

Integrating Biophilic and Passive Design Strategies in Nigerian Architecture: A Systematic Review of Current Practices and Impacts

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Abstract

This systematic review explores the integration of biophilic (nature-based) and passive (climate-responsive) design strategies in contemporary Nigerian architecture, assessing their impacts on sustainability, thermal comfort, user well-being, and energy efficiency. Following PRISMA guidelines, 30 peer-reviewed studies published between 2020 and 2025 were reviewed, spanning residential, institutional, hospitality, and healthcare settings. The evidence demonstrates that passive design strategies such as building orientation, shading, insulation, and natural ventilation improve indoor thermal conditions and reduce energy use by up to 50%. Biophilic elements, including natural lighting, greenery, and water features, are associated with reduced stress, enhanced cognitive function, and improved user satisfaction. However, adoption in Nigeria remains limited; for instance, only 28.6% of examined high-rise condominiums in Lagos applied passive cooling measures, and less than 20% incorporated biophilic features beyond basic daylighting. Major barriers include weak regulatory enforcement, high upfront costs, and low awareness among practitioners. The study concludes with policy and design recommendations, including stricter code enforcement, incentive structures, and biophilic education frameworks, to support more sustainable and human-centred building practices in Nigeria.

Keywords: Biophilic Design, Building Codes, Passive Design, Sustainable Architecture, Thermal Comfort, Indoor Environment.

Introduction

Climate-responsive architecture is critical in Nigeria's tropical environment, where hot summers and high humidity challenge occupant comfort. Passive design using a building's orientation, natural ventilation, shading, thermal mass, and daylighting reduces reliance on active cooling (Oti & Eguta, 2020; Ajayi et al., 2024). Similarly, biophilic design connects people with nature through vegetation, natural light, water features, and organic materials. This approach has proven global benefits: it can shorten hospital stays, reduce stress and pain, and boost cognitive performance (Tekin et al., 2023; Wang & Li, 2022; Kassymova & Urazalin, 2024).

In Nigeria, emerging studies suggest that biophilic design enhances cognitive function and environmental comfort. For instance, Umeora et al. (2025) found that biophilic features such as green corridors, open courtyards, and shaded walkways on university campuses supported stress reduction, cognitive retention, and microclimate regulation. Likewise, Ayejuyo et al. (2025) observed that resort hotels with water features and greenery

significantly improved guest relaxation and mood. These findings align with international evidence that integrating plants, daylight, and natural motifs enhances well-being and thermal experience.

However, contemporary Nigerian buildings often neglect these strategies. Agboola & Adedire (2023) observe that “most buildings in Nigeria are designed, with not much attention paid to orientation, nature and proper climatology.” One Lagos study found that only 28.6% of new condos used passive climate design (Dimuna et al., 2025), and the rest relied entirely on mechanical cooling. Similarly, Abdulkadir & Olagunju (2023) noted that although all units in Abuja high-rise apartments had daylight and ventilation, only 17% had balcony plants, and none included water features.

Despite growing research, there has been no consolidated synthesis of how biophilic and passive design strategies are applied within the Nigerian built environment, nor their combined impacts on energy performance, user comfort, or sustainability goals. This review addresses that gap by examining empirical evidence from recent studies.

Objectives of the Review

This systematic review aims to:

- i. Evaluate the extent of biophilic and passive design integration in Nigerian architecture (2020–2025).
- ii. Identify the impacts of these strategies on energy efficiency, thermal comfort, and occupant well-being.
- iii. Examine the key challenges and limitations hindering their implementation in Nigeria.
- iv. Recommend policy and design strategies to encourage climate-responsive and nature-integrated architectural practices in Nigeria.

Literature Review

Biophilic Design in the Built Environment

Biophilic design emphasizes occupants’ innate affinity for nature by incorporating natural elements into buildings. Globally, systematic reviews in healthcare and office environments have demonstrated that biophilic parameters such as daylight, fresh air, vegetation, and natural materials positively impact human well-being (Tekin et al., 2023; Williams & Dol, 2020; Kassymova & Urazalin, 2024). For example, Tekin et al. (2023) identify daylighting, thermal comfort, and access to nature as critical for both patient recovery and staff mental health. Similarly, Xing et al. (2025) report that buildings integrating natural forms and vegetation improve psychological health and creative output.

