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Using Biophilic Design to Enhance Resilience of Urban Parks in Semarang City, Indonesia

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ABSTRACT

Biophilic design is an approach for creating resilient, sustainable cities by constructing resilient buildings that connect humans and nature by integrating natural adaptation and aesthetic appeal in urban spaces. Biophilic design enables improved climate resilience and mental health. Semarang City in Java, Indonesia is a concrete jungle metropolis that will benefit from the application of biophilic design. Although several urban parks are constructed in public areas, certain design elements remain extremely simple. For example, the vegetated-setting context remains minimal and unable to generate sufficient interest in community physical activities. Hence, the connection between humans and nature is limited, which demonstrates the lack of biophilic design. Thus, the study aims to investigate the use of biophilic design in urban public spaces by promoting resilience. This research uses a quantitative method and analytical tools. Questionnaires and field observations were used to collect data. The study investigated the effectiveness of urban parks on mental health, climate resilience, need for urban park design elements, and the design of urban parks. The study identified three parks with the highest increases in land surface temperatures from 2011 to 2021, which indicates that incorporating biophilic design elements into these locations should be considered. More than half of the users at these parks preferred biophilic design elements, which are effective in lowering air temperature, blending with the surrounding nature, and promoting calming, cost-effective, and beneficial mental and physical health. Using these biophilic elements, the average temperature of the parks could be decreased by approximately 0.5 °C.

Keywords: biophilic climatic design, climate resilience, urban design, urban park

INTRODUCTION

Biophilic cities and resilient contexts are inextricably linked (Beatley, 2011). A chain of relationships that connect the environment and society influences resilience (Beatley & Newman, 2013). For example, waste from one animal can be food for another, unused space can be useful in the right context, and decaying trees can be a resource and provider of the elements of life for various plants and animals (Bayulken et al., 2021). Death, birth, and migration in and out of a community help maintain the composition of species (Beatley & Newman, 2013).

In terms of environmental resilience, biophilic design can provide shade and evapotranspiration, and greenery can reduce perceived temperature, which mitigate the effects of climate change (Africa et al., 2019). Conversely, biophilic design "is essential for providing opportunities to live and work in healthy places and spaces with less stress and greater overall health and well-being" by reconnecting with nature (Cacique & Ou, 2022; Lee & Kim, 2021). As an example, the City of Rotterdam implemented 5,000 m^2 of new vegetation and 50,000 m^2 of green roofs (to increase biodiversity and urban farming) as part of a hybrid system for addressing urban resilience and improving quality of life for urban residents (Tillie & van der Heijden, 2016). In this case, biophilic design was utilized to integrate the adaptation of nature with the aesthetic appeal of urban space by improving human–nature connectivity (Beatley, 2016).

As a result, biophilic cities are closely related to resilience, because the application of biophilic design can help enhance their resilience and sustainability by promoting healthy lives and well-being (Goal 3). Toward this end, biophilic contexts that emphasize contact with nature in public spaces and provide psychological restoration can be used. Moreover, building resilient infrastructures (Goal 9) through sustainable stormwater management, making cities resilient and sustainable (Goal 11) through low-impact development concepts are other examples. Taking immediate action against climate change and its consequences (Goal 13) can be achieved by reducing energy consumption through vegetative climatic effects; and enhancing biodiversity (Goal 15) by integrating buildings, sites, and occupants through the creation of a comprehensive habitat (Bayulken et al., 2021). In other words, the integration of biophilic components into planning and design increases the potential of enhancing urban sustainability (Radha, 2022).

Biophilic design seeks to achieve the benefits of human–nature contact in modern built environments by creating habitats that restore or improve the physical and mental health, fitness, and well-being of humans as biological organisms. In this manner, the species remains viable (Africa et al., 2019). Basic biophilic principles focus on themes of engagement, adaptability, attachment, interaction, and interconnectedness, which are crucial for the effective implementation of design (Ryan & Browning, 2020). Biophilic design is also closely related to parks in urban settings. Such parks should offer therapeutic or healing effects to combat the deteriorating impact of various factors, such as pollution, heat, and stress levels, found in cities (Browning & Ryan, 2020). A number of biophilic elements in urban parks include the use of natural images, spaces designed for flora and fauna habitats, and healing and physical activities that rely on natural materials (Gillis & Gatersleben, 2015).

Semarang, with a total population of approximately 1.65 million and ranking as the fifth most important metropolitan city in Indonesia, faces a persistent need to implement biophilic design in urban parks to embody the concepts of a resilient city. The large population in Semarang makes this aspect a priority. Living in one of the main cities on Java Island, Semarang residents experience high levels of stress and heat due to urbanization. The more people residing in the city, the higher the stress level and temperature; hence, the concept of biophilic in urban public spaces needs to be appropriately considered and utilized (Higueras et al., 2021).

Previous research discussed the advantages of biophilic design and its application in enhancing urban resilience. However, important issues remain unaddressed, such as determining locations and biophilic design elements on the basis of the preferences of urban park users, and how these designs can help mitigate extreme temperatures. Studies on the biophilic design approach are limited; thus, conducting research on this approach through the lens of urban park design and use in Semarang, Indonesia, is important. The major question of this research pertains to the determination of the biophilic design elements needed in an urban park and their mitigation of the high temperatures of Semarang. Toward this end, the current study focuses on biophilic design elements in urban parks and heat mitigation as a result of their implementation and integration into the existing parks in Semarang City.

LITERATURE REVIEW

Biophilic design is associated with the human proclivity to associate with nature in urban settings, such as urban parks, based on the concept of biophilic design, which connect humans to nature for better physical and mental health in the modern urban world (Mcdonald & Beatley, 2021). Natural accessibility and the green environment are associated with stress reduction and improved physical and mental health (Sen & Guchhait, 2021) especially given that city residents nowadays are exposed to extremely high levels of stress and crimes and mental health issues, while the built environment is increasingly beset by problems such as the effect of urban heat islands (UHIs) and air and water pollution (Soderlund & Newman, 2015). According to a report by the WHO, stress levels have increased by 20% since the COVID-19 pandemic, and this increase is related to the isolation that people experienced during lockdowns (Kumar & Nayar, 2021).

Resilience, especially climate resilience, requires adaptability in the face of climate change (Hung & Chang, 2022). In creating climate-resilient cities, a number of novel ideas must be embraced or endorsed in which biophilic design is one of them. Government authorities must understand and utilize the biophilic approach with respect to climate resilience, and these design concepts must be implemented to assist in mitigating climate change (Novosadová & van der Knaap, 2021). In general, those working on landscape design must bear a biophilic design concept in mind, because its use can increase landscape efficiency. Traditionally, biophilic design elements are used in landscape design; however, these elements are frequently not integrated into urban design to the optimum level (Hady, 2021). The proper landscape design in an urban park can result in the increased comfort and livability of a city (Lei et al., 2021), and the effectiveness biophilic design in urban park is evident in the effects on human beings and nature. In other words, urban parks should possess regenerative properties with respect to mental health and the regeneration of nature (Zhang, 2023). These issues are linked, despite the link being less obvious. Examples are numerous. For instance, the increased temperature of the planet and frequency of natural disasters are related to human conditions such as post-traumatic stress syndrome, depression, and anxiety (Clayton, 2020).

The etymology of the word biophilic involves two parts, namely, philia (meaning love) and bio (related to life), such that biophilic design literally refers to a love of life or living things. Thus, this design concept refers to a design that leads to the feeling that a person is aligned with nature (King, 2022). The connection between humans and nature increases the faculty of the mind related to enjoyment, which reduces anxiety and depression (Tharim et al., 2022). Biophilic design in urban parks can also reduce the phenomenon of UHIs, which is a global issue that has developed with the increase in temperature and climate change through particle filtration and carbon dioxide sequestration as well as the rehabilitation and restoration of lost habitats and the enhancement of urban biodiversity (Kellert & Calabrese, 2015). According to Revell and Anda (2014), trees and vegetation can help reduce the effect of UHIs by shading urban surfaces from solar radiation and cooling the city. Moreover, el-Baghdadi and Desha (2017) proposed that green roofs and walls, community gardens, and vegetation in general can help mitigate the UHI effect. Moreover, water features, such as ponds or fountains, can help reduce the effect of UHIs by approximately 1–2 °C (Syafii et al., 2017). Despite the evident benefits, implementing biophilic design in urban parks undoubtedly necessitates a significant investment in terms of planning and maintenance (Zhong et al., 2022).

