Exploring the Resilience of Urban Green Infrastructure: A Comparative Assessment of Resilience in Bangkok Metro Forest Project and The National Garden, Athens

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ABSTRACT

Urban green infrastructure, such as parks and reforestation programs, is critical for building municipal resilience to environmental, social, and economic concerns. The Metro Forest Project in Bangkok shows this by converting an abandoned site into a thriving biological forest utilizing the Miyawaki technique. The PTT Reforestation and Ecology Institute began this initiative, which focuses on using native species to reproduce past landscapes, enhancing biodiversity and ecological resilience. Despite its success, the initiative faces obstacles such as climate change effects, air and water pollution, and obtaining long-term finance. The study's goal is to assess the project's resilience by comparing it to the National Garden of Athens, identifying strengths, flaws, and areas for improvement.

The study used diverse research methodologies, including qualitative and quantitative approaches, to examine the resilience of the Metro Forest Project and the National Garden of Athens. Data were gathered from both secondary and primary sources, including literature studies, field trips, and key informant interviews. The data was examined using a contextualized city resilience paradigm that considered social, environmental, economic, and institutional components. This thorough approach gave a full picture of the resilience status of both urban green areas, allowing for a comparative analysis that yielded valuable insights.

According to the report, the Metro Forest Project successfully boosted urban biodiversity and resilience through innovative design and community engagement. Due to the limitation of this study, the resilience for sitting in the perspective of a broad urban fabric could not be identified. Some ongoing obstacles have been identified including the need for consistent funding, active community participation, and intensive data gathering to monitor environmental changes. To improve the project's resilience, recommendations include creating a strong data collecting system, increasing community participation, improving institutional backing, and performing frequent resilience evaluations. By tackling these issues and using its strengths, the Metro Forest Project can make a substantial contribution to Bangkok's overall resilience programs, supporting a sustainable and livable city environment.

1. INTRODUCTION

1.1. Background

Urban green infrastructure, including parks, forests, and green roofs, plays a critical role in enhancing the resilience of cities worldwide (Gill et al., 2007). Resilience assessment of these spaces involves evaluating their capacity to withstand and adapt to various environmental, social, and economic challenges (Meerow & Newell, 2017). On a global scale, urban green infrastructure helps mitigate the impacts of climate change by reducing the urban heat island effect, improving air and water quality, and providing essential ecosystem services (Kabisch. et. al., 2015). Regionally, green spaces contribute to biodiversity, support wildlife habitats, and offer recreational opportunities that enhance the well-being of urban residents. Locally, these spaces help communities cope with specific environmental stresses, such as flooding, and foster social cohesion by providing common areas for community activities (McPhearson et al., 2013).

Reforestation is a key component of urban green infrastructure, aiming to restore native vegetation and improve ecological health in urban areas. This process not only enhances biodiversity but also helps in sequestering carbon, thus playing a part in climate change mitigation (Walker & Salt, 2006). Reforestation projects, particularly those using methods like Dr. Akira Miyawaki's technique, create diverse and resilient micro-ecologies that are better suited to withstand environmental stresses (Lewis, H. 2022). Such projects highlight the importance of using native species to restore historical landscapes and support local ecosystems (Haase et al., 2014).

However, the implementation of urban green infrastructure and reforestation projects faces several challenges. Globally, these challenges include managing the impacts of climate change, such as increased temperatures and extreme weather events (Gill et al., 2007). Regionally, urban green spaces must address issues like air and water pollution and habitat fragmentation (Kabisch & Haase, 2015). Locally, securing long-term funding, engaging the community, and ensuring accessibility are critical for the success of these projects (Berardi et al., 2019). Despite these challenges, there are significant opportunities to enhance urban resilience. Innovative design and management practices, community involvement, and strong policy support can transform urban areas into resilient and sustainable environments (Walker & Salt, 2006).

The Metro Forest Project in Bangkok is a prime example of integrating these resilience concepts into urban planning. Located in the Prawet district, about 6 kilometers from Suvarnabhumi International Airport, this project serves as a learning center for ecological forests and provides a green space for urban residents. Initiated by the PTT Reforestation and Ecology Institute in early 2012, the project transformed an abandoned dumping site into a thriving green space. The project features an exhibition building made of natural-colored clay, divided into sections that educate visitors on the history and techniques of reforestation, particularly those developed by Dr. Akira Miyawaki.

The Metro Forest Project focuses on using native species to recreate the historical landscape

of mid-19th century Bangkok. This approach not only enhances biodiversity but also ensures the ecological resilience of the forest (Brandt et al., 2019). The project's soil preparation involved creating an optimal growing medium using topsoil, rice husk, coconut coir dust, and chicken manure. Planting techniques followed the Miyawaki method, which promotes diverse micro-ecologies and healthy forest growth (Haase et al., 2014). The elevated skywalks and viewing towers allow visitors to explore the forest and witness its development, fostering a connection between the community and their natural environment.

1.2. Objectives and Scope of Study

The purpose of this study is to estimate the resilience of Bangkok's Metro Forest Project by implementing and comparing the resilience assessment approach used to measure the resilience of the National Garden of Athens. This comparative analysis will assist in identifying the Metro Forest Project's strengths, shortcomings, and possibilities for improving resilience using well- defined resilience indicators. Our research objectives would cover the following,

- To Define and Assess Resilience Indicators for the Metro Forest Project
- To Compare Resilience Assessments of the Metro Forest Project and the National Garden of Athens, Identifying Challenges and Opportunities

1.3. Limitation of the Study

The scope of this study includes a full resilience assessment of the Metro Forest project in Bangkok, as well as a comparison with the National Garden of Athens. The study aims to define resilience indicators across four dimensions: social, environmental, institutional, and economic. The purpose of this study is to provide insights into the Metro Forest project's strengths and flaws by examining data gathered from observation and secondary sources. The study also investigates the broader effects of urban green infrastructure on urban resilience, identifying prospects for increased community engagement, ecological sustainability, and socioeconomic benefits.

However, several limits must be recognized. Due to time and resource restrictions, primary data collection for the Metro Forest project was confined to a single-day site visit, making it difficult to obtain full socioeconomic data. While observation tools provided useful insights, it was not possible to collect and evaluate all relevant data across the four dimensions. As a result, both case studies relied heavily on secondary data sources, which made it difficult to validate the data's legitimacy and correctness. While Google Earth imagery can be useful for morphological studies, it may be imprecise. Furthermore, the lack of laboratory, spatial mapping, and biodiversity assessment methods reduced environmental studies to qualitative description.

2. LITERATURE REVIEW

2.1. Urban Resilience Assessments

The word resilience originates from the Latin word resilio, which means restoring after frustration (Alexander, 2013). The origin of modern resilience theory is generally believed to stem from Canadian ecologist Holling, who applied resilience to the discipline of ecology for the first time and proposed the concept of ecological resilience (Holling, 1973). Since then, the concept of resilience has been revised numerous times and has expanded from a single ecological perspective to multiple perspectives including ecology, the economy, society, technology, and cities (Bahadur & Thornton, 2015; Campanella, 2006; Carver, 1998; Hernandez et al., 2019; Holling, 1973). The study of urban resilience, which combines the theory of resilience with the urban system, has gradually become a popular academic topic.

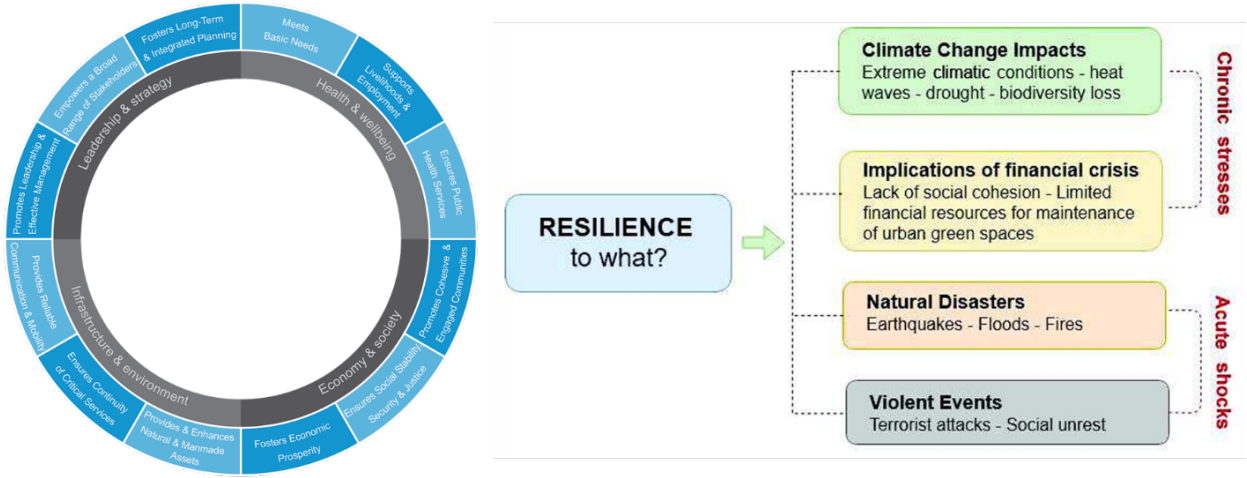

Figure 1 City Resilience Framework, Source: Rockfeller Foundation and ARUP, 2015

Urban resilience refers to the ability of a city or urban area to withstand, adapt to, and recover from shocks and stresses while maintaining its essential functions and overall well-being. It involves the capacity of a city to bounce back and even improve in the face of challenges such as natural disasters, climate change, economic downturns, social inequality, and infrastructure failures.

