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Integrating Biophilic Design and Productive Green Infrastructure as Urban Renewal Strategy for Mixed Use Development in Lagos Island

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ABSTRACT

When redeveloping crowded tropical cities, we need new ways that balance the needs of people, the environment, and the economy. This study looks at ways mixed-use developments on Lagos Island, Nigeria, could include biophilic design and productive green infrastructure as part of efforts to breathe new life into the area. We collected information using structured questionnaires from 303 architects, urban planners, and real estate developers registered with ARCON. SPSS was used to run the analysis and get both descriptive and inferential results. While correlation and regression analyses examined connections between professional experience, design adoption, and perceived urban regeneration success, descriptive statistics described respondents' awareness, adoption, and perceived efficacy of biophilic and PGI tactics. The results show that although there are chances for ecological regeneration, Lagos Island's mixed-use areas are limited by excessive density, a lack of open space, inadequate waste management, and socioeconomic inequities. Green façades, rooftop gardens, and courtyards were found to be the most flexible approaches, and respondents showed a moderate to high awareness of biophilic principles. Productive green infrastructure is becoming more and more popular, and its incorporation is closely linked to perceived gains in social interaction, urban biodiversity, thermal comfort, environmental resilience, and economic value. A framework for policy, planning, and design interventions in tropical urban contexts is provided by the study's conclusion that integrating biophilic design with productive green infrastructure offers a workable, multifaceted strategy for developing mixed-use developments that are resilient, liveable, and economically sustainable.

Keywords: *Biophilic design, Mixed-use development, Lagos Island, Productive green infrastructure, Urban renewal*

INTRODUCTION

Lagos Island exemplifies the pressures of rapid urbanization, with high density, deteriorating environmental conditions, and limited open spaces creating complex urban challenges. Compact building patterns, aging infrastructure, and microclimatic issues such as heat accumulation and reduced ecological permeability characterize this major commercial hub (Koko et al., 2021). These conditions highlight the need for regenerative planning strategies that enhance environmental resilience, spatial quality, and socioeconomic vitality in mixed-use developments. Biophilic design reconnects the built environment to natural systems through vegetation, natural materials, daylight modulation, and sensory engagement, improving environmental performance and occupant well-being (Zhong et al., 2021). Applied beyond individual buildings, it fosters living urban networks that support biodiversity and enrich human experience (Lefosse et al.). Productive green infrastructure demonstrates the value of landscape systems as urban assets, providing climate adaptation, ecological benefits, and revitalized public spaces by enhancing thermal regulation, stormwater management, and place identity (Hanna & Comín, 2021; Sahle et al., 2025). Studies in Nigeria confirm that vegetated envelopes reduce urban heat and improve microclimatic comfort in tropical contexts (Afolabi et al., 2025; Kalu et al., 2025). Combining these approaches reframes mixed-use developments as socio-ecological systems rather than isolated structures (Mbata, 2024). Integrating

green corridors, multipurpose landscapes, and urban agriculture supports environmental regeneration, local economies, and urban liveability. The study aims to develop a context-responsive urban renewal paradigm for Lagos Island that integrates biophilic design and productive green infrastructure to improve socioeconomic vibrancy, spatial quality, and environmental performance. The objectives of the study is to assess environmental, spatial, and socioeconomic conditions in mixed-use areas to identify challenges and ecological regeneration opportunities, to evaluate biophilic design strategies and green infrastructure systems suitable for dense tropical urban contexts, focusing on performance, adaptability, and integration and to formulate design guidelines and spatial strategies demonstrating how biophilic and productive green infrastructure can support resilient, liveable, and economically viable urban renewal.

