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ASSESSING THE EFFECTIVENESS OF BIOPHILIC DESIGN APPROACH IN CONTRIBUTION TO SUSTAINABLE ARCHITECTURAL GOALS

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Abstract. This study investigates the role of biophilic design in addressing environmental issues within the built environment and its contribution to the goals of sustainable architecture. A mixed-method approach comprised a literature review to identify key elements of biophilic design, an online survey with 378 participants from academia and professional fields and focus group interviews with 13 experts. The Relative Importance Index (RII) and thematic analysis were utilized to evaluate the significance of the identified biophilic factors. The study revealed six principal objectives of sustainable architecture and elucidated how biophilic design contributes to these goals through five direct and three indirect benefits. The findings underscore the potential of biophilic design to enhance sustainability in the built environment, particularly in Nigeria. Biophilic design emerges as a valuable strategy in sustainable architecture, promoting human-nature connections and offering tangible benefits. The study highlights the importance of integrating biophilic principles into architectural planning to address environmental challenges effectively.

Keywords: *Biophilic design, sustainable architecture, environmental challenges, relative importance index, human-nature interactions.*

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1. Introduction

The environmental challenges within the human-built environment encompass a multifaceted array of issues stemming from human activities' profound impact on constructed surroundings (Purani & Kumar, 2018; Vuscan & Muntean, 2023; Ojobo *et. al*., 2024). These challenges manifest across ecological, social and economic dimensions, reflecting the intricate interplay between human progress and environmental sustainability. Pollution is a primary concern, originating from urban areas, industrial zones and construction sites. Emissions from vehicles, industries and improper waste disposal contribute to pollution, posing threats to people's wellness and ecosystem balance (Kolawole & Iyiola, 2023; Al-Dulaimi & Al-Taai, 2021). Unsustainable resource use in construction and urban development depletes energy, water and raw materials,

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worsening environmental degradation and hindering ecosystem regeneration.

Biophilic design is not merely a trend but a comprehensive approach to designing spaces that prioritize human well-being, reduce environmental impact and contribute to the overall sustainability and resilience of the built environment. Its significance lies in the potential to create environments that nurture both individuals and the planet (Panagopoulos *et al.*, 2020; Andreucci *et al.*, 2021). Biophilic design incorporates the application of biophilia theory to the fields of architecture, city planning, planning a landscape and sustainability. The biophilic design was offered as a design guide to meet the need for 'natural' in buildings. While it was opined by Purani and Kumar (2018) and Kellert (2018); the connection between humans and their surroundings, resulted in an effective impact on the ecosystem. Given these; biophilic design principles can be applied to a range of building types, including homes, offices, schools and hospitals and can be used to create sustainable and environmentally responsible buildings (Kellert, 2018; Abdelaal, 2019). Thus, biophilic architecture ensures implementing eco-friendly technologies, promoting green infrastructure and fostering a harmonious balance between human development and environmental conservation are essential for creating resilient and sustainable built environments.

In the realm of Nigerian architecture, there exists a pronounced research gap concerning the nuanced environmental challenges embedded within the built environment (Alalade, 2017; Unuigbe, 2021). While global discussions on architecture and sustainability abound, a dedicated exploration of how these principles and challenges manifest in the specific context of Nigeria is conspicuously absent. In addition, the prevailing literature largely skirts the intricacies of Nigerian urbanization and architectural development, failing to capture the unique environmental challenges associated with the human-built environment (Unuigbe, 2021; Agboola *et al.*, 2023). The accelerated urbanization and architectural evolution in Nigeria demand a focused investigation into the environmental sustainability issues endemic to its cities and regions. Key areas requiring targeted research within the Nigerian urban planning and architectural context include a thorough examination of the effects of architectural techniques on local ecosystems, especially considering the distinctive characteristics of Nigeria's biodiversity. The effectiveness of architectural designs and the adaptability to sustainable architectural practices within the Nigerian socio-economic framework, are underexplored areas (Adegoriola *et al.*, 2023; 2024). Understanding how architectural designs contribute to or mitigate the urban heat island effect is pivotal for developing context-specific architectural interventions. Conducting studies that consider the unique socio-economic, cultural and environmental factors shaping architectural practices will not only fill the existing research gap but also pave the way for sustainable architectural interventions tailored to Nigeria's evolving built environment. This study aims to address this gap by investigating the specific environmental challenges faced in Nigerian architecture and how sustainable practices, such as biophilic design, can be adapted to mitigate these issues. By employing a Relative Importance Index to evaluate the significance of various factors, this research will provide a comprehensive analysis of the human-nature interactions within Nigeria's built environment. The research involved seeks the concept and strategies of biophilic design as viewed by the experts in reaction to increasing threats to the environment. The manuscript objectives include:

i. Exploring the direct impacts of the effectiveness of biophilic design towards sustainable architecture

ii. Exploring the indirect impacts of the effectiveness of biophilic design towards sustainable architecture and

iii. Testing several hypotheses related to the effects of integrating biophilic design ideas within city planning, architecture and built environments.

Biophilic design theory suggests that integrating nature into architecture fosters positive connections between humans and their environment, boosting well-being and sustainability (Kellert, 2018; Zhong *et al.*, 2022). This theory is based on recognizing humans' inherent bond with nature and how natural surroundings profoundly affect our health and behaviour.

The manuscript contributes to the ongoing discussion around sustainable design and architecture by presenting a range of expert perspectives on the potential of biophilic design as a strategy for achieving sustainable architecture. The manuscript presents a synopsis of the literature of recent research on biophilic design and sustainable architecture, followed by a series of interviews with experts in the field. The experts are asked to share their opinions on the potential benefits and challenges of biophilic design, as well as their recommendations for future research and development in this area. The review also highlights some of the challenges and obstacles to the implementation of biophilic design in sustainable architecture. The manuscript is divided into four sections. Section two begins with a literature review of existing research on biophilic design and sustainable architecture, outlining the key principles of Biophilic design considering its prospective implications to both building occupants and the environment. Section three comprises the research methods that present a series of discussions with professionals in architecture, design and sustainability. The section four of the manuscript presents the conclusion extracted from the results and findings. It also presents the challenges and future directions of biophilic design, in connection with the recommendations for its implementation in sustainable architecture. This provides guides on the design and planning of sustainable buildings and urban environments.

2. Overview of sustainable architecture, the significance and benefits of biophilic design

Sustainable architecture is a comprehensive approach to architectural design that aims to reduce the negative ecological effects of structures, while promoting health, well-being and social sustainability (Ojobo *et al.*, 2024; Zhong *et al.*, 2022; Nia & Suleiman, 2018). Sustainable architecture emphasizes commitment to the environment and efficient use of resources throughout the building's life cycle. This method tries to reduce buildings' negative environmental effects while increasing their beneficial influence on occupant health and well-being. Biophilic design and sustainable architecture offer a holistic approach to creating built environments that prioritize human health and well-being while minimizing negative impacts on the environment (Kellert, 2018; Grazuleviciute *et al.*, 2022). By adopting the measures into design, professionals can create spaces that promote a connection to nature, enhance human health and well-being and contribute to a sustainable future. Biophilic design and sustainable architecture have been the subject of studies in recent years. Sustainable architecture aims to tackle environmental challenges by harnessing renewable energy, optimizing water and material usage and reducing waste through efficient design and construction practices. The key principles of sustainable architecture are presented in Table 1.

