TEMPORAL EVOLUTION OF BLUE - GREEN INFRASTRUCTURE AND PERCEIVED BENEFITS: A CASE STUDY FOR URBAN CONTEXT OF COLOMBO, SRI LANKA

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Abstract: In contemporary urban planning, flood mitigation through blue–green infrastructure (BGI) is a central pathway to climate-resilient urban form. This article examines the temporal evolution and perceived benefits of BGI at Diyatha Uyana Park, and Bellanwila Park in urban context of Colombo. A mixed-method approach combines temporal land-cover mapping, flood-inundation analysis, and community perception surveys to understand how BGI systems have changed over time and how these changes influence both hydrological performance and user experience. Temporal analyses across pre-BGI, immediate post-BGI, and matured BGI periods reveal significant expansion and stabilization of blue-green networks. Flood-inundation maps for peak rainfall events in 2016 and 2024 demonstrate a measurable reduction in flood extent where BGI elements have become more connected and ecologically mature. Community responses further validate these spatial findings. Reported benefits include reduced flash flood during heavy rain, improved thermal comfort, enhanced visual quality, and increased use for relaxation. Overall, the temporal evolution and perceived benefits at Diyatha Uyana Park and Bellanwila Park shows that planned BGI, designed as multifunctional, and connected systems can reduce urban flood risks while elevating spatial quality and community wellbeing in Colombo.

Keywords: *Blue–Green Infrastructure (BGI), Temporal Mapping, Urban Flood Mitigation, Community Perception, Perceived Benefits*

1. Introduction

Sri Lanka has witnessed significant climate shifts over recent decades, including rising temperatures and altered precipitation patterns primarily due to global warming and related factors. These changes have intensified erratic monsoon behaviour, resulting in more frequent and severe flood events, especially in urban areas where rapid development has disrupted natural ecosystems and hydrological patterns. Urban flooding has emerged as a critical challenge, threatening climate resilience, public health, and socio-economic stability. Flash flooding is particularly problematic in Sri Lankan cities due to small, steep waterways and impervious surfaces (Camp, 2022b), worsened by inadequate drainage and climate change (Met Office, n.d.; Thu Thuy et al., 2017).

Nature-based solutions such as wetlands, forests, and urban parks have proven cost effective for flood management. Sustainable buildings, permeable pavements, and safe flood zones help reframe rainwater as a resource. Wetlands cleanse sewage before it enters water bodies (Cross et al., n.d.), and nature-based infrastructure are more cost-effective solutions than grey alternatives. Blue-Green Infrastructure (BGI) has gained recognition globally for addressing urban water challenges while offering societal and environmental co-benefits. Colombo's history of annual floods, exacerbated by illegal structures and poor wetland management, shows the urgent need for BGI. BGI emphasizes interconnected systems, functioning at multiple scales and providing ecosystem services, flood management, and social integration (Faggian & Sposito, 2009; Faggian et al., 2012)

1.1. RESEARCH GAP

The international studies highlight the hydrological and social benefits of BGI, research in Sri Lanka remains limited in three key areas. First, most local studies focus on general green spaces rather than on integrated blue–green systems. Second, there is little evidence on how BGI performs over time, particularly in relation to flood reduction and ecological maturation.

Third, community perception which is an essential factor for long-term acceptance and success of BGI has not been studied within Colombo's urban parks. Therefore, there is a need for research that combines temporal spatial analysis with community-based insights to understand both the physical evolution and perceived benefits of BGI in Sri Lanka's urban context.

1.2. RESEARCH QUESTION AND OBJECTIVES

The main research question is: "**How has Blue–Green Infrastructure (BGI) evolved over time in Colombo's urban parks, and how do communities perceive its benefits?**" The following three objectives have been identified to address the main research question.

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- Identify and characterize the temporal evolution of BGI at Diyatha Uyana and Bellanwila Park.
- Examine how observed BGI evolution can impact on flood mitigation.
- Study community perceptions, uses, and reported benefits of BGI.

1.3. SCOPE AND LIMITATIONS

The study focuses on two urban parks in Colombo, Diyatha Uyana and Bellanwila Park, where BGI interventions have been introduced during the last two decades. The research examines changes in blue and green cover, flood-inundation patterns, and community perceptions of BGI benefits.

