

# Evaluation of Green Architectural Elements in Enhancing Thermal Comfort in Federal Polytechnic Library, Nasarawa State, Nigeria

Hassan Aliyu Ahmed

Corresponding Email: [aliyuhassanahmed93@gmail.com](mailto:aliyuhassanahmed93@gmail.com)

Aliyu Hassan Ahmed<sup>1</sup>,

[Aliyuhassanahmed93@gmail.com](mailto:Aliyuhassanahmed93@gmail.com)

Williams Amanyi Idakwoji<sup>2</sup>,

[idakwoji.williams@binghamuni.edu.ng](mailto:idakwoji.williams@binghamuni.edu.ng)

Beatrice Chapi Owoicho<sup>3</sup>

The Department of Architecture,  
Faculty of Architecture

<https://doi.org/10.56201/ijgem.vol.12.no10.2026.pg84.93>

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## Abstract

*This study evaluates the efficacy of green architectural elements in enhancing thermal comfort within the main library of the Federal Polytechnic Nasarawa. Situated in a Tropical Savannah climate, the conventional library building functions as a thermal "heat trap," exposing occupants to severe indoor thermal stress, visual glare, and poor air quality that directly impair academic productivity. Utilizing a mixed-methods explanatory sequential design, data was gathered through physical site assessments and structured questionnaires administered to a validated sample of 312 students and 8 library facility managers. The empirical findings reveal that 56.40% of users occupy the facility during peak solar heat gain hours (12:00 PM to 3:59 PM), with excessive heat and glare driving high rates of cognitive fatigue and premature study session abandonment. Furthermore, staff evaluations confirm that heavy reliance on mechanical HVAC systems is operationally unsustainable due to chronic national grid failures and exorbitant generator maintenance costs. In response, both students and management demonstrate overwhelming receptiveness to passive design interventions. The study concludes that integrating bioclimatic strategies (such as optimal East-West orientation, passive cross-ventilation, brise-soleil shading, and biophilic elements) is essential to achieving "passive survivability", stabilize indoor temperatures within the ASHRAE 23°C to 26°C comfort band, and restore the library as a functional academic sanctuary.*

**Keywords:** *Users' Evaluation, Green Architecture, Thermal Comfort, Indoor Environmental Quality (IEQ), Tropical Savannah Climate, Passive Survivability.*

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## 1.0 Introduction

Contemporary academic libraries have evolved into demanding learning environments that require prolonged periods of cognitive engagement (Qiao, 2026). However, the operational success of these facilities is strictly dictated by their indoor environmental quality. When

structural designs fail to mitigate thermal discomfort, visual glare, and poor air quality, they actively degrade occupant well-being, fracture concentration, and ultimately drive students away from the space (Aflaki et al., 2023; Zhang, 2019).

Historically, Nigerian tertiary institutions constructed library facilities using conventional, imported architectural blueprints that completely ignored local climatic realities (Ihunwo & Ezinwo, 2025). These structures rely heavily on concrete envelopes and poor natural ventilation pathways, which creates a dangerous operational dependence on mechanical cooling systems (Ihunwo & Ezinwo, 2025; Maduabum et al., 2026).

This architectural crisis peaks within the Tropical Savannah climatic zone of North-Central Nigeria, home to Federal Polytechnic Nasarawa. Here, extreme daytime temperatures and intense solar radiation turn conventional concrete buildings into thermal reservoirs (Maduabum et al., 2026). By trapping heat, these structures inflict severe thermal stress on students, rapidly degrading cognitive endurance, executive function, and memory retention. To survive these harsh indoor conditions, institutions are forced to rely on mechanical cooling. However, chronic national grid instability and the crippling financial burden of diesel backup generators render this HVAC dependency entirely unsustainable, leaving students repeatedly exposed to the extremes of the microclimate (Omeiza et al., 2022).