RESEARCH METHODOLOGY

Research Methods

The study employed a quantitative approach that utilizes scoring techniques, quantitative descriptive analysis, and site planning. First, the study reviewed several theoretical types of literature related to biophilic design in urban public spaces to fully comprehend the context of a resilient city. The research spanned eight months; specifically, one month was used for preparation, two months for data collection and structuring, and five months for analysis.

Data Collection Techniques

This study relied on quantitative data, which were collected through the distribution and collection of the questionnaire and field observations of residents and other users of urban public spaces in Semarang City. The subsequent texts provide details of the quantitative techniques for data collection.

Questionnaire. The questionnaire was distributed to users of urban public spaces in Semarang City. The objective was to collect information about the effectiveness of biophilic design in urban parks**.** These data are related to several aspects that influence the realization of the biophilic design context**.** The respondents were asked about their design preferences for urban parks in terms of biophilic design**.** To calculate, the study used the Guttman Scale to obtain unequivocal responses from respondents, that is, binary response options such as agree–disagree, yes–no, right–wrong, and positive–negative, among others**.**

The questionnaire focused on six variables of biophilic design and 14 indicators in the form of questions, which referred to the presence of certain biophilic elements in a park. For each question, a positive **(**e.g**.**, Yes) response takes on a value of 1, while a negative (No) response takes on a value of 0. The study obtained the value of the effectiveness of each indicator of the biophilic context of urban parks in Semarang by summing the numerical results of the Guttman Scale**.**

Field Observations. Field observations are intended to identify, validate, and verify the effectiveness of the questionnaire results related to the biophilic design context in urban parks in Semarang as well as the design elements required by urban park users in terms of biophilic design.

Sampling Techniques

All studies that use questionnaires employ sampling techniques. The current study used random sampling, specifically, accidental sampling, with urban park users serving as targets. The study used the Lemeshow formula to compute the required sample size in an unknown population state due to the limited population data on the number of visitors to urban parks in Semarang. The equation (1) provides an example of this calculation using the Lemeshow formula:

$$n = \frac{z^2\, P(1-P)}{d^2}, \qquad (1)$$

where:

n = number of samples;

z = normal table value with a specific alpha;

p = case focus; and

d = alpha (0.05) or 5% of the 95% confidence level:

$$n = \frac{1.960^2\ 0.5\ (1-0.5)}{0.1^2}$$

$$n = 96.04 \approx 100.$$

Urban Heat Island Index

The land surface temperature (LST) method determines the location or object of the study. When solar energy strikes a land surface, the two interact, which heats the ground or the surface of the canopy in vegetated areas. LST, which is a sensitive indicator of changing surface conditions and a good indicator of energy partitioning at the land surface-atmosphere interface, monitors this thermal radiation output (Hulley et al., 2019). The study identified six city-scale parks in Semarang using LST measurements over the previous 10 years. The data used in this study is secondary data in the form of satellite imagery. The specific satellite imagery used comprised Landsat 8 Operational Land Imager (OLI) and Landsat 5 TM satellite imagery, because it is free (open source) and various time series data are available. Appendix A presents a summary of information about the sources of satellite data.

Landsat satellites can detect land cover, such as coastal areas and vegetation, as well as cirrus clouds. Furthermore, Landsat can utilize a thermal detection band, which is known as thermal infrared sensors (Reuter et al., 2015). This sensor detects heat at the Earth's surface and has a spatial resolution of 100 m. For these reasons, this study used Landsat to identify surface temperature dynamics in Semarang City across the 10-year period.

The study used the LST analysis tool in QGIS 3.26.

$$L_\lambda = M_L \times Q_{cal} + A_L, \qquad (2)$$

where:

L_λ = Spectral radiance (W/(m^2 × sr × μm);

M_L = Radiance multiplicative scaling factor;

Q_{cal} = Level-1 pixel value in a digital number (DN); and

A_L = Radiance additive scaling factor.

$$T = \frac{K2}{\ln(\frac{K1}{L_\lambda}+1)}, \qquad (3)$$

where:

T = ToA brightness temperature (K);

K2 = Thermal conversion constant 2;

K1 = Thermal conversion constant 1; and

Lλ = Spectral radiance.

$$LST = \frac{T}{1+(w*\frac{T}{p})\ln(e)} - 273.15. \qquad (4)$$

Equation (1) demonstrates the calculation for converting a digital number (DN) to a spectral radiance, while Equation (2) presents the calculation of top of atmosphere (ToA) brightness temperature. Using these equations, the study further converted the spectral value of radiance to the ToA value of brightness temperature (Equation (2)). Furthermore, the soil surface temperature is calculated using Equation (3), which was obtained from the calculation guide for soil surface temperature using Landsat satellite imagery. To convert the calculation result into Celsius, 273.15 is subtracted, as per Equation (3).

Selection of Parks

Semarang City is home to six urban parks, and the study selected three urban parks that exhibited the highest increases in urban heat from 2011 to 2021. The selection of the research objects is strengthened by the assessment of the effectiveness of city-scale parks in Semarang from the biophilic perspective. The study intends to implement a number of biophilic design elements at the selected urban parks that comprise the use of natural images, spaces designed for flora and fauna habitats, healing, and physical activities with a reliance on natural materials (Gillis & Gatersleben, 2015).

Analytical Techniques

Analysis began with LST analysis and scoring for the selection of the city-scale parks followed by the distribution of the questionnaire to park users. The investigation was further developed with a specific urban heat map of the parks using the Sun Hour extension of SketchUp and site planning design analysis, which focused on the design of the selected urban parks from the biophilic context.

RESULTS AND DISCUSSION

Through biophilic design, urban parks are expected to exert therapeutic or healing effects to combat the deteriorating impact of urban issues such as pollution, heat, and stress levels (Ryan & Browning, 2020). The implementation of biophilic elements in an urban park comprises the use of natural images, spaces designed for flora and fauna habitats, healing, and physical activities, along with reliance on natural materials (Gillis & Gatersleben, 2015).

A natural image design can relax eye muscles, reduce cognitive fatigue, and improve mental and physical health, including stress reduction (Grinde & Patil, 2009; Xue et al., 2019). For this reason, approximately three elements must be loaded into the park design on the basis of the raw image variables, namely, biomorphic/organic forms, natural ornaments, and murals.z

The design of the flora and fauna habitats mainly comprises two forms, namely, community gardens and ponds (van Aalst & Brands, 2021). The components of the design of healing spaces, such as natural sounds and healing gardens, are essential elements in urban parks. Encouraging users to engage in physical activity while enjoying parks through design and other natural features exerts a significant positive impact on health (Mcdonald & Beatley, 2021). Finally, the use of local buildings or natural materials is critical to the creation of natural material designs in urban parks.

Urban Heat Islands Index and Urban Parks in Semarang

The results indicate that the average temperature in Semarang City in 2011 was 25 °C and was expected to increase to 28.9 °C by 2021. In other words, the surface temperature in Semarang City was expected to increase by 3.8 °C during this time period. Central Semarang District (28.5 °C), South Semarang District (28.3 °C), East Semarang District (27.8 °C), and Candisari District (27.8 °C) exhibited the highest recorded temperatures in 2011, whereas Mijen (23.4 °C) and Gunungpati (23.2 °C) produced low temperatures.