This study has several limitations. The analysis of flood inundation was restricted by the availability of satellite data, as Sentinel-1 imagery is only available from 2014 onwards, making it impossible to map pre-BGI flood conditions accurately. In addition, the major rainfall events used for comparison in 2016 and 2024 varied in intensity, which may have caused slight differences in flood extent unrelated to BGI performance. Furthermore, community surveys were conducted mainly among residents and regular park visitors.

2. Review of Literature

Literature review examines urban flooding in Sri Lanka and the role of Blue–Green Infrastructure (BGI) in its implementation and performance. It first reviews global climate change trends and their impacts on urban hydrology, then situates Sri Lanka's vulnerability, especially Colombo's low-lying basins, shrinking wetlands, and ageing drainage. Later it discusses the theories and definitions of BGI, including connectivity, and multifunctionality.

2.1. CLIMATE CHANGE AND URBAN FLOODING

The urban environments are changing rapidly because of changes in the global hydrological circle and impact of climate change. Urban areas are highly vulnerable due to the high ratio of build areas which increase the surface runoff and overruns traditional drainage systems. The Intergovernmental Panel on Climate Change (IPCC) projects state that heavy rainfall and flood events will become more common and especially in tropical and subtropical regions (IPCC, 2021). These changes can disrupt designed drainage systems, as infrastructure designed for past rainfall patterns will not be sufficient. Rapid urbanization, population growth, and the expansion of impervious surfaces reduce natural infiltration, increasing the volume and speed of runoff during heavy rainfall events. Many urban cities, mainly developing countries, lack drainage infrastructure, making them affect by flash flood events, resulting in significant economic losses, public health crisis and social disruption.

Sri Lanka has experienced rapid urbanization over the past few decades. This urban expansion has made drastic changes in natural landscapes shrinking and reducing such as wetlands, marshes, and paddy fields into built up areas dominated by impermeable surfaces (Ranaweera et al., 2020). A series of severe flood events, most notably in 2010, 2016, and 2021, have brought huge disruptions, economic hardships, and displacement to communities across the Colombo city. Meteorological records show a steady rise in both annual mean rainfall and peak precipitation intensity across the Colombo district, with noticeable surge in 2010, 2016, and 2024. These fluctuations, shown in Figure 1, highlight how the rainfall pattern has shifted, making it heavier and more unpredictable than before.

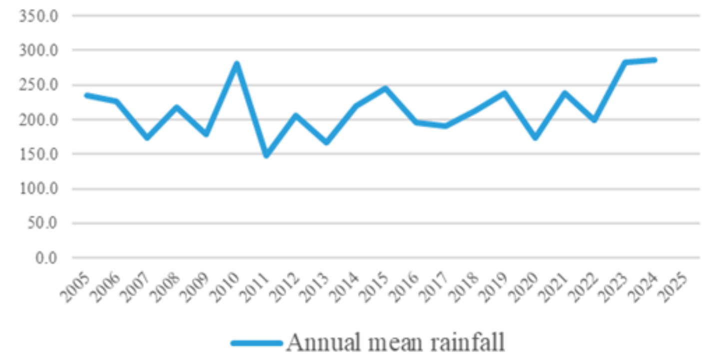

Figure 1: Annual Mean Rainfall of Colombo from 2005 to 2025
(Source: Meteorology department)

2.2 BLUE-GREEN INFRASTRUCTURE AS A STRATEGY

Managing water in cities has become one of the most present challenges in current urban development, as rapid urbanization and climate change continue to place growing pressure on drainage systems. For more than a century, most cities have depended on grey infrastructure, a network of pipes, culverts, and concrete channels built to quickly remove stormwater from urban areas. It is a combination of impervious structure with main objective of moving stormwater away as quickly as possible. In recent years, these limitations have created a need to find new ways to manage stormwater. The focus is gradually moving away from isolated engineering solutions towards integrated landscape-based systems that work with natural hydrological processes rather than against them. Within this shift, BGI has identified as a transformative framework. This brings together flood mitigation, ecological restoration, and urban liveability, allowing ways to cities to become more resilient by letting nature to play an active role in design and function.