LITERATURE REVIEW

Cities everywhere are facing tough social and environmental problems because they're growing quickly, putting pressure on infrastructure, and damaging nature. In Lagos Island, Nigeria, these problems show up as strong heat buildup, flooding, shrinking green areas, and a weaker bond between people and nature in the city. Architects and urban planners are starting to use biophilic design and productive green infrastructure together more often (Zhong et al., 2021). These approaches help bring public spaces to life, bring back natural functions, and breathe new energy into mixed-use neighbourhoods. Biophilic design comes from the simple idea that people naturally feel drawn to nature. This connection shows how, over time, humans have developed a natural tendency to feel better physically and mentally when they are close to nature and its elements. Zhong, Schröder, and Bekkering (2021) assert that biophilic design transcends aesthetic incorporation of vegetation and extends into dynamic spatial systems that promote health, comfort, and performance. Biophilic strategies range from sensory engagement with daylight and vegetation to three-dimensional green structures that functionally integrate plant life within the building fabric (Zhong et al., 2021; Zhong et al., 2024). Lefosse et al (2025) further underscore that biophilic urbanism not only enriches user experience but spatially connects nature across scales, embedding ecological continuity into urban form.

Beyond building interiors, the discussion of biophilic design in urban development has moved toward urban-scale natural systems that support ecological resilience, mobility, and climate adaption. In order to create biophilic cities, Panlasigui et al. (2021) investigate how tools from urban biodiversity planning might be used to create networked green corridors, wetlands, street trees, and pocket ecosystems that benefit native species and improve human access to the outdoors. According to Hanna and Comín (2021), urban green infrastructure needs to be viewed as multipurpose systems that concurrently address climatic, hydrological, and social goals. Lagos Island, which frequently experiences urban heat island amplification, benefits from these multipurpose green

Biophilic Design Principles and Applications in Urban Mixed-Use Developments

Biophilic design changes how we think about architecture and city planning by bringing natural elements, ecological processes, and human senses into the spaces we build. The goal is to bring natural systems into building design and city layouts in a way that goes deeper than just adding plants on the surface (Zhong, Schröder, & Bekkering, 2021). Biophilic strategies are important for making mixed-use developments better places to live and work. These areas often combine homes, shops, and recreational spaces, which can sometimes lead to crowded and stressful environments. Using nature-inspired designs helps improve how people feel inside these spaces and also makes the environment work better overall (Lefosse, Naghibi, Luo, & Van Timmeren, 2025). The idea of human-nature connectedness, which operationalizes patterns of natural elements to affect psychological, physiological, and cognitive consequences, is at the heart of biophilic design. Essential elements that produce spatial narratives that appeal to human visual instincts include natural light, greenery, water features, and material authenticity (Zhong, Schroeder, & Bekkering, 2023). Buildings can become active participants in ecological systems by integrating these elements into vertical and horizontal planes, especially through three-dimensional green spaces. This improves thermal regulation and microclimate stability while also increasing urban biodiversity (Zhong, Schröder, & Bekkering, 2024). These tactics are crucial for reducing environmental stress and enhancing spatial comfort on Lagos Island, which has a dense urban fabric and high urban heat island effects (Afolabi, Ibitoye, Kalu, & Olaoye, 2025). In mixed-use spaces, biophilic approaches often bring together both direct and indirect ways for people to experience nature. Accessible courtyards, rooftop

gardens, and indoor plants give residents a chance to connect with nature in ways they can see and touch. These spaces help people come together and also support mental well-being (Andreucci, Loder, Brown, & Brajković, 2021). Even in carefully designed spaces, using materials, textures, and biophilic elements helps people feel connected to nature. This connection builds a sense of place and keeps the mind engaged (O'Sullivan, Shirani, Hale, Pidgeon, & Henwood, 2023). This kind of multi-scale integration ensures that biophilic design becomes part of how we experience and use urban spaces, not just something that looks nice.



Figure 1. Oasia Hotel Downtown in Singapore Oasia Hotel Downtown, Singapore, showcasing green façade integration as a biophilic strategy in high-density urban form. ; Source: Archdaily; Retrieved February 2026.