Table 1 provides in-depth information that the recorded temperatures of six urban parks in Semarang significantly varied. Evidently, urban parks located in residential areas displayed high temperatures. Specifically, Tugu Muda Park experienced a significant increase in temperature (4.3 °C) over the time period. By contrast, temperatures in Pancasila Field and Tirto Agung Park increased by the relatively low increments of 1.9 °C and 2.1 °C, respectively. On the basis of these findings, it is possible to conclude that all urban parks were subject to the rate of temperature increase that Semarang City experienced from 2011 to 2021 is possible. This finding can be attributed to various factors, including vegetation composition or the amount of green space being significantly less than the surrounding built-up urban areas. Figure 1 illustrates the increase in surface temperature in Semarang City.

Indonesia Kaya Park, Tugu Muda Park, and Srigunting Park produced above-average delta (2.9%) when calculating the average increase in surface temperature across the survey period. The study observed that these three parks require the introduction of biophilic elements, because the surrounding surface temperature is high; however, previous efforts to reduce the UHI phenomenon at these parks have been ineffective.

The assessment of the effectiveness of city-scale parks in Semarang from the biophilic perspective also strengthened the selection of Semarang urban parks as research objects, because they can be categorized based on their suitability for biophilic design. Table 2 provides the effectiveness scores of urban parks in Semarang.

Table 1

Results of Land Surface Temperature (LST) Analysis

Name of urban parks	2011			2021			∆2011–2021
	Mean	Min	Max	Mean	Min	Max	
Srigunting Park	28.3	28.0	28.4	31.2	31.1	31.2	2.9
Pancasila Field	28.5	27.2	29.2	30.3	30.0	31.0	1.9
Indonesia Kaya Park	26.5	26.4	26.8	30.3	29.9	30.9	3.7
Pandanaran Park	28.2	28.0	28.4	30.9	30.9	30.9	2.7
Tugu Muda Park	27.7	27.6	28.0	32.0	31.6	32.3	4.3
Tirto Agung Park	26.7	26.4	26.8	28.8	28.6	29.4	2.1
Average							**2.9**

Figure 1

Increasing LST in Semarang City

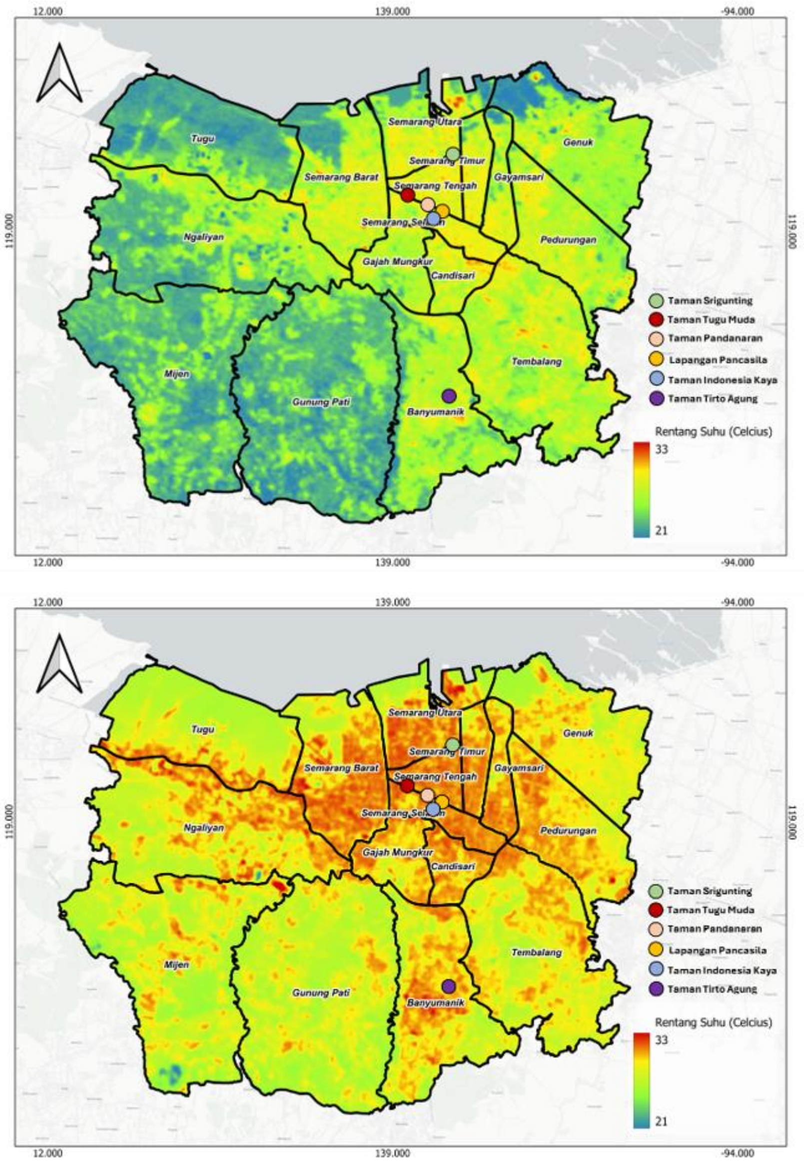


Table 2

Results of Garden Effectiveness Analysis from the Biophilic Context

Parks	Design						
	Green	Natural image	Flora and fauna habitat	Healing space	Physical activities	Natural materials	Total score
Indonesia Kaya Park	87%	80%	76%	79%	71%	76%	65%
Pandanaran Park	80%	60%	59%	94%	59%	56%	68%
Srigunting Park	67%	52%	53%	69%	50%	56%	58%
Tirto Agung Park	56%	46%	41%	66%	72%	88%	67%
Pancasila Field	78%	44%	56%	71%	81%	88%	70%
Tugu Muda Park	58%	48%	69%	72%	63%	81%	65%
Average							**66**%

According to the LST calculation, three park locations with scores less than the average total score of 66%, namely, Indonesia Kaya Park, Srigunting Park, and Tugu Muda Park are those considered to lack biophilic elements or possess biophilic elements that lack effective implementation.

Implementation of Biophilic Design Intended to Increase Resilience in Urban Parks in Semarang

Green roofs, which are also known as vegetated roofs or living roofs, are ballasted ones that consist of a waterproofing membrane, a growing medium (soil), and vegetation (plants) overlying a traditional roof. They are classified according to overall flora, substrate depth, type, and height of plant growth (i.e., intensive, semi-intensive, and extensive green roofs; Agbonyin & Zoras, 2020). In general, 42.7% of the respondents prefer a semi-intensive design for a green roof. The assumption underlying this response is that semi-intensive green roofs are a hybrid of extensive and intensive green roofs, which enables this concept to be rich in biodiversity and capable of high rainwater retention while remaining cost-effective (Kaewpraek et al., 2021). The respondents opted to install green roofs on only a portion (77.7%). of the available roof space. Meanwhile, only 46.6% selected planters and non-distant placement, while 67% were in favor of a green wall design. These decisions are based on aesthetic preferences expressed by park visitors. In addition to green roofs and walls, users expressed their preferences for other green designs such as permeable pavements. Specifically, 70.9% of the respondents responded with grass pavement as the preferred design. Previous research found that grass pavement is more effective than stone paving in terms of decreasing air temperature and increasing thermal comfort (Joo-Young, 2020). Rain gardens are the final component of green design, which were preferred by 88.3% of Semarang residents. Rain gardens aid in the elimination of contaminants, storage of runoff water, reduction of peak flow and nutrient cycles, absorption of heavy metals, and provision of additional benefits such as recreational facilities (Beatley, 2009). The preferences for rain gardens included a rectangular form (40.8%) and proximity to sidewalks (68%). Figure 2 depicts these preferences.