2.2.1. Defining Blue-Green Infrastructure

Blue-Green Infrastructure is not individual technology, but a set of connected nature-based solutions that may be applied on a variety of scales. The BGI components are diverse and reflect various ways of natural process to work with water management. As shown in the table 1, it is possible to define them as vegetated systems, permeable surfaces, and specific water bodies and water storage systems (Fletcher et al., 2015; European Commission, 2013; Depietri and McPhearson, 2017).

Table 1: The Classification of BGI Components
(*Source: Compiled by author*)

	Components of BGI
vegetated systems	Urban Forests, Parks, and Trees
	Green Roofs and Walls
	Bioswales and Riparian Buffers
	Rain Gardens
Permeable Surfaces	Permeable Pavements
Water Bodies and Storage Systems	Constructed Wetlands Retention and Detention Ponds Blue Roofs Rainwater Harvesting Systems

When classifying and evaluation of BGI, its components are examined through three analytical dimensions, **function, position,** and **scale** (Cruijsen, 2015; Pötz & Bleuze, 2012). This explains how each BGI component is spatially positioned, how it hydrologically functions, and how it propagates across the urban context (refer to table 2 and table 3).

Table 2: The Classification Analytical Dimension of BGI
(Source: Compiled by author)

Analytical Dimension	**Definition**	**Resource**
By Function	Hydrological and ecological processes performed by a BGI component. It captures how the element operates, **infiltration** (soaking water into the ground), **detention** (temporarily storing and slowly releasing water), **retention** (holding water for infiltration), and **storage.**	(Cruijsen,2015; potz&Bleuze,2012)
By Position	This concerns the spatial placement of BGI within the urban fabric. It defines where the component is located as, **surface, subsurface**, or **above ground**. This placement helps in the component's visibility, accessibility, and interaction with surrounding built infrastructure.	(Cruijsen,2015; potz&Bleuze,2012)
Bt Scale	This refers to the spatial hierarchy with which the BGI is involved. It determines the sphere of influence of the component, ranging from site-specific or private interventions to interconnected neighbourhood-level systems and up to large, city-wide or regional networks.	(Cruijsen,2015; potz&Bleuze,2012)

Table 3: Classification of BGI Components with Reference to Function and Position
(Source: Compiled by author)

Function	**Surface**	**Subsurface**	**Above Ground**
Infiltration	Ponds, Green, spaces Pervious surfaces	Subsurface storage with retention capacity	Green façade, Green roof
Retention	Wetlands, Retention basins	Subsurface storage Tanks	Rainwater tanks
Retention	Ponds, Water squares	Subsurface storage tanks	Blue roofs
Storage	Seasonal retention storage, Rainwater harvesting Tanks	Subsurface storage tanks	Rainwater tanks

2.2.2. Maturation of Blue-Green Infrastructure

Blue-green infrastructure long-term viability depends on its ability to function as an evolving system that changes over time. BGI is made up of dynamic living systems whose performance may gradually deteriorate or improve. This system goes through an ecological development process over the course of months and years. As plant communities develop and shift, the soil prosperity and infiltration capacity are increased by the stabilization of root systems. (Bratieres et al., 2008; Chandrasena et al., 2020). As ecological processes gain more stability over time, the biological elements become more important. And as a result, when the system evolves, its ability to provide different types of ecosystem services, starting from flood prevention and water purification to biodiversity support can change and improve better.

3. Research Methodology

3.1. RESEARCH METHODOLOGY AND FRAMEWORK

The research methodology (refer to figure 2) is guided by the analytical dimensions of BGI identified in the literature review. Under the **scale**, the study focuses on the regional, urban context, with **Colombo** selected as the primary case study area due to its high flood vulnerability, rapid urbanization, and presence of multiple implemented BGI projects. Using meteorological records and disaster management datasets, five flood-prone sites within Colombo containing visible BGI components were initially identified.