The concept of urban resilience emphasizes the need to build cities that can anticipate and respond effectively to various shocks and stresses, minimizing their negative impacts and

maximizing opportunities for growth and sustainability (Beilin & Wilkinson, 2015). Key elements of urban resilience assessments may include:

a. Robust infrastructure

b. Diverse and inclusive communities

c. Effective governance and institutions

d. Adaptation and flexibility

e. Integrated risk management

f. Resource efficiency and sustainability

g. Knowledge and innovate

h. Environmental Factors

2.2. Urban Green Infrastructure

Urban green infrastructure (UGI) refers to a strategically planned network of natural and semi-natural areas within urban settings designed to deliver a wide range of ecosystem services, including climate regulation, air purification, water management, biodiversity conservation, and recreational spaces (Hansen & Pauleit, 2014). This strategic approach not only addresses environmental issues but also enhances the resilience of urban areas, making them better equipped to handle climate change and other disruptions.

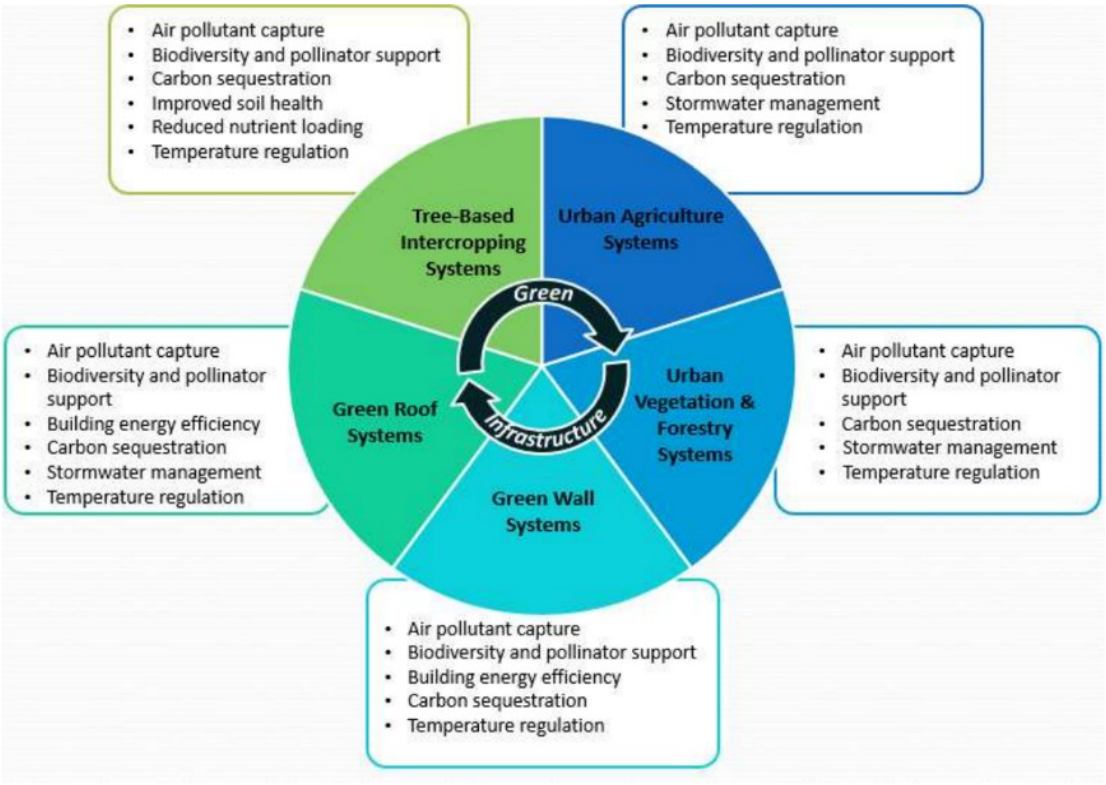

Figure 2 Green infrastructure forms and functions, Source: Anderson et.al.

One of the key benefits of UGI is its ability to mitigate environmental problems. For example, green spaces help reduce the urban heat island effect by cooling the air, which is achieved through shade and the release of moisture by plants (Gill et al., 2007). Additionally, urban forests and green roofs improve air quality by trapping particulate matter and absorbing pollutants (Pugh et al., 2012). In terms of water management, features like green roofs, permeable pavements, and urban wetlands absorb and filter rainwater, reducing the risk of flooding and decreasing the burden on urban drainage systems (Berndtsson, 2010). Furthermore, UGI promotes biodiversity by providing habitats for various species, creating ecological networks that allow flora and fauna to thrive even in densely populated areas (Tzoulas et al., 2007).

Beyond environmental benefits, UGI significantly impacts social well-being. Access to green spaces has been linked to numerous health benefits, such as reduced stress, improved mental health, and increased physical activity (Maas et al., 2009). Urban parks and recreational areas provide opportunities for exercise and relaxation, contributing to lower incidences of chronic diseases (Mitchell & Popham, 2008). Moreover, green spaces foster social interactions and community cohesion by offering places for people to gather and engage in recreational activities (Kazmierczak & Carter, 2010). Community gardens and urban farms encourage social engagement and enhance food security, further contributing to the resilience of urban communities (Armstrong, 2000).

Economically, UGI can increase property values, attract tourism, and reduce infrastructure costs. Proximity to green spaces often enhances property values, benefiting homeowners and municipalities alike (Wolch et al., 2014). Additionally, green infrastructure reduces the need for costly grey infrastructure solutions by naturally managing environmental challenges such as stormwater and air pollution (Tzoulas et al., 2007). For instance, green roofs and walls can reduce energy consumption by providing insulation and cooling, lowering heating and cooling costs (Berardi et al., 2014).

2.3. Resilience Challenges and Opportunities

The resilience of UGI is challenged by rapid urbanization, climate change, and biodiversity loss. Rapid urban expansion often leads to the fragmentation of green spaces, reducing their ability to provide ecosystem services effectively (Hansen et al., 2019). Climate change exacerbates these challenges by increasing the frequency and intensity of extreme weather events, which can damage or destroy urban green spaces (Gill et al., 2007). Furthermore, the loss of biodiversity within urban environments reduces the ecological resilience of these green infrastructures, making them less capable of recovering from disturbances (Hansen & Pauleit, 2014).

Despite these challenges, there are significant opportunities to enhance the resilience of UGI globally. Integrating green infrastructure into urban planning can mitigate some of the adverse effects of urbanization and climate change. For example, green roofs and walls can help manage stormwater, reduce the urban heat island effect, and improve air quality (Berardi et al., 2014). Additionally, promoting biodiversity within urban green spaces can enhance their ecological resilience and provide critical ecosystem services, such as pollination and pest control (Tzoulas et al., 2007). International cooperation and knowledge exchange on best practices for UGI implementation can further enhance global resilience (Kabisch and Haase, 2015).

Locally, the resilience challenges and opportunities of UGI are shaped by specific urban contexts and community needs. For instance, in Bangkok's Metro Forest Project, the challenges include maintaining the newly established green space amidst rapid urbanization and ensuring its integration into the broader urban fabric (PTT Reforestation and Ecology Institute, 2013). The project's focus on native species restoration and community involvement presents opportunities for enhancing urban resilience by fostering a sense of ownership and stewardship among local

residents.

2.4. Dimensions of Resilience Assessment

The study team carried out the literature review to identify the different dimensions of the resilience framework or resilience assessment, which more focused on assessing the resilience of green infrastructures and/or urban spaces. Ibes (2014) highlighted physical characteristics, land use and land cover, the socio-economic of park neighborhoods, and the surrounding built environment. Kotzamani & Alexandri (2019) detailed institution, environmental, social and economic as key dimensions. Fu et al. (2021), used only environmental, economic, and social dimensions to assess the green infrastructure. Karabakan & Mert (2021) used indicators such as stormwater management, green space availability, urban heat island effect, landscape connectivity, landscape connectivity, air quality, and social vulnerability to assess the resilience of green infrastructures in Turkey. Wang & Foley (2021) focused on ecosystem services, sociocultural benefits, and spatial networks to assess the resilience of green infrastructure in Ireland. Mosleh et al. (2023) highlighted the five factors that could influence resilience: policy, design, maintenance, economic, and social.

Table 1 Literature relating to resilience assessment of green infrastructures

Research Title	**Urban Green Space Location**	**Resilience Assessment Dimension**	**Source**
Sustainable Urban Park System	Pheonix, Arizona	Physical Characteristics, Landuse and land cover, Socio-economic of park neighborhoods, and surrounding built environment	Ibes (2014)
Estimation of the Resilience of Urban Parks	National Garden and Pedion Areos, Athens	Institution, Environmental, Social and Economic	Kotzamani & Alexandri (2019)
Assessment of Green Infrastructure Performance through an Urban Resilience Lens	Mill Creek Watershed, Ohio, USA	Environmental, Economic and Social	Fu et. al. (2021)
Measuring the Green Infrastructure Resilience in Turkey	Edremit, Van, Turkey	Stormwater Management, Green spaces accessibility, Urban heat island effect, landscape connectivity, Air Quality, and Social Vulnerability	Karabakan & Mert (2021)

Research Title	Urban Green Space Location	Resilience Assessment Dimension	Source
Assessing the performance of urban open space for achieving sustainable and resilient cities: A pilot study of two urban parks in Dublin, Ireland	Honey Park & Blackrock Park, Ireland	Ecosystem Services, Socio-cultural benefits, Spatial network	Wang & Foley (2021)
Performance Assessment Indicators for Comparing Recreational Services of Urban Parks	Guangzhou, China	Type of recreational physical activities, Degree of satisfaction, Extent of the park to achieve its desired goals	Yang et al. (2021)
Stormwater Green Infrastructure Resilience Assessment: A Socio-Ecological Framework for Urban Stormwater Management		Policy, Design, Maintenance, Economic Factor and Social Factor	Mosleh et. al. (2023)

Amongst the searched documents, the study team finalized the article entitled “Estimation of Resilience of Urban Space " due to its relatability and comparability with the Metro Forest project, in Bangkok. Karatbakan & Mert (2021) highlighted the four dimensions namely Institution, Environment, Social, and Economic as the key dimensions to measure the resilience of urban green space.