Use of Natural Images

Natural spaces and materials can relax eye muscles, reduce cognitive fatigue, and improve mental and physical health, including stress reduction (Grinde & Patil, 2009; Xue et al., 2019). Design elements in the natural image aspect consist of biomorphic/organic forms, natural ornaments, and murals. A total of 89.3% of the respondents preferred organic over geometric garden designs. When applying biomorphic concepts, organic forms in harmony with nature and their surroundings are preferred for park and building designs and are known to promote health and well-being (Zhong et al., 2022). Moreover, the respondents preferred placements and dimensions of roofs and walls, among others, on a monumental scale (65%). The next most popular element was natural ornamentation with 64.1% of users preferring plant over animal ornaments.

The unit of analysis of this study is a city-scale park; thus, adding monumental scale elements and focal points can render these urban parks to appear more magnificent and attractive. The preferred dimension for natural elements in murals is a monumental scale, and the preferred placement is on surfaces of walls (84.5%), which can attract more attention from visitors, because they are perpendicular and tall. Figure 3 depicts the preferences for natural image design.

Figure 2

Preferred Green Design Elements

Note. a semi-intensive green roof, planter green wall, grass pavement, and rain garden. From Biophilic design (p. 45), by S. R. Kellert and E. F. Calabrese, 2015, Biophilic-Design. Copyright 2015 by Stephen R. Kellert and Elizabeth F. Calabrese.

Figure 3

Preferred Natural Image Design Elements

Note. biomorphic forms, natural ornaments, and murals. Natural image designs, such as biomorphic patterns of biophilic design, which can be implemented in urban parks. From Biophilic design (p. 50), by S. R. Kellert and E. F. Calabrese, 2015, Biophilic-Design. Copyright 2015 by Stephen R. Kellert and Elizabeth F. Calabrese.

Flora and Fauna Habitat Design

Community gardens and ponds/aquariums are essential components of flora and fauna habitat design. According to a survey of 100 respondents in Semarang City Park, 52.4% prefer Plot Gardens, which is a system of dividing land into individual plots. Each plot measures approximately 3 m × 6 m. The fact that urban residents prefer to socialize or relax alone or in small groups supports this preference, making park visits especially activities in small groups. Preference is supported by the fact that urban residents prefer to socialize or relax alone or in small groups, making park visits especially activities in small groups (van Aalst & Brands, 2021), particularly for young people who comprise more than 50% of urban park users. Meanwhile, 72.8% preferred ponds over aquariums as fauna habitats. The dimensions of the selected pool size are approximately 3 m x 6 m with 50.5% of the respondents expressing a preference for this option. Figure 4 depicts the preferences for flora and fauna habitat design.

Healing Space Design

Natural sounds and healing gardens are two essential design elements in the design of healing spaces. For example, evidence exists that automobile noise discourages people from walking to work or engaging in other outdoor activities (Beatley, 2018). Urban natural settings with ambient noises are also beneficial for regaining individual attention (Gould Van Praag et al., 2017). In terms of natural sound elements, 80.6% of park users prefer fountains over sound sculptures, because ponds provide benefits, such as calming sounds and the most ecologically diverse freshwater habitats (Milliken et al., 2023). The selected dimension is the larger natural sound dimension (82.2%). In addition to natural sounds, healing gardens are preferred, which. may include reception, social interaction, therapy, and meditation spaces. In this case, 66% of park users prefer social interaction rooms, and 66% opted for meditation rooms. These rooms should exhibit a flower garden and a place to rest as a passive activity (enjoying green plants and relaxing). Stagnant activity areas are more personal, because they are used for those who need to be alone to relax. Therefore, the respondents preferred biophilic designs with a calming effect. Figure 5 depicts the preferences for the design of healing spaces.

Figure 4

Preferences for Design Elements for Flora and Fauna Habitats

(a) (b)

Note. (a): plot garden; (b): pond. From Biophilic design (p. 52), by S. R. Kellert and E. F. Calabrese, 2015, Biophilic-Design. Copyright 2015 by Stephen R. Kellert and Elizabeth F. Calabrese.

Design of Spaces for Physical Activities

The encouragement of physical activity while enjoying parks and other natural features exerts a significant positive impact on health (Mcdonald & Beatley, 2021). The relevant design elements that encourage physical activity include walking/jogging trails and outdoor gyms. Approximately 62.1% of users prefer rubber materials for walking/jogging trails, because rubber tracks are less likely to cause stress fractures in runners compared with asphalt or concrete pavements, which places more pressure on the muscles and leg bones (Kellert & Calabrese, 2015) Meanwhile, for outdoor gyms, the majority of users (58.3%) prefer gym equipment to be placed more than 2 m apart. Notably, the study was conducted during the COVID-19 pandemic, when people were accustomed to following minimum social distancing in public places. Figure 6 depicts the preferences for physical activity design.

Figure 5

Preferences for Healing Space Design

(a) (b)

Note. (a): fountain; (b): social interaction spaces and meditation rooms. From Biophilic design (p. 58), by S. R. Kellert and E. F. Calabrese, 2015, Biophilic-Design. Copyright 2015 by Stephen R. Kellert and Elizabeth F. Calabrese.

Figure 6

Preferences for Design Elements for Physical Activity Spaces

(a) (b)

Note. (a): rubber walking/jogging track; (b): outdoor gym. From Biophilic design (p. 70), by S. R. Kellert and E. F. Calabrese, 2015, Biophilic-Design. Copyright 2015 by Stephen R. Kellert and Elizabeth F. Calabrese.

Use of Natural Materials

Local buildings or natural materials are crucial for biophilic designs in urban parks in Semarang. In this case, the majority of users (68.9%) preferred rock or stone over wood (47.6%), bamboo (33%), rattan (1%), or roots (1%). This preference is considered due to the fact that many rock elements are currently place in all urban parks in Semarang. Furthermore, people prefer natural over artificial materials, because such materials display the organic processes of aging, weathering, and other dynamic features of natural materials, including inorganic forms such as rock or stone (Kellert & Calabrese, 2015). Figure 7 depicts the preferences for natural materials design.

Existing Heat Condition Based on Sun Hours Analysis in SketchUp Extension

Indonesia Kaya Park has the lowest temperature of the three selected parks. According to sun hour analysis, the average temperature at this park was 27.35 °C followed by Srigunting Park, which had an average temperature of 30.03 °C. The one with the highest temperature was Tugu Muda Park with an average temperature of 30.05 °C. The existing spatial heat conditions are considered in terms of the design and placement of biophilic elements, such that the hottest areas benefit from their cooling effects. Figure 8 depicts the sun hour heat map for each of the three studied parks.