Green architecture provides the critical structural framework required to neutralize these localized climatic threats. Green architectural principles emphasize the efficient use of resources, reduction of environmental impacts, optimization of indoor environmental quality, and integration of buildings with their surrounding ecological context (Bhandari, 2025). Within hot-climate regions, passive bioclimatic strategies such as appropriate building orientation, solar shading, natural ventilation, and thermal mass management, have demonstrated considerable potential for improving thermal comfort while minimizing dependence on mechanical systems (Givoni, 1992; Olgyay, 1963). Similarly, biophilic design interventions that strengthen connections between occupants and nature have been empirically associated with improved psychological well-being, reduced stress levels, and enhanced cognitive performance (R. Kaplan & Kaplan, 1989; Peters & D’Penna, 2020).

Although substantial literature exists on sustainable architecture and thermal comfort, significant knowledge gaps remain regarding the application of green architectural strategies within tertiary institutions in Nigeria. Existing studies have predominantly focused on residential or commercial developments, with limited attention given to the unique operational requirements of academic libraries (Geng et al., 2019). Furthermore, there remains insufficient empirical evidence examining the specific barriers to green building delivery and users' perceptions of thermal conditions in these educational facilities (Agboola et al., 2024).

This study therefore evaluates users' perceptions of green architectural elements for enhancing thermal comfort in the proposed design of a library for Federal Polytechnic Nasarawa. Specifically, the research examines the extent of thermal discomfort experienced by users of the existing library facility, identifies suitable green architectural interventions for improving thermal conditions, assesses the suitability of selected thermal design elements in addressing local climatic challenges, and develops a climate-responsive architectural framework capable of supporting sustainable and comfortable learning environments. By providing empirical evidence from a tertiary institution located within the Tropical Savannah climatic zone, the study contributes to the growing discourse on sustainable educational infrastructure and offers practical design guidance for future academic library developments in similar contexts.

## 1.2 Aim and Objectives of the Study

### Aim

The aim of the study is to investigate the influence of green architectural elements on enhancing thermal comfort in the Federal Polytechnic Library, Nasarawa State, Nigeria.

### Objectives

To address the established gaps the objectives are:

1. To assess the extent to which the existing thermal comfort conditions in the Federal Polytechnic Library, Nasarawa State, affect users' cognitive endurance and study duration.
2. To determine the influence of specific green architectural elements on the thermal comfort and academic performance of library users.
3. To evaluate the operational and energy implications of adopting green architectural elements as an alternative to the library's existing mechanical cooling system.

## 2.0 Review of Related Literature

### 2.1 Introduction

The architectural performance of academic libraries in Nigeria is inextricably linked to the localized meteorological realities of their environments. The Tropical Savannah (Aw) climatic zone of North-Central Nigeria is characterized by severe daytime temperatures, intense solar radiation, and a seasonal Harmattan dust regime that collectively shape thermal comfort, ecological dynamics, and atmospheric processes across the region (Muhammed et al., 2024). Historically, many institutional libraries and educational buildings in Nigeria's tropical savannah region have been constructed using standardized design templates and sandcrete block wall systems. While economical and widely available, sandcrete envelopes possess considerable thermal mass and often contribute to heat storage and subsequent heat release into indoor spaces, resulting in elevated indoor temperatures and reduced thermal comfort (Muhammed et al., 2024). Conventional institutional buildings in Nigeria are frequently constructed with sandcrete wall systems that absorb and store heat during the day before releasing it into interior spaces, thereby increasing indoor temperatures and reducing thermal comfort. This thermal burden often necessitates greater reliance on mechanical cooling systems, particularly in the tropical savanna regions where high ambient temperatures prevail (Muhammed et al., 2024; Xi et al., 2025). Consequently, there is an urgent need to evaluate and integrate environmentally responsive architectural frameworks to resolve these infrastructural deficits.