The exterior displays the high-rise's expansive green façade, which incorporates plants. This project is a prime example of tropical biophilic design, which uses plant systems as architectural features to improve biodiversity, urban liveability, and microclimate performance in a densely populated area. The synergistic effect of passive and biophilic design principles within urban formations is substantiated by research. "Passive strategies such as natural ventilation, daylighting, and vegetation-based façades contribute to thermal comfort, reduce energy consumption, and enhance occupant satisfaction in the Nigerian context" Kalu, Ogunnaike and O (2025). Green Façade Solutions: Impact on Surface Temperature and Air Quality in Lagos State Green facades are not only effective in reducing the surface temperature of buildings, they also significantly reduce urban heat islands and air pollution in Lagos State while generating aesthetic and socio-environmental value (Afolabi, Ibitoye, Grace and Olaoye, 2025). Due to the alignment of ecological performance and human-oriented design, biophilic concepts are heralded as a key methodology for urban regeneration, particularly in areas designated for mixed-use and intensive development with restricted open space. The implementation of biophilic frameworks is also consistent with sustainable development agendas and smart urban solutions. According to Alfarsi and Üzümcüoğlu (2025), combining intelligent technology with biophilic systems like sensor-monitored plant growth, climate-responsive shade, and controlled irrigation improves ecological efficiency and user engagement. This integration can turn neglected areas into multipurpose urban nodes that promote leisure, ecological connectedness, and environmental resilience in Lagos Island's mixed-use precincts. Additionally, by enabling local environmental narratives and cultural expressions to be connected to through landscape and architectural design, these interventions aid in the construction of urban identities (Olaoye, Iwaka, Adejumo, Adenubi, & Obiannuji, 2023). However, there are still many obstacles to overcome when applying biophilic design in heavily populated places. Adoption is frequently restricted by physical limitations, upkeep needs, and upfront capital expenses, and regulatory frameworks might not yet completely support integrated green systems (Andreucci et al., 2021; Bouaziz, 2025). The flexibility of design principles across scales, however, is highlighted by lessons learned from comparative studies of biophilic urbanism. This allows for gradual adoption even in complex urban morphologies, from interior courtyards to rooftop ecosystems, vertical gardens, and interconnected urban green networks (Panlasigui, Spotswood, Beller, & Grossinger, 2021).

Productive Green Infrastructure as a Strategy for Urban Renewal and Climate Resilience

A key part of urban redevelopment plans is productive green infrastructure (PGI), especially in crowded, environmentally stressed areas like Lagos Island. Unlike traditional green spaces, PGI focuses on functional ecosystems that improve urban beauty and strengthen social ties. It also offers clear benefits such as food production, stormwater management, carbon capture, and microclimate regulation (Hanna & Comín, 2021). PGI meets both environmental and economic goals in mixed-use developments by integrating ecological services directly into urban design. It transforms unused or damaged areas into valuable assets. In terms of design, PGI employs permeable public spaces, vertical gardens, rooftop farming, and landscape architecture to promote active human-nature interactions. As stated by Ai and Kim (2025), the strategic design of plant landscapes in urban and industrial regions improves natural connectivity and maximizes land use efficiency, allowing for the simultaneous use of spaces for recreation and production. The integration of PGI in mixed-use developments can be an effective strategy to reduce flooding, lower ambient temperatures, and clean up the air in Lagos Island, which is facing serious issues of land use and urban heat island intensification (Afolabi, Ibitoye, Kalu, & Olaoye, 2025).



