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PASSIVE COOLING AND BIOPHILIC PERFORMANCE IN CONTEMPORARY NIGERIAN INSTITUTIONAL LIBRARIES: A COMPARATIVE PRECEDENT ANALYSIS

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ABSTRACT

Contemporary institutional libraries in Nigeria face increasing pressure to maintain thermal and visual comfort while limiting dependence on energy-intensive mechanical cooling. Although passive and biophilic strategies are increasingly discussed in Nigerian architectural research, evidence on how these strategies are integrated within institutional libraries remains fragmented. This study comparatively assesses six library precedents; three Nigerian cases and three international benchmarks using a Precedent Extraction Protocol (PEP) that examines seven architectural categories: courtyard integration, atrium/stack ventilation, vegetation integration, shading, cross ventilation, daylighting, and façade environmental control. The assessment indicates that the Nigerian cases demonstrate particular strengths in daylighting (median 5) and cross ventilation (median 4), while façade environmental control (median 2; range 1–4), atrium/stack ventilation (median 2; range 2–4), and vegetation integration (median 3; range 2–3) show greater limitations. These findings suggest that the key challenge is not the absence of passive or biophilic measures, but their incomplete coordination across the building envelope, landscape, and ventilation systems. The principal practical contribution of the study is a proposed integrated library design matrix that links façade control, shading, vegetation, courtyard planning, daylighting, and stack-assisted ventilation into a coordinated design approach. The matrix provides a context-sensitive basis for developing and evaluating future Nigerian institutional library briefs and designs. The PEP is used as a comparative design-assessment tool rather than a substitute for measured environmental performance.

Keywords: Biophilic Design, Institutional Libraries, Passive Cooling, Precedent Analysis, Thermal Performance.

1 INTRODUCTION

Institutional libraries require stable thermal and visual conditions because they accommodate prolonged occupancy, concentrated study activities and, in many cases, sensitive collections. In warm climates, the challenge is not simply to introduce individual passive measures but to coordinate solar control, ventilation, daylighting, landscape and building form so that one strategy does not undermine another. Passive approaches such as orientation, shading, natural ventilation, daylighting, courtyards and vegetation can reduce heat gain and support indoor environmental quality, but their effectiveness depends on how they are combined within the building system (Kolani et al., 2023; Musa et al., 2024).

Evidence from Nigerian libraries points to this integration problem. Ayoosu et al. (2020), in an assessment of 10 libraries, found that 80% had north–south orientation, yet only 29% used external vertical shading, 36% used horizontal shading and 21% combined both forms of shading. The implication is that a favourable orientation may exist without sufficient control of solar exposure or support for comprehensive natural ventilation. More recent evidence reinforces this pattern: Akinola and Amadhe (2026) reported positive user perceptions of natural lighting and spatial flexibility across three Delta State academic libraries, but satisfaction with air-condition-free ventilation was comparatively lower. Taken together, these studies suggest that the presence of passive features should not be interpreted as evidence of an integrated environmental system.

Biophilic design extends this environmental agenda by connecting occupants with natural light, vegetation, natural materials, views and outdoor spaces. These relationships can support comfort and wellbeing, but their architectural value is greatest when nature-based elements also perform environmental functions, for example, vegetation providing shade and evapotranspirative cooling, courtyards supporting airflow, and controlled daylight reducing dependence on artificial lighting (Kellert & Calabrese, 2015; Tekin et al., 2023; Yin et al., 2023). Recent Nigerian evidence indicates that biophilic adoption remains uneven, with cost, regulatory enforcement and practitioner awareness identified as barriers (Kalu et al., 2025).

The resulting research problem is therefore one of integration rather than simple adoption. Existing Nigerian studies tend to examine passive cooling or biophilic elements separately, while fewer studies compare how several environmental strategies operate together within institutional libraries. This study addresses that gap through a structured comparison of three Nigerian libraries and three international precedents. The international cases are used as design benchmarks, not as direct climatic equivalents to identify architectural strategies that may be adapted to Nigerian conditions. The study asks: (1) which environmental categories show the clearest differences between the Nigerian and benchmark cases; (2) where is there meaningful variation among the Nigerian cases themselves; and (3) how can the observed patterns be translated into an integrated, library-specific design framework?