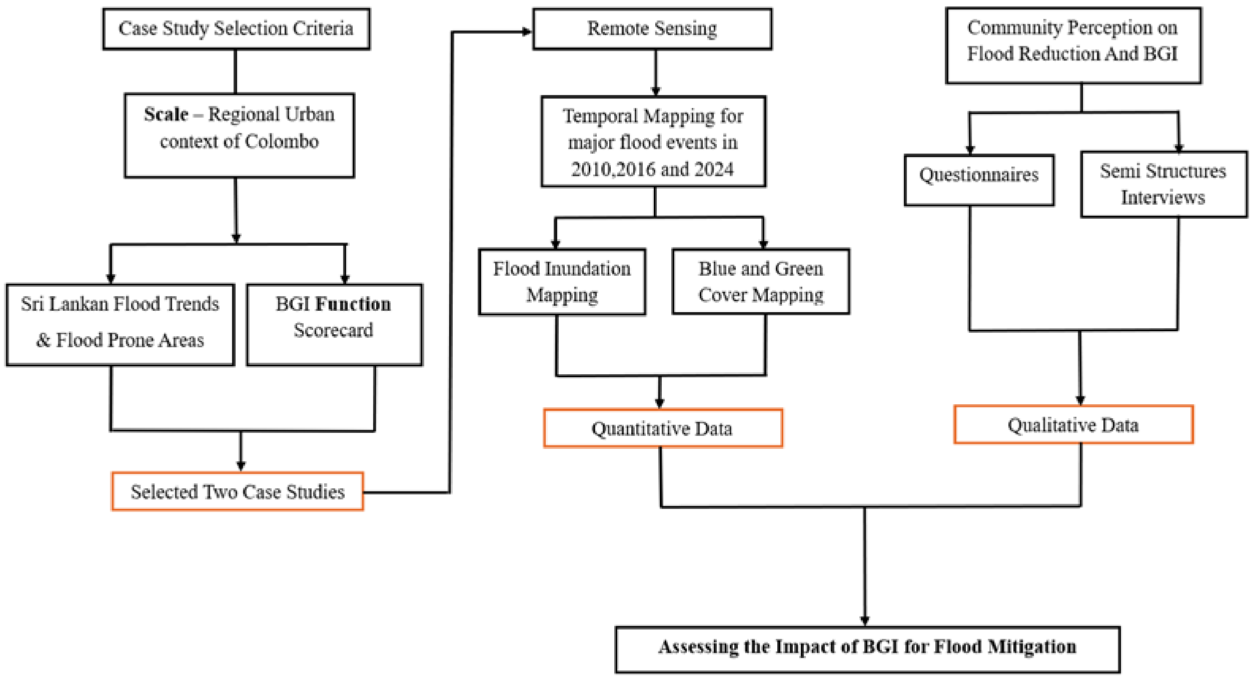

Figure 2: Research Methodology of the Study
(Source: Compiled by author)

The methodology focused on assessing the temporal evolution of flood inundation and BGI evolution through distinct years for the selected two sites.

- Pre-BGI Phase (2010) - The natural landscape condition before design interventions.
- Post-BGI Immediate Phase (2016) - The early operational phase, approximately two to three years after major BGI implementation.
- Post-BGI Mature Phase (2024) - A stabilized phase, approximately eight to ten years after implementation, allowing for vegetation establishment and hydrological adaptation.

These years were selected based on meteorological data, identifying periods of highest recorded rainfall and major flood alerts to ensure hydrologically relevant comparisons. Flood inundation mapping was conducted using Sentinel-1 and meteorological datasets for major flood incident years of 2016 and 2024. A community questionnaire was done to capture the subjective domain of perceived benefits of urban park. A total sample of 60 participants, including residents, frequent park users, and occasional visitors, was surveyed through a structured questionnaire and open-ended interviews. The theoretical framework (refer to figure 3) explains how the study connects theoretical concepts into measurable components.