Biophilic design operates on several key principles aimed at fostering strong ties between the built environment and the natural world, thereby enhancing well-being, sustainability and harmony with nature (Table 2). It underscores the importance of incorporating natural elements into building design to enhance human health and well-being while lessening the environmental impact of constructed environments (Kellert, 2018; Santiago, 2016). This involves integrating features like natural light, vegetation and water elements into buildings, alongside using sustainable materials and minimizing energy consumption. Biophilic design, coined by biologist Wilson, represents a comprehensive approach to architectural and environmental design aimed at re-establishing individuals' connection with the natural world (Panagopoulos *et al.*, 2020; Kellert, 2018; Kayihan, 2018). The enhancement to achieve good aesthetics involves the intentional integration of natural elements, patterns and processes into built environments to create spaces that resonate with humans' innate yearning for connection to nature, thus nurturing well-being.

By acknowledging and integrating humans' inherent connection to nature, biophilic design endeavours to cultivate healthier, more supportive and inspiring living and working spaces. Its favourable effects on mental health and the surrounding environment confirm the importance of Wilson's Biophilia concept. Research by Ryan et al. (2014) and Cramer and Browning (2008); support the foundational aspects of biophilic design, demonstrating that its integration enhances occupants' overall health and satisfaction, as well as their performance and productivity levels. Through the incorporation of these principles, biophilic designers can craft environments that improve human health and well-being.

Table 1. Some of the key principles of sustainable architecture

Main Principles	Detailed descriptions	References
1. Energy efficiency	Sustainable buildings are built to be extremely energy cost-effective, with attributes like outstanding performance insulating properties, effective. systems for heating and cooling and energy sources that are sustainable.	Vallero and Brasier (2008); Ahmed et al. (2022).
2. Water conservation	Rainwater collection systems and water-efficient landscaping are examples of sustainable building features that strive to reduce water consumption.	Varma (2022); Rahman et al. (2019).
3. Use of sustainable materials	Sustainable buildings use sustainable resources, such as materials that are recyclable and that have a low environmental impact in their production and disposal.	Panagopoulos & Herman (2020); Kellert (2018).
4. Indoor environmental quality	Sustainable architecture focuses on the general wellness of occupants of structures by establishing settings that are well-ventilated, well-lit and free of harmful chemicals and pollutants.	Asim and Shree (2019); Berto et. al. (2018).
5. Social sustainability	Sustainable architecture also seeks to promote social sustainability by creating buildings that are accessible, equitable and supportive of community well-being.	Nia and Suleiman (2018); Grazuleviciute et al. (2022).

Table 2. Key principles of biophilic design

Main components	Target Principle	References
1. Nature in the space: It includes features like indoor gardens, living walls, water features, natural light and views of nature.	This principle involves incorporating natural elements such as plants, water and natural light into the built environment. This can create a connection between the interior and exterior spaces and provide a sense of calm and relaxation.	Panagopoulos, et al. (2020); Asim and Shree (2019).
2. Natural shapes and forms: It creates a sensory experience that is calming and restorative.	This principle involves incorporating natural shapes and forms into building design, such as curved walls, organic shapes and patterns found in nature. This can help create a more harmonious and calming environment.	Rai et al. (2020).
3. Human-scale design: Focuses on creating spaces that are comfortable and appropriate for human use	This includes features like appropriate lighting, ergonomic furniture and spaces that promote movement and interaction.	Grazuleviciute et al. (2022).
4. Natural materials: This principle involves using natural materials such as wood, stone and bamboo in building design.	These materials can provide a tactile and sensory experience for building occupants and contribute to a more natural and sustainable environment.	Panagopoulos & Herman (2020)
5. Views and vistas: This principle involves incorporating views of nature, such as trees, water features, or natural landscapes, into building design	Views of nature can promote relaxation and reduce stress, which can contribute to better overall well-being.	Berto et al. (2018).
6. Multi-sensory experience: This principle involves engaging all the senses in building design, including sight, sound, touch and smell.	This can create a more immersive and stimulating environment for building occupants.	Asim & Shree (2019).
7. Positive sensory experience: It creates a positive sensory experience	It incorporates elements like colour, texture and scent to promote feelings of calm and well-being.	Asim and Shree (2019); Berto et al. (2015).

3. Theoretical Framework and Hypothesis Developments

Principles of biophilic design involve maximizing natural light, using natural materials and promoting sensory engagement, ultimately fostering biodiversity in urban settings. The key tenets of Biophilic Design Theory (BDT) include the innate human-nature connection as shown in Figure 1. The figure depicts how biophilic design and planning integrate four core scientific domains: visual appeal, psychology of people, sustainable development and urban architecture. These domains encompass various scopes, including ecological preferences, restoring contexts, urban visual appeal and urban sustainability (Kellert, 2018; Sulaiman & Fahad, 2021). By incorporating nature-inspired elements, biophilic design enhances environmental sustainability by mimicking natural processes. Research conducted on biophilic design and sustainable architecture has shown the positive impacts that these approaches can have on human health, well-being and the environment (Purani & Kumar, 2018; Berto *et al.*, 2015); while an infusion of natural elements and green spaces will contribute to improved air quality and promote better water management practices in urban environments. According to Kellert (2018) and Lei et al. (2008) an overview of the concept of biophilic design explores its potential to lead to a significant reduction in air and water pollution. The hypothesis posits that a greater infusion of natural elements and green spaces will contribute to improved air quality and promote better water management practices in urban environments. The effect of biophilic design elements on occupants' health and well-being by Andreucci et al. (2021); explores the impact of biophilic design elements on the health and well-being of building occupants, including improvements in mental health, cognitive function and overall well-being.

• Thus, Hypothesis (H1): Incorporating biophilic design principles into urban planning and architecture will improve human health and well-being, as well as the environmental sustainability of buildings.

As reinstated by Abdulkadir and Olagunju (2023); biophilic design could promote sustainable architecture and can contribute to the reduction of energy consumption and improvement of indoor air quality. This suggests that the integration of natural elements, such as recycling stations with greenery, will foster a greater environmental consciousness among occupants, resulting in reduced waste generation and increased recycling rates.

Hence, Hypothesis (H2): Biophilic design interventions in the built environment will positively influence waste reduction and recycling behaviours.

As revealed by Lee and Kim (2021); a biophilic framework emphasizes the effects of climate change adaptation, a common city challenge; that also has impacts on health outcomes. This hypothesis proposes that the strategic use of green roofs, vegetation and permeable surfaces will contribute to temperature regulation, thus reducing the heat island effect in densely populated areas and ultimately enhancing the overall environmental quality.

Thus, Hypothesis (H3): The application of biophilic design in urban settings will mitigate the urban heat island effect.

Nitu et al. (2022); identified that the biophilic strategic method encompasses these components, such as daylight availability in buildings and its consequences on energy design tactics, that enhance human well-being. This suggests that the incorporation of natural light, passive solar design and other biophilic elements will lead to reduced reliance on artificial lighting and heating, consequently lowering energy consumption in buildings.

Therefore, Hypothesis, (H4): Biophilic design principles in architecture will positively impact energy consumption patterns.

The application of biophilic design in urban open spaces as opined by Andreucci et al. (2021); Xue et al. (2019); indicates the capability of biophilic design in urban open spaces and its potential to improve environmental sustainability, to reduce heat island effects and promote biodiversity. Creating green corridors, pocket parks and wildlife-friendly urban landscapes will attract diverse flora and fauna, fostering biodiversity and creating a more resilient and ecologically balanced urban ecosystem.

Hence, Hypothesis (H5): Implementation of biophilic design strategies in urban spaces will contribute to increased biodiversity.

Overall, biophilic design creates a connection between the built environment and nature, which can contribute to an overall sense of well-being and connection to the natural world. This can help promote a more sustainable lifestyle by encouraging people to appreciate and protect the natural environment.

