RESEARCH AND REVIEWS IN SUSTAINABILITY
Volume 2 (2026) · ISSN 2977-8441

REVIEW

Passive Architectural Design Parameters for Indoor Thermal Performance in Tropical Savannah, Nigeria: A Review of Residential Buildings

Benjamin Moral[1*]

[1] Faculty of Architecture, Department of Architecture, Bingham University, Karu, Nasarawa State, Nigeria

RECEIVED 16 June 2026 · REVISED 29 July 2026 · ACCEPTED 20 August 2026 · PUBLISHED 20 August 2026

ABSTRACT

Residential cooling is among the fastest-growing energy burdens in Nigeria, where households account for a dominant share of national electricity demand and where grid supply remains intermittent. The tropical savannah (Köppen Aw) belt that spans the country's Middle Belt presents a distinct thermal challenge: a hot, low-humidity dry season with a large diurnal temperature range, followed by a warm, humid wet season with suppressed night-time cooling. Passive architectural design offers a low-cost, grid-independent route to indoor thermal comfort, yet the evidence base is fragmented and skewed towards the hot-humid south and the semi-arid far north, leaving the savannah residential sector comparatively under-theorised. This paper presents a systematic review, conducted in line with the PRISMA 2020 protocol, of 66 studies retrieved from Scopus and Google Scholar and screened for relevance to passive design, residential buildings and tropical-savannah conditions. The synthesis is organised around eight parameter families and yields three contributions. First, it proposes an evidence-weighted sensitivity hierarchy in which the roof, ventilation and external shading dominate the achievable comfort gains per unit cost. Second, it isolates a savannah-specific seasonal-duality problem, in which thermal-mass strategies that suit the dry season can become counterproductive during humid wet-season nights, and argues that adaptive or hybrid envelopes outperform single-strategy solutions. Third, it documents a persistent evidence-to-practice gap and converts the findings into a staged decision framework and a tiered set of guidelines for architects and policymakers. The review concludes that savannah residential comfort is achievable largely through fabric and ventilation measures, but only if design priorities are sequenced and codes are enforced.

KEYWORDS Passive design, Thermal comfort, Tropical Savannah, Residential buildings, Building envelope, natural ventilation, Nigeria

1. Introduction

The residential sector is a decisive battleground for energy and climate policy across the Global South, and Nigeria illustrates the stakes with unusual clarity. Households consume the largest single share of national energy, with electricity for space cooling making a growing contribution as incomes rise and urban populations expand (Kwag *et al.* 2019). Earlier accounting placed the domestic sector at between 55 and 61 per cent of national energy use, a figure that has not fallen as air-conditioning has diffused (Alkali *et al.* 2021). The problem is compounded by an electricity grid that cannot reliably meet existing demand, so that mechanical cooling is frequently sustained by private generators, raising both household costs and carbon emissions. Against this backdrop, any design strategy that reduces the cooling load before mechanical systems are engaged carries disproportionate value.

Passive architectural design, the deliberate use of building form, fabric and openings to moderate the indoor climate without active energy input, is the most direct expression of that logic. Its appeal in the Nigerian context is threefold: it is largely capital-light, it is independent of the grid, and it

* Corresponding author. Email address: arcbenmoral@gmail.com (Benjamin Moral)

© 2026 The Author(s).
Published by Caravel Press.

doi.org/10.65582/rrs.2026.017

aligns with a long indigenous tradition of climate-responsive building that predates mechanical cooling (Oluwarotimi 2026). Continental reviews confirm both the breadth of passive techniques applicable across African climates and the unevenness of their deployment (Santos *et al.* 2022).Yet the uptake of passive strategies in contemporary practice remains weak, and the research that should guide it is unevenly distributed across the country's climate zones.

Nigeria is not climatically homogeneous. Its building-relevant climate divides broadly into a hot-humid coastal south, a semi-arid far north, and a tropical-savannah belt that occupies the Middle Belt and much of the centre. This savannah band, classified Aw in the Köppen-Geiger scheme, is defined by a pronounced wet and dry seasonality. The dry season brings intense solar radiation, low relative humidity and a wide diurnal temperature swing, while the wet season is warmer at night, more humid and offers little nocturnal relief. The thermal design problem in the savannah is therefore qualitatively different from that of either neighbouring zone, and strategies optimised for hot-humid Lagos or the arid far north do not transfer cleanly (Xi *et al.* 2025; Bedra and Li 2025).