### 2.2 Theoretical Backing

To comprehensively address the dual challenges of environmental sustainability and user well-being, this study is grounded in the synthesis of Bioclimatic Architecture Theory and Attention Restoration Theory (ART). Pioneered by (Olgyay, 1963) and mathematically refined by (Givoni, 1992), Bioclimatic Architecture Theory posits that the built environment must be designed as a direct, site-specific response to regional climatic conditions. It argues against energy-intensive, standardized mechanical cooling, proposing instead that the building envelope should act as a permeable filter that naturally mitigates thermal stress based on localized meteorological data (Almusaed, 2011).

While bioclimatic theory addresses the physical building envelope, Attention Restoration Theory (ART) addresses the psychological requirements of library users. Developed by (R. Kaplan & Kaplan, 1989), ART asserts that human beings possess a limited capacity for "directed attention," which is heavily taxed during rigorous academic tasks. Prolonged periods of directed attention in stressful or uncomfortable environments rapidly induce cognitive

fatigue(S. Kaplan, 1995). ART suggests that integrating "restorative environments" (specifically natural, biophilic elements) captures involuntary attention, allowing the brain's directed attention mechanisms to rest and recover, thereby sustaining academic stamina (Ayinla & Sunday, 2025).

### **2.3 Green Architecture**

Green architecture in the context of institutional design represents a paradigm shift from buildings as static resource consumers to dynamic, climate-responsive systems (Cole, 2012). For developing nations with unstable energy infrastructure, literature emphasizes "passive survivability" the ability of a building to remain habitable and functional during extended grid failures (Wilson, 2005). Achieving this in a Savannah microclimate relies on three primary passive bioclimatic strategies. First, optimal spatial orientation along the East-West axis minimizes the exposure of long facades to intense morning and afternoon solar radiation (Givoni, 1998). Second, the deployment of solar shading and envelope design, such as deep roof overhangs and brise-soleil (louvers), intercepts direct solar heat gain before it penetrates the building envelope (Datta, 2001). Finally, passive natural cross-ventilation relies on strategic spatial layouts and operable windows to capture prevailing winds, creating a pressure differential that effectively flushes residual hot air out of the building (Linden, 1999).

### **2.4 Thermal Comfort**

In architectural science, user comfort is a quantifiable physiological state. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) defines comfort as a condition of mind expressing satisfaction with the thermal environment. Human cognitive function is optimized within a narrow temperature band, typically between 23°C and 26°C (Aflaki et al., 2023). When conventional library designs cause indoor temperatures to exceed this threshold, the human body expends significant metabolic energy attempting to thermoregulate, which directly induces lethargy and thermal fatigue.

Furthermore, true environmental comfort in an academic setting requires the optimization of visual and acoustic conditions. Unprotected glazing introduces harsh solar glare that washes out digital screens and causes severe eye strain (Osterhaus, 2005). Concurrently, heavy reliance on noisy mechanical generators and the use of highly reflective interior finishes create acoustic reverberations that shatter concentration (Ana et al., 2009; Cucharero et al., 2019). Green architectural interventions, such as external light diffusion and the integration of porous acoustic materials, are necessary to stabilize these environmental variables.

### **2.5 Academic Enhancement of Users**

The primary function of an academic library is to support teaching, learning, and knowledge acquisition. Studies have shown that indoor environmental quality—including thermal comfort, air quality, lighting, and acoustics—has a significant influence on occupants' concentration, cognitive performance, mental fatigue, and overall learning outcomes(A. A. Lawal et al., 2025; Al Horr et al., 2016). When students are subjected to severe heat, visual glare, and sterile architecture often termed "sick building syndrome", they experience rapid cognitive depletion, leading to high abandonment rates where users prematurely leave the library to seek cooler informal spaces. Conversely, empirical post-occupancy evaluations demonstrate that optimizing thermal, visual, and acoustic comfort directly enhances academic productivity. Research has demonstrated that biophilic design interventions, including indoor vegetation and living-wall installations, can reduce physiological stress responses and enhance psychological restoration during cognitively demanding activities. Such environments have also been associated with improved attentional performance and more favorable conditions for

learning and knowledge retention(Serra et al., 2025; Xing et al., 2025). Therefore, the physical architecture of the library ceases to be merely a shelter; it transforms into an active pedagogical tool that directly dictates and enhances the academic output of the student population.