2 LITERATURE REVIEW

The literature is synthesised around a common argument: passive cooling and biophilic design are most useful for institutional libraries when they are coordinated as an environmental system rather than applied as isolated features.

2.1 Passive cooling and Integrated Environmental Performance in Institutional Libraries

Passive cooling reduces heat gain and promotes heat dissipation through orientation, solar control, natural ventilation, thermal mass and appropriate building configuration (Santamouris & Kolokotsa, 2013; Szokolay, 2014). Evidence from Nigerian libraries indicates that orientation is relatively common, but complementary passive measures such as external shading and natural ventilation are inconsistently applied (Ayoosu et al., 2020).

Source: Akinola and Amadhe (2026).

Figure 1: Courtyard configuration supporting natural ventilation and passive environmental control

Recent work in Delta State similarly suggests that users value natural lighting and spatial flexibility while air-condition-free ventilation is less satisfactory (Akinola & Amadhe, 2026). These findings suggest that daylighting and natural ventilation can serve as architectural strengths, but their effectiveness may be limited when solar exposure, façade control, and airflow paths are not properly coordinated.

2.2 Biophilic Strategies, Spatial and Environmental Performance

Biophilic strategies establish connections between occupants and natural elements through vegetation, daylight, natural materials, views and outdoor spaces (Tekin et al., 2023). Recent evidence indicates that these elements can contribute to environmental quality, thermal and visual comfort, psychological well-being and occupant satisfaction (Tekin et al., 2023). However, their application in Nigerian buildings remains relatively limited and is often restricted to basic daylighting and landscaping (Kalu et al., 2025).

Courtyards can support natural ventilation by creating shaded intermediate spaces and influencing airflow within and around buildings. Their effectiveness depends on factors such as courtyard geometry, proportions, orientation, openings and their relationship with surrounding spaces (Han et al., 2023). Atriums can similarly support vertical air movement through buoyancy-driven or stack ventilation, particularly where building depth limits direct cross-ventilation. Research indicates that the effectiveness of passive ventilation depends on the interaction between building configuration, openings and prevailing airflow conditions (Apolinário et al., 2026). Moosavi et al. (2015) further indicate that cross ventilation coupled with stack effects can improve cooling in tropical atrium and courtyard configurations.

Ayoosu et al. (2020) found that Nigerian libraries generally demonstrated favourable orientation but had inadequate external shading. This indicates that orientation alone does not guarantee effective environmental performance. At the building envelope, shading and façade design play an important role in balancing natural daylight with solar heat gain. Overall, the literature suggests that these elements work best when they are considered together: the building form helps create opportunities for natural light and airflow, the landscape helps cool and improve the surrounding environment, while the façade controls excessive sunlight without blocking useful daylight and fresh air.

Source: Tekin et al. (2023).

Figure 2: Integration of daylight, vegetation and natural elements in a library environment.

2.3 Building Performance and Research Gap

The Nigerian literature provides evidence of the use of individual passive and biophilic design strategies, but there is still limited research examining how these strategies are integrated collectively across institutional libraries within a common assessment framework. This study therefore draws on international precedents not to rank buildings as simply "better" or "worse," but to broaden the comparison and identify design approaches that may be adaptable to the Nigerian context. The selected precedents reflect different climatic and architectural conditions. The King Fahad National Library in Riyadh illustrates approaches to solar control and façade design within a hot-arid climate, while the University of Indonesia Central Library and Universiti Teknologi MARA Library provide examples from humid tropical settings where daylighting, vegetation and natural ventilation are important design considerations. Given Nigeria's diversity of climatic conditions, ranging from humid tropical environments to savanna regions, none of these international examples can be regarded as a direct climatic equivalent. Their relevance instead lies in the specific architectural strategies and mechanisms that may be adapted to different Nigerian conditions. The comparison therefore focuses on transferable design principles rather than assuming that these buildings perform under climatic conditions identical to those in Nigeria.