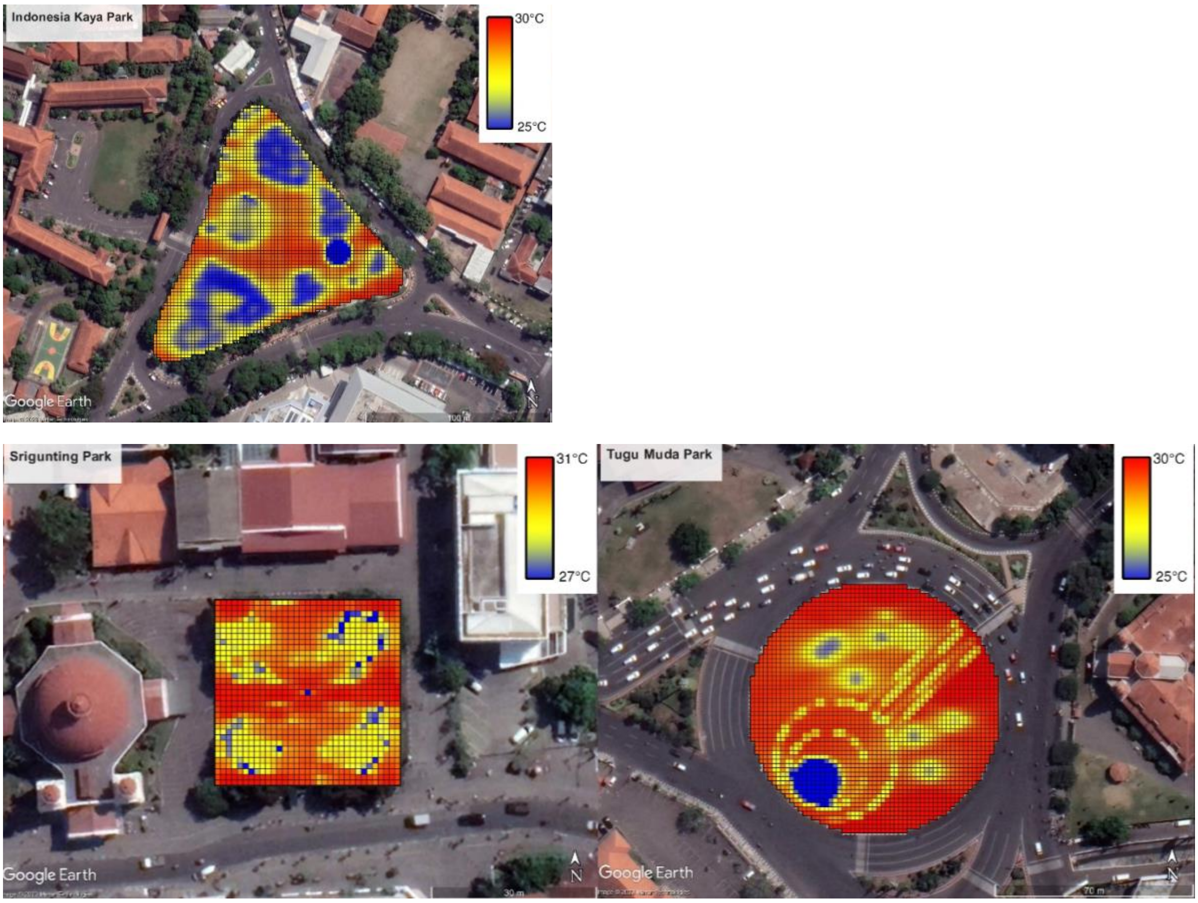
Figure 7

Rocks Used as a Natural Material Design Element

Note. From Biophilic design (p. 80), by S. R. Kellert and E. F. Calabrese, 2015, Biophilic-Design. Copyright 2015 by Stephen R. Kellert and Elizabeth F. Calabrese.

Figure 8

Sun Hour Heat Map of Indonesia Kaya, Srigunting, and Tugu Muda Parks



Note. Adapted from Map of the Indonesia Kaya Park, Srigunting Park, and Tugu Muda Park, by Google Earth, 2023. Copyright 2023 by Google LLC.

Application of the Biophilic Design Model to Urban Parks in Semarang

Users of Indonesia Kaya Park prefer mural elements with a monumental scale (82%), which are typically placed on the walls of buildings in or adjacent to the park. Figure 9 presents an illustration of a two-dimensional placement of biophilic elements in Indonesia Kaya Park, while Figure 10 depicts a three-dimensional biophilic design element as a result of the preferences expressed by users. The placement of these elements is in accordance with the existing conditions demonstrated in the urban heat map.

Residents of Srigunting Park strongly prefer (81%) for a portion of building roofs to be devoted to green roofs as well as murals on walls (81%). Figure 11 is an illustration of a two-dimensional placement of biophilic elements in Srigunting Park, while Figure 12 depicts the use of three-dimensional biophilic design elements as a result of the preferences of users of Srigunting Park. To determine the placement of the elements, the study considered the existing conditions presented in the urban heat map.

Users of Tugu Muda Park expressed a strong preference for semi-intensive green roofs (81%), biomorphic forms (94%), monumental-scale murals (94%), and fountains (81%). Figure 13 illustrates a two-dimensional model of the placement of biophilic elements in Tugu Muda Park, and Figure 14 depicts three-dimensional biophilic design elements based on the preferences of park users. The study considered the existing condition of UHIs for such a placement.