Table 2 Finalized Resilience Framework for the Comparative Assessment

Dimension type	Environmental	Social	Institutional	Economic
Criteria	1.1 Total area of green space 1.2 Components of the built environment (within a 300 m radius of the green space) 1.3 Green space characteristics 1.4 Quality/ Adequacy of equivalent 1.5 Component of Circular Economy 1.6 Climate Data 1.7 Environmental Quality	2.1 Demographic profile of residents – potential users -, in the wider area 2.2 Land use within the urban park 2.3 Accessibility - Connectivity 2.4 Safety 2.5 Social Networks 2.6 Emergency plan	3.1 Maintenance cost of green space 3.2 Annual revenue from commercial activities within the park 3.3 Activate alternative funding sources to enhance resilience	4.1 Green Space Management Model 4.2 Action plans and risk assessment plans 4.3 Monitoring - evaluation model

3. METHODOLOGY

3.1. Concepts and Approaches

The study assesses the resilience of the urban green spaces situated in Athens i.e. The Garden of Athens and Bangkok i.e. The Metro Forest Project, Bangkok adopting the contextualized version of the city resilience framework. The study team employed mixed research methods i.e. qualitative and quantitative approaches utilizing the city resilience framework to explore the resilience status of the two urban green spaces and compare their resiliency status on identified dimensions of resilience i.e. social, economic, environmental, and institutional. The contextualized resilience framework enabled the study team to link up the framework selection process to the measurement, analysis, and comparison of urban green space based on their characteristics and significance to the respective cities, and well-alignment with the objectives of this comparative study.

3.2. Overall Methodology Process

The study adopts a mixed research method design, examining the resilience status of the two urban green spaces namely The Garden of Athens, and The Metro Forest Project, Bangkok through a series of secondary and primary data collection, analysis, and interpretation stages. Following the approval from the supervisor at the Asian Institute of Technology (AIT), the study team carried out the data collection and analysis, emphasizing the contextualized version of the city resilience framework as defined by Karatbakan & Mert (2021). The data were collected through both secondary (literature review) and primary sources (key informant interviews and observation). The data were then placed into the resilience framework under four dimensions i.e. social, environmental, economic, and institutional for further analysis and comparison between the resilience status of two urban green spaces. From the data collected through diverse approaches, strength, weakness, opportunities, and threat (SWOT) analysis was further carried out to draw meaningful insights and detail the study objectives.

3.2. Study Area

The study focuses on the urban reforestation site Metro Forest Project located in Dok Mai. Dok Mai is a sub-district in Bangkok's Prawet district, in the city's southeast. This region is distinguished by a mix of residential developments, business sectors, and green spaces, resulting in a vibrant urban atmosphere. Dok Mai's strategic location near major roads and transit hubs, such as Srinagarindra Road and the Ban Thap Chang Station of the Airport Rail Link, improves connection and accessibility, making it an important element of Bangkok's urban fabric.

The existence of green spaces and recreational sites in Dok Mai improves the quality of life for its inhabitants. These green spaces provide numerous ecological benefits, including lowering the urban heat island effect, increasing air quality, and providing locations for entertainment and relaxation. Furthermore, the district's proximity to key transportation arteries such as the Motorway - Rama 9 and the Burapha Withi Expressway allows for efficient movement of people and commodities, contributing to its economic vitality and connectedness within Bangkok.

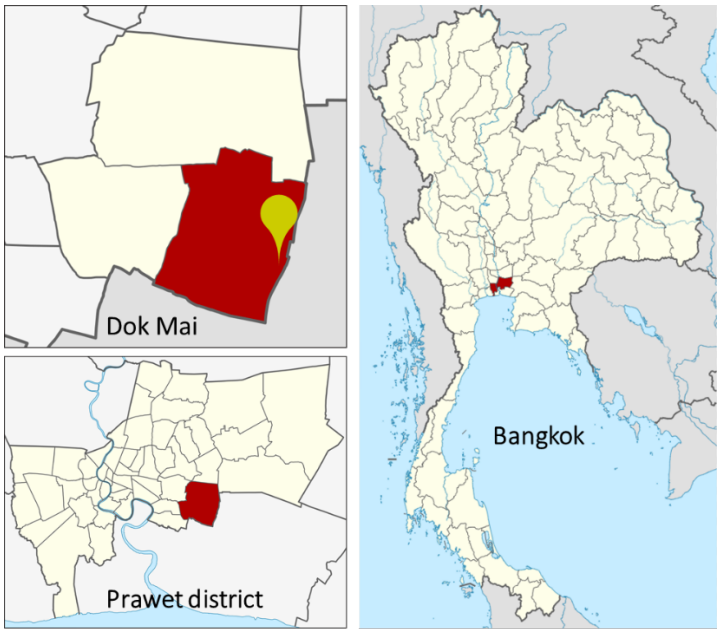

Figure 3 Study area base map

Dok Mai's morphology has changed significantly throughout the years (Fig: 3.2), owing to urbanization and development forces. The terrain has shifted from primarily agricultural land to a more urbanized one with mixed-use developments. This transformation has presented important issues, such as balancing urban development with the preservation of green places and biodiversity. The project focuses on understanding these changes and how they affect the area's resilience, particularly in the face of natural problems such as flooding.

Figure 4Study area Morphological changes from 2006-2024, Source: Time laps Google Earth Pro

The urban system in Dok Mai is supported by important transportation links that improve connection. However, the area is vulnerable to several threats, the most serious of which is environmental, such as flooding. The growth of urban areas has put a strain on remaining green spaces and biodiversity, prompting proactive steps to boost resilience. The primary goal is to explore solutions for mitigating these vulnerabilities and promoting sustainable urban development. Dok Mai's resilience development is consistent with the larger Resilient Bangkok programs, which seek to improve the city's ability to endure and adapt to a variety of stresses and shocks. These efforts emphasize the need of incorporating green infrastructure into urban design to build a more sustainable and resilient city. In Dok Mai, efforts are being undertaken to create and maintain green spaces, establish effective flood management systems, and encourage community participation in resilience-building activities.

3.3. Data Collection

The required data to measure and compare the resilience of two selected cases were collected through both secondary and primary sources. From secondary sources, the review of existing literatures on the background, design, and significance of the two urban green spaces was carried out. Furthermore, the data related to the parameters or dimensions of resilience for the case of The National Garden of Athens was taken from secondary sources. Meanwhile, the data related to the parameters or dimensions of resilience for the case of the Metro Forest Project was taken through primary sources. As a primary source, the study team went to the project area, observed the sites, used the checklist comprised of the dimensions and indicators of the resilience, and collected the required data as possible as it could be. During the data collection process, study team interacted with the project staff as well as the visitor to know about their perception, which provided the qualitative aspect to the findings. The primary data collection method enabled the study team to understand the design, social, environmental, and economical characteristics of the Metro Forest Project, while the demographic status for Bangkok was taken from secondary sources i.e. census.

3.4. Data Analysis

The study team consisting of the students taking the “Urban Resilience Assessment” course from the Asian Institute of Technology (AIT) visited the Metro Forest Project, Bangkok, and collected the required data as per the resiliency framework and its indicators. Both sets of qualitative and quantitative datasets were collected during the site visit. The data collected from both primary and secondary sources were filled into the contextualized city resilience framework and were analyzed to discuss the resilience of the selected urban green spaces under each dimension of the resilience. The comparative analysis was carried out to discuss and interpret the resilience of both urban green spaces for each dimension. As the preferred article also included the SWOT analysis for the Garden of Athens, the study team also analyzed a similar one for the Metro Forest Project, to provide additional insights other than the resilience assessment, and their comparison. Broadly, the study team analyzed the findings under each dimension of resilience and also had a detailed SWOT analysis for both of the urban green spaces.

4. RESULT

4.1. Case Study 1: Metro Forest Project, Bangkok

4.1.1. Brief Description (Design and Features)

The Metro Forest Project lies in the Prawet District, Bangkok within an area of 4.74 acres. It began its construction work in 2013 with the objective of improving the health of city dwellers, contributing to Bangkok's tourism industry, and becoming a recreational center for all age groups. Before the construction work, the survey was carried out to have a soil test and water test to understand the salinity status and water table status.

Figure 5 Site area Metro Forest, Source: landezine.com

The finding showed the challenge in terms of having natural plant growth and reforestation as planned. However, with the adoption of raised berm technique for plantation, the project is currently considered one of the innovative projects in the areas of the ecological sector and/or green infrastructure sector, as it helped in promoting afforestation, eco-sustainable reforestation, and instigated green awareness amongst the public through reclamation of the abandoned site (Tian & Wang, 2018). An equally interesting and significant aspect of the project is the plantation of the mixed floral species, giving priority towards both fast-growing species as well as slow-growing

species with the objective of building the forest through the plantation of native trees and provisioning adequate time to grow naturally in between the fast-growing species.