Building-performance research also highlights the distinction between design intention and actual building performance. Fedoruk et al. (2015) demonstrate that differences between anticipated and achieved performance can result from factors such as specification, implementation, building controls and operation, while Tuohy and Murphy (2015) emphasise the importance of feedback between design decisions and building operation. In view of this, the present study does not claim to measure actual thermal or energy performance. Instead, it focuses on the observable integration of passive cooling and biophilic strategies within the selected architectural precedents.

The literature gap addressed by this study is therefore specific: there is a need for a transparent and comparative approach for examining how passive cooling and biophilic strategies are brought together in institutional library design. Such an approach should also recognise the limitations of precedent-based assessment and avoid presenting architectural scores as substitutes for measured environmental performance. The study responds to this gap through the Precedent Extraction Protocol (PEP) and the development of a synthesis-oriented design matrix that translates the observed patterns into potentially adaptable design considerations for Nigerian institutional libraries.

3 METHODOLOGY

A comparative case study approach was used to examine how passive cooling and biophilic strategies are integrated in institutional libraries. The methodology prioritised transparent architectural comparison rather than simulation or measured environmental performance.

3.1 Research approach

This study adopts a comparative Research-about-Design (RaD) approach (Zhang, 2024). It systematically extracts and compares patterns of passive cooling and biophilic integration from documented architectural precedents. Yin’s (2018) multiple-case study framework structures the cross-case logic, replication strategy, and use of multiple sources of evidence such as drawings, published project documentation, photographic records, and structured observation. The emphasis is on architectural integration of environmental mechanisms rather than measured thermal or energy performance.

3.2 Case selection and benchmark rationale

Six institutional libraries were purposively selected based on institutional function, availability of architectural information, contemporary relevance and the ability to identify passive or biophilic design features. The Nigerian cases were Bingham University Library, Karu; Modibbo Adama University Library, Yola; and Federal University of Technology Minna Library. These cases provide variation within Nigeria rather than a single 'regional' condition. The international benchmarks were King Fahad National Library, Riyadh; University of Indonesia Central Library, Depok; and Universiti Teknologi MARA Library, Shah Alam.

The six cases were selected to enable both literal and theoretical replication (Yin, 2018): the Nigerian libraries provide internal variation across institutional and climatic contexts within the country, while the international cases serve as documented exemplars of specific passive and biophilic mechanisms whose transferability can be examined. This approach is particularly appropriate because Nigerian conditions vary from humid tropical environments to tropical savanna; recent evidence from Kaduna, for example, identifies the savanna context as one in which high daytime temperatures and cooling demand create a strong case for passive design (Xi et al., 2025).

3.3 Data sources and Precedent Extraction Protocol

A Precedent Extraction Protocol (PEP) was developed for this study as a structured observational tool for characterising the degree of architectural integration of passive and biophilic strategies. It draws on established practices of architectural precedent analysis, in which buildings are systematically read for transferable design knowledge (Eilouti, 2009; Pakiding et al., 2024), and on multi-criteria approaches to design assessment. Seven categories such as courtyard integration (CI), atrium/stack ventilation (ASV), vegetation integration (VI), shading strategy (SS), cross ventilation (CV), daylighting strategy (DS), and façade environmental control (FEC), were derived from the literature on passive cooling and biophilic design. Each category is scored on a five-point ordinal scale (1 = absent or negligible integration; 5 = highly integrated) according to observable evidence in drawings, photographs, and published documentation. The scale captures the extent of architectural integration indicated by the available evidence; it does not measure indoor temperature, energy use, airflow, or daylight levels. Scores were assigned by the lead researcher. Because the data are ordinal and the sample is small, medians and ranges are reported rather than means.