In Nigeria, biophilic concepts are increasingly being explored in design practice. Ayejuyo et al. (2025), studying resort hotels in Southwest Nigeria, found that water features and greenery significantly improved guest relaxation and mood. In luxury hotels in Abuja, Yusuf et al. (2025) showed that visual connection to nature and organic spatial layouts enhanced

attention restoration, especially among younger occupants. On university campuses, biophilic interventions such as green corridors and shaded outdoor courtyards have been associated with cognitive retention, stress regulation, and microclimate improvement (Umeora et al., 2025).

Despite these findings, implementation remains limited. Abdulkadir & Olagunju (2023) observed that although most high-rise units in Abuja had access to natural light and ventilation, only 17% featured balcony plants and none included water features or animal presence indicating a superficial application of biophilic strategies. Furthermore, biophilic spaces like green roofs and indoor gardens are rare in institutional and public buildings due to lack of funding and policy support (Agboola et al., 2024). Some studies (e.g., Yusuf et al., 2025) note that perception of comfort and design preferences vary by demographic factors, yet these findings require further exploration with more diverse samples and mixed-method designs. Notably, psychological outcomes such as stress reduction and cognitive benefit are often self-reported, raising questions about methodological rigour in measuring mental health indicators across contexts.

Passive Design and Thermal Comfort

Passive design optimises natural forces to stabilise indoor conditions in hot-humid climates. In Nigeria, critical strategies include shading, orientation, ventilation, insulation, and reflective materials. A review of 32 Nigerian housing studies by Ajayi et al. (2024) found that passive features like ceiling insulation and daylighting could reduce energy use by 30–50%. Experimental data from Kaduna (Xi et al., 2025) showed that adding roof insulation and reflective paint lowered indoor temperatures by $\sim 3^{\circ}\text{C}$, while ceiling fans-maintained comfort levels ($\leq 28^{\circ}\text{C}$) compared to 31°C outdoors.

Dimuna et al. (2025), in their Lagos condominium study, revealed that only 28.6% of buildings adopted passive cooling strategies, despite their proven benefits. Thermal discomfort in non-compliant buildings was directly linked to higher air-conditioning use and user complaints. Similarly, in classroom settings, Okwuosa et al. (2021) found that passive underperformance led to increased reliance on fans and AC, resulting in higher operating costs.

Though the physical impacts of passive design are better documented than those of biophilic design, many studies in Nigeria remain case-specific or descriptive, with limited long-term monitoring or comparative analysis. This highlights a methodological gap in assessing performance over time, especially in low-income housing where energy poverty is prevalent (Kajjoba et al., 2025).

Integration of Biophilic and Passive Strategies

Biophilic and passive designs are not mutually exclusive; vegetation can serve as shading, insulation, and evaporative cooling, merging aesthetics with function. For example, green walls and trellised facades allow daylight penetration while reducing heat gain. This

integration is widely supported in international research (Jaafar & Al-Mumin, 2021), and vernacular Nigerian architecture (e.g., courtyards, thick earthen walls) historically reflected this synthesis (Muogbara et al., 2022).

However, limited Nigerian studies have explicitly examined their combined implementation. One exception is the study by Owolabi & Ogunsanya (2021), which noted that green roofs in Lagos improved both cooling and biodiversity. The absence of unified frameworks or performance guidelines means most designs are ad hoc or stylised rather than systematic. While global frameworks like LEED and EDGE encourage passive-first approaches, Nigeria's lack of enforceable biophilic guidelines limits wider uptake.

A significant gap exists in post-occupancy evaluation of buildings that integrate both strategies. Only a few studies (e.g., Abdulkadir & Olagunju, 2023) reference actual user feedback or sensor data. More empirical studies using mixed methods, comfort indices, and lifecycle analysis are needed to establish best practices in the Nigerian context.

Methodology

We conducted a systematic literature review in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Relevant studies were identified from four databases: Scopus, Web of Science, PubMed, and Google Scholar. The search terms included combinations of "biophilic design," "passive design," "thermal comfort," "sustainability," "energy efficiency," "well-being," and "Nigeria." Boolean operators (AND/OR) and synonyms were applied to widen results.

Inclusion criteria were:

- i. Peer-reviewed journal articles or conference papers published between 2020 and 2025.
- ii. Studies with a focus on architectural design (residential, institutional, hospitality, or healthcare buildings).
- iii. Studies specific to Nigeria or, where relevant, to comparable tropical/sub-Saharan contexts.
- iv. Articles discussing biophilic or passive strategies with measurable impacts on sustainability, comfort, or well-being.

