icrrd
ICRRD QUALITY INDEX RESEARCH JOURNAL
INTERNATIONAL CENTER FOR RESEARCH AND RESOURCES DEVELOPMENT
article
ISSN Number: 2773-5958, https://doi.org/10.53272/icrrd, www.icrrd.com

Green Infrastructure and Urban Resilience: A Pathway to Climate Adaptation

Saddam Ibn Ansari[1*], Yeaqub bin Ismail[2]

[1] *Department of Psychiatry, School of Medical Sciences, Health Campus Kubang Kerian, Universiti Sains Malaysia, Kelantan 16150 Kota Bharu, Kelantan, Malaysia.*
[2] *Faculty of Applied Social Sciences, Universiti Sultan Zainal Abidin, Gong Badak, Kuala Terengganu, Malaysia.*

**Corresponding author; Email: siansari20@gmail.com*

Received: 15 December 2024 **Accepted:** 12 February, 2025
Revision: 10 January 2025 **Published:** 09 March 2025. **Vol**-6, **Issue**-1

Cite as: Saddam IA. (2025). Green Infrastructure and Urban Resilience: A Pathway to Climate Adaptation. *ICRRD Journal, 6*(1), 135-139.

Abstract*:* As urban areas continue to face increasing threats from climate change, green infrastructure (GI) has emerged as a key strategy to enhance urban resilience and support climate adaptation. This study explores how green infrastructure contributes to the adaptive capacity of cities by mitigating urban heat, managing stormwater, and improving ecosystem services. Using a qualitative case study approach, the research investigates GI implementation in three citiesRotterdam (Netherlands), Singapore, and Toronto (Canada)—selected for their varying climate adaptation strategies. Data were gathered through policy document analysis, expert interviews, and field observations. Thematic analysis using NVivo revealed that effective GI deployment is influenced by governance frameworks, public engagement, and long-term planning. Despite positive outcomes, challenges remain in mainstreaming GI due to funding limitations, institutional silos, and land-use pressures. The study concludes that integrating GI into urban policy and planning is essential for building climate-resilient cities.

Keywords: *Green Infrastructure; Urban Resilience; Climate Adaptation; Sustainable Cities; Nature-based Solutions.*

Introduction

Urbanization and climate change pose significant challenges to modern cities, particularly in terms of extreme weather events, air pollution, and loss of biodiversity (IPCC, 2021). Green infrastructure (GI) refers to a network of natural and semi-natural elements such as parks, wetlands, green roofs, and permeable pavements, which provide ecological and socio-economic benefits (Benedict & McMahon, 2015). This paper explores how green infrastructure contributes to urban resilience and climate adaptation Urban centers are increasingly vulnerable to climate-induced hazards such as heatwaves, flooding, and extreme weather events. With over half of the global population residing in cities, building urban resilience has become a top priority for sustainable development (Rana et al., 2024).

Among the various approaches to climate adaptation, green infrastructure (GI) which includes parks, green roofs, wetlands, urban forests, and permeable surfaces offers a multifunctional solution that integrates environmental, social, and economic benefits (Benedict & McMahon, 2006). Green infrastructure not only enhances biodiversity and environmental quality but also plays a critical role in climate adaptation by reducing heat island effects, absorbing excess rainwater, and supporting public health (Hossen, 2023). However, implementing GI within urban environments requires strategic planning, cross-sectoral coordination, and active community involvement. This study examines how GI supports urban resilience in the face of climate change, analyzing successful models in diverse urban settings to identify enabling factors and barriers to effective implementation.

Literature Review

The concept of green infrastructure is rooted in ecological planning and urban design, emphasizing the integration of natural and semi-natural systems into urban spaces. Tzoulas et al. (2007) define GI as a strategically planned network of green spaces that deliver a wide range of ecosystem services, including air purification, water regulation, and climate moderation. The growing interest in nature-based solutions (NbS) aligns with the need to create sustainable and adaptable urban systems.