3.4 Assessment criteria and analytical approach

Seven categories were assessed: courtyard integration (CI), atrium/stack ventilation (ASV), vegetation integration (VI), shading strategy (SS), cross ventilation (CV), daylighting strategy (DS), and façade environmental control (FEC). Because the PEP scale is ordinal and the sample is small, medians and ranges are used rather than means as the primary comparative statistics. Case-level medians are reported to show within-case patterns, while category medians and ranges are used to compare the Nigerian and international groups. Differences between group medians are interpreted descriptively and are not treated as statistically significant effects.

3.5 Reliability and methodological limitations

The PEP is an interpretive architectural-analysis instrument rather than a quantitative performance metric. The present study used a single-assessor application; inter-rater reliability was therefore not calculated. Scores should be understood as indicative of the degree of integration visible in the available documentation. This limitation is mitigated by retaining the raw case-level scores, reporting medians and ranges, and avoiding claims of measured environmental performance. Future applications of the protocol should employ at least two independent assessors and report inter-rater agreement. Additional limitations include uneven availability and resolution of drawings and photographs across cases, and the well-documented gap between design intent and operational performance (Fedoruk et al., 2015; Tuohy & Murphy, 2015).

4 RESULTS

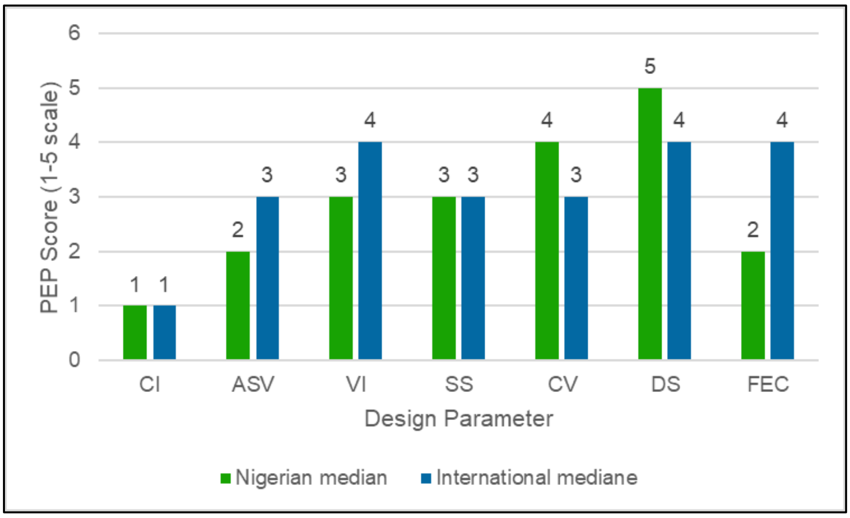
The PEP results are presented as ordinal indicators of architectural integration. Table 1 retains the individual case scores so that variation among the Nigerian libraries remains visible. Group medians and ranges are used to avoid implying precision that the five-point assessment scale cannot support.

Table 1: Comparative PEP Scores of the Six Institutional Libraries

Case	CI	ASV	VI	SS	CV	DS	FEC	Case median
Nigerian cases								
Bingham University Library	1	2	3	1	2	3	1	2
Modibbo Adama University Library	1	4	3	4	4	5	4	4
FUTMINNA Library	5	2	2	3	4	5	2	3
Nigerian median (range)	1 (1–5)	2 (2–4)	3 (2–3)	3 (1–4)	4 (2–4)	5 (3–5)	2 (1–4)	3 (2–4)
International cases								
King Fahad National Library	1	5	3	5	3	5	5	5
University of Indonesia Central Library	1	2	5	3	2	4	4	3
UiTM Library	4	3	4	3	4	4	3	4
International median (range)	1 (1–4)	3 (2–5)	4 (3–5)	3 (3–5)	3 (2–4)	4 (4–5)	4 (3–5)	4 (3–5)
Median difference (Nigerian–International)	0	−1	−1	0	+1	+1	−2	−1

CI = Courtyard Integration; ASV = Atrium/Stack Ventilation; VI = Vegetation Integration; SS = Shading Strategy; CV = Cross Ventilation; DS = Daylighting Strategy; FEC = Façade Environmental Control. Values in group rows are median (range).
Source: Author's construct (2026).