## 2.6 Knowledge Gaps and Conceptual Framework

While global research has consistently demonstrated the effectiveness of passive cooling and sustainable design strategies in improving thermal comfort and reducing building energy demand, empirical investigations within Nigerian tertiary institutions remain limited, particularly in the tropical savannah climate zone (Xi et al., 2025). Existing studies have largely focused on classrooms and general educational buildings, with relatively little attention given to the environmental performance of large academic library spaces. Furthermore, assessments of Nigerian university libraries have revealed deficiencies in thermal comfort and overall indoor environmental quality, highlighting the need for context-specific interventions and further research within library environments (Akanmu et al., 2021). Consequently, this study addresses this gap by evaluating users' perceptions of thermal comfort conditions within university libraries and proposing practical architectural strategies for improving indoor environmental quality in public tertiary institutions

## 3.0 Methodology

### 3.1 Research Design and Case Study Area

This study adopted a single-case study research design within an explanatory sequential mixed-methods framework. This approach enabled an in-depth, localized assessment of the physical environment alongside the subjective experiences of its users. The geographical locus was the Federal Polytechnic Nasarawa Main Library, situated in the Tropical Savannah climate (Köppen classification Aw) of North-Central Nigeria. This location is characterized by extreme daytime temperatures frequently exceeding 34°C, intense direct solar radiation, and a prolonged dry season dominated by dust-laden Harmattan winds, providing an optimal testing ground for passive bioclimatic evaluation.

**3.2 Population and Sampling Technique** The target population comprised the individuals directly interacting with and managing the facility, totaling approximately 10,000 students according to the school website. To determine a statistically valid quantitative sample for the student population, the Taro Yamane formula was applied:

$$n = \frac{N}{1 + N(e)^2}$$

Where

n represents the sample size,  
N is the total population, and  
e is the margin of error at 0.05.

This calculation yielded a required sample size of 385 respondents. A stratified random sampling technique was utilized to administer the surveys across different academic faculties to ensure a diverse cross-section of library users.

Concurrently, a purposive sampling technique was employed to select a qualitative sub-sample of 8 institutional staff (comprising library administrators and facility maintenance managers) who possessed direct knowledge of operational constraints and energy expenditures.

### 3.3 Data Collection and Analysis

Data collection was executed in three stages: physical site reconnaissance (recording ambient temperature and daylight metrics), the administration of structured 5-point Likert scale

questionnaires to students, and face-to-face key informant interviews with the selected staff. Out of the 385 distributed questionnaires, 312 valid student responses were retrieved and processed. Quantitative data was analyzed using descriptive statistics (frequencies and percentages), while qualitative observational and interview data were analyzed thematically to identify patterns of infrastructural decay and energy dependency.

## 4.0 Results and Discussion

### 4.1 Library Usage Patterns and Environmental Exposure

To contextualize the users' thermal experiences, it is critical to understand when and for how long the facility is utilized.

The demographic distribution of the 312 valid student respondents ensured broad institutional representation, with the highest participation from the School of Applied Sciences (33.33%) and Environmental Studies (30.77%). Crucially, the data revealed a severe misalignment between user behavior and the building's environmental performance. The majority of respondents (56.40%) utilize the library during the afternoon hours (12:00 PM to 3:59 PM), which directly coincides with the region's peak solar heat gain period. During these hours, an overwhelming majority (69.20%) of users are forced to sit wherever space is available, regardless of proximity to glare-inducing windows or poorly ventilated interior zones, exposing them to the harshest climatic conditions while attempting to study.