As of 2024, there are over 60000 trees with over 280 unique floral species, creating the opportunity for botanists and environmental researchers to explore the vegetation pattern and/or ecological diversity and their resilience. From the coverage perspective, the structure comprised 75% forest, 10% water and 15% land.

The notable design of the project is about instilling the capacity to reduce flooding during the wet season through an effective water system circulation across the project coverage area, maintaining the vegetation growth rate, and adding to the aesthetics. Furthermore, the project has installed renewable energy that can generate electricity of 16800 kW/Yr. Considering the objective of attracting tourists or visitors from different age groups, the management placed the cinema room to display short movies, the canopy skywalk for the visitors to visit the project areas, and learn about diverse floral species, and the observation tower to have a 360-degree bird's eye view of the project area.

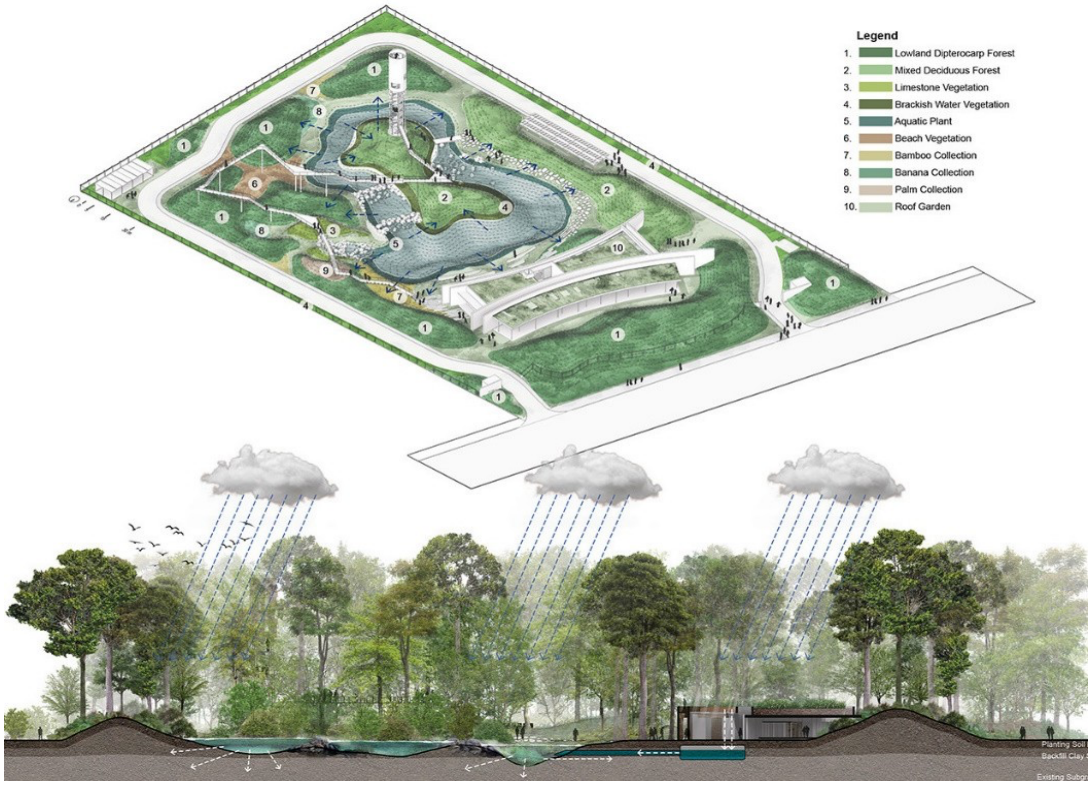

Figure 6 Site area Metro Forest and stormwater runoff design strategies, Source: Landezine.com

4.1.2. Resilience Assessment

Environmental Dimension: The environmental dimension comprises of total area of green space, components of the built environment, green space characteristics, quality/adequacy, components of circular economy, and climate-specific data. The Metro Forest Project is spread

over a 1.92-hectare land area with the plantation of over 60000 florae, which have 75% of the vegetation coverage, 10% of the water surfaces and the rest being built-area. The surrounding land is being used for residential purposes. From the construction period of the park itself, there have been significant changes in the surrounding spaces, with increased construction activity. From the infrastructure quality perspective, the project is relatively new and has just been over a decade of construction, thus the quality of existing furniture, railing, and other infrastructures looks to be in good shape. There lies the presence of cleaning staff, who carry out the cleaning on daily basis. As the number of visitors are higher, the waste management bins are also placed at different spots to ensure all visitor dump or dispose their waste in appropriate place. The floral species, themselves work as the secondary water treatment, however, from the infrastructure set-up perspective, wastewater treatment plants or the floral species known for the water treatment are not being planted on the site. From an interaction, it was found that the project doesn't have specific data collection practices for climatic variability, instead refers to the city-level data and internet sources.

Social Dimension: The green infrastructure is situated at the Bangkok, which is considered as one of the countries with good economic status. The average population size of the country is 3 people per household with the age-group scenario as 16.45% (0-14 years), 72% (15-64 years), and 11.82% (65 years and above). The age group shows a high proportion of the working age group in the country. Meanwhile, the employment rate amongst the working age group population is 98.3%, which is significantly high. Even though there lies a higher employment rate, the population below the poverty rate exists at 5.4% due to inconsistent employment status, high inflation rate, and the lower wage rate. Overall, the literacy status is 94.1%. From the land use perspective, the project doesn't have any specific park for children or adult, but have presence of walking space, from where visitor can explore the forest area. The project also has the space accommodating the cafe and the visual area to promote recreational, health, and educational aspects associated with the project. Even though the infrastructure is somehow far from the central part of the city, it is still easily accessible from the main road. Considering the infrastructure design, it doesn't have any bicycle lanes but can be accessible by people with disabilities. From the safety and security perspective, infrastructure can be considered safe and secure, as has controlled entrances to manage the flow of visitors, and also surveillance and security personnel. Lighting has been installed to ensure visitor safety during evening hours as well. Numerous non-governmental organization (NGOs) have shown interest to collaborate with the project to promote the ecological education across the country.

Institutional Dimension: The Institutional dimension incorporated the components such as the green space management model, and the monitoring and evaluation model. The project is being managed by the PTT (public company limited) since its design period. Throughout the project design, construction, and operation period, there have been numerous collaborations with diverse stakeholders, researchers, and local communities to promote the project's contribution to city resilience. The structure is designed with the purpose of promoting ecological resilience, and contributing towards the city's urban resilience, thus seems to have a long-term strategic management plan. As the structure is relatively new, it is yet to be specifically included or highlighted in Bangkok or Thailand's overall urban development-specific legal instruments. The

project management team collect and analyze the data on the tree growth, as it adopts innovative approach, and have wider range of local or native floral species. Project prepared the annual report and made it available to the public, upon need, that incorporates the plantation activities, maintenance works, and community events. Overall, the project management team discusses the ecological aspect of the structure, the significance or impact it made on the city through economic, social and ecological means, and prepares the action plan to strengthen the ecological resilience through continued operation and maintenance works.

Table 3 Dataset for the resilience indicators, Metro Forest Project, Bangkok

Dimension	**Indicator**	**Description of Metro Forest Project**
Environmental Dimension		
1.1 Total area of green space	1.1.1 Total area (in hectares)	19200 m^2
1.2 Components of the built environment (within 300 m radius from the green space)	1.2.1 Building density/average floor area ratio	Not available
	1.2.2 Average building height/ average number of floors	16ft
	1.2.3 Average Road Width	Not Available
	1.2.4 Land Use	Mostly Residential
	1.2.5 Residential density (number of residents/ Ha)	Data not available
1.3 Green space characteristics	1.3.1 Soil cover percentage	
	1.3.2 Percentage of vegetation cover	75%
	1.3.3 Percentage of impermeable surfaces	Data not available
	1.3.4 Number of trees/1000m^2 of green space	3125
	1.3.5 Percentage of water surfaces	10
	1.3.6 Endemic/alien species ratio	100:0
	1.3.8 Percentage of built surfaces	1.95
1.4 Quality/Adequacy of equivalent	1.4.1 Urban Furniture Quality	Need for maintenance for some of the urban furniture
	1.4.2 Infrastructure Quality	Well maintained
	1.4.3 Cleanliness – Maintenance	The presence of the cleaning staff, who carries out the cleaning and maintenance work regularly
1.5 Component of Circular Economy	1.5.1 Waste Recycling	Presence of separate waste disposal bin.
	1.5.2 Composting of organic matter/waste	Compost their byproducts
	1.5.3. Secondary water treatment	Not available
	1.5.4. Use of renewable energy sources / Annual electricity production (in	Yes, the use of renewable energy

