural ground infiltration and amplifying surface runoff during periods of intense rainfall. Conventional flood management infrastructure—including concrete drainage networks and flood barriers—has proven increasingly inadequate, especially in the context of climate change, which continues to intensify the frequency and severity of extreme weather events. This evolving threat landscape necessitates a paradigm shift toward more sustainable, adaptive, and resilient flood mitigation strategies.

Green infrastructure (GI) presents a viable and ecologically sound alternative. Encompassing interventions such as permeable pavements, green roofs, bioswales, rain gardens, and constructed wetlands, GI integrates natural hydrological processes into urban systems, thereby reducing flood risks while simultaneously offering co-benefits such as enhanced biodiversity, improved air and water quality, and aesthetically enriched public spaces. In the context of Cebu City, where seasonal flooding poses substantial risks to vulnerable communities, disrupts economic activities, and strains municipal resources, the adoption of GI holds significant potential.

Despite growing global interest in GI, research examining its applicability and effectiveness in tropical, high-density urban contexts—such as Cebu City—remains limited. Most existing literature is centered on temperate regions in developed nations, which differ markedly in socio-environmental conditions. This study seeks to address this knowledge gap by evaluating the performance, sustainability, and cost-effectiveness of GI for urban flood control in Barangay Lorega, Cebu City. Through localized data and stakeholder engagement, the research aims to inform urban policy and planning processes, offering a scalable model for climate-adaptive and community-oriented flood resilience in comparable urban settings.

MATERIALS & METHODS

This study employed a descriptive-quantitative research design to evaluate the effectiveness of green infrastructure (GI) in urban flood control, specifically within Barangay Lorega, Cebu City. The methodology integrated both quantitative and qualitative research techniques, allowing for a comprehensive analysis of GI performance across multiple dimensions. The quantitative aspect focused on collecting empirical data related to flood reduction efficiency, environmental quality indicators, and economic sustainability metrics. These included measurements such as drainage capacity, runoff reduction rates, and cost-benefit assessments associated with GI implementation.

To complement the quantitative findings, a qualitative component was conducted through structured interviews with key stakeholders, including urban planners, community leaders, and residents. These interviews aimed to capture perceptions, experiences, and attitudes regarding the planning, application, and maintenance of GI systems. The qualitative data provided valuable context to the numerical results by revealing insights into the social impact, community engagement, and acceptability of GI in a tropical urban environment.

By combining these methodological approaches, the study achieved a holistic assessment of green infrastructure. The integration of statistical analysis and stakeholder narratives ensured that both the technical effectiveness and social dimensions of GI were thoroughly examined. This dual approach enhanced the depth and reliability of the findings and supported the development of context-specific recommendations for sustainable urban flood management in Cebu City.

RESULTS AND DISCUSSION

Is there a significant difference in effectiveness in urban flood control when grouped according to their profile?

Table 1 explains the significant difference in effectiveness in urban flood control when grouped according to their profile. The result shows that sex (*t-value* = 2.040, *p-value* = 0.155), age (*F* = 1.383, *p-value* = 0.241), civil status (*F* = 0.860, *p-value* = 0.425), and education (*F* = 0.642, *p-value* = 0.589) revealed an insignificant difference in the effectiveness in urban flood control.

Table 1
Test of Significant Difference of the Effectiveness in Urban Flood Control when they are Grouped According to Profile

Test of Difference in t-test

Profile	Effectiveness in Urban Flood Control					
	Category	Mean	t-value	p-value	Decision on Ho	Remarks
Sex	Male	3.36	2.040	0.155	Failed to Reject	Not Significant
	Female	3.41				

Significant if p -value < 0.05

Legend: H_0 is rejected if Significant

H_0 is failed to reject if Not Significant

Therefore, the null hypothesis which declares that there is no significant difference in effectiveness in urban flood control when grouped according to their profile is failed to reject.

