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BIOPHILIC INTEGRATION IN URBAN PUBLIC SPACE DESIGN : A CASE STUDY OF BNI URBAN FOREST PARK, BANDA ACEH

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ABSTRACT

Urban public spaces play an important role in improving environmental quality and human well-being; however, studies examining the implementation of biophilic design in tropical urban parks remain limited, particularly in the context of coastal cities in Indonesia. This study addresses this gap by exploring the integration of biophilic design principles in BNI Urban Forest Park (Hutan Tibang), Banda Aceh. The objectives are to identify existing biophilic elements, evaluate their ecological and restorative functions, and formulate recommendations to strengthen biophilic integration in tropical urban public spaces. A qualitative-descriptive methodological framework was employed through literature review, analysis of park management documents, field observation, visual documentation, and theoretical assessment based on Kellert's biophilic design framework. The results reveal that the park incorporates several key biophilic elements, including mangrove vegetation, tree canopies, visual connections with water, and natural-material walkways, which contribute to ecological quality, thermal comfort, and visitor well-being. Nevertheless, deficiencies were identified in environmental education facilities, biodiversity interpretation, accessibility, and integrated blue–green infrastructure. These findings suggest that while the park demonstrates substantial biophilic potential, further interventions are needed to enhance its ecological and social performance. Practical implications include the implementation of interpretive signage, functional zoning, small-scale bioretention systems, sustainable vegetation management, and community-based conservation programs. The study contributes to the development of biophilic design strategies for resilient and inclusive tropical urban parks.

Keywords : Biophilic design, Urban park, Ecological infrastructure, Mangrove

ABSTRAK

Ruang publik perkotaan memainkan peran penting dalam meningkatkan kualitas lingkungan dan kesejahteraan manusia, namun studi yang meneliti implementasi desain biofilik di taman kota tropis masih terbatas, khususnya dalam konteks kota-kota pesisir di Indonesia. Studi ini mengisi kesenjangan tersebut dengan mengeksplorasi integrasi prinsip-prinsip desain biofilik di Taman Hutan Kota BNI (Hutan Tibang), Banda Aceh. Tujuan studi ini adalah mengidentifikasi dan mengevaluasi fungsi ekologis dan restoratif dari elemen biofilik yang ada, serta merumuskan rekomendasi guna memperkuat integrasi biofilik di ruang publik perkotaan tropis. Kerangka metodologi kualitatif-deskriptif digunakan melalui tinjauan pustaka, analisis dokumen pengelolaan taman, observasi lapangan, dokumentasi visual, dan penilaian teoritis berdasarkan kerangka desain biofilik Kellert. Hasil penelitian menunjukkan bahwa taman tersebut menggabungkan beberapa elemen biofilik utama, termasuk vegetasi mangrove, kanopi pohon, koneksi visual dengan air, dan jalan setapak berbahan alami, yang berkontribusi pada kualitas ekologis, kenyamanan termal, dan

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kesejahteraan pengunjung. Studi ini juga mengidentifikasi kekurangan yang ada yaitu dalam fasilitas pendidikan lingkungan, interpretasi keanekaragaman hayati, aksesibilitas, dan infrastruktur biru-hijau yang terintegrasi. Temuan ini menyimpulkan bahwa meskipun Taman Hutan Kota BNI (Hutan Tibang), Banda Aceh memiliki potensi biofilik yang substansial, intervensi lebih lanjut diperlukan untuk meningkatkan kinerja ekologis dan sosialnya. Implikasi praktisnya meliputi implementasi papan informasi interpretatif, zonasi fungsional, sistem bioretensi skala kecil, pengelolaan vegetasi berkelanjutan, dan program konservasi berbasis komunitas. Studi ini diharapkan dapat berkontribusi pada pengembangan strategi desain biofilik untuk taman kota tropis yang tangguh dan inklusif.

Kata kunci : *Desain biofilik, Taman kota, Infrastruktur ekologis, Mangrove.*

Introduction

The rapid growth of urban development in Indonesia has increasingly prioritized economic expansion and infrastructure provision, often at the expense of environmental quality and human well-being. The reduction of urban green spaces contributes to rising temperatures, declining air quality, biodiversity loss, and increasing levels of psychological stress among urban residents (Hashem & Al-Qudah, 2020). In response to these challenges, biophilic design has emerged as an important approach for integrating natural elements into the built environment to promote ecological sustainability, physical comfort, and human health (Kellert, 2015; Xue et al., 2023). Grounded in Wilson's (1984) biophilia hypothesis, biophilic design seeks to strengthen human–nature connections through the intentional incorporation of natural systems, materials, and experiences within urban environments.