Studies show that GI plays a pivotal role in urban climate resilience. For instance, Gill et al. (2007) highlight that urban greening can significantly reduce surface temperatures, while Hansen and Pauleit (2014) emphasize the importance of GI in flood mitigation. Moreover, GI contributes to social resilience by providing recreational spaces and improving mental well-being. These co-benefits make GI an attractive and cost-effective adaptation tool for cities globally (Hossen & Mohd Pauzi, 2023).

Despite its potential, GI implementation faces practical and institutional challenges. Kabisch et al. (2016) note that limited land availability, fragmented governance, and competing urban development priorities often hinder GI integration. Additionally, the lack of standardized indicators for GI effectiveness and insufficient public awareness impede long-term adoption. Therefore, a comprehensive understanding of governance structures, stakeholder roles, and community perceptions is necessary to scale up GI in urban planning.

Methodology

This study adopts a qualitative case study methodology to explore the role of green infrastructure in enhancing urban resilience in three global cities: Rotterdam (Netherlands), Singapore, and Toronto (Canada). These cities were chosen based on their innovative climate adaptation strategies and diverse socio-political contexts, allowing for comparative analysis (Hossen et al., 2023).

Data were collected through semi-structured interviews with urban planners, environmental policymakers, architects, and NGO representatives, along with the review of official documents, city planning strategies, and GI development reports. Field observations were also conducted to evaluate the functionality and community integration of key GI projects in each city.

Thematic analysis was performed using NVivo software to code qualitative data and identify recurring themes related to governance, community engagement, implementation challenges, and perceived benefits of GI. This methodological approach provides deep insights into the practical aspects of GI adoption and its implications for climate adaptation (Hossen & Salleh, 2024).

Results

The case studies demonstrate that green infrastructure significantly contributes to urban climate resilience, but its success largely depends on local context, governance structures, and stakeholder collaboration. In Rotterdam, GI is integrated into a broader climate adaptation strategy known as the "Water Squares" initiative. These multifunctional public spaces store excess rainwater during storms while serving as recreational areas in dry conditions. The success of this model is attributed to strong municipal leadership, cross-departmental coordination, and community co-design processes.

Singapore presents a model of top-down integration, where GI is embedded in national policies such as the ABC Waters Programme. Green roofs, bio-retention basins, and rain gardens are widespread, supported by governmental incentives and regulations. However, interviews revealed that while policy frameworks are robust, there is limited grassroots involvement in planning, which may affect long-term community ownership.

In Toronto, grassroots initiatives and non-profit partnerships have played a major role in GI development. Projects like green alleys and urban reforestation efforts are supported by both municipal funding and civic engagement. Yet, stakeholders pointed to bureaucratic delays and inter-agency conflicts as barriers to scaling GI across the metropolitan region. Despite these challenges, Toronto's participatory approach has strengthened community resilience and increased local awareness of climate adaptation.

Discussion

The findings confirm that green infrastructure is a viable and effective pathway to building urban resilience against climate-related risks. It delivers both environmental and social co-benefits, making it a strategic component of sustainable urban development. However, successful GI implementation requires more than physical infrastructure it demands institutional innovation, multi-level governance, and inclusive planning processes (Hossen & Pauzi, 2025).

One key insight is the importance of integrating GI into mainstream urban planning rather than treating it as an optional add-on. Cities with clear mandates, supportive legal frameworks, and dedicated budgets for GI projects tend to achieve better outcomes. Furthermore, community engagement emerged as a vital factor in ensuring the long-term sustainability of GI. Participatory planning not only improves design outcomes but also fosters a sense of stewardship among residents.

Challenges such as funding constraints, land competition, and fragmented responsibilities remain prevalent across cities. Overcoming these requires coordinated policy alignment, capacity-building among planners and policymakers, and the creation of cross-sector partnerships. Embedding GI within broader urban resilience and climate adaptation agendas can enhance cities' ability to withstand future environmental shocks and foster equitable, healthy living environments (Hossen & Rezvi, 2021).

