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EVALUATION OF PASSIVE COOLING STRATEGIES USED IN SELECTED UNIVERSITY SENATE BUILDINGS IN TROPICAL SAVANNAH CLIMATE OF NIGERIA

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ABSTRACT

Purpose: *In Nigeria's tropical savannah climate marked by high temperatures and intense solar radiation university senate buildings struggle to maintain thermal comfort without excessive energy consumption. This study evaluates how passive cooling strategies contribute to energy efficiency and comfort in selected senate buildings. The aim is to assess the effectiveness of passive cooling applications in Ahmadu Bello University (Zaria), University of Abuja, and Federal University of Agriculture Makurdi.*

Design/methodology/approach: *A qualitative case study approach was adopted. Data were collected through on-site observations, architectural plan reviews, and cooling audits. Assessment focused on three passive cooling categories: heat prevention (orientation, shading, landscaping, reflective colors), heat modulation (insulation and thermal mass), and heat dissipation (natural ventilation). Each building's performance was scored based on observed design features and cooling strategies integrated into their architectural layouts.*

Findings: *Results reveal varying levels of passive cooling effectiveness across the buildings. ABU's eight-story senate building performed strongly in shading (21/30) and ventilation (9/10) aided by courtyards, recesses, and airflow channels. UNIAB's three-story bisected courtyard design achieved balanced performance in orientation (7/10) and insulation (10/15). FUAM's semi-circular senate building showed strength in landscaping (19/25) but scored low in orientation (4/10) and reflective color use (10/20) due to its circular form and warm-toned external finishes. Overall, the study found inconsistent application of passive cooling strategies, with weaknesses in orientation and reflective surfaces reducing overall cooling efficiency.*

Research limitations/Implications: *The study is limited to three case buildings within Nigeria's tropical savannah region, which may affect broader generalization. Performance scores were based on qualitative assessments and visual audits rather than long-term thermal measurements.*

Practical implications: *The findings emphasize the need for integrated, climate-responsive design approaches in institutional buildings. Improved alignment of building orientation, wider use of reflective materials, enhanced insulation, and optimized natural ventilation can significantly reduce reliance on mechanical cooling systems. These improvements can lower operational costs, reduce energy consumption, and enhance occupant comfort in university environments.*

Originality/value: *This study provides actionable insights into the effectiveness of passive cooling strategies in Nigerian university senate buildings, an area with limited empirical documentation. It demonstrates how building form, material choices, and spatial layout interact to influence thermal performance in a tropical savannah climate.*

Keywords: Passive Cooling, Thermal Comfort, Energy Efficiency, Tropical Savannah Climate, University Senate Buildings

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1.0 INTRODUCTION

In Nigeria’s tropical savannah climate, characterized by high temperatures, intense solar radiation, and seasonal humidity fluctuations, institutional buildings like university senate structures face challenges in maintaining thermal comfort while minimizing energy consumption (Mustapha et al., 2022). The reliance on mechanical cooling systems, worsened by unreliable electricity supply, leads to high operational costs and environmental impacts (Ibitoye et al., 2022). Passive cooling strategies, such as natural ventilation, shading, thermal mass, and optimal building orientation, offer sustainable solutions by reducing cooling loads without active energy inputs (Khosla et al., 2021). These strategies align with traditional Nigerian architectural practices, such as courtyards and high thermal mass materials, which have historically mitigated heat gain effectively (Oludare et al., 2021).

This study evaluates the application of passive cooling strategies in selected university senate buildings within Nigeria’s tropical savannah climate, specifically at Ahmadu Bello University (Zaria), University of Abuja, and Federal University of Agriculture (Makurdi). Focusing on strategies like orientation, shading devices, landscaping, reflective surfaces, insulation, thermal mass, and natural ventilation, the research examines their implementation and effectiveness in enhancing indoor comfort and energy efficiency. By analyzing case studies, the study identifies gaps in current practices and highlights opportunities for context-specific adaptations to inform energy-efficient institutional building designs in similar climatic regions.

2.0 LITERATURE REVIEW

Passive cooling strategies are critical for energy-efficient building design in tropical savannah climates, leveraging natural ventilation, shading, and thermal mass to reduce cooling loads (Santamouris & Kolokotsa, 2023). Studies highlight that proper building orientation and shading devices, such as overhangs and vegetation, can reduce indoor temperatures by up to 6°C (Kamal, 2022). High thermal mass materials, like concrete and brick, stabilize indoor environments, while reflective surfaces and landscaping further mitigate heat gain (Mandal et al., 2020; Prieto et al., 2021). Research emphasizes integrating these strategies with local climatic conditions to enhance thermal comfort and sustainability in Nigerian institutional buildings (Daramola et al., 2021).