Dimension	Indicator	Description of Metro Forest Project
	kWh / m^2 of green space) from renewable energy sources	
	1.5.5. Annual electricity consumption (in kWh / m^2 of green space) from conventional energy sources	Data not available
	1.5.6. Annual water consumption (in m^3 /m^2 of green space)	Data not available
1.6 Climate Data	1.6.1. Annual recording of climate data	Collect data on the plant, and soil. Data not available about climatic characteristics
1.7 Environmental Quality	1.7.1. Atmospheric pollutants (CO_2, N_2O_x, S_2O_x, O_3, particulate matter)	Good Numerical value between 0-49
	1.7.2. Soil Quality (acidity or alkalinity, salinity, etc.)	Data not available
	1.7.3. Water quality (acidity, salinity, organic load)	Data not available
	1.7.4. Noise pollution	Far from major noise sources
Social Dimension		
2.1 Demographic profile of residents – potential users -, in the wider area	2.1.3. Employment rate – Unemployment rate	98.3% employment rate amongst the Thai population (2022) Unemployment rate: 0.9% of total labor force
	2.1.4. Percentage of population at risk of poverty - vulnerable households	5.4% live below national poverty line (Thailand, 2022)
	2.1.5 Educational status	94.1% literacy status (Thailand. 2021)
2.2 Land use within the urban park	2.2.1. Sports facilities	Doesn't have specific sports facilities
	2.2.2. Playgrounds	Doesn't have a specific playground
	2.2.3. Recreation (café-restaurants)	Does have cafe
	2.2.4. Cultural facilities	Have space to play a video about the forest
	2.2.5. Educational programs	Collaborate with academic institutions to conduct research, and education excursion tours. Offers education programs and activities focused on awareness, reforestation techniques, etc.
2.3 Accessibility - Connectivity	2.3.1. Accessibility by public transport	Easily accessible from the main road

Dimension	Indicator	Description of Metro Forest Project
	2.3.2. Bicycle lanes - bicycle parking spaces	No
	2.3.3. Accessibility for the disabled	Accessible For the disable
2.4 Safety	2.4.1. Site enclosure – controlled entrances	Have controlled entrances to manage the flow of visitor, enhancing safety, security, and monitoring.
	2.4.2. Surveillance - security personnel	The site includes surveillance and security measures.
	2.4.3. Adequate lighting	Lighting has been installed to ensure visitor safety during evening hours
2.5 Social Networks	2.5.1. Active citizen groups - associations, NGOs, volunteers	Different government and non-government agencies including academic researchers show keen interest in diverse activities
2.6 Emergency plan	2.6.1. Plan for use of the site in case of emergency (earthquakes etc.)	Have a set of emergency plan
Economic Dimension		
3.1 Maintenance cost of green space	3.1.1. Detailed annual maintenance cost of the site/m^2	Data not available
	3.1.2. Number of employees in the management and maintenance of the site / m^2	Data not available
3.2 Annual revenue from commercial activities within the park	3.2.1. Revenue from renting recreation spaces	No such practice
	3.2.2. Revenue from the plant nursery	The project does have a nursery. However, the revenue-specific data is not available
	3.2.3. Revenue from organizing cultural activities	The project keeps on having community-focused activities. However, the revenue-specific data is not available
3.3 Activate alternative funding sources to enhance resilience	3.3.1. Leverage funding from European programs	The project received funding from PTT and other collaborations. EU-specific funding is not known.
	3.3.2. Sponsorships – Crowdfunding	Funding received from different sources. Visitor can pay as per their willingness separately.
Institutional Dimension		
4.1 Green Space Management Model	4.1.1. Management by a public or private body	Managed by PTT Public Company Limited
	4.1.2. Co-management with active	Collaboration with diverse

Dimension	Indicator	Description of Metro Forest Project
	citizen groups - NGOs	stakeholders, researchers, and local communities for project construction, operation, and awareness activities
	4.1.3. Long-term strategic management plan	Guided by a long-term vision to promote ecological resilience
	4.1.4. Clear legislative - administrative framework	Government policy talks about urban resilience and urban management but is not specific about one or other projects.
4.2 Action plans and risk assessment plans	4.2.1. Scenario-based Risk Assessment and Risk Management Plans	Assessment carried out prior to the project start. The management practices are being followed up.
	4.2.2. Hazard Maps	Have different layers of the project map that somehow talk about the hazard, but not an explicit level.
4.3 Monitoring - evaluation model	4.3.1. Periodic data collection and digitalization and database enrichment	Data on tree growth and species diversity are collected in a periodic manner
	4.3.2. Annual report of actions	Prepare the report on annual actions that include plantation activities, maintenance works, and community events.
	4.3.3. Evaluating the effectiveness of actions	Management discusses the growth of the project, including its operational aspects.
	4.3.4. Certification of all materials and evaluation process	Ensures all materials used meet environmental and sustainability standards

4.1.3. Strength, Weakness, Opportunities, and Threat (SWOT) Analysis

The study carried out the Strength, Weakness, Opportunity, and Threat (SWOT) analysis of the Metro Forest Project, Bangkok. Key areas of strength from the Metro Forest Project are about its significance to improve air pollution, reduce urban heat island effect, contributes towards carbon sequestration, and enhance the biodiversity through introduction of the diverse floral species within its space. The first and foremost advantage is the creation of green space within the urban area in Bangkok. Furthermore, it helped to improve the physical and mental well-being of the visitors, who come for the recreational activities. The engagement of the public within themselves, and their interaction aid in enhancing the social cohesion amongst the visitor from

diverse background and communities. The inflow of visitors can also contribute towards the economic aspect of the city, as it can serve as a tourist attraction spot in the longer-term. The design of the structure itself, as well as the floral diversity, attract researchers and education institutions to carry out their field visits and conduct research associated with social, economic, and ecological aspects. The project is designed in such a way, that it can help in floodwater management as well, thus reducing the flood-associated risks and impacts. The Miyawaki method adopted during the design and early stage of the plantation period reduces long-term maintenance needs through the self-sustaining ecosystem.

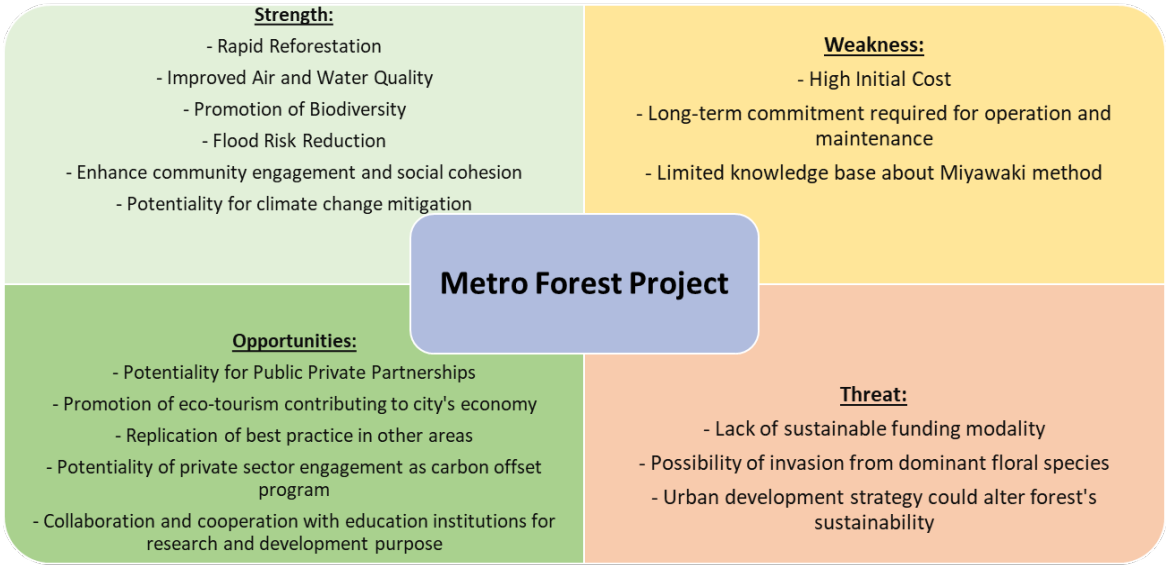

Figure 7 The SWOT Analysis of the Metro Forest Project

Key areas of weakness of the Metro Forest Project are about its high infrastructure development cost during its early stage, that includes the construction, plantation and maintenance works. The project is still in its early stages, and its full benefit or its sustainability is yet to be explored and discovered. As the project comprised of both native floral species as well as the foreign spaces, the potentiality of eco-gentrification remains, also the potentiality of having invasive species remains, if the care is not provided in an appropriate manner. Even with multiple benefits, the limited space of the project restricts the scope and scale of biodiversity and green cover. The concept of the Miyawaki is relatively new in the Thailand context, thus the technical resources to deal with the challenges (if any) could remain the weakness of the project.

Key areas of opportunity of the Metro Forest Project includes the potentiality of collaboration and cooperation with the academic institutions, as well as private agencies for the

research works, operation and maintenance of parks. With the success of the project, the surrounding area could also get the opportunity to engage in economic activities, which is almost none till this study period. The government can portray the project as best practice and innovative action in areas of ecological management in global forums and networks, that further can pave the way for additional financial resources, not only to manage the forest but also to invest and/or replicate in other areas. The forest can pave opportunity for the non-governmental agencies as well as government agencies to raise awareness about the significance of green infrastructure, and environmental issues. As the green infrastructure is considered as one of the key components of urban resilience, the project can also contribute towards having positive resiliency of the Bangkok city.

There lies the potential threat from the government agencies to utilize the forest project area into other urban development structures in long-run. Within the forest area itself, there could be the invasion of the floral species, alongside the introduction of the diverse pests, and diseases. In the early stage, the project is garnering public interest but may not remain the same for the long term, as its far away from the city area. In that context, the lack of public interest and the government's interest can alter the project's sustainability.