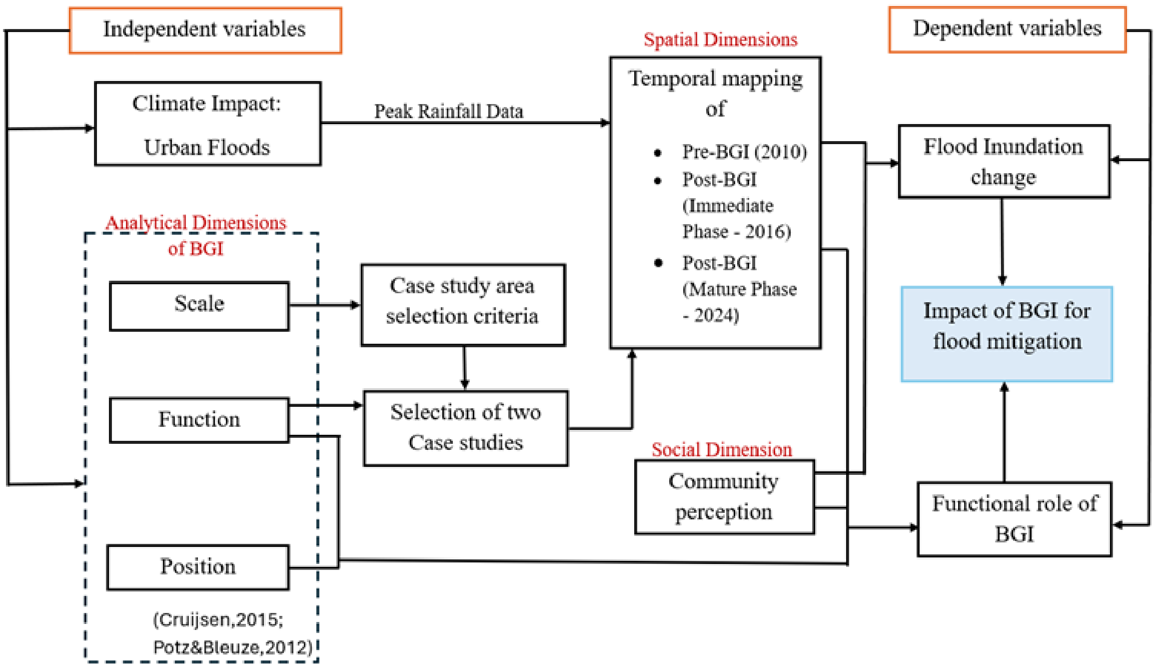

Figure 3: Theoretical Framework
(Source: Compiled by author)

3.2. SELECTION OF CASE STUDIES

Five Urban parks in Colombo developed within the last 15 years were selected by considering their contribution to the flood mitigation. Each site was assessed and scored by functions of BGI. This process produced a ranked list of potential case studies. The scorecard provides guided selection and forms the basis for later evaluation of site performance, ensuring methodological consistency.

Table 4: Evaluation of Urban Parks
(Source: Compiled by author)

Name of the site	Points for Pre BGI conditions	Points for Post BGI conditions
Diyatha Uyana Wetland Park, Battaramulla	13	21
Bellanwila Park, Bellanwila	16	19
Linear Park – Beira Lake	5	7
Katubedda walking pathway	10	10
Kelimadala, Borelasgamuwa	10	13

For this study, two sites were selected to examine the Impact of BGI in urban flood management. The selection was based on the presence and improvement of functionality of BGI interventions within the parks (refer to table 4). The chosen sites are **Diyatha Uyana in Battaramulla** and **Bellanwila Park in Boralesgamuwa,** both, which demonstrate highest number of integrated BGI functional diversity designed to enhance water retention, infiltration, detention, storage, and ecological resilience in an urban context.

4. data analysis, and findings

This chapter investigates how BGI has been evolved and the benefits of them in selected two case study areas of Diyatha Uyana in Battaramulla, and Bellanwila Park, Borelasgamuwa.

The study uses temporal and spatial comparative data analysis. Three distinct layers of data have been compiled and analyzed

- Blue – Green Infrastructure Expansion- - Identify the growth of green and blue spaces (for the years of 2010,2016 and 2024).
- Flood Inundation Maps- Identify flood extent over time (for the years of 2016 and 2024).
- Community perception analysis, with questionnaires and interview data from 60 participants to capture perception on BGI components and perceived benefits of parks.

4.1 CASE STUDY 1 - DIYATHA UYANA

Figure 4: Diyatha Uyana study area
(Google Earth Pro)

Diyatha Uyana and its surrounding area were selected as one of the case studies for this research. It is situated close to Water's Edge Hotel at Polduwa junction in Battaramulla and developed to current position in 2012. This Park has been built on marshland on the banks of the Diyawanna Oya which acts as a natural flood retention (refer to figure 4).