4. Materials and Methods

4.1. Measurement of Variables

The direct impacts of biophilic design on sustainable architecture refer to the specific effects and outcomes that biophilic design has on advancing sustainable architecture. It indicates the immediate and tangible effects or consequences of biophilic design strategies and principles. The direct impacts of biophilic design on sustainable architecture refer to the specific effects and outcomes that biophilic design has on advancing sustainable architecture. It indicates the immediate and tangible effects or consequences of biophilic design strategies and principles. These impacts can include changes or improvements in various aspects of architectural design, construction and use of buildings. Direct impacts of biophilic design towards sustainable architecture encompass the specific ways in which incorporating biophilic design principles directly contributes to making architectural practices more sustainable, environmentally friendly and conducive to human well-being as presented in Table 3.

The indirect impacts of biophilic design refer to the secondary or unintended effects that the integration of natural elements into the built environment can have on various aspects beyond immediate human well-being and environmental sustainability (Attia, 2018; Jiang, 2019; Agboola *et al*., 2018). These indirect impacts (Table 4) may include effects on social interactions, economic outcomes and broader ecosystem dynamics. For example, biophilic design elements such as indoor greenery and natural light may contribute to improved social cohesion and productivity in workplaces, leading to indirect economic benefits through increased employee satisfaction and performance (Jim & Chen, 2006; Muhamad *et al*., 2022). Additionally, creating habitat for local wildlife through biophilic design practices can have positive ecological impacts by supporting biodiversity and promoting ecosystem resilience. Overall, understanding and considering these indirect impacts is essential for fully appreciating the multifaceted benefits of biophilic design and optimizing its implementation in diverse contexts.

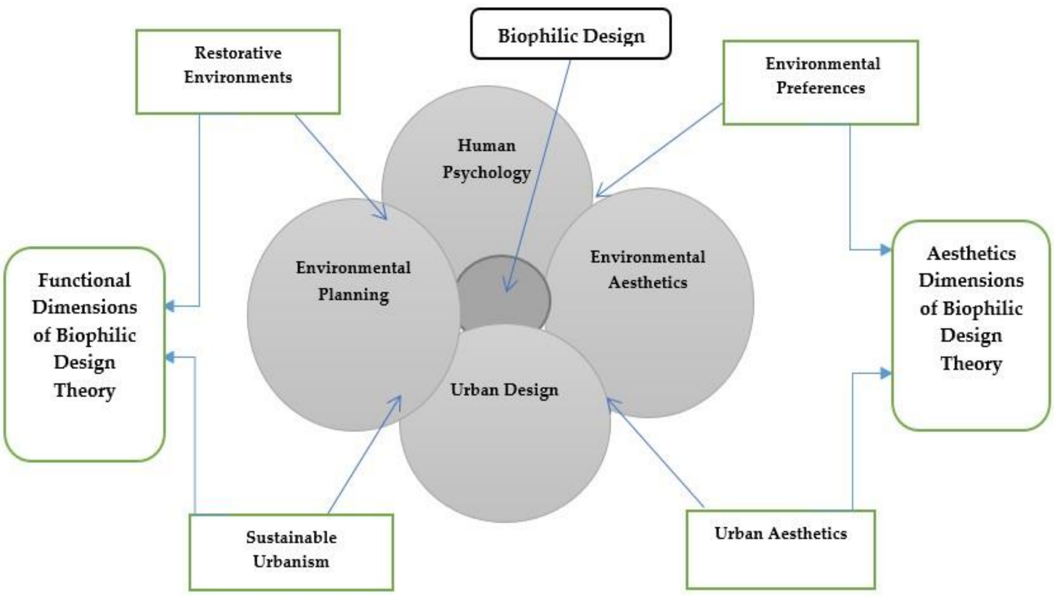

Figure 1. The framework of Biophilic design and planning
Source: Kellert (2018); Sulaiman & Fahad (2021)

Table 3. Direct Impacts of Biophilic Design Towards Sustainable Architecture

Main design features	Detailed design corporations	References
1. Reduced energy consumption	The biophilic design integrates natural elements like sunlight, plants and water features into architectural spaces, aiming to decrease reliance on artificial lighting, air conditioning and heating. This approach fosters sustainability in building design by curbing energy consumption.	Panagopoulos et al. (2020); Grazuleviciute et al. (2022).
2. Improved indoor air quality / optimizing thermal comfort	Plants used in biophilic design can help improve indoor air quality by removing pollutants and providing oxygen. Improved air quality can contribute to the health and well-being of building occupants.	Panagopoulos et al. (2020); Asim and Shree (2019); Berto, et al. (2015).
3. Increased occupant well-being	Biophilic design can create spaces that are more comfortable and inviting for building occupants. Natural elements such as plants and water features can reduce stress and promote relaxation, which can contribute to better overall well-being. Biophilic design can help improve indoor air quality by reducing the amount of pollutants and toxins in the air. Plants used in biophilic design can help purify the air and provide oxygen.	Panagopoulos et al. (2020); Berto et al. (2015); Rai et al. (2020).
4. Reduced environmental impact	Biophilic design incorporates sustainable materials and reduces energy consumption, which can reduce the environmental impact of building design. Sustainable building design can contribute to the overall health of the planet and help reduce the negative impact of human activity on the environment.	Grazuleviciute et al. (2022).
5. Improved water conservation	Biophilic design can help improve water conservation by incorporating features such as rain gardens and green roofs that help capture and reuse rainwater.	Grazuleviciute et al. (2022).
6. Reduced waste	Biophilic design can help reduce waste by incorporating sustainable materials and designing buildings that can be recycled at the end of their useful life.	Grazuleviciute et al. (2022).
7. Enhanced biodiversity	Biophilic design can help enhance biodiversity by incorporating natural habitats for plants and animals. This can contribute to the overall health of ecosystems and promote sustainability.	Panlasigui et al. (2021); Baldwin et al. (2011).
8. Enhanced productivity	Biophilic design can enhance productivity and creativity. Natural elements such as plants and natural light can help improve concentration and focus.	Beatley (2011); Dadvand et al., (2015).
9. Increased connection to nature	Biophilic design creates a connection between the built environment and nature, which can contribute to an overall sense of well-being and connection to the natural world. This can help promote a more sustainable lifestyle by encouraging people to appreciate and protect the natural environment.	Panagopoulos et al., (2020); Berto et al., (2015).

Table 4. Indirect Benefits of Biophilic Design Towards Sustainable Architecture

Main design features	Detailed design corporations	References
1. Enhanced Well-Being	Biophilic design fosters connections with nature, leading to improved mental health, reduced stress levels and increased productivity among occupants.	Beatley (2011); Dadvand et al. (2015).
2. Increased Sustainability	Incorporating natural elements into design promotes environmental conservation by lowering energy consumption, enhancing air quality and encouraging sustainable practices.	Kellert (2018); Kahn et al. (2009); Kujundzic et. al. (2023).
3. Improved Social Interaction	Biophilic spaces encourage social interaction and community engagement, fostering a sense of belonging and connectivity among occupants, ultimately contributing to a more cohesive and vibrant built environment.	Ferrara (2022); Bratman et al. (2012).
4. Greater Creativity and Innovation:	Biophilic design stimulates creativity and innovation by providing inspiring environments that encourage exploration and problem-solving, leading to increased ingenuity and productivity in work and educational settings	Joye (2007).
5. Enhanced Healing and Recovery	Biophilic elements in healthcare facilities promote faster healing and recovery rates among patients by reducing stress, anxiety and pain levels, ultimately improving overall health outcomes and reducing the length of hospital stays.	Weeland et al. (2019); Hindley et al. (2023).
6. Increased Property Value	Biophilic design features, such as green spaces and natural lighting, can enhance property values by creating desirable and aesthetically pleasing environments that attract buyers and tenants, leading to higher demand and potentially higher resale or rental prices.	Jim and Chen (2006); Muhamad et al. (2022).