4.2. Case Study 2: National Garden of Athens

4.2.1. Brief Description (Design and Features)

The National Garden of Athens, formerly known as the Royal Garden, is one of the largest urban green spaces in the heart of Athens, Greece, with a linkage to ancient and modern history. It is spread across 15.8 hectares of land, with prominent historical and horticultural landmarks, lies between Kolonaki and Pangrati, and is near the Greek Parliament Building (the old palace). The garden was originally designed as the Royal Garden, and began its plantation work in 1839 AD at

2.5 hectares of land, bringing the concept of modern design of Western European landscape garden from Germany to Greece. The floral species were chosen in a way, that could adapt well to the environmental conditions (climate, air, and water) of Athens. The historical plants include pines, cypresses, yuccas, elms, gallus and lilies. With the mixture of floral species across the world, including native species, the National Garden now boasts over 7000 trees, 40000 shrubs, 5700 bushes, 9400 plants (519 plant species), 85 species of birds, 4 types of reptiles and three species of amphibians. The enriched floral species include evergreen as well as deciduous trees, perennial

herbaceous plants, climbers, succulents, cacti annuals, lawns, etc. The garden's botanical richness made it the first greenhouse in modern Greece, where saplings are grown and later replanted into the park.

Besides the diverse floral species, another equally important and interesting part of the National Garden is its irrigation management practice. The water for irrigation passes from the highest northern part of the garden to the lowest part and is circulated across the garden through a complex and ingenious system of surface channels and lakes and is characterized as a Peisistratus aqueduct. The 6.5-meter-long and 10–12-meter depth structure existed and has been functional since the 6th century B.C., thus adding historical or ancient significance to the garden. The irrigation through the ancient canal structure helps to maintain the greenery of the garden and keeps it evergreen across the year-around period. Furthermore, the irrigation system is adding aesthetic value to the garden, including an enhancement of the landscape.

Figure 8 Site area the National Garden of Athens, Source: Google Earth Pro

The increased significance of the garden for urban development and its residents paved the way for its launching as a public park or public urban green space in 1927 (Paraskevopoulou et. al. 2020). Since then, the garden has been serving the city in social, cultural, historical, environmental, ecological, and economic ways. The garden has remained the center of attraction

for all age groups populations, as it includes sightseeing features, a zoo, ponds, a lake, a library, and a playground. Alongside other parks inside Athens, the National Garden remained the key urban green space to explore and understand for tourists, planners, researchers, and academicians. Broadly, the development of the national garden over the course of the period has a direct linkage with the progress of the modern Greek state as well as the development of Athens as a modern European capital. In 2011, the garden was officially classified as a historic site and is currently operational with the objective of transferring historical knowledge from generation to generation through the protection, preservation, and reinforcement of the historical character of the national garden; enhancing the ecological resilience of garden and urban resilience of Athens; and engage communities and wider stakeholders ranging from researcher to non-governmental organizations and education institutions.

Paraskevopoulou et al. (2020) carried out a quantitative assessment to understand the perception amongst the visitor about their impression of the National Garden from park design, visitation and park management aspects. The accessibility to the garden is very convenient as people can access it through public transport, by foot, or by private car. Citing the multiple benefits of the garden itself, the repeated visiting characteristics amongst the people are found to be high. A higher proportion of people visit the garden for tranquility purposes, followed by exercise, child walking outdoors, socialization, and cycling purposes. A quarter proportion of the people visit the entire garden, while an equal proportion of people visit partial locations such as lakes, fountains, cafe shops, and paths. Two-thirds found the aesthetics and maintenance of planting as satisfactory level, while one-third suggested their improvement. Half of the surveyed people reported the furniture to be upgraded or repaired to meet the aesthetic of the garden. Regardless Of the presence of security personnel, a considerably high proportion of people find the garden a little safe. The findings from the assessment also somehow resemble the resilience assessment carried out by Alexandria (2019), as explained in 4.2.2.

4.2.2. Resilience Assessment

The multi-disciplinary concept of resilience has been defined in diverse ways, depending on the thematic areas and objectives. Broadly, resilience is understood as the ability of the individual system or structure to bounce back and regain its originality after hazardous incidents. In the context of urban resilience, Rockafeller Foundation (2015) defined ``The capacity of individuals, communities, institutions, businesses and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience". Similar to the varying definitions, there has not been a uniform resilience assessment framework or the set-of-indicators applied by the researchers as of this write-up. Karabakan & Mert (2021) suggest that urban resilience needs to be observed and understood from the local context, as there can never be a "one-size-fits-all" approach to assess the resilience of any structures or systems. Kotzamani & Alexandria (2019) simplified the existing urban green infrastructure resilience framework into 16 crucial qualitative and quantitative criteria to assess the resilience of the National Garden of Athens.

Environmental Dimension: The National Garden of Athens is spread over 22-hectare land with the 72.5% coverage of vegetation, and only 1.4% of the water surfaces, while the rest being built up areas. The garden lies in the center of Athens, surrounded by historic and archaeological sites such as the Acropolis, Panathenaic Stadium, and the Temple of Zeus. As the garden is built in 1800-1900, the infrastructure is mostly from those periods itself, with relatively lesser upgrade on existing infrastructures, resulting the vulnerability and degradation in the quality of infrastructures. The existing infrastructures required regular maintenance, whether it be furniture or the overall construction (built-up areas) as a whole. Even though the area is huge, it is hard to find the separate recycling bins inside the garden space, however, the disposal bins are placed in different areas, but without the segregation of waste. For the regular operation, maintenance and cleaning work, garden does have the staff sufficient to cover the garden area. Even though the garden has existed for a long time, it didn't have any water treatment plants (primary or secondary), releasing the leachate directly into the canal or irrigation sources. The structure also doesn't have any usage of renewable energy, thus there lie the issues with lightning during the evening or night period. From the data collection perspective, the garden management team collect data on the plant, soil and climatic characteristics on regular basis and store them digitally. As the majority of the floral species are imported from different part of the world, the regular update of the soil and climate specific data becomes mandatory.

Social Dimension: The garden is situated at the center of Athens with numerous economic activities in the surrounding area. The population composition is 2.5 persons per household with the age group characteristics as 13.87% (0-14 years), 63.3% (15-64 years), and 22.82% (65 years and above). The employment rate of the working-age population is at 89.5%, indicating a significant number of unemployed groups across the country, that further contribute towards the population below the poverty line, which is reported to be 22.40%. Having said that, the literacy status is pretty impressive and lies at 99.30%. The Garden structure offers numerous benefits to all age group populations with its existing sports facilities, playgrounds, recreational spaces, and cultural activities that take place across the year. Also, the archaeological structure provides educational benefits to the researchers and visitors. The garden lies at the heart of the city, meaning it's easily accessible by all age groups through all means of transportation. Gardens with ample space for children, and adults also prioritize the person with disabilities and the bicycle preferring groups to promote environment-friendly mobility across the city. Due to the bigger size of the garden, the number of staff to look at the safety and security is considerably lower, including the lighting during evening and night, which is reported to be poor. For safety and security period, the main gate opens up at early hour and get closed by the evening period. Due to the garden's feature of attracting all age-group population, it promotes the social cohesiveness amongst the visitors, who can come, stay and interact with each other strengthening the social connectivity and cohesiveness.

Institutional Dimension: The garden has been managed by a private organization for the last decade, but is still under the government administration. The inclusion of the garden into the Athens Resilience Strategy 2030 shows its significance to the city's resilience, and governance, and also indicates towards having the long-term vision to operate and maintain the garden infrastructure. The municipality of Athens is responsible for the management of the National

Garden, as it is officially categorized as a site with historical significance during the 2010s. The garden has the management team, that collect the green space management related data and make analysis in the GIS and smart application. The management team periodically develops the report and shares with government bodies regarding the progress, and the need for upgradation or maintenance works to improve the condition.

Table 4 Dataset for the resilience indicators - The National Garden of Athens

Dimension	**Indicator**	**Description of the National Garden of Athens**
Environmental Dimension		
1.1 Total area of green space	1.1.1 Total area (in hectares)	22.0 hectare
1.2 Components of the built environment (within a 300 m radius of the green space)	1.2.1 Building density/average floor area ratio	Data not available
	1.2.2 Average building height/ average number of floors	Data not available
	1.2.3 Average road width	Data not available
	1.2.4 Land Use	Historic and Archaeological sites such as the Acropolis, Panathenaic Stadium, and Temple of Zeus
	1.2.5 Residential density (number of residents/ Ha)	250 residents/Ha
1.3 Green space characteristics	1.3.1 Soil cover percentage	Data not available
	1.3.2 Percentage of vegetation cover	72.52% of the soil coverage
	1.3.3 Percentage of impermeable surfaces	Data not available
	1.3.4 Number of trees/1000m^2 of green space	0.044 trees/m^2
	1.3.5 Percentage of water surfaces	1.4%
	1.3.6 Endemic/alien species ratio	0.9%
	1.3.7 Biodiversity index	Data not available
	1.3.8 Percentage of built surfaces	1.05%
1.4 Quality/Adequacy of equivalent	1.4.1 Urban Furniture Quality	Need for maintenance for some of the urban furniture
	1.4.2 Infrastructure Quality	Need for maintenance of some infrastructure, especially the pathways