4.1.1. Blue – Green Infrastructure Expansion in Diyatha Uyana

Figure 5: BGI Expansion Over the Years in Diyatha Uyana
(Source: Google Colab)

The mappings of BGI over 2010, 2016, and 2024 demonstrate a clear transformation from a degraded marshland into a functional BGI system. Blue infrastructure was strengthened through restoration and expansion of reservoirs and wetlands, improving its hydrological connection, water retention and storage capacities. Green infrastructure actions like vegetation planting, turfing, buffer zone creation, increase the filtration, retention, and reduced groundwater runoff. By 2024, the combined intervention creates a stabilized blue-green system. (refer to figure 5)

4.1.2. Functional Roles of BGI in Spatial Dimension

The table 5, reveal how BGI components are physically embedded within the spatial dimension of the diyatha uyana. Each BGI type, natural tanks, constructed wetlands, bioswales and surface drains, permeable pavements, detention/retention ponds, and vegetated covers, operates at distinct positions such as surface or subsurface levels, reflecting a coordinated hydrological design

Table 5: Classification of BGI Components According to Its Position in Diyatha Uyana
(Source: Compiled by author)

NO	BGI Components	Position
1	Natural tanks	Surface
2	Permeable pavements	Surface
3	Constructed wetlands	Surface
4	Bioswales & Surface drains	Surface/ Subsurface
5	Detention/ retention ponds	Surface
6	vegetated cover	Surface

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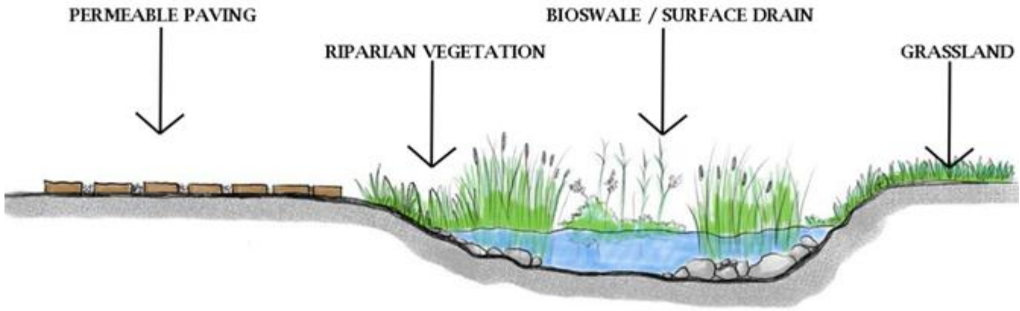

Figure 6: Functions of Bioswales and Pavements
(Source: Compiled by author)

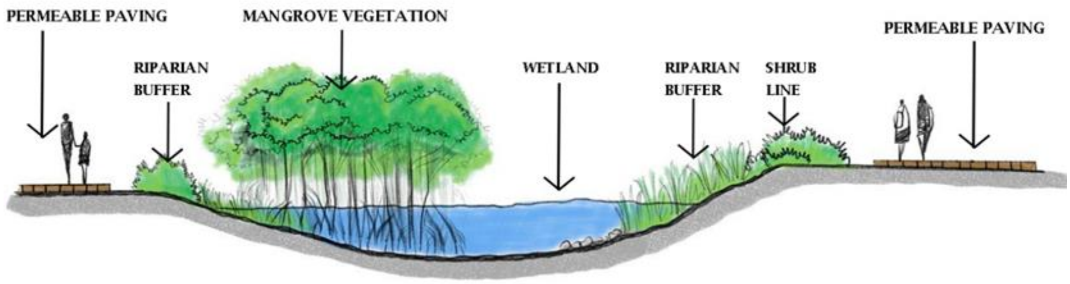

Figure 7: Function of Riparian Buffer and Wetlands
(Source: Compiled by author)

Permeable paving and surrounding drains transfer runoff to a riparian filter strip and a vegetated bioswale, while nearby grassland provides overflow capacity and extra infiltration. Bioswales and shallow depressions hold runoff for a time to promote slow infiltration. This infiltration reduces the volume and peak rate of surface runoff, lengthens the time of concentration, and distributes water to the subsurface, thereby helping to sustain the local water table. Excess flow passed toward a sequence of detention and retention areas. (refer to figure 6 and figure 7).