Figure 2: Example of vertical green architecture with layered vegetation, demonstrating how plants can be incorporated into structural forms to support ecological function in dense cities; Source: Fordors Travel Guide

An example of vertical green architecture. The layered greenery on several balconies and façade of this high-density urban skyscraper is another example of biophilic architecture, which encourages ecological regeneration and environmental resilience. Empirical studies show that productive green infrastructure (PGI) enhances urban resilience. Nature-positive projects combining urban infrastructure with productive landscapes improve environmental quality, community engagement, and climate regulation, with green walls and roofs reducing solar gain, energy use, and improving comfort (Sahle et al., 2025; Afolabi et al., 2025). PGI also fosters socioeconomic productivity through edible landscapes, community gardens, and micro-farms, supporting food security, local economies, and social cohesion (Bouaziz, 2025). By treating cities as living systems, PGI enables holistic, ecologically regenerative, and socially responsive urban renewal aligned with biophilic principles (Lefosse et al., 2025). Its integration requires attention to spatial, maintenance, and policy constraints, but adaptive solutions like vertical gardens, rooftop soil blocks, and automated irrigation make PGI feasible in dense areas (Andreucci et al., 2021; Ibitoye, 2025). PGI also facilitates place-making by linking green spaces to cultural and spatial narratives, allowing Lagos Island to develop sustainable, aesthetically distinct, and culturally connected commercial, residential, and recreational areas, enhancing both ecological and sociocultural resilience (O'Sullivan et al., 2023; Olaoye et al., 2023).

RESEARCH METHOD

This study examined how combining biophilic design with productive green infrastructure can support urban renewal in mixed-use developments on Lagos Island using a quantitative approach grounded

in empirical evidence. The research targeted ARCON-registered real estate developers, architects, and urban planners who possess practical experience in urban development. Because the population size was not finite, Cochran’s formula for infinite populations was applied with a 95% confidence level, 50% variability, and a 5% margin of error, producing an initial sample of 384. After accounting for a 20% non-response rate, the effective sample size was adjusted to about 303 participants. Primary data were collected through a structured questionnaire administered both online and offline to maximise accessibility and response rates. The instrument explored respondents’ awareness of biophilic principles, the extent of productive green infrastructure adoption, and perceived benefits, challenges, and strategies for urban renewal. Responses were measured using a five-point Likert scale ranging from strong disagreement to strong agreement. Data analysis was conducted with SPSS, generating descriptive statistics such as frequencies, percentages, and mean scores to summarise knowledge and perceptions. Inferential techniques, including correlation and regression analysis, were used to test relationships between biophilic design adoption, green infrastructure integration, and perceived urban regeneration outcomes. This analytical process enabled the identification of trends and supported evidence-based recommendations for sustainable mixed-use development in Lagos Island.

RESULTS AND DISCUSSION

The outcome of the 303 participants on biophilic design and productive green infrastructure in mixed-use developments on Lagos Island is presented and explained in this section. Descriptive and inferential statistics were analysed using SPSS to determine the perceived efficacy, awareness, and adoption of the techniques. To show how professional experience and background influence perceptions and the implementation of sustainable urban renewal projects, the analysis is linked to architectural and urban planning principles.

Analysis of Data

The demographic details of the participants in the study on Lagos Island's integration of biophilic design and productive green infrastructure are shown in this section. Knowing these characteristics helps interpret the results by shedding light on the study sample's makeup, experience, and professional background.

Table 1: Demographic Distribution of Respondents

Variable	Category	Frequency (n)	Percentage (%)
Age Group	25–34 years	78	25.7
	35–44 years	124	40.9
	45–54 years	71	23.4
	55+ years	30	9.9
Gender	Male	215	70.9
	Female	88	29.1
Professional Role	Architect	142	46.9
	Urban Planner	95	31.4
	Property Developer	66	21.7
Years of Experience	Less than 5 years	56	18.5
	5–10 years	102	33.7
	11–20 years	94	31.0
	More than 20 years	51	16.8
Total		303	100

The sample is largely mid-career, with most respondents aged 35–44 and having 5–10 years of experience. The group is predominantly male but includes notable female representation. Architects form the largest professional category, followed by urban planners and property developers. Overall, the profile reflects an experienced and practice-focused cohort capable of providing reliable insights on sustainable development strategies in Lagos Island.