4.2. Data Gathering, Sampling Method and Analysis

The survey took place in March 2022, employing a mixed-methods study that employs both quantitative and qualitative data collection and analysis methods. Various factors of the Biophilic design strategy were extracted from the literature review and were consequently viewed by respondents (experts and professionals) via online survey questionnaires (378) and focus group interviewees (13). The biophilic design factors were grouped into appropriate categories and ensured are clear and measurable. The study utilizes an online survey questionnaire and focus group interviews to collect data from experts and professionals in the field of sustainable architecture and biophilic design.

The questionnaires were developed by the researchers, drawing insights from relevant literature and have three sections namely; A, B and C, each aligned with the study's focus. Section A addressed the demographic characteristics of the professionals, while Sections B and C explored the direct impacts and indirect benefits of biophilic design on sustainable architecture, respectively. Sections B and C employed a five-point Likert scale, ranging from “1” for strongly disagree to “5” for strongly agree. On the other hand, the focus group interviews were used to collect in-depth qualitative data on the direct and indirect benefits of biophilic design. The interviews were conducted with a small group of participants who have expertise in connection with the biophilic concept. Focus group analysis is a qualitative research method used to gather insights and understandings from a diverse group of individuals on the question do you see biophilic design contributing to sustainable architecture and what are some of the key benefits of incorporating natural elements into building design? This method involves bringing together a small group of participants, typically 13 individuals, who share common characteristics or experiences relevant to the research focus.

This study addresses this gap by investigating the specific environmental challenges faced in Nigerian architecture and how sustainable practices, such as biophilic design, can be adapted to mitigate these issues. Thus, by employing a Relative Importance Index to evaluate the significance of various factors, this research will provide a comprehensive analysis of the human-nature interactions within Nigeria's built environment. The quantitative research analysis method adopted was the Relative Importance Index (RII) and Mean values for appropriate rating as previously utilized by the previous studies (Holt, 2014; Gunduz & Ahsan, 2018). The RII is a statistical technique that allows researchers to determine the relative importance of different factors associated with biophilic design and sustainable architecture objectives. Meanwhile for the qualitative data gathered, the thematic approach was used to analyze the collated data. The thematic analysis involves identifying and categorizing themes that emerge from the data. This study ensured that participants' privacy and confidentiality were protected. The study obtained informed consent from participants and maintained the anonymity of the participants throughout the study. After collection, the questionnaires were coded and analyzed using simple descriptive statistics. A sum of the weighted values (SWV) was calculated for each variable over the total value, followed by a ranking based on the index. Variables were ranked from first to last in descending order of weight according to the Likert scale coding, indicating the importance of factors. Results were then presented using tables and charts

$$Q=EFx/N, \tag{1}$$

where, Q=Mean, Σ=Summation, Fx=Frequency of x and N=Number of occurrences.

To calculate the perception aggregate index (I) for each service, ratings on the 5-point Likert scale were assigned weight values of 5, 4, 3, 2 and 1. The sum of the weighted values (SWV) for each variable was derived by multiplying the weight value of each rating by the number of responses for that rating. The relative importance index (RII) for each variable was then obtained by dividing the SWV of each variable by the total number of respondents (N), represented as “N”. Thus, the Relative Index (RII) equals SWV/N.

5. Results

Data cleaning is an essential step in the research process, involving the meticulous review and rectification of errors in the data before proceeding with analysis. This includes activities such as identifying missing data, assessing outliers and conducting normality and multi-collinearity tests. Three hundred and seventy-eight respondents participated via an online platform. Normality tests indicated that the data distribution fell within the acceptable range of kurtosis and skewness (+2 to -2) as supported by (Jones, 1969). The reliability of all variables surpassed the threshold of Cronbach's Alpha coefficient (α) of 0.6, indicating reliability and acceptability (Taber, 2018). Cronbach's alpha values for the questionnaire ranged from 0.80 to 0.95, signifying a high degree of consistency among the variables. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy yielded a score of 0.812, affirming the questionnaire's suitability (Napitupulu *et al*., 2017). Bartlett's sphericity test demonstrated significance at 0.001, with a threshold of 0.7 utilized to ascertain the reliability of latent constructs. Socio-demographic data from respondents allows researchers to contextualize their findings and understand how various factors may influence perceptions, attitudes and behaviours related to biophilic design.

Therefore, Table 5, summarizes the demographic characteristics of the respondents. Gender Distribution indicates females 211 (55.82%) and Males 167 (44.17%); this gender distribution suggests a relatively balanced representation of both genders within the sample, which enhances the generalizability of the findings to some extent. The majority of respondents (76.45%) report being married, while a smaller proportion (23.55%) indicate being non-married (which may include single, divorced, widowed, or separated individuals). The data reveals a relatively even distribution of respondents across different age groups. The largest proportion of respondents falls within the age range of 30–49, comprising 38.09% of the sample. The age groups of 18–29 and 50 above represent 28.30% and 33.59% of the sample, respectively. The presence of respondents across a wide range of age groups indicates a diverse sample, capturing perspectives from both younger and older individuals. This diversity is beneficial for the study as it allows for a more comprehensive understanding of the biophilic environments considering various life stages, experiences and perspectives.

The data presents a diverse range of educational qualifications among the respondents, reflecting varying levels of academic achievement. The majority of respondents hold either a bachelor's degree (39.15%) or a master's degree (42.85%), indicating a relatively high level of educational attainment within the sample. A smaller proportion of respondents have attained a doctoral degree (11.90%), while a minority report primary or high school education (6.08%). The distribution of respondents across different educational levels signifies the diversity of perspectives and expertise within the sample. Individuals with higher academic qualifications, such as master's and doctoral degrees, bring specialized knowledge and expertise to the study, potentially enriching the research findings. This implied that educational qualifications influence cognitive abilities, problem-solving skills and critical thinking, which may impact respondents' perceptions, attitudes and behaviours toward biophilic environments.

Focusing on the respondents’ familiarity with the concept of biophilic design; the data presents a range of familiarity levels with the concept of biophilic design among the respondents. The majority of respondents indicate varying degrees of familiarity, with 46.03% considering themselves familiar with the concept and 26.98% reporting being very familiar. A smaller proportion of respondents, comprising 24.86%, indicate only somewhat familiarity, while a negligible percentage (2.12%) claim no familiarity with biophilic design. The distribution of respondents across different familiarity levels signifies the diverse range of knowledge and awareness about biophilic design within the sample. Individuals with different levels of familiarity may have varying degrees of understanding, appreciation and engagement with biophilic design principles, influencing their perceptions and preferences in the built environment. Familiarity with biophilic design may shape respondents' attitudes, preferences and behaviours related to architectural and environmental design.

Figures 2 and 3; revealed the Relative Importance Index (RII) of the direct impacts of biophilic design towards sustainable architecture. The results of a survey on various variables related to environmental and occupant well-being aspects of buildings or spaces such as energy consumption, indoor air quality, occupant well-being, environmental impact, water conservation, waste reduction, biodiversity enhancement, productivity enhancement and connection to nature. Increased connection to nature (Variable 9) ranks first in importance, with a high level of agreement among respondents; while the enhanced biodiversity (Variable 7) ranks second, also with a relatively high level of agreement. Reduced environmental impact (Variable 4) ranks third, despite having a negative skewness and high kurtosis, which might indicate some extreme responses. Reduced waste (Variable 6) ranks lowest in importance, with the highest standard deviation, indicating more variability in responses and potentially less agreement among respondents.