**Table 1: Primary Time of Library Use**

| S/N          | Time of Day                       | Number of Respondents | Percentage (%) |
|--------------|-----------------------------------|-----------------------|----------------|
| 1            | Morning (8:00 AM to 11:59 AM)     | 72                    | 23.10%         |
| 2            | Afternoon (12:00 PM to 3:59 PM)   | 176                   | 56.40%         |
| 3            | Evening (4:00 PM to Closing time) | 64                    | 20.50%         |
| <b>Total</b> |                                   | <b>312</b>            | <b>100%</b>    |

*Analysis:* As demonstrated in Table 1, the majority of respondents (56.40%) utilize the library during the afternoon hours. This directly coincides with the region's peak solar heat gain period, meaning the bulk of the student body is exposed to the harshest interior climatic conditions while attempting to study.

**4.2 Objective 1: The Impact of Thermal Stress on Cognitive Endurance** The empirical assessment of the existing Indoor Environmental Quality (IEQ) confirmed the presence of a severe "heat trap" phenomenon.

**Table 2: Academic Impact and Cognitive Fatigue Feedback**

| S/N | Statement (Academic Impact)                                                                            | SD<br>(1) | D<br>(2) | N<br>(3) | A<br>(4) | SA<br>(5) |
|-----|--------------------------------------------------------------------------------------------------------|-----------|----------|----------|----------|-----------|
| 1   | The excessive heat inside the library causes me to feel tired and lose concentration quickly.          | 40        | 64       | 40       | 128      | 40        |
| 2   | I frequently leave the library earlier than planned because the physical environment is uncomfortable. | 48        | 80       | 40       | 136      | 8         |
| 3   | I prefer studying in alternative, informal spaces (like under trees) because they are cooler.          | 24        | 96       | 40       | 96       | 56        |

*Analysis:* The data unequivocally links physical discomfort to a decline in academic performance. A dominant 168 respondents (combining Agree and Strongly Agree) reported that excessive indoor heat causes rapid cognitive fatigue. Consequently, 144 students admitted to frequently abandoning the library earlier than planned, and 152 users explicitly stated a

preference for studying in alternative, informal spaces simply because they offer cooler environments than the purpose-built academic facility.

### 4.3 Objective 2: Receptiveness to Green Architectural Interventions

To evaluate potential solutions, students were surveyed on their receptiveness to specific sustainable design alternatives.

**Table 3: User Evaluation of Proposed Green Solutions**

| S/n | Statement (Proposed Solutions)                                                                               | SD<br>(1) | D<br>(2) | N<br>(3) | A<br>(4) | SA<br>(5) |
|-----|--------------------------------------------------------------------------------------------------------------|-----------|----------|----------|----------|-----------|
| 1   | I would study longer if the library relied on natural, cooling breezes rather than failing air conditioners. | 56        | 64       | 24       | 128      | 40        |
| 2   | The use of external window shades would improve my reading experience by reducing glare.                     | 32        | 64       | 32       | 128      | 56        |
| 3   | The inclusion of indoor plants and natural views (biophilic design) would help reduce my study stress.       | 48        | 64       | 24       | 168      | 8         |

*Analysis:* There is overwhelming empirical support for the integration of green architectural elements. For passive cooling, 168 students agreed they would study longer if the library utilized natural breezes. Furthermore, 184 respondents affirmed that external window shades (brise-soleil) would eliminate visual glare, and 176 users agreed that biophilic design integrations would actively restore attention and reduce study stress.

**4.4 Objective 3: Operational and Energy Barriers (Facility Management Perspective)** To address the final objective, the 8 surveyed facility managers and senior library staff evaluated the operational sustainability of the current mechanical infrastructure.