Test of Difference in ANOVA

Profile	Effectiveness in Urban Flood Control					
	Category	Mean	F-value	p-value	Decision on H_0	Remarks
Age	18-22	3.33	1.383	0.241	Failed to Reject	Not Significant
	23-27	3.44				
	28-32	3.50				
	33-47	3.36				
	38 and Older	3.28				
Civil Status	Single	3.43	0.860	0.425	Failed to Reject	Not Significant
	Married	3.34				
	Widow	3.50				
Education	High School	3.38	0.642	0.589	Failed to Reject	Not Significant
	College Degree	3.40				
	Master's Degree	3.37				
	Doctorate Degree	3.00				

Significant if p -value < 0.05

Legend: H_0 is rejected if Significant

H_0 is failed to reject if Not Significant

Furthermore, the analysis reveals that factors such as sex, age, civil status, and educational attainment do not show a significant difference in the effectiveness of urban flood control. The analysis suggests that demographic variables, such as age, sex, and education, may not significantly impact the effectiveness of urban flood management. Instead, the success of flood control efforts appears to depend more on structural, environmental, and policy-related factors. Urban flooding is a growing challenge, particularly in cities where dense populations, critical infrastructure, and interconnected systems are highly vulnerable to water inundation (Kubal et al., 2009). The social and economic repercussions of urban flooding are projected to intensify due to population growth, continued development in flood-prone areas, and the increasing frequency and severity of extreme weather events driven by climate change (Driver et al., 2020). This underscores the importance of focusing on broader, systemic strategies to improve flood management outcomes rather than targeting interventions based solely on these personal attributes.

Does green infrastructure for urban flood control influence the effectiveness in urban flood control?

Table 2 explains the influence of green infrastructure for urban flood control to the effectiveness in urban flood control. The study shows that green infrastructure for urban flood control in terms of

Community Engagement and Awareness has 0.170, the only predictor that influence the effectiveness in urban flood control.

Moreover, with a per-unit increase in community engagement and awareness, there is a 0.170 increase in effectiveness in urban flood control.

The fitted regression model 1 is expressed as follows:

$$\hat{Y} = 2.141 + 0.170 X_4$$

where:

\hat{Y} = Effectiveness in Urban Food Control

X_4 = Community Engagement and Awareness

The effectiveness of urban flood control is significantly shaped by community engagement and awareness. Communities that are informed and actively involved tend to play a crucial role in preventive measures, reporting issues, and collaborating with local authorities. These actions foster a more coordinated and effective response to flood risks, leading to better outcomes in managing urban floods. Urban flooding is a growing global concern, exacerbated by factors such as population growth, urbanization, and climate change (Fenner et al., 2019). Addressing this challenge requires a comprehensive and integrated approach that combines diverse strategies to mitigate flood impacts while distributing responsibilities and costs among a wide range of stakeholders (Driver et al., 2020).

Awareness is a critical factor in effective urban flood control. Well-informed communities are better equipped to understand flood risks, implement mitigation strategies, and follow safety protocols. This knowledge enhances their preparedness, reducing the overall impact of flooding and fostering resilience in urban areas. When communities and stakeholders are aware of potential risks, they can take timely actions such as evacuations or reinforcing flood defenses, which are vital for minimizing damage and disruption (Chong et al., 2018). Engaged and prepared communities play an indispensable role in mitigating flood risks and ensuring efficient disaster response (Ye et al., 2021).

Moreover, when community members take an active role in flood control efforts, they develop a stronger sense of ownership and responsibility, which greatly improves the overall effectiveness of these initiatives. Empowering communities through education and active participation lays the groundwork for sustainable urban flood management. To make flood control more effective, agencies and local governments should prioritize building strong community engagement and increasing public awareness. Programs such as community education, participatory decision-making, and awareness campaigns can help create a collaborative environment where both authorities and residents work together to reduce flood risks and improve outcomes.

Moreover, the linear regression analysis for Model 2 examines the relationship between Green Infrastructure Urban Flood Control and the effectiveness of urban flood management.