Figures 4 and 5 present the results of a survey on various variables related to the impacts of indirect factors, in the context of built environments. Various indirect variables measured include enhanced well-being, increased sustainability, improved social interaction, greater creativity and innovation, enhanced healing and recovery and increased property value. For priority of health and well-being; variables like "Enhanced Healing and Recovery" rank highest in importance, indicating that respondents highly prioritize features or interventions that contribute to health and well-being outcomes. This underscores the significance of designing spaces that promote healing, recovery and overall well-being, such as healthcare facilities or wellness-oriented environments. As regards sustainability and social Interaction; "Increased Sustainability" and "Improved Social Interaction" also rank high in importance, suggesting that respondents value aspects related to environmental sustainability and social connectivity. This highlights the importance of incorporating sustainable practices and fostering social interactions in urban planning and design to create vibrant, resilient communities.

Results in Table 6; present the outcomes of testing several hypotheses related to the effects of incorporating biophilic design principles into urban planning, architecture and built environments.

Hypothesis (H1): Incorporating biophilic design principles into urban planning and architecture will improve human health and well-being, as well as the environmental sustainability of buildings. This hypothesis is supported. The beta coefficient (β) of 0.230 indicates a positive relationship between incorporating biophilic design principles and improving human health, well-being and environmental sustainability. The statistically significant p-value ($p = 0.005$) suggests that this relationship is robust and unlikely to have occurred by chance.

Hypothesis (H2): Biophilic design interventions in the built environment will positively influence waste reduction and recycling behaviours. This result is equally supported. The beta coefficient of 0.604 indicates a strong positive influence of biophilic design interventions on waste reduction and recycling behaviours. The significant p-value ($p = 0.001$) reinforces the strength of this relationship.

Hypothesis (H3): The application of biophilic design in urban settings will mitigate the urban heat island effect. Similarly, this hypothesis is supported. The beta coefficient of 0.567 suggests a positive impact of biophilic design on mitigating the urban heat island effect. The statistically significant p-value ($p = 0.000$) underscores the robustness of this relationship.

Hypothesis (H4): Biophilic design principles in architecture will positively impact energy consumption patterns. Also, the result is supported. The beta coefficient of 0.218

indicates a positive influence of biophilic design principles on energy consumption patterns. The significant p-value ($p = 0.004$) confirms the strength of this relationship.

Hypothesis (H5): Implementation of biophilic design strategies in urban spaces will contribute to increased biodiversity. The results of this hypothesis are supported. The beta coefficient of 0.782 suggests a strong positive association between implementing biophilic design strategies and increased biodiversity. The significant p-value ($p = 0.001$) underscores the robustness of this relationship. About the quantitative analysis; Table 7 presents the key factors contributing to the effectiveness of biophilic design as identified by the focus group participants. One fundamental aspect of biophilic design is the maximization of access to natural light. Through strategic placement of features such as large windows, skylights and light wells, designers can harness the benefits of natural light while reducing reliance on artificial lighting sources. This not only enhances energy efficiency but also creates visually appealing and inviting spaces. In addition to natural light, the incorporation of natural materials plays a crucial role in biophilic design. Materials such as wood, stone and bamboo not only add visual interest but also evoke a sense of warmth and authenticity. By opting for sustainable, renewable resources, designers can minimize the ecological footprint of their projects while enhancing sensory experiences for occupants. Tactile qualities and unique textures engage the senses, creating a tangible connection to the environment and promoting a deeper sense of well-being.

Furthermore, biophilic design extends beyond mere aesthetics to encompass dynamic elements that evolve. Features such as seasonal changes in vegetation or movable partitions create spaces that resonate with natural rhythms, fostering engagement and exploration. This approach not only promotes a sense of connection to nature but also encourages occupants to interact with their surroundings in meaningful ways. By embracing change and evolution in design, spaces can adapt to the needs and preferences of their users, creating environments that inspire and enrich the human experience.

Water features, such as fountains, ponds, or waterfalls, also play a significant role in biophilic design. These elements create soothing auditory and visual stimuli, fostering a sense of tranquillity and connection to nature. By integrating water features into indoor and outdoor spaces, designers can create immersive environments that promote relaxation and well-being. The sound of flowing water and the visual spectacle of shimmering surfaces provide moments of respite from the stresses of daily life, inviting occupants to pause, reflect and rejuvenate.

Moreover, biophilic design emphasizes the importance of providing views of natural landscapes from interior spaces. Whether it's a lush park, vibrant garden, or tranquil water body, these vistas serve as windows to the outdoors, connecting occupants with the natural world. By integrating natural views into design, spaces become more open and expansive, blurring the boundaries between indoor and outdoor environments. This creates opportunities for occupants to immerse themselves in the beauty and serenity of nature, fostering a deeper appreciation for the world beyond our walls. Summarily, biophilic design offers a holistic idea by integrating features designers can create environments that inspire, rejuvenate and enrich the lives of those who inhabit them.

Table 5. Socio-demographic profile of the respondent's variables

Variables		**Frequency n =378**	**Percentage (%)**
Gender	Female	211	55.82
	Male	167	44.17
Marital status	Married	289	76.45
	Non married	89	23.55
Age Level	18–29	107	28.30
	30–49	144	38.09
	50 above	127	33.59
Academic qualifications	Primary / High school	23	6.08
	Bachelor's degree	148	39.15
	Master's degree	162	42.85
	Doctoral Degree	45	11.90
Professional Affiliations	Architects and Designers	77	20.37
	Environmental Psychologists	39	10.31
	Urban Planners and Landscape Architects	53	14.02
	Sustainability Consultants	68	17.98
	Researchers and Academics	63	16.66
	Building Owners and Facility Managers	78	20.63
Family income	0-5,000	64	16.93
	5,001-10.000	69	18.25
	10,001-20,000	63	16.67
	20,001-30,000	51	13.49
	30.001-40,000	55	14.55
	40,000-60,000	53	14.02
	> 60,000	23	6.08
Years of Experience	1–5 years	89	23.54
	6–10 years	98	25.92
	11–15 years	117	30.95
	16–20 years	74	19.57
Familiarity with the concept of biophilic design	Not at all	08	2.12
	Somewhat	94	24.86
	Familiar	174	46.03
	Very familiar	102	26.98