Dimension	Indicator	Description of the National Garden of Athens
	1.4.3 Cleanliness – Maintenance	The presence of the cleaning staff, who carries out the cleaning and maintenance work on a regular basis
1.5 Component of Circular Economy	1.5.1 Waste Recycling	No separate recycling bins
	1.5.2 Composting of organic matter/waste	Compost their byproducts
	1.5.3. Secondary water treatment	Data not available
	1.5.4. Use of renewable energy sources / Annual electricity production (in kWh / m^2 of green space) from renewable energy sources	Do not use any renewable energy
	1.5.5. Annual electricity consumption (in kWh / m^2 of green space) from conventional energy sources	0.19 kWh/m^2
	1.5.6. Annual water consumption (in m^3 /m^2 of green space)	6.49 m^3/1000m^2
1.6 Climate Data	1.6.1. Annual recording of climate data	Collect data on the plant, soil, and climatic characteristics regularly and store them digitally
1.7 Environmental Quality	1.7.1. Atmospheric pollutants (CO_2, N_2O_x, S_2O_x, O_3, particulate matter)	Data not available
	1.7.2. Soil Quality (acidity or alkalinity, salinity, etc.)	Data not available
	1.7.3. Water quality (acidity, salinity, organic load)	Data not available
	1.7.4. Noise pollution	Data not available
Social Dimension		
2.1 Demographic profile of residents – potential users -, in the wider area	2.1.1. Population composition – family status	2.5
	2.1.2. Percentage of population by age group	13.87% (0-14 years) 63.3% (15-64 years) 22.82% (65 years or above)
	2.1.3. Employment rate – Unemployment rate	89.52%
	2.1.4. Percentage of population at risk of poverty - vulnerable households	10.80%

Dimension	Indicator	Description of the National Garden of Athens
	2.1.5 Educational status	99.30%
2.2 Land use within the urban park	2.2.1. Sports facilities	Offer space and area for the sports
	2.2.2. Playgrounds	Offers numerous attractions including a playground for children
	2.2.3. Recreation (café-restaurants)	The presence of café and restaurants inside the parking space, where the visitor can consume their leisure time with nature, music, and foods
	2.2.4. Cultural facilities	Occurrence of the cultural events year- around period to promote local culture and pass it from generation to generation. The Garden is equipped with a collection of statues, as well as archaeological artifacts from the 19th century.
	2.2.5. Educational programs	Rich with the ancient and modern history of Athens, appropriate for researchers and education institutions from different backgrounds including environment, social science, archaeology, botany, and engineering.
2.3 Accessibility - Connectivity	2.3.1. Accessibility by public transport	Easily accessible by bus lines, and the metro, as well as on foot
	2.3.2. Bicycle lanes - bicycle parking spaces	Data not available
	2.3.3. Accessibility for the disabled	Can be easily accessed by persons with different disabilities in most of the areas, apart from the domain, where Roman mosaic flooring is at a lower level than the surrounding garden
2.4 Safety	2.4.1. Site enclosure – controlled entrances	Open during day time only
	2.4.2. Surveillance - security personnel	Presence of security personnel
	2.4.3. Adequate lighting	Get closes at night time
2.5 Social Networks	2.5.1. Active citizen groups - associations, NGOs, volunteers	Yes, there is a presence of community-based organizations involved in different activities within the garden
2.6 Emergency plan	2.6.1. Plan for use of the site in case of emergency (earthquakes etc)	Have the site for evacuation
Economic Dimension		
3.1 Maintenance cost of green space	3.1.1. Detailed annual maintenance cost of the site/m^2	Data not available
	3.1.2. Number of employees in the management and maintenance of the site / m^2	0.18 employees/1000 m^2, including agronomists, gardeners, and workers

Dimension	Indicator	Description of the National Garden of Athens
3.2 Annual revenue from commercial activities within the park	3.2.1. Revenue from renting recreation spaces	Data not available
	3.2.2. Revenue from the plant nursery	Data not available
	3.2.3. Revenue from organizing cultural activities	Data not available
3.3 Activate alternative funding sources to enhance resilience	3.3.1. Leverage funding from European programs	Data not available
	3.3.2. Sponsorships – Crowdfunding	Data not available
Institutional Dimension		
4.1 Green Space Management Model	4.1.1. Management by a public or private body	Management was given to the private organization
	4.1.2. Co-management with active citizen groups - NGOs	Management was given to the private organization
	4.1.3. Long-term strategic management plan	Is integrated into the Athens Resilience Strategy for 2030
	4.1.4. Clear legislative - administrative framework	Municipality of the Athens is responsible for the management of the National Garden
4.2 Action plans and risk assessment plans	4.2.1. Scenario-based Risk Assessment and Risk Management Plans	Data not available
	4.2.2. Hazard Maps	Data not available
4.3 Monitoring - evaluation model	4.3.1. Periodic data collection and digitalization and database enrichment	Have the management team, collect the green space management-related data and make analysis in GIS and smart agriculture application
	4.3.2. Annual report of actions	Have a practice of developing an annual report of action
	4.3.3. Evaluating the effectiveness of actions	Integration of the garden's management into city resilience and climate change adaptation
	4.3.4. Certification of all materials and evaluation process	Data not available

4.1.1. Strength, Weakness, Opportunities, and Threat (SWOT) Analysis

The National Garden of Athens comprises a unique **strength** in the form of having urban green space with historical significance, as well as a connectedness to modern history, richness in ecological value, and public appeal. Garden comprised a higher percentage of green cover, that aid in promoting a favorable microclimate, with well-maintained trees and a significant portion of

water-permeable surfaces. The Garden lies in the central part of the city, making it accessible to all, either by vehicle or by foot, enhancing the opportunity to have repeat visits amongst the visitors. The inclusion of playing areas makes the structure favorable for both adults as well as children, giving its advantage to most of the park, which are more of an adult-friendly structure. The structure is categorized as a historical structure, thus giving it additional significance, and is now under the government department to carry out the maintenance and upgrade of existing structures and facilities. Furthermore, it is being included in the long-term strategy as well, paving the potentiality of upgrading existing structures and practices, and covering the identified weak areas.

Alongside the strengths, National Garden Athens do have its own share of **weaknesses**, and areas of improvement. The climatic condition remains one of the key areas posing the challenge, which affects the health and diversity of the floral species. There was a lack of interpretive signage, which acted as a barrier for public understanding of the garden's rich historical identity and significance. Other areas of weakness include the aging infrastructure, inadequate maintenance, damaged furniture, etc. Due to the ageing infrastructures, and the size of the garden itself, the operation and maintenance cost is relatively higher, that may or may not be covered with the payment received from donations and visitors. Even though the infrastructure provides numerous benefits (health, recreational, social, environmental, and economic), the potentiality of the expansion is already limited due to the surrounding areas being either residential or commercial.

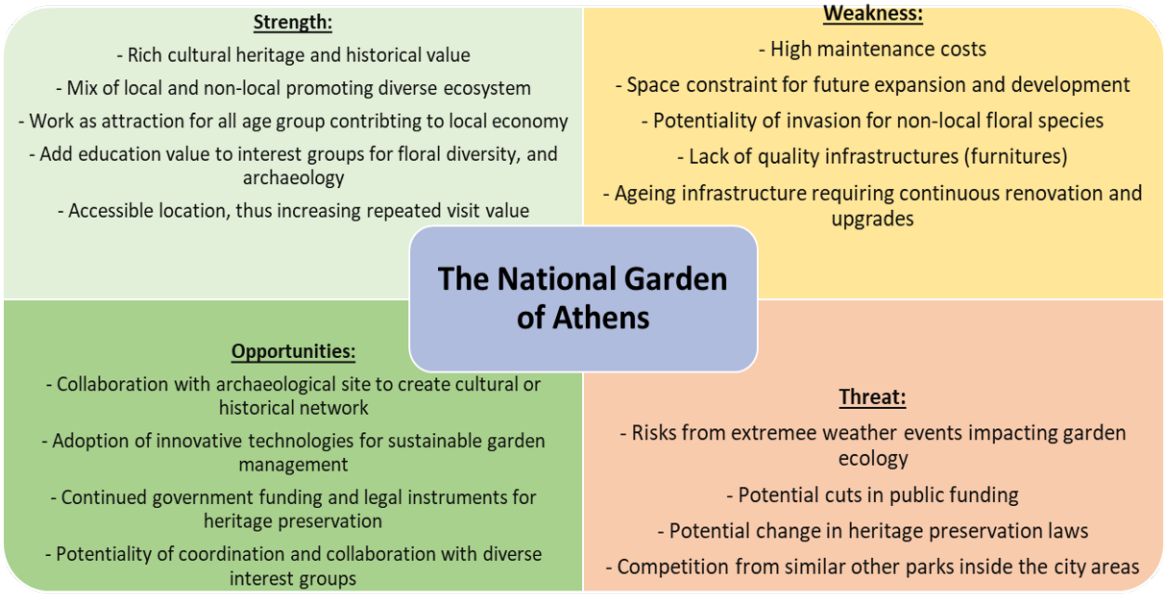

Figure 9 SWOT analysis of the National Garden of Athens

The Garden possesses a wider range of **opportunities** for its management, visitors, researchers, and academic institutions within the city/country or outside of the country. The structure provides opportunities for the researchers to understand the visitors' perception towards

the structure, and the benefit it made on a wider scale. Secondly, the local floral species have survived for centuries, even with the introduction of floral species from other countries. The resistive ability of the local floral species and ecological aspect at a broader level could be an interesting topic to explore for the researchers. Furthermore, the collaboration with adjacent green spaces and archaeological sites can create a more extensive and engaging network.

From an external factor perspective, gardens do have potential **threats**, especially from the safety, security, and extreme weather perspective. Climate change remains a major threat to the floral species, which can jeopardize the health and diversity of the floral species. Secondly, there lies the threat of eco-gentrification from the floral species, which are brought from different parts of the world. The local species could get overshadowed due to a huge compilation of external floral species. Even though the garden is being included in government strategy, it can have funding crisis due to the competitiveness in the number of urban green spaces inside the city. Furthermore, there lies the potentiality of change in heritage preservation laws, that can pose threat to the garden infrastructure.