Figure 9

Placement of Biophilic Elements in Indonesia Kaya Park

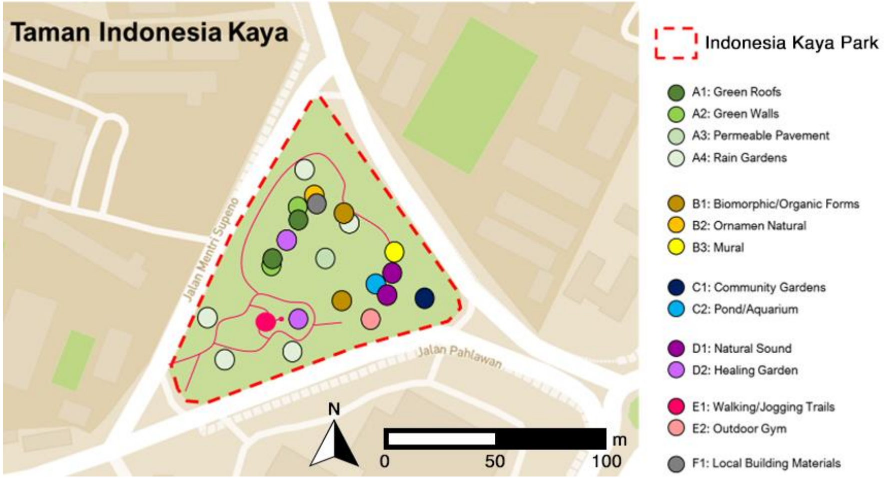


Figure 10

3D Design Illustration of Biophilic Elements in Indonesia Kaya Park

Figure 11

Placement of Biophilic Elements in Srigunting Park

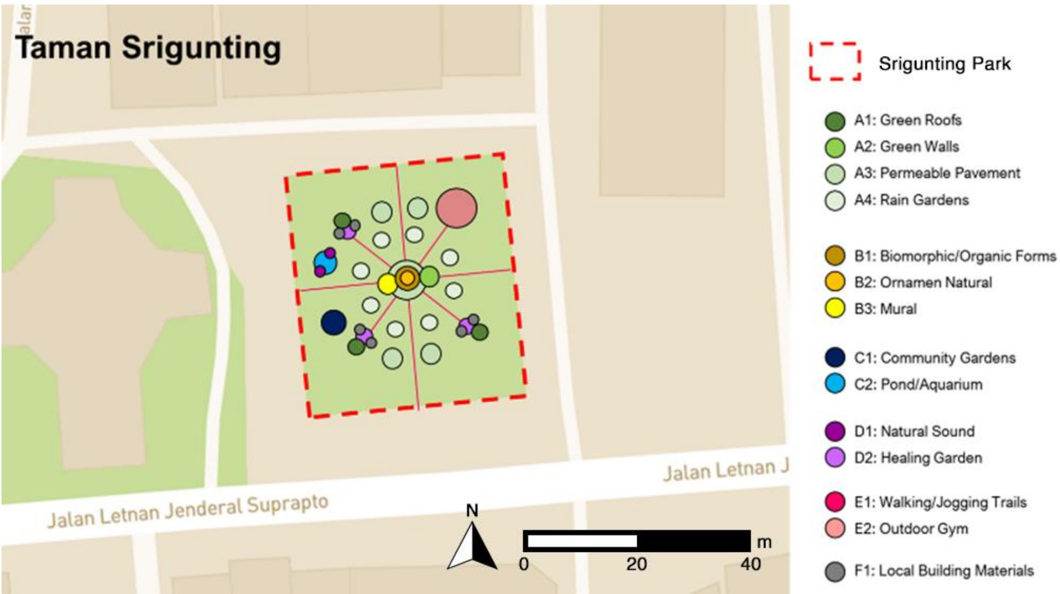


Figure 12

Biophilic Elements of the 3D Design for Srigunting Park

Figure 13

Placement of Biophilic Elements on Tugu Muda Park

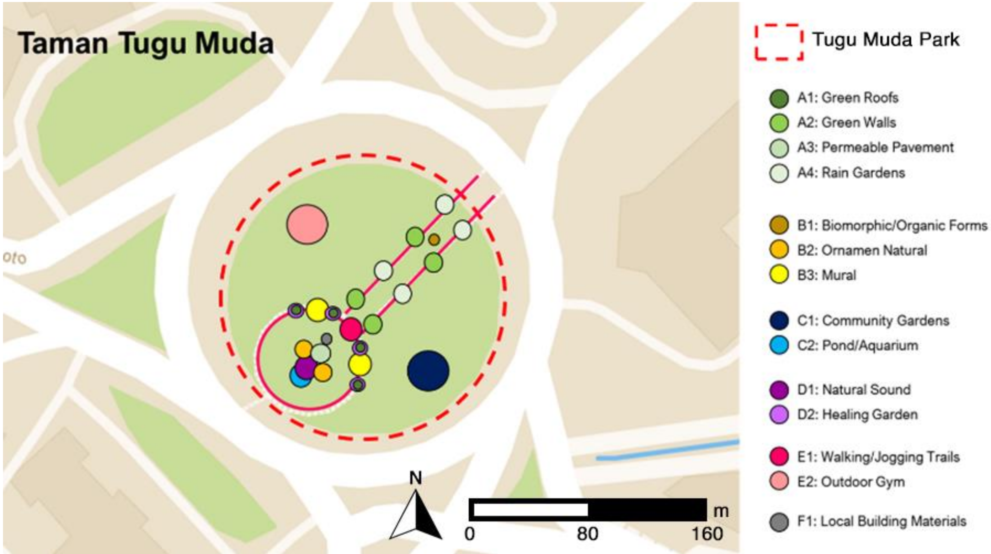
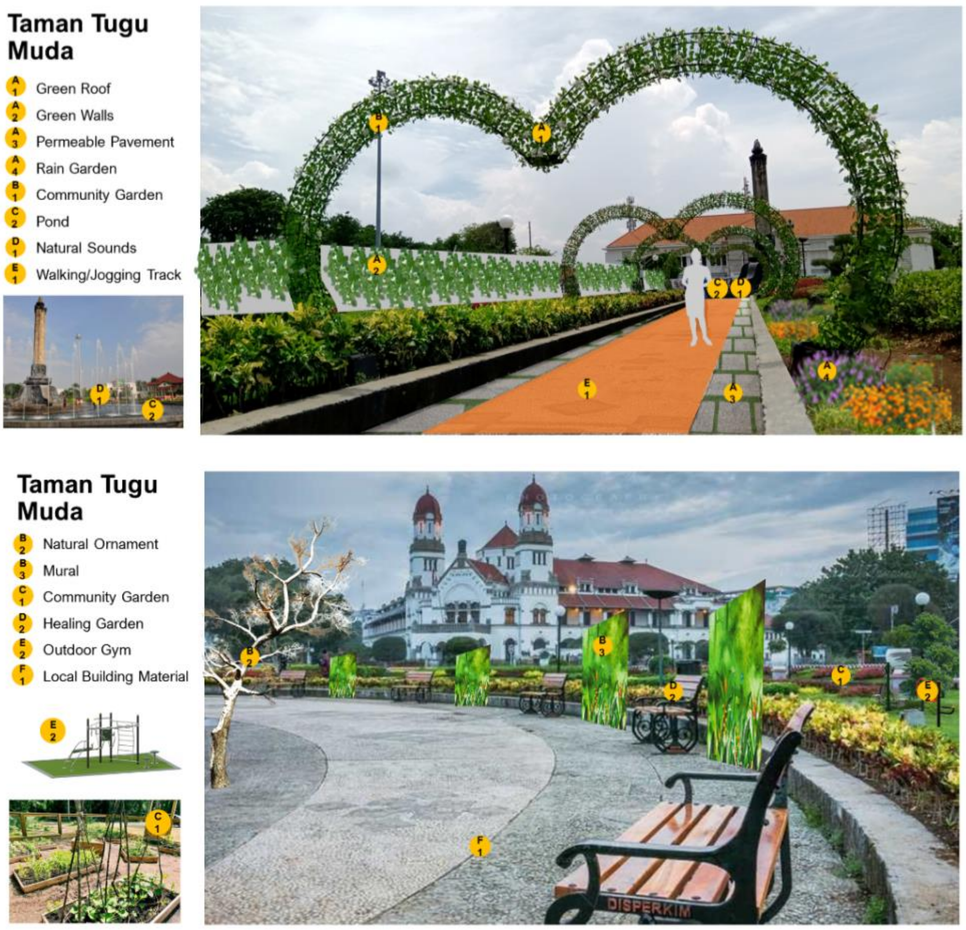


Figure 14

Illustration of a 3D Design of Biophilic Elements in Tugu Muda Park



Biophilic Design Model for Decreasing the Urban Heat Island Index

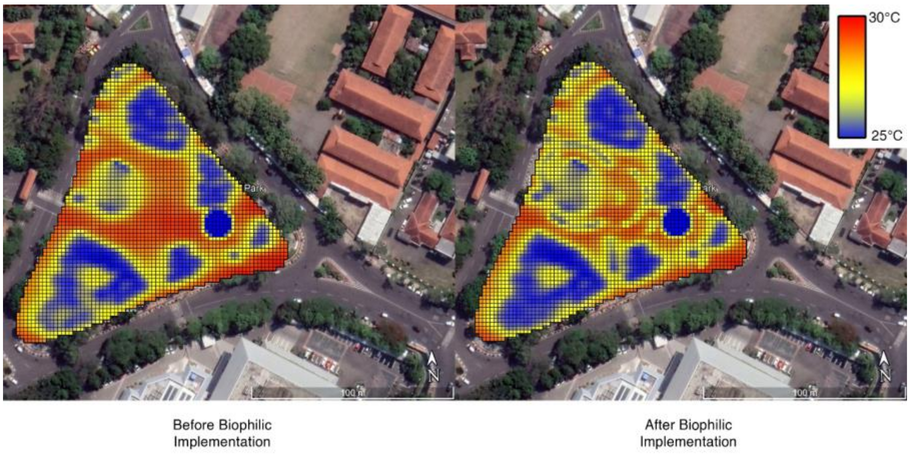
The implementation of the biophilic design model can decrease the UHI index in Indonesia Kaya Park (Figure 15). Green walls and roofs placed around the building decrease the temperature (Revell & Anda, 2014), which leads to a decrease of 0.55 °C in average temperature from 27.32°C to 26.77°C in Indonesia Kaya Park (Figure 18 in Appendix B).

In Srigunting Park, the implementation of various biophilic elements, including fountain and green roofs (Figure 16) can reduce the average temperature in the area by 0.7°C. This reduction is in accordance with the result of Syafii et al. (2017), that is, the effects of urban cooling can be achieved through bodies of water. Figure 19 in Appendix B displays the specific decrease of temperature in the area.

Tugu Muda Park can manage to lower its temperature by 0,4 °C through biophilic elements such as green walls and roofs and biomorphic forms (Figure 17). This urban park is one with the highest temperature in Semarang, and the decrease in temperature can be achieved through the implementation of biophilic elements. Figure 20 in Appendix B provides the details of the temperature decrease.