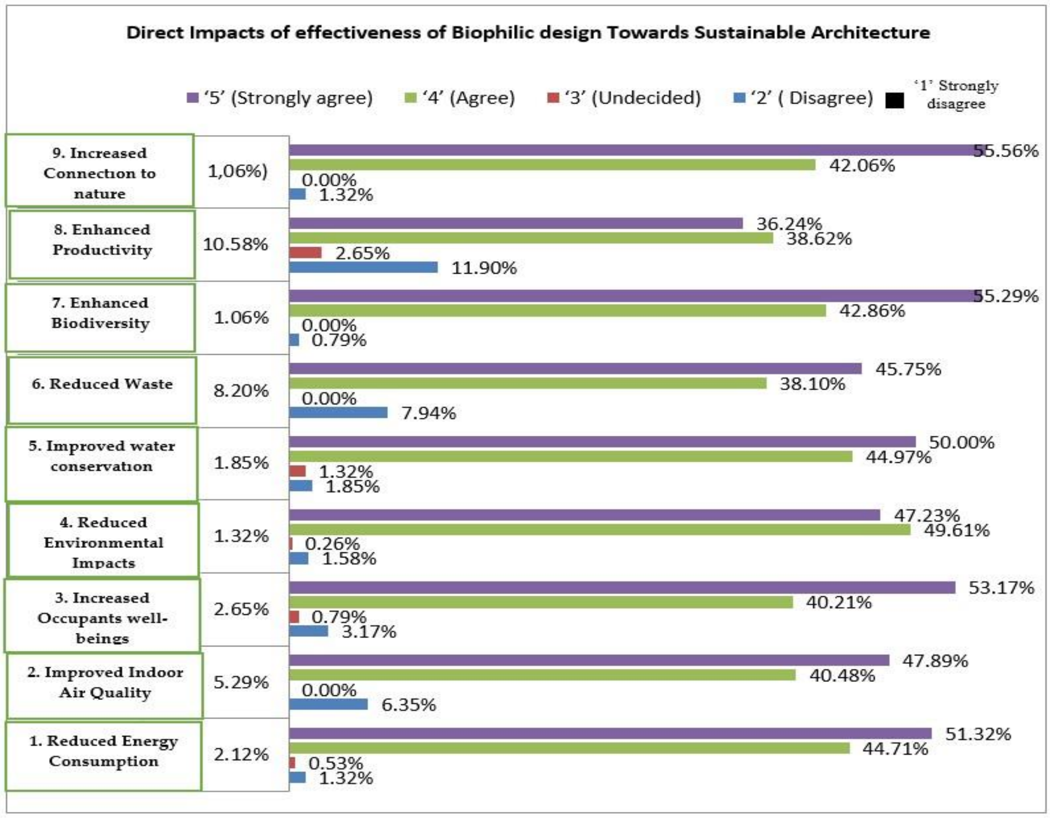

Figure 2. Direct Impacts of the effectiveness of Biophilic design Towards Sustainable Architecture

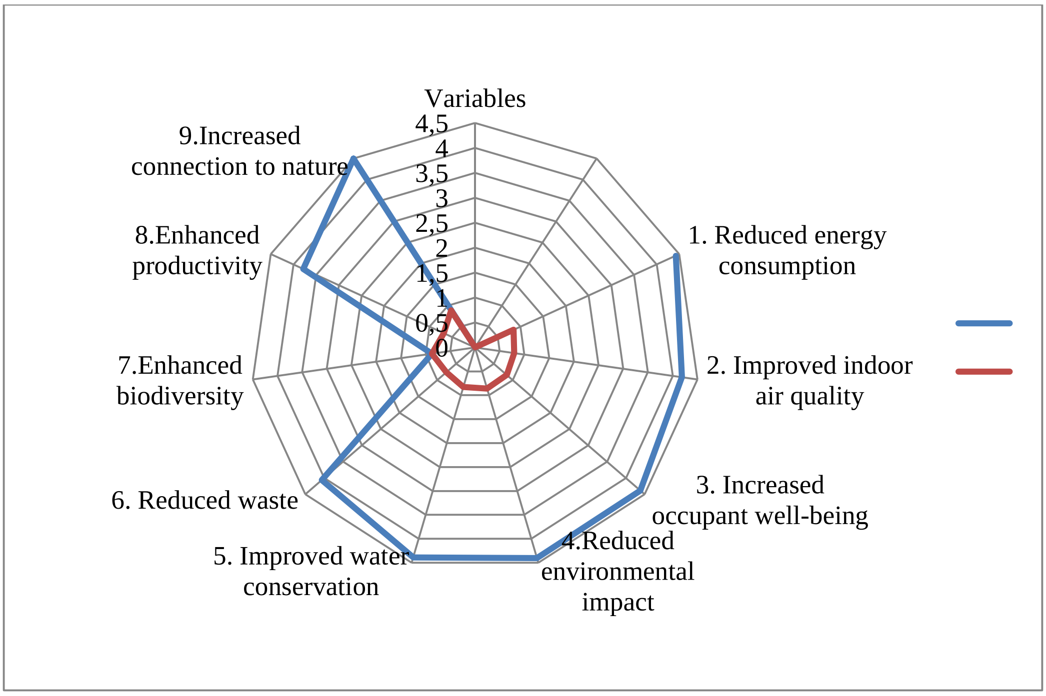

Figure 3. Direct Impacts of the effectiveness of Biophilic design Towards Sustainable Architecture

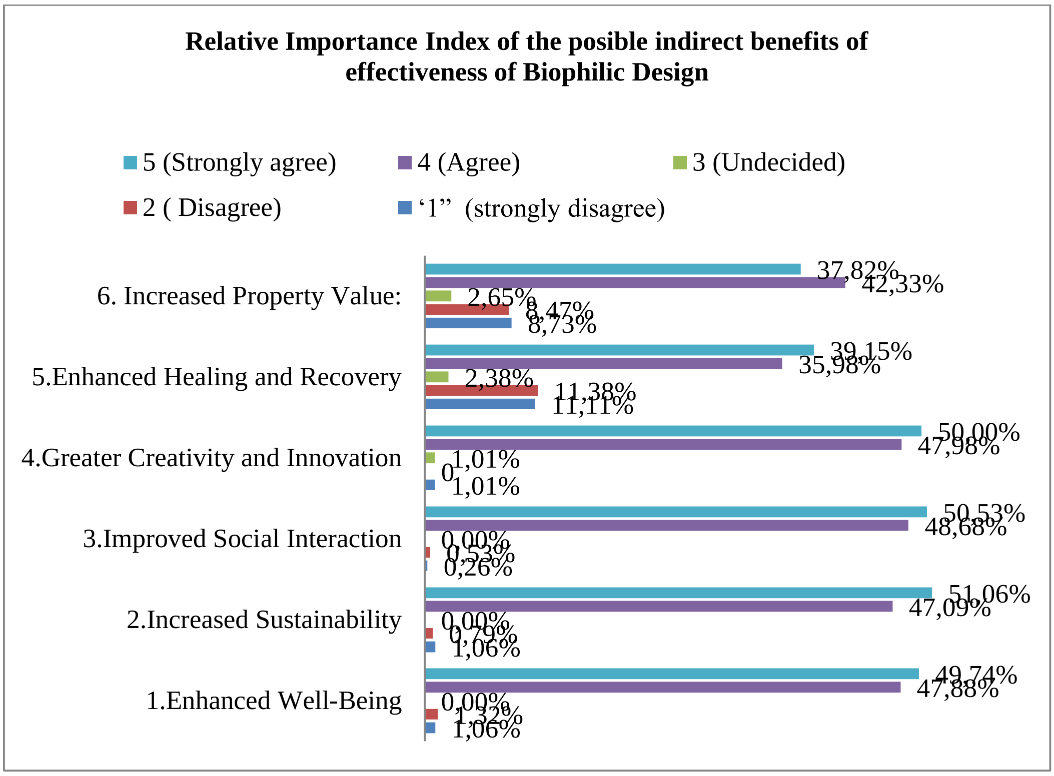

Figure 4. Relative Importance Index of the possible indirect benefits of the effectiveness of Biophilic Design