The escalating energy demands and environmental challenges in Nigeria’s tropical savannah climate underscore the need for sustainable building solutions, particularly in institutional structures like university senate buildings. High reliance on mechanical cooling systems increases operational costs and greenhouse gas emissions, exacerbating climate change impacts (Mustapha et al., 2022). This study is significant as it evaluates passive cooling strategies to enhance energy efficiency and thermal comfort, addressing gaps in their practical application within Nigeria’s context. By analyzing case studies, it provides actionable insights for architects, builders, and policymakers to promote sustainable design practices. The aim is to evaluate passive cooling strategies used in selected university senate buildings in Nigeria’s tropical savannah climate, with the objective to assess their application and effectiveness in reducing cooling loads, ultimately informing sustainable architectural practices with reduced environmental impact

3.0 METHODOLOGY

This study adopts a qualitative case study approach to evaluate passive cooling strategies in three university senate buildings: Ahmadu Bello University (ABU, Zaria), University of Abuja (UNIAB), and Federal University of Agriculture (FUAM, Makurdi). Data were collected through on-site observations, architectural plan reviews, and cooling audits, focusing on the implementation of heat prevention (orientation, shading, landscaping, reflective colors), heat modulation (insulation, thermal mass), and heat dissipation (natural ventilation) strategies. This approach aligns with qualitative research principles for in-depth contextual analysis of architectural designs (Rashid et al., 2019). The assessment utilized a scoring system to rate the presence and effectiveness of these strategies (e.g., 0–10 or 0–30 scales) based on design features observed in each building, a method supported for evaluating architectural interventions (Oluigbo, 2011). Comparative analysis across the case studies identified the extent of strategy application and areas for improvement, ensuring context-specific insights for Nigeria's tropical savannah climate (Olotuah, 2015).

4.0 PRESENTATION AND DISCUSSION OF RESULTS

CASE STUDY I: Ahmadu Bello University Zaria

Ahmadu Bello University's Senate building, constructed in the 1980s, is an eight-story structure with an integrated podium and tower, centrally located on the Samaru campus, south of the Kashim Ibrahim Library and east of Convocation Square. As the campus's most prominent building, it is accessible from the main gate. The square-shaped building features recesses for shading, single-banked corridors for enhanced ventilation, and a double-volume reception lobby with staircases and three lifts for efficient traffic flow. Natural ventilation is facilitated by strategically placed larger windows and stack ventilation at the ground floor and the second-floor senate chamber. A courtyard extends from the third to eighth floors, promoting air circulation for cooling. Outdoor vegetation further aids in transferring cooler air into the building, enhancing thermal comfort through passive cooling strategies tailored to the tropical savannah climate.

Plate I: Building with shading devices Source: Author's fieldwork (2025).

Table 1: Passive Cooling Strategies for Senate Building Ahmadu Bello University Zaria

Passive Cooling Strategy	Passive Cooling Strategy	Requirement	Level Of Reflection	Remark
Heat prevention strategy	*orientation*	-Shorter part of the building should be exposed to the sun. -Design of narrow building forms with longer walls to take advantage of prevailing winds	3 3	The floor plan is square in shape and all axis are the same scores 6/10
	shading	-use of vertical and horizontal shading devices on east and west façade -use of horizontal shading device on south façade -use of vertical shading along north façade -use of long overhang along sun path	5 5 5 3	Vertical and horizontal shading devices were used at all sides of the building. Recesses and overhangs were used along sun path. The buildin g scores 21/30
		-use of balconies and window recesses -use of building mass to produce shadow/shade	3 3	

	landscape	-extensive use of landscape in the environment -use of shrubs or other plantings to shade paved areas -use of tall trees to provide shade for the building against direct solar heat gain -use of grasses as ground cover to improve evaporation -use of soft landscape in courtyards	4 3 1 1 3	Hard and soft landscape was used such as grasses, shrubs, trees, walkways and vehicular roads. The building scores 14/30
	Use of light color on external surfaces	-use of lighter colors on external walls -use of light-colored roofing materials -use of lightcolored surfaces on shading devices -use of light-color surface finishes on walkways, driveways and other landscape elements	4 3 4 3	light was used on the building façade The building scores 14/20
Heat modulation strategies	*insulation*	-provide roof ventilation -provide ceilings in all offices to insulate from the heat generated inside roof space -use of	3 3 2	No adequate roof ventilation system Ceiling was used at the last floor for insulation The building scores 8/15

		wall tiles on the external surfaces to		
		maximize wall insulation		
	Thermal mass	-compact planning of buildings to minimize heat gain -use of building materials with high thermal mass for construction of external walls on east and west façades	2 5	the building was compactly designed to reduce heat gain no special thermal mass insulation system was employed the building scores 7/10
Heat dissipation strategies	*Natural ventilation*	-Use of windows with maximum open area for ventilation -positioning of windows for cross ventilation	4 5	The windows were strategically placed to take advantage of the prevailing and cross ventilation The building scores 9/10
	Natural cooling	-use of larger openings along south facade -use of water bodies in courtyard to provide cool breezes	4 4	Large openings were used to utilize airflow from courtyard The building scores 8/10

Key: very low =1, low=2, average= 3, high =4 and very high= 5 Source: Author's fieldwork (2025).