Organic waste originates from plant material and other living organisms, including fruit peel waste, which is one of the most commonly generated forms (Illahi et al., 2023). When organic waste is allowed to accumulate without adequate management, it can lead to unpleasant odours, deterioration of water and soil quality, and the emissions of methane gas, which contribute significantly to environmental degradation (Novianto, 2022; Panataria et al., 2022). One effective approach to addressing this issue is convertion of organic waste into value-added products, such as eco-enzymes, which are used as organic liquid fertilizers (OLF). This approach not only reduces the negative impact of household organic waste but also supports the creation of a cleaner and healthier environment (Septinar et al., 2024).

Previous studies have demonstrated the benefits of biophilic public spaces in enhancing mental well-being, social interaction, place identity, and thermal comfort (Beatley, 2016 & Browning et al., 2014). However, most biophilic design studies have been conducted in temperate urban settings, while empirical evaluations in tropical coastal cities remain limited. In particular, there is a lack of research examining how biophilic principles are integrated into mangrove-based urban parks, despite their significant ecological and social value (Abbas et al., 2024). This gap is especially relevant in Indonesia, where mangrove ecosystems play a critical role in climate adaptation, coastal protection, biodiversity conservation, and community resilience.

Banda Aceh provides a highly relevant context for addressing this research gap. As a rapidly developing coastal city that is vulnerable to climate change, flooding, and environmental degradation, Banda Aceh requires public spaces that

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simultaneously support recreation, ecological restoration, and urban resilience. BNI Urban Forest Park (Hutan Tibang) represents a unique case because it combines urban park functions with a mangrove ecosystem, creating opportunities for both environmental conservation and public engagement with nature. Despite its strategic importance, no previous study has systematically evaluated the extent to which biophilic design principles have been implemented in this park or assessed their contribution to ecological and social functions.

The scientific novelty of this study lies in the application of a biophilic evaluation framework to a tropical mangrove-based urban park, a context that remains underrepresented in the literature. Unlike previous studies that focus primarily on the presence of green elements, this research evaluates the adequacy and effectiveness of biophilic features in supporting visitor well-being, ecological performance, and environmental education (Meutia et al., 2024). Furthermore, the study develops a contextual evaluation model based on Kellert's (2015) framework that can be adapted for other tropical coastal urban parks. Given the increasing need for climate-adaptive, inclusive, and environmentally resilient public spaces, evaluating biophilic integration in mangrove-based urban parks is both scientifically important and practically urgent. The findings are expected to inform future urban park planning and contribute to sustainable urban development policies in Banda Aceh and other tropical coastal cities.

Biophilic design originates from the biophilia hypothesis proposed by Wilson (1984), which argues that humans possess an innate tendency to seek connections with nature. This concept was further developed by Kellert (2015), who translated biophilia into a design framework that integrates natural elements, processes, and spatial characteristics into the built environment. From an environmental psychology perspective, biophilic design is supported by Stress Recovery Theory (Ulrich, 1991) and Attention Restoration Theory (Kaplan & Kaplan, 1989), both of which suggest that exposure to natural environments can reduce stress, restore cognitive capacity, and improve psychological well-being. Together, these theories establish a foundation for understanding how nature-based design contributes to healthier and more restorative urban environments.

Several frameworks have been developed to evaluate the implementation of biophilic design. Kellert (2015) categorizes biophilic experiences into three dimensions: direct experience of nature, indirect experience of nature, and experience of space and place. Complementing this approach, Browning, Ryan, and Clancy (2014) introduced the widely adopted 14 Patterns of Biophilic Design, including visual and non-visual connections with nature, presence of water, natural materials, dynamic light, prospect, refuge, and place-based relationships. These indicators provide measurable criteria for assessing the extent to which public spaces foster meaningful interactions between people and nature. In the context of urban parks, vegetation, water bodies, natural pathways, biodiversity, and environmental interpretation facilities are commonly used as indicators of biophilic quality.

A growing body of research demonstrates that biophilic environments generate both ecological and public health benefits. Urban green spaces improve air quality, reduce urban heat island effects, support biodiversity conservation, and enhance

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climate resilience (Yin et al., 2020). At the same time, contact with nature has been associated with lower stress levels, improved mental health, increased physical activity, and stronger social interaction among urban residents (Ulrich, 1991; Browning et al., 2014). Consequently, biophilic design is increasingly recognized as a strategy that simultaneously addresses environmental sustainability and public health challenges in rapidly urbanizing cities.