Objective i: Examining Existing Environmental, Spatial, and Socio-Economic Conditions

Using a 5-point Likert scale (1 being Very Low and 5 being Very High), respondents evaluated the environmental, spatial, and socioeconomic issues of the current mixed-use areas on Lagos Island. The descriptive data are shown in Table 8.

Table 2: Assessment of Urban Challenges and Opportunities

Indicator	Frequency (n)	Percent (%)	Mean	Std. Deviation	Rank	Cumulative %
Overcrowding / High Density	303	100	4.32	0.78	1	100
Poor Waste Management	303	100	4.05	0.84	2	100
Limited Open / Recreational Spaces	303	100	3.87	0.91	3	100
Traffic Congestion & Noise	303	100	3.72	0.95	4	100
Socio-economic Inequalities	303	100	3.55	0.88	5	100
Potential for Ecological Regeneration	303	100	3.41	0.82	6	100

The constraints of space and environmental stress in mixed-use areas were supported by the identification of overcrowding and waste management as the most pressing concerns. The possibilities for ecological regeneration were moderately graded (Mean = 3.41), indicating that the potential of initiatives such as PGI and biophilic design is recognized.

Objective ii: Evaluating Biophilic and Green Infrastructure Strategies

Participants rated the performance, adaptability, and integration of selected biophilic and productive green infrastructure strategies suitable for tropical coastal urban contexts (1 = Very Poor, 5 = Excellent).

Table 3: Evaluation of Biophilic and PGI Strategies

Strategy	Frequency (n)	Percent (%)	Mean	Std. Deviation	Rank	Cumulative %
Green Façades / Living Walls	303	100	4.18	0.72	1	100
Rooftop / Vertical Gardens	303	100	4.02	0.79	2	100
Courtyards & Pocket Parks	303	100	3.88	0.85	3	100
Rainwater Harvesting Systems	303	100	3.75	0.82	4	100
Edible Landscapes / Urban Farming	303	100	3.63	0.88	5	100
Permeable Pavements / Green Streets	303	100	3.55	0.91	6	100

Vertical gardens and green façades received the highest ratings for integration and performance, demonstrating their suitability for tropical climates and dense urban forms (Afolabi, Ibitoye, Kalu, & Olaoye, 2025; Ai & Kim, 2025). Permeable surfaces and edible landscapes received lower scores, indicating moderate adoption and perceived integration complexity.

Inferential Analysis:

The association between adoption of productive green infrastructure and knowledge of biophilic design was investigated using a Pearson correlation. The findings showed a significant positive connection ($r = 0.72$, $p < 0.01$), indicating that greater implementation is linked to better awareness. Knowledge and competence are important drivers of integration, as evidenced by regression analysis, which also revealed

that awareness and professional experience jointly predicted 65% of the variance in PGI adoption ($R^2 = 0.65$, $p < 0.001$).

Objective iii: Formulating Design Guidelines and Spatial Strategies

The perceived efficacy of combining biophilic and PGI tactics for resilient, liveable, and financially feasible urban redevelopment was assessed by the respondents.

Table 4: Perceived Effectiveness of Biophilic + PGI Integration

Outcome Indicator	Frequency (n)	Percent (%)	Mean	Std. Deviation	Rank	Cumulative %
Environmental Resilience	303	100	4.25	0.70	1	100
Thermal Comfort & Microclimate Improvement	303	100	4.12	0.73	2	100
Enhanced Social Interaction	303	100	3.95	0.81	3	100
Economic Value / Property Appreciation	303	100	3.82	0.85	4	100
Urban Biodiversity Enhancement	303	100	3.74	0.79	5	100
Cultural and Place Identity Strengthening	303	100	3.66	0.83	6	100

Thermal comfort and environmental resilience were thought to be greatly improved by combining biophilic and PGI techniques. These solutions are valued not just for ecological performance but also for community and market benefits, as evidenced by the favourable recognition of social and economic outcomes (Zhong, Schröder, & Bekkering, 2021; Panlasigui et al., 2021).