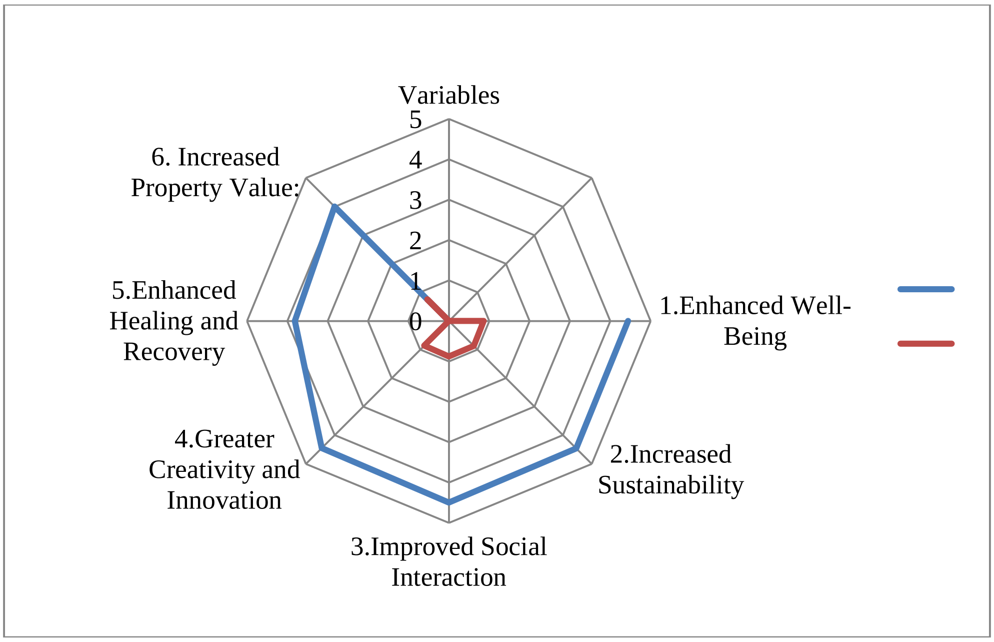

Figure 5. Relative Importance Index of the possible indirect benefits of effectiveness of Biophilic Design

Table 6. Summary of the Tested hypotheses

Hypothesis and its Narration	Beta coefficients (β)	Estimate of Standard error	Degree of freedom *(df)*	T-Statistics	Significant values (p)	Decision
Hypothesis (H1): Incorporating biophilic design principles into urban planning and architecture will improve human health and well-being, as well as the environmental sustainability of buildings.	0.415	0.015	2	6.023	0.005*	Supported
Hypothesis (H2) Biophilic design interventions in the built environment will positively influence waste reduction and recycling behaviours.	0.537	0.009	2	-.336	0.002*	Supported
Hypothesis (H3) The application of biophilic design in urban settings will mitigate the urban heat island effect.	0.656	0.403	2	2.461	0.001*	Supported
Hypothesis, (H4) Biophilic design principles in architecture will positively impact energy consumption patterns.	0.369	0.035	2	-2.673	0.004*	Supported
Hypothesis (H5) Implementation of biophilic design strategies in urban spaces will contribute to increased biodiversity.	0.782	0.016	2	6.311	0.001*	Supported

Table 7. Key factors contribute to the effectiveness of biophilic design as identified by the Focus group participants

Excerpts from the focus group notes	Main theme	Sub-theme	Implications/Findings
Natural Light: *Maximizing access to natural light and reducing reliance on artificial lighting* (P1).	Enhancing Indoor Environments for Health and Sustainability.	Maximizing Access: Leveraging Large Windows, Skylights and Light Wells.	By prioritizing access to natural light in our designs, we can create spaces that are not only illuminated but also enriched, inviting occupants to thrive in environments that celebrate the beauty and benefits of daylight.
Biomorphic Forms and Patterns: *a sense of nature, promoting visual interest and psychological well-being* (P2).	Harmonizing Built Environments with Natural Forms.	Organic Integration: Infusing Architecture and Interiors with Curves and Patterns.	By integrating these elements into our designs, we not only enhance the aesthetic appeal of spaces but also foster environments that support the holistic health and happiness of their occupants.
Indoor Greenery: *Introducing plants and living walls into indoor spaces for creating healthier and more inviting environments* (P3).	Enhancing Spaces with Biophilic Elements.	Living Landscapes: Introducing Plants for Healthier and Inviting Interiors.	By introducing these elements into our designs, we not only create healthier indoor environments but also foster a deeper connection to nature, enriching the overall experience of those who inhabit the space.
Views of Nature: *Providing views of natural landscapes, such as parks, gardens, or water bodies, from interior spaces connects occupants with the outdoors* (P4).	Fostering Connection with Outdoor Environments	Scenic Vistas: Integrating Natural Views for Relaxation and Restoration.	These natural views offer moments of respite and inspiration, enriching the human experience within the built environment and fostering a deeper appreciation for the world beyond our walls.
Natural Materials: *Using natural materials like wood, stone and bamboo in construction and furnishings enhances sensory experiences, evokes a sense of warmth and authenticity and reduces environmental impact* (P5).	Sustainable Sensations: Enhancing Environments with Natural Materials	Organic Aesthetics: Embracing Wood, Stone and Bamboo for Warmth and Authenticity.	Embracing natural materials in our designs is not just a matter of aesthetics; it's a conscious choice that enhances the overall well-being of occupants while contributing to a more sustainable and environmentally responsible built environment.
Water Features: *Incorporating water features like fountains, ponds, or waterfalls creates soothing auditory and visual stimuli, fostering a sense of tranquillity and connection to nature* (P6).	Enhancing Spaces with Water Features.	Harmonious Hydration: Creating Tranquillity and Natural Connection with Water.	Water features serve as powerful tools for enhancing well-being and promoting a deeper connection to the natural world, enriching the human experience within the built environment.
Thermal Comfort: *Designing spaces with optimal thermal conditions, such as proper ventilation,*	Optimizing Thermal Conditions for Sustainable Living.	Efficient Environments: Implementing Strategies for	By prioritizing thermal comfort in our designs, we can create spaces that are not only energy-efficient but also

insulation and passive heating/cooling strategies, enhances occupant comfort and reduces energy consumption (P7).		Comfort and Energy Efficiency.	conducive to the health and productivity of those who inhabit them.
Dynamic and Evolving Spaces: *Creating spaces that evolve, such as seasonal changes in vegetation or movable partitions, fosters a sense of connection to natural rhythms and promotes engagement and exploration* (P8).	Embracing Change for Engaging Spaces.	Natural Evolution: Incorporating Seasonal Shifts and Flexible Elements for Connection and Exploration.	Embracing the concept of change and evolution in our designs, we create spaces that inspire and enrich the human experience, fostering a harmonious relationship between people and nature.
Habitat Integration: *Designing buildings and landscapes to support local biodiversity, such as green roofs, bird-friendly architecture and native plantings, promotes ecological resilience and enhances the overall ecosystem* (P9).	Cultivating Habitats for Ecological Resilience.	Native Nurturing: Incorporating Local Biodiversity for Ecosystem Enhancement.	'Prioritizing biodiversity in our designs can create environments that are not only beautiful but also vibrant, thriving and resilient in the face of environmental challenges.
Biophilic Engagement: *Encouraging interaction with nature through amenities like outdoor seating areas, walking trails and community gardens fosters a sense of stewardship and promotes physical activity and social cohesion among occupants* (P10).	Cultivating Connections for Community Well-being.	Outdoor Engagement: Fostering Stewardship and Social Cohesion through Nature Amenities.	'Designing spaces that facilitate interaction with nature, can inspire and empower individuals to embrace a deeper connection to their surroundings and one another".

6. Discussion

6.1. Direct Impacts of the effectiveness of Biophilic design Towards Sustainable Architecture

The high ranking of variables such as "Increased connection to nature" and "Enhanced biodiversity" suggests that respondents place significant importance on incorporating elements of nature and promoting biodiversity in built environments. This implies that strategies aimed at integrating green spaces, natural elements and biodiversity-friendly designs could be well-received and valued by stakeholders. This is supported by Panagopoulos et al. (2020) and Yassein and Ebrahiem (2018); biophilic design utilizes natural components and textures in the design of buildings and places to improve the relationship between people and their surroundings. Considering the environmental consciousness; variables like "Reduced energy consumption", "Reduced environmental impact" and "Improved water conservation" indicate a strong concern for environmental sustainability. These findings in tandem with the studies of Wijesooriya, and Brambilla (2021); suggest that strategies aimed at reducing energy usage, minimizing environmental footprints and conserving water resources are likely to be positively perceived and considered important in sustainable building practices.