The standardized coefficient (β) of 0.161 indicates a modest but positive impact, suggesting that implementing green infrastructure measures contributes to improved flood control. The t-value (2.291) and statistically significant p-value (0.023) support the conclusion that this predictor has a meaningful influence on the outcome.

The adjusted R^2 value of 0.021 indicates that only 2.1% of the variation in the effectiveness of urban flood control is explained by Green Infrastructure Urban Flood Control. Although the predictor has a statistically significant impact, as evidenced by its p-value of 0.023, the model's low explanatory power suggests that other factors likely play a much larger role in shaping urban flood control outcomes. This underscores the need to explore additional predictors to better understand the complex dynamics of flood management. Urban flooding remains a growing concern, with catastrophic events in cities like

New Orleans, New York, and Houston demonstrating the severe social, economic, and ecological consequences of inadequate flood control measures (Mostafavi, 2023).

The ANOVA results, with an F-value of 5.249 and a p-value of 0.023, confirm that the model is statistically significant. The F-value indicates that the overall regression model provides a better fit to the data than a model with no predictors. The p-value further suggests that the relationship between the predictor and the outcome is unlikely to be due to random chance, affirming the importance of Green Infrastructure Urban Flood Control in influencing flood management outcomes, even if its overall impact is modest in the context of the model.

The fitted regression model 2 is expressed as follows:

$$\hat{Y} = 2.807 + 0.179 X_1$$

where:

\hat{Y} = Effectiveness in Urban Food Control

X_1 = Green Infrastructure in Urban Flood Control

Table 2
Linear Regression Analysis of Green Infrastructure in Urban Flood Control Influence the Effectiveness in Urban Flood Control

Model 1

Predictors	Unstandardized Coefficients		Stand. Coeff. β	t-value (p-value)	Interpretation
(Constant)	2.141	.344		6.228(0.000)	
X ₁ : Types of Green Infrastructure	.101	.069	.106	1.475(0.142)	Not Significant
X ₂ : Implementation Scale	.019	.062	.022	.309(0.759)	Not Significant
X ₃ : Design and Maintenance Practices	.074	.046	.113	1.616(0.108)	Not Significant
X ₄ : Community Engagement and Awareness	.170	.064	.185	2.640(0.009)	Significant

Note: Adjusted R²=0.054 ANOVA for Regression: F=3.842, p=.005

Model 2

Predictors	Unstandardized Coefficients		Stand. Coeff. β	t-value (p-value)	Interpretation
(Constant)	2.807	.252		11.129(0.000)	
X ₁ : Green Infrastructure Urban Flood Control	.179	.078	.161	2.291(0.023)	Significant

Note: Adjusted R²=0.021 ANOVA for Regression: F=5.249, p=.023

What program can be recommended to have a sustainable approach to environmental protection and be more effective in urban flood control in Cebu City?

Table 3 presents a set of recommended programs aimed at fostering a sustainable approach to environmental protection and enhancing urban flood control in Cebu City. These programs address key challenges such as improving drainage systems, promoting green infrastructure, and raising public awareness on flood mitigation. By integrating nature-based solutions like rain gardens and permeable pavements, the city can reduce flood risks while enhancing water quality and supporting biodiversity. The program also emphasizes the importance of community engagement and capacity building, ensuring that residents and local stakeholders are equipped to actively participate in flood management efforts. These strategies, when implemented effectively, can contribute to a more resilient and sustainable urban environment in Cebu City.