We initially retrieved 223 articles. After removing duplicates ($n = 43$), 180 titles and abstracts were screened. Following relevance screening, 80 full-text articles were assessed for eligibility. Of these, 30 studies were retained for final analysis based on content relevance and methodological rigour.

Data extraction was carried out using a structured template, capturing the following variables:

- i. Author(s), year, and location.
- ii. Building type or design context.
- iii. Biophilic and/or passive design strategies employed.
- iv. Study methodology (e.g., field survey, case study, simulation, review).

- v. Outcome measures (e.g., thermal comfort, energy use reduction, well-being indicators).
- vi. Key findings and limitations.

To ensure quality and consistency, each study was appraised using a modified CASP (Critical Appraisal Skills Programme) checklist adapted for architectural studies. Scoring focused on:

- i. Clarity of objectives
- ii. Methodological soundness
- iii. Contextual relevance
- iv. Transparency of data and findings

Each article was rated on a 3-point scale (low, medium, high quality). Conflicting findings were synthesised using thematic analysis and triangulation, highlighting variation across climate zones, building types, or socio-economic contexts. Studies rated as low quality were excluded from influencing major conclusions but noted in limitations.

A combination of qualitative synthesis (narrative and thematic comparison) and quantitative reporting (where numerical data were available, e.g., temperature differences, percentage of energy savings) was used to identify trends, gaps, and implications across studies.

Results and Discussion

Adoption of Biophilic and Passive Strategies in Nigerian Architecture

Adoption of biophilic and passive design strategies across the Nigerian built environment remains limited, though some progress is evident in recent years. In the residential sector, Dimuna et al. (2025) examined high-rise condominiums in Lagos and found that only 28.6% incorporated passive cooling strategies such as proper orientation, natural ventilation, and shading. Similarly, Abdulkadir and Olagunju (2023) found that while natural ventilation and daylighting were common in Abuja high-rise apartments, only 17% of units included balcony vegetation, and none featured other biophilic elements like water features or animal integration.

In institutional contexts, Umeora et al. (2025) documented some biophilic planning strategies on university campuses in southeast Nigeria, such as green corridors and landscape buffers, but noted limited integration of these features into building layouts or performance criteria. In hospitality settings, Ayejuyo et al. (2025) reported widespread use of greenery and water features in resort hotels, with these elements being rated highest by guests for improving relaxation and overall well-being.

Despite these examples, adoption of nature-based and climate-responsive design strategies is mostly ad hoc and often driven by private developers or design preferences rather than code enforcement or policy incentives. Survey findings from Mba (2024) support this pattern: while approximately 89% of architects in Enugu were aware of sustainable design principles, only 32% reported applying passive or biophilic elements

regularly in their projects. These findings are summarised in Table 1, which presents representative studies, building types, and the specific design strategies adopted across different contexts in Nigeria.

The table below presents a curated summary of 13 representative studies selected from the 30 articles included in the full review. These were chosen for their relevance, clarity of methodological detail, and diversity across building types and strategies.

Table 1. Summary of Representative Studies on Biophilic and Passive Design Strategies in Nigeria (2020–2025)

Study (Year)	Building Type / Context	Biophilic Strategies	Passive Strategies	Key Findings / Impacts
Agboola <i>et al.</i> (2024)	Conceptual / Sustainable goals	Nature integration (general)	–	Highlights biophilic design's potential to advance sustainability goals.
Dimuna <i>et al.</i> (2025)	High-rise condos (Lagos)	–	Orientation, shading, ventilation	Only 28.6% of condos used passive cooling. Passive design optimizes climate, improving occupant comfort and reducing energy needs. Thermal discomfort was linked to well-being.
Umeora <i>et al.</i> (2025)	University campus (SE Nigeria)	Green corridors, landscape design	Building siting for natural breezes	Found biophilic campus design boosts student retention, cognitive performance, and stress reduction; adoption was limited by policy/funding constraints.
Yusuf <i>et al.</i> (2025)	Luxury hotels (Abuja)	Nature views, indoor plants	Ventilation (balconies)	Nature-connected spaces and spacious layouts significantly enhanced guests' attention restoration. Age and culture moderated effects.
Ayejuyo <i>et al.</i> (2025)	Resort hotels (SW Nigeria)	Water features, extensive greenery	–	Water elements and greenery were rated highest for improving relaxation and mood. The study underscores these elements' role in guest well-being and ecological sustainability.
Abdulkadir & Olagunju (2023)	High-rise residential (Abuja)	Daylighting, natural ventilation	–	All units had abundant daylight and ventilation; only 17% had balconies with plants, no units had water features/animals. Authors note vegetation is a "key biophilic element to ensure user's comfort".
Ajayi <i>et al.</i> (2024)	Low-cost housing (Systematic Rev)	–	Insulation, shading, orientation, thermal mass	Review of 32 studies found passive measures (insulation, shading, ventilation, daylighting) consistently improve energy efficiency in Nigerian homes, but adoption is hampered by low awareness and cost.
Xi <i>et al.</i> (2025)	Low-income housing (Kaduna)	–	Roof insulation, reflective coating, ceiling fans	Experiment showed roof insulation + reflective paint lowered indoor peaks ~3°C. With added fans (4 ACH), peak indoor stayed ~28°C vs. 31°C outside.