**Table 4: Staff Evaluation of Energy Demands and Viability (1 = Not Sustainable, 5 = Highly Sustainable)**

| S/N | Statement (Operational Challenges)                             | 1 | 2 | 3 | 4 | 5 |
|-----|----------------------------------------------------------------|---|---|---|---|---|
| 1   | Daily energy demands regarding artificial cooling and lighting | 4 | - | 2 | - | 2 |
| 2   | Financial/maintenance burden of diesel generators              | - | 2 | 4 | 2 | - |
| 3   | Impact of reduced mechanical dependency on operational budget  | - | 2 | - | 4 | 2 |

*Analysis:* From a facility management perspective, the existing architecture is functionally and economically crippled by grid dependency. Half of the staff rated daily energy demands for artificial cooling as entirely unsustainable (Rating 1), heavily disrupting daily operations. However, management recognizes the economic imperative of sustainable alternatives; 75% of the staff (6 respondents rating 4 or 5) agreed that achieving "passive survivability" by drastically reducing mechanical HVAC dependency would highly benefit the institution's long-term operational budget.

## 5.0 Conclusion and Recommendations

### 5.1 Conclusion

This study set out to evaluate users' perceptions of thermal comfort and the receptiveness of both students and facility management to green architectural interventions at the Federal Polytechnic Nasarawa Main Library. The findings confirm that the existing library functions as a thermal "heat trap," with the majority of users (56.40%) occupying the facility during peak solar heat gain hours and reporting measurable declines in concentration, study duration, and preference for informal outdoor spaces as a direct consequence. These outcomes validate the

study's grounding in Attention Restoration Theory (R. Kaplan & Kaplan, 1989): when the physical environment imposes additional thermal and visual stress on users, it depletes the directed attention required for academic work rather than supporting it.

At the same time, the results demonstrate strong convergence between user experience and architectural theory. Students expressed overwhelming receptiveness to passive cooling, solar shading, and biophilic interventions, while facility managers independently corroborated that continued reliance on mechanical HVAC is both operationally unsustainable and financially unviable given chronic grid instability. This alignment between occupant preference, staff operational concerns, and Bioclimatic Architecture Theory (Olgyay, 1963; Givoni, 1992) suggests that passive design is not merely a theoretical ideal but a practical necessity for tertiary institution libraries within the Tropical Savannah climatic zone.

The study therefore concludes that achieving "passive survivability" (Wilson, 2005) in the proposed library design is both technically achievable and institutionally desired. Reorienting the building along the East-West axis, integrating brise-soleil shading and deep roof overhangs, enabling cross-ventilation, and incorporating biophilic elements would collectively address the thermal, visual, and psychological deficiencies identified across all three research objectives, while reducing the institution's dependence on an unreliable and costly mechanical cooling infrastructure.

## 5.2 Recommendations

Based on these findings, the following recommendations are proposed:

1. **Building orientation:** The proposed library design should adopt an East-West long-axis orientation to minimize direct solar exposure on the largest façades during peak heat gain hours (12:00 PM–3:59 PM), when the majority of users are present.
2. **Solar shading:** Brise-soleil louvers and deep roof overhangs should be incorporated on exposed façades to intercept direct solar radiation before it penetrates the building envelope, directly addressing the glare and discomfort reported by users.
3. **Passive ventilation:** Operable windows and strategic spatial layouts should be designed to capture prevailing winds and enable cross-ventilation, reducing reliance on mechanical cooling in line with facility managers' operational concerns.
4. **Biophilic integration:** Indoor vegetation, living walls, or views to natural elements should be incorporated into reading areas to support attention restoration and reduce study-related stress, consistent with user demand identified in this study.
5. **Phased reduction of mechanical dependency:** Given that facility managers rated current HVAC-related energy demands as largely unsustainable, the institution should pursue a phased transition that prioritizes passive strategies first, retaining mechanical cooling only as a supplementary system for extreme conditions.
6. **Further research:** Future studies should extend this evaluation through post-occupancy assessment once passive interventions are implemented, and should include instrument reliability testing (e.g., Cronbach's alpha) to strengthen the empirical basis of similar user-perception surveys in other Nigerian tertiary institutions.

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