The application of biophilic design is particularly relevant in tropical cities, where high temperatures, humidity, and rapid urban expansion create challenges for environmental quality and outdoor comfort. Urban parks in tropical regions provide critical ecosystem services, including microclimate regulation, stormwater management, carbon sequestration, and recreational opportunities. In coastal cities, mangrove-based urban parks provide additional ecological functions, including shoreline protection, flood mitigation, and habitat preservation. In Banda Aceh, BNI Urban Forest Park represents a unique tropical urban park that combines mangrove ecosystems with recreational functions, creating opportunities for ecological conservation and public engagement with nature. Previous studies have highlighted the ecological value of the park's vegetation diversity and its role as an urban green space, yet its biophilic characteristics have not been systematically evaluated.

Although biophilic design has been widely discussed in architecture and urban planning literature, most studies focus on indoor environments, office buildings, healthcare facilities, or large metropolitan parks in temperate regions. Research examining biophilic integration in tropical urban parks, particularly those based on mangrove ecosystems, remains limited. Furthermore, previous studies in Banda Aceh have primarily investigated vegetation distribution, environmental functions, or park management, without assessing the effectiveness of biophilic elements in supporting ecological performance, visitor well-being, and environmental education. Therefore, a significant research gap exists in understanding how biophilic principles are implemented and evaluated within tropical mangrove-based urban parks. This study addresses that gap by applying a biophilic evaluation framework to BNI Urban Forest Park and developing recommendations for enhancing the ecological, social, and restorative functions of urban public spaces in coastal tropical cities.

Methods

This study employed a qualitative descriptive case study approach to examine the implementation of biophilic design principles in BNI Urban Forest Park, Banda Aceh, Indonesia. A qualitative approach was selected because the research focuses on understanding spatial characteristics, environmental quality, and human interactions with natural elements within an urban forest setting. The study aims to identify biophilic design elements present in the park and evaluate their contribution to ecological functions and visitor experiences.

Study Area

The research was conducted at BNI Urban Forest Park, an urban green open space located in Banda Aceh, Indonesia. The park was selected as a case study because it represents one of the city's prominent urban ecological landscapes that integrates mangrove vegetation, waterfront areas, pedestrian pathways, recreational

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facilities, and social interaction spaces. As a multifunctional urban green space, the park provides opportunities to examine how biophilic design principles are manifested within a tropical coastal urban environment. The diversity of natural and built elements makes the site suitable for evaluating the relationship between environmental quality and human experience.

Theoretical Framework

The study adopts Kellert's biophilic design framework as the primary analytical tool. According to Kellert (2015), biophilic design consists of three major dimensions: (1) direct experience of nature, (2) indirect experience of nature, and (3) experience of space and place. This framework was selected because it provides a comprehensive structure for identifying and evaluating physical and spatial characteristics that promote human–nature connections. Supporting literature from Beatley (2011) and Ulrich (1984) was used to interpret the potential ecological, psychological, and social benefits associated with the identified biophilic elements.

Data Collection

Data collection was conducted through non-participant field observation and documentation studies. Six observation points were purposively selected to represent the diversity of spatial functions, environmental characteristics, and user activities within the park. These observation points included: (1) the main entrance zone, (2) the mangrove boardwalk area, (3) the waterfront/canal zone, (4) the recreational and play area, (5) the seating and social interaction zone, and (6) the core mangrove vegetation area.

Field observations were undertaken over two consecutive days during periods of peak park utilization, namely in the morning (07:00–09:00) and afternoon (16:00–18:00). These observation periods were chosen to capture variations in environmental conditions, including natural lighting, thermal comfort, shading effects, and visitor activity patterns. The two-day observation period is considered adequate for qualitative environmental assessment because the study focuses on documenting relatively stable physical and spatial characteristics rather than measuring seasonal ecological changes. Similar observation-based studies on biophilic environments have utilized short-term intensive field assessments to identify spatial attributes and environmental qualities.

Observation activities focused on documenting vegetation characteristics, water elements, pedestrian circulation, natural materials, visual connectivity with nature, shading conditions, accessibility, and supporting facilities. Environmental conditions and user activities were recorded through field notes, photographs, and site sketches. Weather conditions during data collection were relatively stable, ranging from sunny to partly cloudy, enabling clear observation of landscape features and visitor behavior.

To strengthen the observational findings, secondary data were collected from planning documents, site maps, aerial imagery, management reports from the Banda Aceh Environmental Agency (DLHK Banda Aceh), and archival records related to the park's development and management.

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Data Analysis

The collected data were analyzed using descriptive-visual analysis combined with thematic classification. First, all observed landscape elements were systematically documented and described according to their physical characteristics and spatial functions. Subsequently, these elements were classified using Kellert's biophilic design framework. Each identified feature was categorized into one of the three dimensions: direct experience of nature, indirect experience of nature, or experience of space and place.

The analysis then examined the extent to which the identified biophilic elements contribute to environmental quality and visitor experiences. Triangulation between field observations, photographic documentation, and secondary sources was employed to enhance the credibility and validity of the findings. The analysis results seved as the basis for formulating recommendations to strengthen the biophilic quality of BNI Urban Forest Park and enhance its function as an urban ecological landscape.