For occupant well-being; variables such as "Improved indoor air quality" and "Increased occupant well-being" also hold significant importance, though slightly lower than environmental concerns. This highlights the recognition of good indoor air quality for occupant well-being and satisfaction. Implementing measures to enhance indoor air quality and promote occupant well-being could contribute to better satisfaction and productivity among building occupants. This is in tandem with the study of Berto et al., (2015) and Rai et al. (2020); in that biophilic design may contribute to environmentally friendly design by lowering energy usage and increasing the quality of indoor air, promoting occupant well-being; reducing environmental impact and increasing connection to nature. By addressing these priorities in a balanced manner, stakeholders can contribute to creating healthier, more environmentally friendly and resilient built environments.

6.2. Indirect Impacts of the effectiveness of Biophilic design Towards Sustainable Architecture

Various indirect variables measured include enhanced well-being, increased sustainability, improved social interaction, greater creativity and innovation, enhanced healing and recovery and increased property value. For the priority of health and well-being; variables like "Enhanced Healing and Recovery" rank highest in importance, indicating that respondents highly prioritize features or interventions that contribute to health and well-being outcomes as supported by the previous studies of Beatley (2011) and Dadvand et al. (2015). This underscores the significance of healthcare facilities or wellness-oriented environments. As regards sustainability and social Interaction; "Increased Sustainability" and "Improved Social Interaction" also rank high in importance, suggesting that respondents value aspects related to environmental sustainability and social connectivity. This highlights the importance of incorporating sustainable practices and fostering social interactions in urban planning and design to create vibrant, resilient communities in line with the previous studies of Ferrara (2022), Bratman et al. (2012).

For creativity, innovation and property value; "Greater Creativity and Innovation" and "Increased Property Value" rank lower compared to other variables, which still hold relevance despite the low ranks. These results indicate that while creativity, innovation and property value are considered important, they might not be perceived as critical as health, sustainability and social factors. The variability in responses, as indicated by the standard deviations and skewness values, suggests that there may be differing opinions or perceptions among respondents regarding the importance of certain variables. This underscores the complexity of urban development and the need for a nuanced understanding of stakeholders' priorities and preferences., as viewed by Weeland (2019) and Hindley et al. (2023). By addressing these indirect priorities in urban planning and design, stakeholders can contribute to creating more liveable, sustainable and resilient cities and communities.

6.3. Indirect Impacts of the effectiveness of Biophilic design Towards Sustainable Architecture

The outcomes of testing several hypotheses related to the effects of incorporating biophilic design ideas into a city's planning, architecture and built environments. The results indicate strong support for the majority of hypotheses, suggesting that incorporating biophilic design principles into various aspects of urban planning and architecture can yield positive outcomes related to human health, well-being, environmental sustainability, waste reduction, biodiversity and pro-environmental attitudes. However, there are a couple of hypotheses where the results were not supported, indicating that further research or refinement of these concepts may be necessary to fully understand their impacts. The theoretical implications of the tested hypotheses on the effects of incorporating biophilic design ideas into built environments are significant and multifaceted:

i. Positive Impact on People's Health and Wellness: The findings indicate that incorporating biophilic design concepts can improve the well-being and health of individuals. This implies that urban planners, architects and developers can prioritize incorporating natural elements and connections to nature to promote the well-being and health of individuals and users of urban spaces as agreed by the previous studies of Panagopoulos et al. (2020) and Grazuleviciute et al. (2022).

ii. Enhanced Environmental Sustainability: The results indicate that biophilic design interventions positively influence environmental sustainability, waste reduction and energy consumption patterns. This highlights the significance of biophilic design in contributing to sustainable urban development by mitigating environmental impacts and promoting resource efficiency in building operations and urban infrastructure (Kellert, 2018; Kahn *et al.,* 2009).

iii. Biodiversity Conservation and Urban Heat Island Mitigation: Implementing biophilic design strategies in urban settings can contribute to increased biodiversity. This highlights the significance of incorporating vegetation into a city's landscapes to promote biodiversity conservation efforts and improve urban microclimates (Kujundzic *et al.,* 2023).

iv. Promoting environmental viewpoints and habits: Spending time in biophilic environments may lead to the development of stronger connections among people's environmental viewpoints and habits. This suggests that exposure to nature in urban settings can foster a sense of environmental stewardship and promote sustainable lifestyles among urban residents.

v. Challenges and Areas for Further Exploration: While most hypotheses received strong support, some did not achieve statistical significance. This highlights the complexity of biophilic design interventions and the need for further research to better understand their impacts on fostering innovation in workspaces and promoting sustainable food production practices through urban farming initiatives.

7. Conclusion and recommendations

The objectives of this study are to highlight the critical areas needing attention, propose practical solutions tailored to the Nigerian context and contribute to the global discourse on sustainable architecture with insights from Nigeria's unique perspective. Hence, the hypothesis that biophilic design and planning positively solve the environmental challenges associated with the human-built environment was explored. The current research has added to the corpus of information about biophilic design and planning and its potential to positively impact sustainable architecture objectives. The study's findings provide a framework for architects, developers and policymakers to design and develop sustainable buildings that incorporate biophilic design strategies. The study found that biophilic design can contribute to achieving sustainable architecture objectives, as it has multiple advantages, such as increased ventilation, lower levels of anxiety, enhanced efficiency and aesthetics and reduced energy consumption. The study identified important goals of sustainable architecture that offer a foundation for building and constructing environmentally friendly buildings.

The findings of this study hold significant practical implications for sustainable architecture and biophilic design, particularly within the context of Nigerian urbanization and environmental challenges. By identifying the critical factors through the Relative Importance Index, this research offers practical insights that can guide the integration of biophilic principles and sustainable practices in Nigerian architecture.

Firstly, the results highlight the necessity of incorporating natural elements into building designs to enhance the well-being of occupants and improve environmental performance. This can be achieved through strategies such as green roofs, vertical gardens and the use of natural materials, which not only promote biodiversity but also mitigate urban heat island effects and improve air quality.

Secondly, the study underscores the importance of contextualizing sustainable architecture within Nigeria's unique socio-economic and cultural landscape. This involves adapting global sustainable practices to local conditions, considering factors such as climate, available resources and traditional building methods. For instance, utilizing locally sourced materials can reduce the environmental impact of construction and support local economies.

Moreover, the research emphasizes the role of policy and education in advancing sustainable architecture. By informing policymakers about the critical areas identified in this study, there is potential to develop targeted regulations and incentives that encourage sustainable building practices. Additionally, raising awareness and providing education on biophilic design principles among architects, builders and the general public can foster a culture of sustainability.

To encourage the adoption of biophilic design strategies in Nigeria's built environment space, this study recommends raising awareness about the benefits of biophilic design, fostering collaboration among stakeholders, considering local context and evaluating the impact of biophilic design strategies. By incorporating these biophilic design factors, architects and designers can create environments that enhance well-being, promote sustainability and reconnect people with the natural world within the built environment. In terms of the limitation of the study; while this study emphasizes biophilic design principles, it may not fully explore other important aspects of sustainable architecture, such as energy efficiency, water management and waste reduction. A future study on a holistic approach that integrates these elements would provide empirical evidence to support a comprehensive understanding of biophilic sustainable architecture practices. Also, more research is needed through controlled studies in different building types, contexts and populations. It should be noted that the cultural context plays an important role in the design and implementation of biophilic design strategies, thus further research is needed to explore how biophilic design can be adapted to different cultural contexts and preferences.

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