4.2. Comparative Analysis

The National Garden of Athens and the Metro Forest Project, Bangkok do have distinct similarities as well as differences based on their design, ecological characteristics, and their contribution to socio-cultural aspects of the respective city. From a plantation perspective, both structures have adopted the proven approach of plantation, where both local as well as non-local species can resist and grow without harming or destroying each other. The metro forest project adopted a diverse plantation strategy based on their appropriateness to the soil, climatic conditions, and growth pattern, while the national garden adopted the plantation strategy to sustain the non-local floral species as well as native species. However, from a dominant perspective, the Metro Forest project has given priority to the local or native species, while the National Garden gave priority to the foreign floral species, to convert the structure into a floral museum. From the disaster management perspective, both structures play key roles in stormwater management as well as flood risk management. Considering the ecological pattern, both sets of structures help mitigate the urban heat island effect by lowering the local temperature. People can learn about the floral diversity as well as archeological significance from the National Garden Project, while there lies the opportunity for people to explore floral diversities, alongside the ecological resilience of the Metro Forest Project. The government's priority in maintaining and preserving the both of the structures gives them institutional resilience. Both structures contribute towards recreational activities, alongside tourism activities, further aiding in the local economy, which can be utilized for further maintenance and upgrading of the needed structures within the projects, giving economic resilience to a certain level.

Metro forest project focuses more on the self-sustainability of the ecosystem through the use of native plants, promoting biodiversity and fostering the habitat for beneficial insects and

pollinators, making the ecosystem more resistant to disturbances from pests. Meanwhile, the National Garden emphasizes more on the historical aspects providing a sense of place and cultural identity contributing towards community resilience. Both structures provide ample opportunities for recreational activities and social interaction, thus contributing towards social resilience.

Table 5 Comparative analysis between two case studies, for each of the dimensions of resilience

Dimensions of Resilience	**Metro Forest Project, Bangkok (case study 1)**	**National Garden of Athens, Greece (case study 2)**	**Comparative Analysis for Resilience Status**
Social	- Raises public awareness about environmental stewardship - Potential for community engagement in volunteering and educational program - Limited existing social connection due to a relatively new project	- Provides recreational space for social interaction and community events - Established social connection as a historic landmark	Case study 2 > Case study 1
Environmental	- Rapid establishment of diverse forest ecosystem adopting innovative Miyawaki approach - Dominant local and native floral species - Potential to contribute towards air quality and water quality	- Established and matured floral species provide shade and cooling effects - Dominant imported floral species - Limited potential for further biodiversity increment	Case study 1 > Case study 2
Economic	- Potential for cost saving in carbon sequestration compared to other mitigation strategies - Requires high initial investment cost for construction and plant materials - Limited direct economic benefits besides potential tourism - Potential contribution towards increased property value in surrounding areas	- Requires ongoing maintenance costs, and needs proper investigation of imported floral species - Contribute toward increased property value in surrounding areas - Potential for educational programs to generate revenue	Case study 2 > Case study 1 (due to its potentiality of increasing revenue through collaborative programs and continued attraction for visitors)

Dimensions of Resilience	Metro Forest Project, Bangkok (case study 1)	National Garden of Athens, Greece (case study 2)	Comparative Analysis for Resilience Status
Institutional	- Backed by innovative reforestation methodology - May require support from the regulatory body to have sustainable operation and maintenance - Needs further work to get included in Bangkok City's urban development plan and strategy	- Established institutional framework for management and maintenance - Is included in the city's resilience strategy - Backed by the government for long-term operation and maintenance - Is categorized under historical infrastructure (official)	Case study 2 > Case study 1
Overall: From an ecological perspective, the metro forest project gives multiple advantages over the national garden. However, from other dimension such as social, economic and institutional, the garden offers significant opportunities compared to the metro forest project. Also, the operation timeline and the engagement of the government to promote the infrastructure make the National Garden comparatively resilient over the Metro Forest Project.			

CHAPTER -5: CONCLUSION & RECOMMENDATION

5.1. Conclusions

This study aimed to examine the resilience of Bangkok's Metro Forest Project by using and comparing the resilience assessment approach utilized at the National Garden of Athens. Key findings show that the Metro Forest Project, through its creative utilization of native species and the Miyawaki approach, successfully increased urban biodiversity, established a resilient green space, and lessened environmental pressures such as flooding. The project's design promotes ecological sustainability, offers crucial ecosystem services, and encourages community from the resilience perspective, the national garden of Athens is found to be comparatively more resilient than the metro forest project, Bangkok due to its advantage on social, economic and institutional dimensions, while the metro forest project does possess higher advantage on environmental dimension. The national garden of Athens thrives on established connection built over its long history i.e. 1800s, while the metro forest project is comparatively new, with its establishment and operation for just over one decade. The aspects of higher accessibility to all age-group brings additional resilience aspects towards national garden, as it provides ample opportunity for social cohesiveness, connectedness and coordinative approaches. Additionally, the national garden of Athens is categorized as the historical site due to its linkage with ancient and modern history, including archaeological features, and has been intensively included in the city resilience strategy as well. The Metro Forest project being the new project, is yet to be intentionally included in city's resilience strategy or urban development strategy, makes it comparatively lesser resilient from

institutional dimensions. However, from the environmental perspective, the metro forest project prioritize towards local and native species, makes the growth of the floral species suitable towards local climate and soil conditions. But for the national garden of Athens, the majority of the floral species are imported one, for which special care and attention is required to have their sustained growth in Athens' climatic condition and soil condition, which makes it less resilient compared to Metro Forest project.

From the SWOT analysis perspective, metro forest project is reported to have strengths such as the innovative reforestation methodology that could be replicated to other areas depending on their success rate, and their rapid establishment of a diverse ecosystem. Meanwhile, the strength of national garden is about its established social connections, long-standing institutional frameworks and the accessibility to all age-groups providing additional benefits, in economic aspect as well. The metro forest project is relatively new project with just one decade of its establishment and operation period have limited social connections and is yet to be included in city's resilience strategies or urban development strategies and required high investment costs during these periods. Meanwhile, the national garden has already reached its potentiality of expansion due to the existing commercial and residential areas in surrounding spaces, and has the relatively lower quality infrastructures, increasing the structural vulnerability. Each project offers community engagement programs and can have long-term funding opportunities, especially in research and development areas in thematic areas like urban resilience, ecological resilience, contribution towards human health aspects, etc. However, the metro forest project faces the threats of lack of long-term funding, as it's still not included in city's resilience framework or strategies. Meanwhile, both the infrastructure faces the similar threats of having potential damage from extreme weather events.

Despite the excellent execution and positive consequences of the Metro Forest Project, there are still obstacles. These include the requirement for ongoing funding, strong community engagement, and extensive data collection to track climatic fluctuation and other environmental issues. Addressing these challenges through innovative management practices, strong policy support, and active community involvement can strengthen the Metro Forest Project's resilience and contribute to the larger Resilient Bangkok initiatives, resulting in a more sustainable and livable urban environment.

5.2. Lessons Learned

One key lesson is the importance of tailoring urban resilience assessments to local contexts. Both projects demonstrate that a "one-size-fits-all" approach is not effective and that understanding local ecological and social dynamics is crucial. Another lesson is the benefit of diverse planting strategies. The Metro Forest's use of native species supports ecosystem sustainability, while the National Garden's mix of local and non-local plants enriches the cultural and historical experience. Additionally, multi-functional green spaces that provide ecological, recreational, and educational benefits are valuable. These spaces enhance urban resilience by supporting biodiversity, offering recreation, and fostering community engagement. Government involvement and prioritization of

maintenance are also essential for long-term sustainability, as shown by both projects. Finally, public awareness and engagement are vital. Effective signage and educational programs help raise awareness about the ecological and historical importance of these spaces, fostering a sense of ownership and responsibility among the public.

5.3. Recommendations

To assess and improve the Metro Forest Project's resilience and sustainability, the identified constraints must be addressed while also using the project's benefits. Given the reliance on secondary data and limited primary data gathering, developing a strong data-collecting system is critical. Regular field visits, community surveys, and the use of advanced tools such as spatial mapping and biodiversity assessments will help to ensure accurate and thorough data collection. Cross-referencing secondary data from several sources improves validity and reliability. Systematic environmental monitoring is required to appropriately measure the project's ecological impact. Implementing climate-specific data collecting stations, monitoring plant health, and assessing stormwater and flood management systems will all provide useful insights. Using current technologies, including remote sensing and IoT devices, can increase the precision and frequency of data collection.

Strengthening community involvement is critical to project sustainability and social harmony. Organizing frequent community events, educational programs, and seminars will help people feel more invested and engaged. Establishing feedback systems to include community perspectives will guarantee that the initiative properly addresses local requirements. Improving institutional support and encouraging cooperation with government agencies, NGOs, academic institutions, and the commercial sector would help to increase the project's resilience. Creating a long-term strategic management plan that combines policy support, financial sustainability, and stakeholder participation is critical. Regularly upgrading the project management framework to integrate fresh research findings and best practices will ensure its long-term effectiveness.

Conducting regular resilience assessments and changing methods based on findings is critical to the project's long-term success. Identifying new issues, assessing the efficiency of current resilience measures, and making appropriate improvements will ensure that the project remains responsive to changing environmental, social, and economic situations. Emphasizing adaptive management approaches will help the project stay robust and sustainable in the long run. These comprehensive methods, which include extensive data collecting, community participation, environmental monitoring, institutional collaboration, and continual resilience evaluation, will considerably improve the Metro Forest Project's ability to withstand and adapt to a variety of challenges.

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