Figure 15

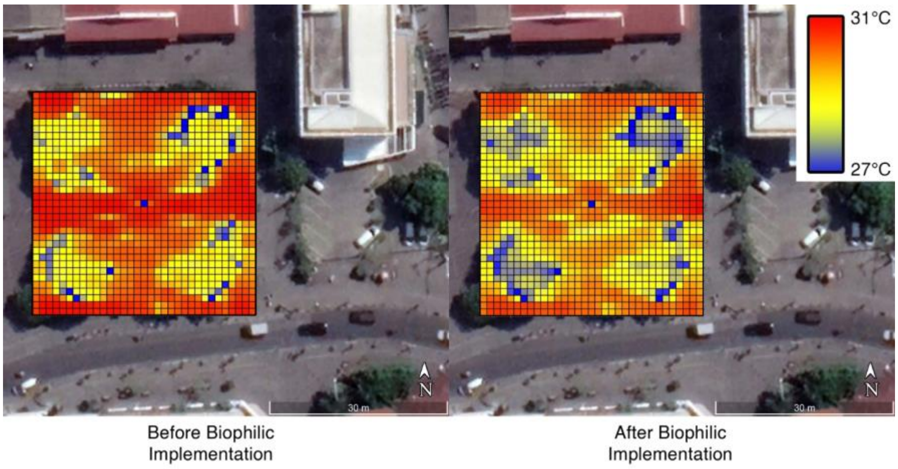
Implementation of Biophilic Design and Temperature in Indonesia Kaya Park



Note. Adapted from Map of Indonesia Kaya Park, by Google Earth, 2023. Copyright 2023 by Google LLC.

Figure 16

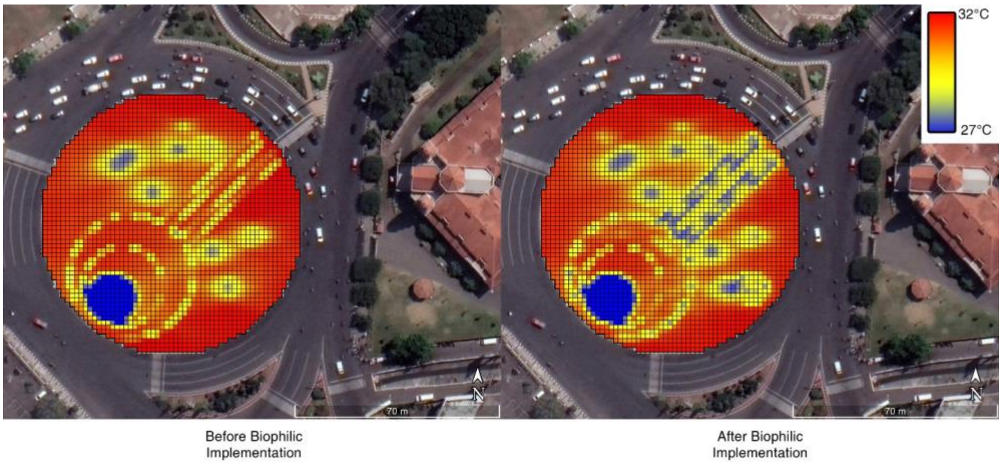
Implementation of Biophilic Design and Temperature in Srigunting Park



Note. Adapted from Map of Srigunting Park, by Google Earth, 2023. Copyright 2023 by Google LLC.

Figure 17

Implementation of Biophilic Design and Temperature in Tugu Muda Park



Note. Adapted from Map of Tugu Muda Park, by Google Earth, 2023. Copyright 2023 by Google LLC.

CONCLUSION

The study identified the three parks using the LST method and by scoring the effectiveness of six urban parks. It found that three of the parks in Semarang City exhibited high levels of urgency with respect to the application of biophilic design, especially for the objective of lowering the temperatures in the parks. The selected parks were Srigunting, Indonesia Kaya, and Tugu Muda Parks, which have one thing in common: each is in the city center and each experienced above-average temperature increases (2.9 °C) across the 10-year period prior to the study due to various factors such as the composition of vegetation or the small area of green spaces relative to the surrounding built-up urban areas. Thus, the study conducted an assessment of the preferences of park users in terms of biophilic design. The result indicated that 88%–90% of users prefer park designs that incorporate biophilic concepts.

Furthermore, in terms of green, natural image, flora and fauna habitat, healing space, physical activities, and natural material designs, more than half of the respondents prefer the integration of biophilic elements that can effectively decrease air temperature, blend with the surrounding nature, provide a calming effect, and that are affordable in terms of cost and beneficial in terms of mental and physical health. These preferences are consistent with those of previous studies. The respondents prefer the use of biomorphic/organic forms that comprise the elements of natural image design. The reason is that, as an example, it results in a structure that blends with nature and its surroundings while promoting health and well-being. Furthermore, with respect to the design for flora and fauna habitats, 52.4% prefer garden plots over community gardens, in which the garden is divided into individual plots. This preference is attributable to the fact that urban park users prefer to socialize or relax at the park in small groups for most of the time. The implementation of biophilic design in urban parks in Semarang can decrease the average temperature by approximately 0.5 °C. The underlying reason is that biophilic elements, such as green roofs and water features, can decrease the temperature in surrounding areas.

In this regard, the study recommends governmental authorities to integrate biophilic design principles and regenerative attributes into all urban parks. Furthermore, further research be conducted on carbon footprints in the areas occupied by urban parks, because this factor is also related to climate change and city resilience, and biophilic elements can be used to lower these carbon footprints.

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REFERENCES

Africa, J., Heerwagen, J., Loftness, V., & Balagtas, C. R. (2019). Biophilic design and climate change: Performance parameters for health. *Frontiers in Built Environment, 5*, Article 28. https://doi.org/10.3389/fbuil.2019.00028

Agbonyin, A., & Zoras, S. (2020). Techno-economic inquiry into implementation barriers in green roof adoption as an energy retrofit measure in temperate climates: UK study. *IOP Conference Series: Earth and Environmental Science, 410*(1). https://doi.org/10.1088/1755-1315/410/1/012014

Bayulken, B., Huisingh, D., & Fisher, P. M. J. (2021). How are nature based solutions helping in the greening of cities in the context of crises such as climate change and pandemics? A comprehensive review. *Journal of Cleaner Production, 288*, Article 125569. https://doi.org/10.1016/j.jclepro.2020.125569

Beatley, T. (2009). Biophilic urbanism: Inviting nature back to our communities and into our lives. *William & Mary Environmental Law and Policy Review, 34*, 209.

Beatley, T. (2011). *Biophilic cities: Integrating nature into urban design and planning*. Island Press. https://doi.org/10.5822/978-1-59726-986-5

Beatley, T. (2016). *Handbook of biophilic city planning and design*. Island Press. https://doi.org/10.5822/978-1-61091-621-9_1

Beatley, T. (2018). *Blue biophilic cities: Nature and resilience along the urban coast.* Palgrave Macmillan Cham. https://doi.org/10.1007/978-3-319-67955-6

Beatley, T., & Newman, P. (2013). Biophilic cities are sustainable, resilient cities. Sustainability, 5(8), 3328–3345. https://doi.org/10.3390/su5083328

Browning, W. D., & Ryan, C. O. (2020). Nature inside: A biophilic design guide. Routledge.