Results and Discussion

The evaluation indicates that direct-experience biophilic elements constitute the strongest component of BNI Urban Forest Park. Mangrove vegetation dominates the landscape and provides continuous visual and ecological connections with nature. The extensive tree canopy contributes to thermal comfort by reducing solar exposure and improving microclimatic conditions. Water elements in the form of canals and ponds further enhance the sensory quality of the environment through visual and auditory stimulation. According to Kellert (2015), direct experiences of nature represent the most effective mechanism for establishing emotional and psychological connections between humans and natural systems. The findings demonstrate that BNI Urban Forest Park successfully fulfills this dimension through its extensive vegetation cover and natural ecosystem characteristics (Rahman, 2021; Nisa, 2022).

The results of visual documentation also reveal that the wooden pedestrian path (boardwalk) is one of the strong indirect experiences of nature elements in the park. Wood materials provide natural textures and aromas that enhance the visitor's sensory experience, supporting the pattern of material connection with nature described by Browning et al. (2014). The arrangement of paths that follow the natural contours of mangrove areas creates an organic pattern of space and increases its legibility, in line with the concept of imageability according to Lynch (2013). In addition, the presence of facilities such as park benches, children's play areas, and basketball courts indicate that the park serves an important social function and facilitates interaction among diverse visitors.

Table 1. Evaluation of Biophilic Elements

No	Biophilic Elements	Category Kellert	Adequacy Level
1	Mangrove Vegetation	Direct experience	Height
2	Tree Canopy	Direct experience	Height
3	Water Element	Direct experience	Medium
4	Natural Material	Indirect experience	Medium
5	Education Board	Experience of place	Low
6	Universal Accessibility	Experience of place	Low

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Table 2. Biophilic Elements, Description, along with Pictures

No	Biophilic Elements	Description	Pictures
1	Mangrove Vegetation	Available	
2	Wooden pedestrian path	Available	
3	Presence of water (pond / Canal)	Available	
4	Activity Space	Available	
5	Garden Bench	Available	
6	Pedestrian path	Available	

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7	Signs and directions	Available	
8	Drainage and catchment	Available	  

The findings from Table 2 indicate that the application of biophilic design in BNI Banda Aceh Urban Forest Park is particularly effective within the context of a tropical climate. The combination of mangrove vegetation, shade trees, and water features contributes to thermal comfort by reducing ambient temperatures, increasing shading, and improving microclimatic conditions. These characteristics are especially important in tropical cities where high temperatures and humidity can reduce outdoor activity. The presence of natural elements supports psychological restoration and encourages longer visitor engagement, demonstrating the potential of biophilic design as a climate-responsive strategy for urban public spaces in Banda Aceh.

The study also highlights the importance of integrating blue–green infrastructure to strengthen ecological performance and environmental sustainability. Although ponds, canals, and mangrove ecosystems are already present, their functions could be enhanced through bioretention systems, infiltration ponds, and sustainable stormwater management. Such interventions would not only improve water regulation but also increase ecological resilience against flooding, coastal erosion, and climate-related environmental pressures. Furthermore, the findings reveal that inclusivity and accessibility remain areas requiring improvement. The provision of ramps, tactile paving, accessible pathways, and inclusive signage would enable broader participation by elderly visitors and people with disabilities. From a policy perspective, the Banda Aceh City Government should consider incorporating biophilic design principles, universal accessibility standards, and blue-green infrastructure strategies into urban park planning and management policies (Wang et al., 2022). Such measures would support the development of resilient, inclusive, and environmentally sustainable public spaces while advancing Banda Aceh's vision as a livable and climate-adaptive city.

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Conclusion

This study demonstrates that BNI Banda Aceh Urban Forest Park has successfully integrated several key biophilic design elements, particularly through direct experiences with nature, including mangrove vegetation, wooden pathways, ponds, and canals. These features enhance ecological quality, strengthen human–nature connections, and support important environmental functions such as coastal protection, habitat provision, and improved air quality. The study also contributes to the application of biophilic design theory in tropical urban parks and proposes an evaluation framework that can be adapted for similar public green spaces.

Despite these strengths, several aspects require improvement, including environmental education facilities, biodiversity interpretation, blue-green infrastructure, universal accessibility, and functional zoning. These findings provide practical guidance for planners and local authorities to improve the ecological and social performance of urban parks. However, the study is limited to a single case study and qualitative assessment methods. Future research should incorporate quantitative approaches and comparative analyses across multiple urban parks to better evaluate the effectiveness of biophilic design in enhancing environmental sustainability and visitor well-being.

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