4.1.3. Spatial Analysis of Flood Inundation in Diytha Uyana

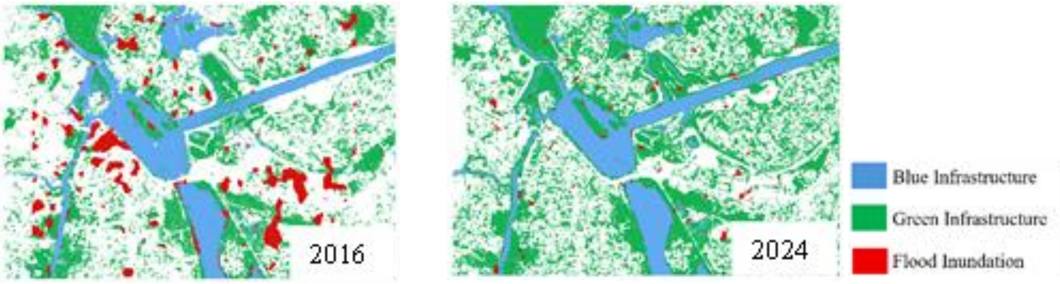

Figure 8: Flood Inundation and BGI expansion in Diytha Uyana in 2016 and 2024
(Source: Google Colab and Google Earth Engine)

The spatial and temporal analysis (refer to figure 8) shows a progressive transformation from fragmented marsh edges into a continuous blue-green network by 2024. This continuity has strengthened both hydrological function and ecological connectivity, ensuring that stormwater during peak rainfall events stays within designed blue areas, reducing flash flooding on surrounding built areas.

4.1.4. Community perception of BGI in Diytha Uyana

Figure 9: User Visitation Frequency in Diyatha Uyana
(Source: Compiled by author)

The distribution of community perception at Diyatha Uyana (refer to figure 9), illustrates the social multifunctionality associated with BGI led parks and aligns with the study's lenses of social responsiveness and community integration. Respondents expressed that **"We enjoy spending time here, and the air feels cleaner".** Overall, the pattern points to strong public acceptance of blue–green settings and co benefits like health, recreation, liveability that accompany flood mitigation goals. This shows that parks are actively used and socially compatible landscapes, and the purpose of visiting shows the multifunctionality of BGI. The finding confirms that Diyatha Uyana serves diverse user needs.

4.2 CASE STUDY 2 - BELLANWILA PARK

Bellanwila - Atthidiya Weras Ganga open space is one of the most attractive open spaces in the Colombo suburbs and significantly surrounding land values are changed after the project (refer to figure 10). The Bellanwila Park has been built as the first step of the "Weras Ganga" project in 2014 with the objective of controlling the flood threat surrounding weras lake (refer to figure 10).

Figure 10: Bellanwila Parks study area
(Google Earth Pro)

4.2.1. Blue – Green Infrastructure Expansion in Bellanwila Park

Figure 11: BGI Expansion Over the Years in Bellanwila Park
(Source: Google Colab)

The mappings of BGI in years of 2010, 2016, and 2024 demonstrate a clear transformation from a degraded marshland into a functional BGI system. Blue infrastructure was strengthened through restoration and expansion of reservoirs and wetlands, improving its hydrological connection, water retention, and storage capacities. Green infrastructure actions like vegetation planting, turfing, buffer zone creation, increase the filtration, retention, and reduced groundwater runoff. By 2024, the combined intervention creates a stabilized blue-green system. (Figure 11)

4.2.2. Functional Roles of BGI in Spatial Dimension

Table 6: Classification of BGI Components According to Its Position in Bellanwila Park
(Source: Compiled by author)

NO	BGI components	Position
1	Permeable pavements	Surface
2	Bioswales	Surface
3	Detention/ retention ponds	Surface
4	Surface drains & vegetated cover	Surface
5	Constructed wetlands	Surface
6	Natural tanks	Surface

The table 5, highlight a well-connected system of BGI operating across multiple layers WITH their positional relationships.

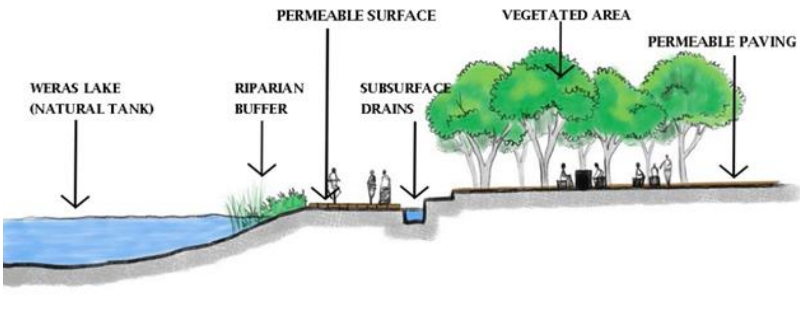

Figure 12: Function of Tank, and Riparian Buffer
(Source: Compiled by author)