CASE STUDY II: University of Abuja (UNIAB) Senate Building

The Senate building at the University of Abuja's main campus, designed by ALAG Architects in 2005, is a three-story structure serving as the central administrative hub. It houses offices for staff, faculty representatives, student representatives, security, and chief administrative personnel. The senate chamber, located on the first floor with its roof extending to the third floor, is a key feature. The Vice Chancellor's office, deputy registrar's office, general office, VC's conference room, and supporting facilities occupy the third floor. A single lift, reserved for the Vice Chancellor and designated individuals, provides vertical movement. The building comprises four interconnected rectangular office blocks surrounding a central courtyard, with an additional rectangular block dividing the courtyard into two at a 45-degree angle, enhancing spatial organization and passive cooling through the courtyard design.

Plate II: Front view of the building with horizontal shading devices
Source: Author's fieldwork (2025).

Table 2: Passive Cooling Strategies for Senate Building University of Abuja

Passive cooling strategies	Passive cooling strategies	requirement	Level of reflection	remark
Heat prevention strategies	orientation	-shorter part of building should be exposed to the sun path -Design of narrow building form with longer walls taking advantage of prevailing winds	4 3	the longer part of the building faces, the North-side axis The building scores 7/10

	Shading	-use of vertical and horizontal shading devices on east and west façade -use of horizontal shading device on south façade -use of vertical shading along north façade	4 3 3 3	Horizontal shading devices were predominately used with less of vertical shading and hence increase heat gain The building form couldn't provide shading the building
		-use of long overhang along sun path -use of balconies and window recesses -use of building mass to produce shadow/shade	2 2	the building scores 17/30
	landscape	-extensive use of landscape in the environment -use of shrubs or other plantings to shade paved areas -use of tall trees to provide shade for the building against direct solar heat gain -use of grasses as ground cover to improve evaporation -use of soft landscape in courtyards	4 3 3 2 2	Hard and soft landscape were used such as grasses, shrubs, trees, walkways and vehicular roads. The building scores 14/25

	Use of light color on External surfaces	-use of lighter colors on external walls -use of light-colored roofing materials -use of light-colored surfaces on shading devices -use of light-color surface finishes on walkways, driveways and other landscape elements.	4 2 3 3	Light-color was used on the building façade; ash color also was used. The building scores 12/20
Heat modulation strategies	*insulation*	-provide roof ventilation -provide ceilings in all offices to insulate from the heat	3 4	No adequate roof ventilation system Ceiling was used at the last floor for insulation The building scores 10/15
		generated inside roof space -use of wall tiles on the external surfaces to maximize wall insulation	3	
	Thermal mass	-compact planning of buildings to minimize heat gain -use of building materials with high thermal mass for construction of external walls on east and west façades	3 4	the building was averagely compacted to reduce heat gain no special thermal mass insulation system was employed the building scores 7/10

Heat dissipation strategies	Natural ventilation	-Use of windows with maximum open area for ventilation -positioning of windows for cross ventilation	4 4	Large windows were used to maximize ventilation The building scores 8/10
	Natural cooling	-use of larger openings along south facade -use of water bodies in courtyard to provide cool breezes	4 3	Large openings were used to utilize airflow from courtyard The building scores 7/10

Key: very low =1, low=2, average= 3, high =4 and very high= 5
Source: Author's fieldwork (2025).

CASE STUDY III: Federal University of Agriculture, Makurdi (FUAM) Senate building.
The senate building is built to serve as the central administrative building in the university main campus. The building plan consists of two semi-circular office blocks of varying diameter. The site topography has high level difference between the two opposite semicircle plans and it was duly utilized as part of the architecture of the building. Due to difference in levels, the larger part of the semi-circle is a two-storey building while the smaller part is a one storey building. The building accommodates senate chamber, offices for staffs, governing council chamber, VC`s office and other facilities.

Plate III: The use of both vertical and horizontal shading
Source: Author's fieldwork (2025).