Table 3
Programs that can be Recommended to have a Sustainable Approach to Environmental Protection and more Effective in Urban Flood Control in Cebu City

Program Recommendation	Objective
Green Infrastructure Implementation Program	To integrate nature-based solutions (e.g., rain gardens, green roofs, permeable pavements) to manage urban flooding and improve water quality.
Community Engagement and Education Campaign	To increase public awareness of sustainable flood management practices and encourage community participation in flood prevention.
Sustainable Urban Drainage Systems (SUDS) Implementation	To enhance the existing drainage systems by integrating sustainable solutions like rainwater harvesting, green drainage, and detention basins.
Flood Control and Ecosystem Restoration Program	To restore natural habitats like wetlands and floodplains, which enhance flood resilience and improve water quality.
Training and Capacity Building for Flood Management Staff	To provide ongoing training for urban planners and maintenance staff in the latest flood control and green infrastructure practices.
Resilience and Climate Change Adaptation Strategy	To integrate climate change projections into urban planning and flood management strategies.

CONCLUSION

This study underscored the growing necessity of sustainable urban flood control strategies in light of Cebu City's vulnerability to seasonal flooding and the limitations of traditional infrastructure. The findings confirmed that demographic factors such as sex, age, civil status, and education do not significantly influence perceptions of flood control effectiveness. Instead, community engagement and awareness emerged as the most impactful factors in enhancing urban flood control outcomes. This emphasizes that effective flood mitigation is less about individual characteristics and more about collective participation, informed action, and shared responsibility within urban communities.

Moreover, the results revealed a modest yet statistically significant relationship between green infrastructure (GI) and the overall effectiveness of flood management. Specifically, GI practices—

when coupled with strong community engagement—contributed positively to reducing flood risks and improving environmental resilience. However, the limited explanatory power of the regression models suggests that GI alone is insufficient and must be integrated with broader systemic interventions, including policy reforms, infrastructure investment, and climate adaptation strategies. The modest R^2 values indicate that while GI plays a valuable role, it is one component within a complex urban resilience framework.

Therefore, this research advocates for a multi-pronged approach to urban flood management in Cebu City—one that prioritizes green infrastructure, fosters community education, and strengthens institutional capacities. Recommended programs such as implementing sustainable urban drainage systems, promoting nature-based solutions, and investing in training for flood management personnel provide actionable pathways toward environmental protection and urban resilience. This study contributes to the discourse on sustainable urban planning by offering evidence-based insights that can inform policy and guide future research in similarly challenged tropical urban centers.

Recommendations

Based on the findings and conclusion, the following recommendations may be provided for various entities in Cebu City, Philippines:

Local Government Officials of Cebu City. Local government officials may prioritize the integration of green infrastructure into urban flood management policies and allocate resources to support community engagement programs. They might also establish partnerships with private sectors, NGOs, and academic institutions to ensure the sustainable implementation of GI initiatives.

Urban Planners and Environmental Engineers. Urban planners and environmental engineers may incorporate GI principles into city zoning plans and infrastructure designs, emphasizing eco-friendly, flood-resilient solutions. They might also advocate for multi-functional designs that integrate flood control with urban aesthetics and biodiversity conservation.

Environmental Protection Agencies. Environmental protection agencies may focus on public awareness campaigns and education programs to promote understanding and support for GI among the population. They might also conduct regular assessments of GI projects to evaluate their environmental impact and effectiveness in flood control.

Residents of Cebu City. Residents may actively participate in community engagement programs and support local GI projects through volunteerism and advocacy. They might also adopt practices that complement GI initiatives, such as proper waste management and tree planting within their neighborhoods.

Academics and Researchers in Environmental Science. Academics and researchers may explore the long-term impacts of GI on urban flood control and environmental protection through empirical studies. They might also work on developing innovative GI solutions tailored to Cebu City's unique urban and environmental challenges.

Non-Governmental Organizations (NGOs) Focused on Climate Resilience. NGOs might focus on mobilizing resources and expertise to implement pilot GI projects in flood-prone areas. They may also serve as mediators between communities and local governments to ensure inclusive and participatory project planning.

Construction and Real Estate Developers. Developers may integrate GI components into residential and commercial projects to contribute to sustainable urban development. They might also collaborate

with urban planners and local governments to align their developments with city-wide flood control strategies.

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