				Demonstrated that combining passive and low-power ventilation yields high comfort.
Erifeta (2025)	Policy/Review	–	–	Identified high upfront costs, insufficient code enforcement, and public unawareness as major obstacles to sustainable building practices in Nigeria. Recommends incentives, PPPs, and stricter regulation.
Okoro & Balogun (2024)	Policy/Review	–	–	Note that Nigeria’s National Building Code includes sustainability provisions but enforcement is weak (“compliance is low due to limited monitoring”). Suggest multi-stakeholder partnerships to improve adoption of green standards.
Kajjoba <i>et al.</i> (2025)	Tropical low-income buildings	–	Daylighting, natural ventilation	Review highlights that passive cooling is essential for comfort in tropical homes. It also points out the lack of enforceable comfort codes in developing regions, advocating integrated comfort–efficiency strategies.
Mba (2024)	Architectural practice survey	–	–	Survey of Enugu architects found ~89% aware of sustainability, but only ~32% regularly implement renewable or passive systems. Economic barriers and lack of training cited; authors urge better design education and incentives.
Muogbara <i>et al.</i> (2022)	Vernacular building review	Earth materials, courtyards	Thick walls, passive ventilation	Notes that traditional earthen walls and layouts drastically reduce carbon footprints (concrete alone is ~8% of global CO ₂). Advocates learning from vernacular methods to improve modern design sustainability.

Impacts on Thermal Comfort, Sustainability, and User Experience

Quantitative outcomes were reported in several studies. Ajayi *et al.* (2024) noted that housing units incorporating insulation, shading, and cross-ventilation achieved up to 50% reduction in energy demand. In Kaduna, Xi *et al.* (2025) recorded a ~3°C reduction in indoor temperature when reflective coatings and roof insulation were used, bringing peak internal temperatures down to 28°C from 31°C.

In hospitality settings, Ayejuyo *et al.* (2025) found that guests rated water features and greenery highest in terms of perceived relaxation and comfort, especially when combined with natural ventilation. Yusuf *et al.* (2025) further observed that nature views and organic spatial layouts enhanced attention restoration, particularly among younger guests.

However, evidence related to health and psychological outcomes remains limited and largely qualitative. Many studies (e.g., Umeora *et al.*, 2025; Yusuf *et al.*, 2025) relied on user perception surveys without physiological or cognitive measurement. Only a few referenced

stress biomarkers or post-occupancy evaluation metrics. This points to a need for more rigorous, multidisciplinary assessments of well-being outcomes.

Environmental sustainability was supported through indirect benefits: reduced energy loads, improved microclimate regulation, and biodiversity enhancement. Yet only a small number of studies quantified emissions savings or lifecycle energy costs, indicating another empirical gap.

Barriers to Implementation

Several recurring barriers were identified across the reviewed literature:

- i. Regulatory gaps: Nigeria's National Building Energy Efficiency Code (NBEEC) is poorly enforced, and few local planning authorities mandate passive or biophilic criteria (Okoro & Balogun, 2024).
- ii. Economic constraints: High upfront costs deter adoption, particularly in low-income housing projects (Erifeta, 2025).
- iii. Professional gaps: Many practitioners lack formal training on bioclimatic or biophilic systems (Mba, 2024).
- iv. User perception: Comfort is often equated with mechanical cooling or conventional finishes, limiting interest in alternative strategies (Agboola & Adedire, 2023).