Inferential Analysis:

According to regression analysis, perceived urban renewal success is substantially predicted by the adoption of biophilic and PGI tactics ($\beta = 0.71$, $t = 12.54$, $p < 0.001$). Professional experience and perceived effectiveness showed a moderate correlation ($r = 0.53$, $p < 0.01$), indicating that more seasoned practitioners are more aware of the comprehensive benefits of these therapies.

Table 5: Regression and Correlation Analysis of Biophilic & PGI Adoption on Perceived Urban Renewal Effectiveness

Predictor Variable	Unstandardized Coefficient (B)	Std. Error	Standardized Coefficient (β)	t-value	p-value	Correlation (r)
Biophilic & PGI Adoption	0.68	0.05	0.71	12.54	<0.001	0.72
Professional Experience	0.45	0.07	0.42	6.43	<0.001	0.53
Constant	1.12	0.11	—	10.18	<0.001	—

Dependent Variable: Perceived Urban Renewal Effectiveness

β (Standardized Coefficient): Indicates the strength of the predictor in influencing the dependent variable

t-value & p-value: Determine significance of predictors

Correlation (r): Shows the strength and direction of association between each predictor and the outcome

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Summary of Findings

The study explored how biophilic design and productive green infrastructure can support urban regeneration in mixed-use developments on Lagos Island. Lagos Island's urban environment faces high density, limited open space, poor waste management, traffic congestion, and socio-economic disparities, yet it presents opportunities for nature-positive interventions. Respondents showed moderate to high awareness of biophilic concepts and valued courtyards, rooftop gardens, and green façades for their adaptability to dense tropical settings. Adoption of productive green infrastructure is growing but uneven, constrained by space, cost, maintenance, and technical capacity, highlighting the need for strategic planning, capacity building, and supportive policies. Integration of these strategies is perceived to improve environmental resilience, thermal comfort, social interaction, biodiversity, and economic value. Regression analysis showed professional experience moderately influences understanding of these benefits, while adoption strongly predicts perceived urban regeneration effectiveness. Overall, biophilic and productive green solutions are economically viable and socially and environmentally beneficial, making them essential for creating resilient, liveable mixed-use developments on Lagos Island.

CONCLUSION

The study examined how biophilic design and productive green infrastructure can drive urban renewal in mixed-use developments on Lagos Island. Findings show the area faces key constraints including congestion, poor waste management, high density, limited open space, and socio-economic disparities, yet holds strong potential for ecological improvement through nature-integrated design. Green walls, rooftop gardens, and courtyards emerged as the most suitable strategies for dense tropical conditions. Professionals across architecture, planning, and real estate demonstrate moderate to high awareness of biophilic principles, though adoption of green infrastructure remains uneven due to cost, space, and maintenance concerns. Perceived benefits include improved environmental resilience, thermal comfort, social interaction, biodiversity, and property value. Statistical results indicate that while professional experience shapes perceptions, the adoption of biophilic and productive green infrastructure is the strongest predictor of perceived urban regeneration effectiveness. Overall, integrating these approaches can significantly enhance the resilience, liveability, and economic viability of mixed-use developments.

RECOMMENDATION

To maximise the impact of biophilic design and productive green infrastructure in Lagos Island, courtyards, pocket parks, rooftop and vertical gardens should be prioritised for thermal comfort, social interaction, and environmental quality. Permeable surfaces, rainwater harvesting, and urban agriculture enhance ecological and economic value. Policy incentives, technical guidelines, and professional training can address cost, space, and maintenance barriers. Strategic spatial planning ensures optimal placement and connectivity, maximising ecological, social, and economic benefits for resilient and sustainable mixed-use developments.

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