Table 3: Passive Cooling Strategies for Senate Building of Federal University of Agriculture, Makurdi (FUAM)

Passive cooling strategies	*Passive cooling strategies*	Requirement	Level of reflection	remark
Heat prevention strategies	*orientation*	-shorter part of building should be exposed to the sun path -Design of narrow building form with longer walls taking advantage of prevailing winds	2 2	the building is circular and most parts are exposed to the sun path the building scores 4/10
	Shading	-use of vertical and horizontal shading devices on east and west façade -use of horizontal shading device on south façade -use of vertical shading along north façade -use of long overhang along sun path -use of balconies and window recesses -use of building mass to produce shadow/shade	3 3 3 4 3 2	Vertical and horizontal shading devices were used to reduce heat gain the building. The roofs also have eaves that serves as shade to the building. The building scores 18/30
	landscape	-extensive use of landscape in the environment -use of shrubs or other plantings to shade paved areas -use of tall trees to provide shade for the	4 4 3	Both soft and hard landscape were used, grasses, shrubs, trees, walkways and vehicular roads for landscaping.

		building against direct solar heat gain -use of grasses as ground cover to improve evaporation -use of soft landscape in courtyards	4 4	The asphalt used on roads absorbs heat. The building scores 19/25
	Use of light color on external surfaces	-use of lighter colors on external walls -use of light-colored roofing materials -use of light-colored surfaces on shading devices -use of light-color surface finishes on walkways, driveways and other landscape elements	4 2 2 2	Warm colours were used with stripe of light colour The roof was decked and bituminous felt was used The building scores 10/20
Heat modulation strategies	*insulation*	-provide roof ventilation -provide ceilings in all offices to insulate from the heat generated inside roof space -use of wall tiles on the external surfaces to maximize wall insulation	2 2 2	no roof ventilation was provided ceilings were only providing at the last floor no wall tiles on exterior wall surfaces the building scores 6/15
	Thermal mass	-compact planning of buildings to minimize heat gain -use of building materials with high thermal mass for construction of external walls on east and west façades	3 3	the building was averagely compacted to reduce heat gain no special thermal mass insulation system was employed the building scores

				6/10
Heat dissipation strategies	*Natural ventilation*	-Use of windows with maximum open area for ventilation -positioning of windows for cross ventilation	3 4	Large windows were used to maximize ventilation The building scores 7/10
	Natural cooling	-use of larger openings along south facade -use of water bodies in courtyard to provide cool breezes	4 4	Large openings were used to utilize airflow from courtyard The building scores 8/10

Key: very low =1, low=2, average= 3, high =4 and very high= 5 Source: Author's fieldwork (2025).

This study evaluates passive cooling strategies in three university senate buildings in Nigeria's tropical savannah climate: Ahmadu Bello University (ABU, Zaria), University of Abuja (UNIAB), and Federal University of Agriculture (FUAM, Makurdi). ABU's eightstory Senate building, built in the 1980s, employs a square plan with recesses, singlebanked corridors, a courtyard from the third to eighth floors, and vegetation for cooling, scoring high in shading (21/30) and ventilation (9/10). UNIAB's three-story building, designed in 2005, features four rectangular blocks around a bisected courtyard, with strong orientation (7/10) and insulation (10/15), but less effective shading (17/30). FUAM's semicircular, one- to two-story structure leverages topography and excels in landscaping (19/25), yet underperforms in orientation (4/10) and reflective colors (10/20) due to circular design and warm-toned finishes. These case studies revealed varied implementation of heat prevention, modulation, and dissipation strategies, highlighting the need for integrated, context-specific designs to optimize energy efficiency and thermal comfort in Nigeria's tropical savannah climate (Daramola et al., 2021).

5.0 CONCLUSION AND RECOMMENDATIONS

The evaluation of passive cooling strategies in the senate buildings of Ahmadu Bello University (ABU, Zaria), University of Abuja (UNIAB), and Federal University of Agriculture (FUAM, Makurdi) demonstrates their potential to enhance energy efficiency and thermal comfort in Nigeria's tropical savannah climate. ABU's effective use of shading, ventilation, and courtyards sets a benchmark, while UNIAB's orientation and FUAM's landscaping highlight context-specific strengths. However, inconsistent application, such as FUAM's suboptimal orientation and reflective color use, underscores gaps in holistic implementation (Daramola et al., 2021). These findings emphasize the need for integrated, climate-responsive designs to reduce reliance on mechanical cooling, lowering operational costs and environmental impact (Khosla et al., 2021). Future designs should prioritize optimal building orientation to minimize solar heat gain, as seen in UNIAB (Olotuah, 2015). Employing egg crate shading and reflective surfaces, as effectively used at ABU, can enhance heat prevention (Kamal, 2022). Dense landscaping, like FUAM's, should be paired with courtyards and large openings to boost natural ventilation and cooling (Prieto et al., 2021). Architects should integrate these strategies early in the design process, ensuring compliance with local climatic conditions to promote sustainable institutional architecture in Nigeria.

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