The individual Nigerian cases show substantial internal variation. Bingham University Library has a case median of 2 (range 1–3), Modibbo Adama University Library has a median of 4 (range 1–5), and FUTMINNA Library has a median of 3 (range 2–5). This variation is analytically important: the Nigerian group cannot be treated as a uniformly underperforming category. FUTMINNA, for example, records the maximum score for courtyard integration (5), while Bingham records 1; Modibbo Adama records 5 for daylighting, while Bingham records 3.



Source: Author's construct (2026).

Figure 3: Comparative Gap Analysis

Figure 3 compares the median PEP scores of the Nigerian and international groups across the seven categories. It highlights where the Nigerian cases show relative strengths and where the benchmark cases provide stronger precedents.

The median comparison indicates the largest Nigerian disadvantages in façade environmental control (median difference −2), vegetation integration (−1) and atrium/stack ventilation (−1). The Nigerian group is stronger in cross ventilation (+1) and daylighting (+1), while courtyard integration and shading have equal group medians. These differences should be read as patterns in the assessed architectural evidence, not as measured performance gaps.

4.1 Category patterns

Façade environmental control is the clearest area for improvement: the Nigerian median is 2 (range 1–4), compared with 4 (range 3–5) internationally. Vegetation integration shows a Nigerian median of 3 (range 2–3), compared with 4 (range 3–5). Atrium/stack ventilation records medians of 2 and 3 respectively. Conversely, Nigerian cross ventilation and daylighting medians are 4 and 5, compared with 3 and 4 internationally. The category ranges also demonstrate that good regional practice exists, particularly in ventilation and daylighting. The evidence therefore points to selective weaknesses in integration rather than a general absence of passive strategies.

5 DISCUSSION

The assessment indicates a difference in the pattern of passive and biophilic integration between the Nigerian and international cases, but the evidence does not justify describing this as a statistically significant performance gap. The more useful finding is the configuration of strengths and weaknesses within the Nigerian cases. Their median is strongest in daylighting and cross ventilation, whereas façade control, atrium/stack ventilation and vegetation show more limited integration. This pattern is consistent with Nigerian studies that identify useful passive features alongside gaps in shading, ventilation integration and vegetation (Ayoosu et al., 2020; Akinola & Amadhe, 2026; Kalu et al., 2025).

The variation among Nigerian cases is particularly important. FUTMINNA's courtyard score of 5 suggests that courtyard-based spatial organisation can be a viable local strategy, while Bingham's score of 1 demonstrates that the presence of the library typology alone does not guarantee such integration. Modibbo Adama's high daylighting, shading and façade scores also indicate that stronger environmental integration is possible within Nigerian institutional settings. Rather than treating international benchmarks as models to copy, these differences suggest that Nigerian design practice already contains transferable strengths that can be combined with selected international envelope and landscape strategies.

The façade finding has the clearest design implication. A façade that admits daylight and air without sufficient solar control can compromise thermal performance; conversely, aggressive shading can reduce useful daylight if it is not calibrated to orientation and opening geometry. The literature on passive design therefore supports an integrated approach in which shading, window placement, façade materials and ventilation openings are designed together (Musa et al., 2024; Kolani et al., 2023).

Vegetation should likewise be treated as an environmental component rather than decoration. Courtyard planting, shade trees and landscape surfaces can alter local microclimate, provide visual connection to nature and support outdoor comfort. Han et al. (2023) demonstrate that courtyard surface and landscape configuration can influence microclimatic conditions, while biophilic design research emphasises the value of meaningful contact with natural elements (Tekin et al., 2023; Yin et al., 2023).