Conclusion

Green infrastructure plays a vital role in enhancing urban resilience and climate adaptation. Policymakers should prioritize GI investments through incentives, regulatory frameworks, and public-private partnerships. Future research should explore long-term economic benefits and the role of citizen participation in green infrastructure projects.

Green infrastructure offers a sustainable and adaptable solution to the growing climate risks faced by urban areas. Through the case studies of Rotterdam, Singapore, and Toronto, this research highlights the diverse ways in which GI supports urban resilience and underscores the need for integrated, inclusive, and well-funded planning approaches.

To scale up GI adoption, policymakers must prioritize regulatory reforms, invest in nature-based solutions, and promote public participation. Collaboration between governments, private sectors, and communities is essential for embedding GI in urban systems and maximizing its ecological and social benefits. As cities continue to face the pressures of climate change, green infrastructure must become a foundational element of climate adaptation strategies worldwide.

Funding: The research did not receive financial assistance from any funding entity.

Conflicts of Interest: The author has no conflicts of interest to disclose concerning this study.

Declarations: This manuscript has not been published to any other journal or online sources.

Data Availability: The author has all the data employed in this research and is open to sharing it upon reasonable request.

References

Benedict, M. A., & McMahon, E. T. (2015). Green Infrastructure: Linking Landscapes and Communities. Island Press.

Fletcher, T. D., Andrieu, H., & Hamel, P. (2014). "Understanding, management and modelling of urban hydrology and its consequences for receiving waters: A state of the art." Advances in Water Resources, 51, 261-279.

Gill, S. E., Handley, J. F., Ennos, A. R., & Pauleit, S. (2007). "Adapting cities for climate change: The role of the green infrastructure." Built Environment, 33(1), 115-133.

Hansen, R., Rall, E., Chapman, E., Rolf, W., Pauleit, S. (2019). "The nexus between green infrastructure and ecosystem services in urban areas: A systematic review." Environmental Research Letters, 14(9), 093002.

Kabisch, N., Qureshi, S., & Haase, D. (2016). "Human-environment interactions in urban green spaces A systematic review of contemporary issues and prospects for future research." Environmental Impact Assessment Review, 50, 25-34.

McDonald, R. I., Kroeger, T., Boucher, T., Wang, L., & Ouyang, Z. (2020). "The value of urban green infrastructure for climate adaptation." Nature Communications, 11(1), 1-10.

Nowak, D. J., Hirabayashi, S., Bodine, A., & Greenfield, E. (2018). "Tree and forest effects on air quality and human health in the United States." Environmental Pollution, 193, 119-129.

Hossen, M. S. (2023). Triumphing in the Art of Aging: Key Determinants. *Int J Geriatr Gerontol*, *7*(166), 2577–2748.

Hossen, M. S., & Mohd Pauzi, H. B. (2023). Embracing Housing Alternatives for the Enhancement of Wellbeing in the Aging Population: A Qualitative Study J Aging Neuro Psychol 4: 120. *DOI*, *10*, 2688–6499.

Hossen, M. S., Pauzi, H. B. M., & Salleh, S. F. B. (2023). Enhancing Elderly Well-being Through Age-

Friendly Community, Social Engagement and Social Support. *American J Sci Edu Re: AJSER-135*.

Hossen, M. S., & Pauzi, H. M. (2025). Bibliometric Analysis of Social Support for the Older Adults. *Ageing International*, *50*(1), 1–24.

Hossen, M. S., & Rezvi, A. (2021). Impact of Covid-19 Pandemic on Mental Health among Bangladeshi Senior Citizens: A Cross-Sectional Study. *CRRD QUALITY INDEX RESEARCH JOURNAL*, *2*(3), 22–33.

Hossen, M. S., & Salleh, S. F. B. (2024). Social influences on the psychological well-being of elderly individuals. *Journal of Humanities and Applied Social Sciences*.

Rana, M. M., Sultana Jahan, M. S., Rashid, A., & Hossen, M. S. (2024). Poetic Alleviation from Turmoil: A Critical Analysis of Wallace Stevens‟ Selected Poems. *World*, *14*(4), 372.