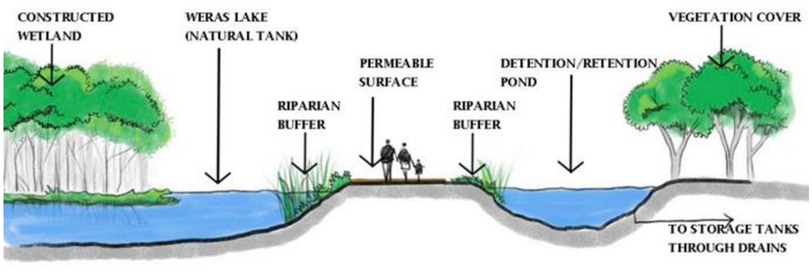

Figure 13: Function of Wetland, and Vegetation Cover
(Source: Compiled by author)

Figure 12 illustrates a graded BGI sequence that incorporates infiltration and distributed storage from upland to lake. Permeable paving and the permeable surface infiltrate rainfall into a gravel subbase, providing initial storage and reducing surface runoff. Figure 13 shows a designed BGI sequence that manages stormwater through detention and retention. Finally, controlled drains route pass water to storage tanks for reuse

4.2.3. Spatial Analysis of Flood Inundation in Bellanwila Park

By 2024 (Figure 14), the site displays clear evidence of BGI maturation. Tanks and canals have expanded and stabilized through natural sedimentation and plant succession. Retention ponds support a diverse composition of aquatic and emergent vegetation, and vegetated cover provide shade. These mature ecological layers collectively enhance infiltration, retention, detention and storage by reducing surface runoff. The evolution of vegetation density and root structure has increased surface roughness and soil stability, moderating water velocity and promoting gradual groundwater recharge. As a result, Bellanwila park functions as a self-regulating system where natural processes withstand flood incidents**.**

Figure 14: Flood Inundation and BGI expansion in Bellanwila Park in 2016 and 2024
(Source: Google Colab and Google Earth Engine)

4.2.4. Community perception of BGI in Bellanwila Park

Figure 15: User Visitation Frequency in Bellanwila Park
(Source: Compiled by author)

Figure 15 shows that the park is actively used, and purposes of visit demonstrate the multifunctional aspects, with user distributed across everyday activities. This profile suggests a destination park where blue–green settings support routine recreation and family use, not merely transit. The pattern aligns with social dimension, users report comfort, safety, and amenity, and connects to flood-mitigation performance, as sustained walking and leisure imply paths and edges remain usable after rain. The respondents emphasize that the park is now used by a diverse range of communities compared to its neglected past. Participants commented, **"it's very good to be in this space on hot days because the design makes it cooler".**

5. Conclusion

The findings reveal that the implementation of Blue–Green Infrastructure (BGI) in Colombo's flood-prone zones has transformed both the hydrological performance and spatial quality of the urban landscape. By examining the temporal evolution of BGI systems across 2016 and 2024 the study shows that strategically integrated blue and green networks contribute to reducing the risk of flooding and visible changes in the urban environment. **In both parks**, BGI strategy prioritizes storage integration within an existing network of canals and drainage systems. The design directs stormwater into enlarged wetlands and tank**s**, routed through vegetated areas. This arrangement transforms the parks into a dynamic storage landscape, where wetlands absorb and detain excess water, while green buffers provide shade, and recreational value. The community perception analysis reveals that community acceptance of BGI is highest when its functions are visible, comfortable, and socially interactive. **In both parks**, participants engage with the parks' wetlands, shaded walkways and water bodies. Many respondents noted the cooler microclimate, richer biodiversity, and calm atmosphere created by the continuous BGI network. This helps to perceive the park not only as flood infrastructure but as a recreational urban landscape.

The research points that public parks in flood-prone areas can be designed as dual purpose infrastructures, floodable areas that accept periodic inundation, so that flood management coexists with recreation and habitat provision. In conclusion, the study shows that Colombo's path to flood management can be achieved through its landscapes. BGI components integrations gives connected networks, and maturing systems that protect the city from flooding, enrich its ecology, and elevate everyday urban experience.

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