Cacique, M., & Ou, S.-J. (2022). Biophilic design as a strategy for accomplishing the idea of healthy, sustainable, and resilient environments. *Sustainability, 14*(9), Article 5605. https://doi.org/10.3390/su14095605

Clayton, S. (2020). Climate anxiety: Psychological responses to climate change. *Journal of Anxiety Disorders, 74*, Article 102263. https://doi.org/10.1016/j.janxdis.2020.102263

el-Baghdadi, O., & Desha, C. (2017). Conceptualising a biophilic services model for urban areas. *Urban Forestry & Urban Greening, 27*, 399–408. https://doi.org/10.1016/j.ufug.2016.10.016

Gillis, K., & Gatersleben, B. (2015). A review of psychological literature on the health and wellbeing benefits of biophilic design. *Buildings, 5*(3), 948–963. https://doi.org/10.3390/buildings5030948

Gould van Praag, C. D., Garfinkel, S. N., Sparasci, O., Mees, A., Philippides, A. O., Ware, M., Ottaviani, C., & Critchley, H. D. (2017). Mind-wandering and alterations to default mode network connectivity when listening to naturalistic versus artificial sounds. *Scientific Reports, 7*, Article 45273. https://doi.org/10.1038/srep45273

Grinde, B., & Patil, G. G. (2009). Biophilia: Does visual contact with nature impact on health and well-being? *International Journal of Environmental Research and Public Health, 6*(9), 2332–2343. https://doi.org/10.3390/ijerph6092332

Hady, S. I. M. A. (2021). Activating biophilic design patterns as a sustainable landscape approach. *Journal of Engineering and Applied Sciences, 68*(1), 1–16. https://doi.org/10.1186/s44147-021-00031-x

Higueras, E., Román, E., & Fariña, J. (2021). Guidelines for healthier public spaces for the elderly population: Recommendations in the Spanish context. In J. Martinez, C. A. Mikkelsen & R. Phillips (Eds.), *Handbook of quality of life and sustainability* (pp. 35–51). Springer. https://doi.org/10.1007/978-3-030-50540-0_3

Hulley, G. C., Ghent, D., Göttsche, F. M., Guillevic, P. C., Mildrexler, D. J., & Coll, C. (2019). 3 - Land Surface Temperature. In G. C. Hulley & D. Ghent (Eds.), *Taking the temperature of the earth* (pp. 57–127). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-12-814458-9.00003-4

Hung, S.-H., & Chang, C.-Y. (2022). How do humans value urban nature? Developing the perceived biophilic design scale (PBDs) for preference and emotion. *Urban Forestry & Urban Greening, 76*, Article 127730. https://doi.org/10.1016/j.ufug.2022.127730

Joo-Young, S. (2020). A study on the application of biophilic design pattern in educational space. *Journal of Korean Institute of Educational Facilities, 27*(3), 3–14. https://koreascience.kr/article/JAKO202024063516566.page

Kaewpraek, C., Ali, L., Rahman, M. A., Shakeri, M., Chowdhury, M. S., Jamal, M. S., Mia, M. S., Pasupuleti, J., Dong, L. K., & Techato, K. (2021). The effect of plants on the energy output of green roof photovoltaic systems in tropical climates. *Sustainability, 13*(8), Article 4505. https://doi.org/10.3390/su13084505

Kellert, S., & Calabrese, E. (2015). *The practice of biophilic design*. Biophilic-design. https://www.biophilic-design.com/_files/ugd/21459d_81ccb84caf6d4bee8195f9b5af92d8f4.pdf

King, B. C. (2022). The biophilia hypothesis and mental health: A call for biophilic design. In I. Akpinar, G. Firdevs, G.W. Ebbini, E. Gorgul, S. Kristo & H. Turkoglu (Eds.), *Emerging approaches in design and new connections with nature* (pp. 253–265). IGI Global. https://www.igi-global.com/chapter/the-biophilia-hypothesis-and-mental-health/293319

Kumar, A., & Nayar, K. R. (2021). COVID-19 and its mental health consequences. *Journal of Mental Health, 30*(1), 1–2. https://doi.org/10.1080/09638237.2020.1757052

Lee, S., & Kim, Y. (2021). A framework of biophilic urbanism for improving climate change adaptability in urban environments. Urban *Forestry & Urban Greening, 61*, Article 127104. https://doi.org/10.1016/j.ufug.2021.127104

Lei, Q., Yuan, C., & Lau, S. S. Y. (2021). A quantitative study for indoor workplace biophilic design to improve health and productivity performance. *Journal of Cleaner Production, 324*, Article 129168. https://doi.org/10.1016/j.jclepro.2021.129168

Mcdonald, R., & Beatley, T. (2021). *Biophilic cities for an urban century: Why nature is essential for the success of cities*. Palgrave Pivot Cham. https://link.springer.com/book/10.1007/978-3-030-51665-9#about-this-book

Milliken, S., Kotzen, B., Walimbe, S., Coutts, C., & Beatley, T. (2023). *Biophilic cities and health. Cities and Health, 7*(2), 175–188. https://doi.org/10.1080/23748834.2023.2176200

Novosadová, L., & van der Knaap, W. (2021). The role of biophilic agents in building a green resilient city; the case of Birmingham, UK. *Sustainability, 13*(9), Article 5033. https://doi.org/10.3390/su13095033

Radha, C. H. (2022). Biophilic design approach for improving human health in the built environment. *International Transaction Journal of Engineering, Management, & Applied Sciences \& Technologies, 13*(9), 1–12. https://tuengr.com/V13/13A9TM.pdf

Reuter, D. C., Richardson, C. M., Pellerano, F. A., Irons, J. R., Allen, R. G., Anderson, M., Jhabvala, M. D., Lunsford, A. W., Montanaro, M., Smith, R. L., Tesfaye, Z., & Thome, K. J. (2015). The thermal infrared sensor (tirs) on landsat 8: Design overview and pre-launch characterization. *Remote Sensing, 7*(1), 1135–1153. https://doi.org/10.3390/rs70101135

Revell, G., & Anda, M. (2014). Sustainable urban biophilia: The case of greenskins for urban density. *Sustainability, 6*(8), 5423–5438. https://doi.org/10.3390/su6085423

Ryan, C. O., Browning, W. D. (2020). Biophilic design. In V. Loftness (Ed.), *Sustainable built environments*. Encyclopedia of sustainability Science and technology series (pp. 43–85). Springer. https://doi.org/10.1007/978-1-0716-0684-1_1034

Sen, S., & Guchhait, S. K. (2021). Urban green space in India: Perception of cultural ecosystem services and psychology of situatedness and connectedness. *Ecological Indicators, 123*, Article 107338. https://doi.org/10.1016/j.ecolind.2021.107338

Soderlund, J., & Newman, P. (2015). Biophilic architecture: A review of the rationale and outcomes. *AIMS Environmental Science, 2*(4), 950–969. https://doi.org/10.3934/environsci.2015.4.950

Syafii, N. I., Ichinose, M., Kumakura, E., Chigusa, K., Jusuf, S. K., & Wong, N. H. (2017). Enhancing the potential cooling benefits of urban water bodies. *Nakhara: Journal of Environmental Design and Planning, 13*, 29–40. https://ph01.tci-thaijo.org/index.php/nakhara/article/view/104607

Tharim, A. H. A., Ahmad, A. C., Saarani, P. S. N., Haossain, N. Q. R., Purwanto, E., Tafridj, I. S. I., Purisari, R., & Prasetio, T. (2022). The determinant factors of biophilic design strategies and occupants'psychological performance in office building. *Malaysian Journal of Sustainable Environment, 9*(3), 87–106. https://doi.org/10.24191/myse.v9i3.18292

Tillie, N., & van der Heijden, R. (2016). Advancing urban ecosystem governance in Rotterdam: From experimenting and evidence gathering to new ways for integrated planning. *Environmental Science & Policy, 62*, 139–144. https://doi.org/10.1016/j.envsci.2016.04.016

van Aalst, I., & Brands, J. (2021). Young people: Being apart, together in an urban park. *Journal of Urbanism: International Research on Placemaking and Urban, 14*(1), 1–17. https://doi.org/10.1080/17549175.2020.1737181

Xue, F., Lau, S. S. Y., Gou, Z., Song, Y., & Jiang, B. (2019). Incorporating biophilia into green building rating tools for promoting health and wellbeing. *Environmental Impact Assessment Review, 76*, 98–112. https://doi.org/10.1016/j.eiar.2019.02.004

Zhang, R. (2023). Integrating ergonomics data and emotional scale to analyze people's emotional attachment to different landscape features in the Wudaokou Urban Park. *Frontiers of Architectural Research, 12*(1), 175–187. https://doi.org/10.1016/j.foar.2022.06.007

Zhong, W., Schröder, T., & Bekkering, J. (2022). Biophilic design in architecture and its contributions to health, well-being, and sustainability: A critical review. *Frontiers of Architectural Research, 11*(1), 114–141. https://doi.org/10.1016/j.foar.2021.07.006