The atrium/stack finding adds a second layer to the ventilation argument. Cross ventilation is a relative strength in the Nigerian cases, but atrium/stack ventilation is weaker. This suggests an opportunity to combine horizontally driven airflow with vertical buoyancy-driven exhaust, especially in deeper multi-storey libraries. Moosavi et al. (2015) similarly identify the combined action of cross ventilation and stack effect as a productive passive-cooling configuration in tropical settings.

Taken together, the results support a specific conceptual contribution: Nigerian institutional libraries can be evaluated and designed through an integration sequence rather than through isolated strategy checklists. The proposed sequence is (1) control solar heat at the façade, (2) use shaded courtyards and vegetation to moderate the immediate microclimate, (3) connect courtyards and occupied spaces to cross-ventilation paths, (4) use atria or stack elements to support vertical exhaust where building depth requires them, and (5) protect daylight quality while controlling glare and solar gain. This sequence converts the observed gaps into an actionable design matrix for institutional library briefs.

Table 2: Proposed integrated design matrix for Nigerian institutional libraries

Priority gap	Integrated design response	Library-specific application	Performance check
Façade control + shading	External shading + controlled openings + solar-responsive envelope	Shade reading areas, control east/west exposure, coordinate WWR with daylight needs	Check solar exposure, glare, indoor temperature and user comfort
Vegetation + courtyard	Landscape as microclimate infrastructure	Use shade trees, planted courtyards and permeable/low-heat surfaces around reading and circulation spaces	Review shade coverage, outdoor comfort and vegetation condition
Cross + stack ventilation	Horizontal airflow linked to vertical exhaust	Provide low-level inlets, high-level outlets and atrium/stack zones where building depth limits crossflow	Verify airflow paths, operability and post-occupancy comfort
Daylight + solar control	Useful daylight without excessive heat/glare	Prioritise shaded daylight openings and deeper light distribution to reading spaces	Assess daylight quality, glare and reliance on artificial lighting
Brief + post-occupancy feedback	Performance criteria embedded from design to operation	Include passive-design requirements in library briefs and evaluate completed buildings	Compare intended strategies with observed operation

Source: Author's synthesis from the comparative assessment and reviewed literature (2026).

6 CONCLUSION

This study examined six institutional library precedents to understand how passive cooling and biophilic strategies are integrated. The findings indicate that the Nigerian cases demonstrate notable strengths, particularly in daylighting and cross ventilation, but show more limited integration of façade environmental control, vegetation, and atrium/stack ventilation. The findings also show that the level of integration varies across the Nigerian cases.

The study does not suggest that Nigerian libraries should simply follow international models. Instead, it shows that local libraries already have valuable strengths, while international precedents offer useful lessons on how complementary strategies can be better coordinated and sequenced. The main contribution of the study is therefore a framework and integrated design matrix for coordinating passive cooling and biophilic strategies in Nigerian institutional libraries, providing practical guidance for future library design and evaluation.

RECOMMENDATIONS

Based on the comparative evidence, the following library-specific recommendations are proposed:

- Institutional library briefs should specify coordinated requirements for external shading, façade solar control, daylight access and natural ventilation rather than treating each as a separate item.
- Courtyards and vegetation should be planned as environmental infrastructure, using shade, planting and landscape surfaces to support microclimate moderation and meaningful contact with nature.
- Reading and study spaces should receive orientation-specific façade and shading responses, with particular attention to glare, solar heat gain and the relationship between window area and daylight quality.
- Where library depth or multi-storey configuration limits cross ventilation, courtyards should be connected to atrium or stack-assisted ventilation paths to support vertical air movement.
- Institutional clients should require post-occupancy review of passive strategies so that actual operation can inform subsequent library projects, specifications and maintenance decisions.

The PEP is best viewed as a diagnostic tool for assessing and comparing architectural precedents, rather than as a replacement for actual environmental measurements. Its main strength is that it helps make the extent to which different passive and biophilic strategies are integrated within a building more visible and easier to compare, particularly during the early stages of design and precedent selection. Future studies could improve the strength of the approach by involving an independent second assessor, testing inter-rater reliability, and, where feasible, complementing the assessment with measured or simulated environmental performance data.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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