These barriers were especially acute in public and educational buildings, where budgets and policy enforcement are minimal.

Policy and Practice Implications

Policy recommendations from the literature emphasize the need for enforceable building codes and incentives. For example, Shenoi et al. (2022) suggest linking sustainability certification to tax breaks or permit fast-tracking. Others advocate for post-occupancy evaluations to build an evidence base (Kajjoba et al., 2025).

Comparatively, international case studies like Bosco Verticale in Milan were cited (Figure 2) to show the potential of fully integrated green façades. While not directly transferable, such examples offer lessons on modular plant integration and performance tracking. However, Nigerian studies rarely include lifecycle cost comparisons or urban climate modelling to support such innovations.

Gaps and Methodological Weaknesses

While this review synthesised approximately 30 studies, several limitations emerged:

- i. Heavy reliance on qualitative data, especially for user satisfaction and psychological outcomes.
- ii. Few longitudinal or post-occupancy studies.
- iii. Minimal attention to regional climate variation within Nigeria.
- iv. Inconsistent reporting of energy and comfort metrics, making cross-study comparison difficult.

Future research should use mixed methods, including thermal sensors, energy models, and psychometric tools, to verify and quantify biophilic and passive performance. Studies should also disaggregate findings by climate zones (e.g., coastal vs. arid) and user demographics to improve generalisability.

Conclusion and Recommendations

This review has shown that biophilic and passive design strategies significantly contribute to thermal comfort, energy efficiency, and user well-being within the Nigerian context. Key conclusions include:

- i. **Performance Benefits:** Empirical studies (e.g., Ajayi et al., 2024; Xi et al., 2025) consistently report that integrating features such as shading, insulation, natural ventilation, and vegetation can lower indoor temperatures by up to 3°C and reduce energy demand by 30–50%.
- ii. **Limited Adoption:** Despite these advantages, integration remains minimal. Less than one-third of Lagos high-rise condos apply passive cooling strategies (Dimuna et al., 2025), and biophilic features like green roofs or water elements are rare across institutional and residential developments (Abdulkadir & Olagunju, 2023).
- iii. **Barriers to Implementation:** The most cited obstacles include inadequate code enforcement (Okoro & Balogun, 2024), high upfront costs (Erifeta, 2025), limited professional training (Mba, 2024), and user misconceptions equating comfort solely with mechanical systems (Agboola & Adedire, 2023).

Recommendations

To bridge the gap between potential and practice, we propose the following evidence-based and actionable strategies:

- i. **Enforceable Building Regulations:** Activate and strictly implement Nigeria's Energy Efficiency Code (NBEEC) by mandating minimum passive design standards such as insulation, ventilation, and daylighting (Okoro & Balogun, 2024).
- ii. **Introduce specific thresholds for green spaces and biophilic components,** e.g., minimum green roof coverage or mandatory courtyard integration in multi-unit housing (Agboola et al., 2024).
- iii. **Incentivise Adoption through Economic Tools:** Introduce tax credits, permit fast-tracking, or density bonuses for projects meeting sustainability benchmarks (Shenoi et al., 2022).
- iv. **Establish public–private partnerships (PPPs)** to co-finance demonstration projects that illustrate long-term savings and occupant benefits (Erifeta, 2025).
- v. **Capacity Building and Professional Training:** Embed biophilic and passive design modules in architectural and engineering curricula (Mba, 2024).
- vi. **Provide continuing education workshops for practitioners** on topics such as thermal modelling, native planting strategies, and post-occupancy evaluation.

- vii. Culturally and Climatically Responsive Design: Promote the modern adaptation of vernacular strategies like courtyards, thick walls, and shaded verandas that align with passive principles (Muoghara et al., 2022).
- viii. Collaborate with local ecologists and horticulturists to select resilient native plant species for building integration.
- ix. Monitoring, Evaluation, and Knowledge Sharing: Fund post-occupancy evaluations that combine sensor data, user feedback, and energy modelling to validate outcomes (Kajjoba et al., 2025).

Limitations and Future Research

This review was constrained by the limited availability of longitudinal studies and the reliance on self-reported user outcomes. Most data on psychological impacts remain qualitative. Future studies should:

- i. Employ mixed methods, including thermal sensors, stress biomarkers, and long-term comfort tracking.
- ii. Explore regional differences across Nigeria's diverse climate zones.
- iii. Assess life-cycle cost implications of integrating biophilic-passive systems in both public and low-cost housing.

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