Despite this distinctiveness, the savannah residential sector is under-served by the literature. Studies cluster around the hot-humid south, where building physics is dominated by humidity and ventilation (Onyenokporo and Ochedi 2019; Okafor *et al.* 2022; Okanlawon 2025), and around the far north, where aridity and thermal mass take centre stage. Work that explicitly addresses the savannah is sparse, frequently confined to non-residential building types such as classrooms and offices (Abba 2020; Mustapha 2023; Oluwatayo and Miracle 2025), and rarely synthesised into design-ready guidance. Xi et al. (2025) note directly that research on passive design strategies in the Nigerian savannah is limited, which itself constitutes a barrier to wider implementation.

This review responds to that gap. Its aim is to consolidate and critically interrogate the evidence on passive architectural parameters for indoor thermal performance in savannah residential buildings, and to convert that evidence into actionable guidance. The objectives are:

1. to characterise the savannah thermal-design problem and frame it theoretically;
2. to systematically identify and screen the relevant literature;
3. to analyse the principal passive parameters and rank their relative leverage; and
4. to develop a decision framework and guidelines for practitioners and policymakers.

Three research questions follow. Which passive parameters deliver the greatest thermal benefit per unit of cost in the savannah residential context? How should the seasonal duality of the savannah climate shape parameter selection? And why, given a robust evidence base, does passive design remain under-adopted? The contribution is a savannah-specific, parameter-level synthesis that advances beyond description towards a prioritised, climate-sensitive design logic.

2. Climate Context and Theoretical Framing

2.1. The tropical-savannah thermal problem

The Köppen Aw climate is a tropical climate with a dry winter, characterised by mean monthly temperatures above 18 degrees Celsius year round and a marked dry season. In the Nigerian Middle Belt this manifests as a single rainy season, roughly April to October, separated by a dry season during which the Harmattan, a dust-laden north-easterly wind, depresses humidity and widens the gap between daytime and night-time temperatures. Table 1 summarises indicative climate characteristics for representative savannah settlements, illustrating the internal variation between lowland cities such as Lokoja and Makurdi and the cooler Jos Plateau.

Table 1. Indicative climate characteristics of representative tropical-savannah (Aw) settlements in Nigeria.

Settlement (state)	Sub-region	Mean annual temp. (°C)	Dry-season peak max. (°C)	Mean annual rainfall (mm)	Dominant thermal stressor
Abuja (FCT)	North-central	~25.5	~37	~1,400	High insolation; dry-season heat
Kaduna (Kaduna)	North-central	~25.0	~37	~1,300	Large diurnal range
Minna (Niger)	North-central	~27.0	~38	~1,300	High daytime heat
Lokoja (Kogi)	Confluence belt	~27.5	~39	~1,150	Combined heat and humidity
Makurdi (Benue)	North-central	~27.5	~38	~1,290	Sustained high temperature
Jos (Plateau)	Highland Aw	~22.0	~30	~1,400	Cool highland; wide diurnal range

Note. Values are indicative long-term normals compiled for contextual orientation and rounded; they are not derived from the reviewed corpus. Internal variation, particularly the Jos Plateau anomaly, underlines that the savannah is not thermally uniform.

Two features of this regime drive the design problem. The first is the intensity and verticality of solar radiation, which loads horizontal surfaces, above all the roof, far more heavily than vertical walls. Savannah-specific measurement confirms that the roof can account for the majority of fabric heat gain in low-rise buildings, with one classroom study attributing close to 70 per cent of total heat gain to the roof (Abba 2020). The second is the seasonal asymmetry of the cooling task: the dry season rewards strategies that buffer the diurnal swing, whereas the humid wet season rewards strategies that maximise air movement and limit moisture retention. Figure 1 maps the principal heat-transfer pathways and the points at which passive interventions act.

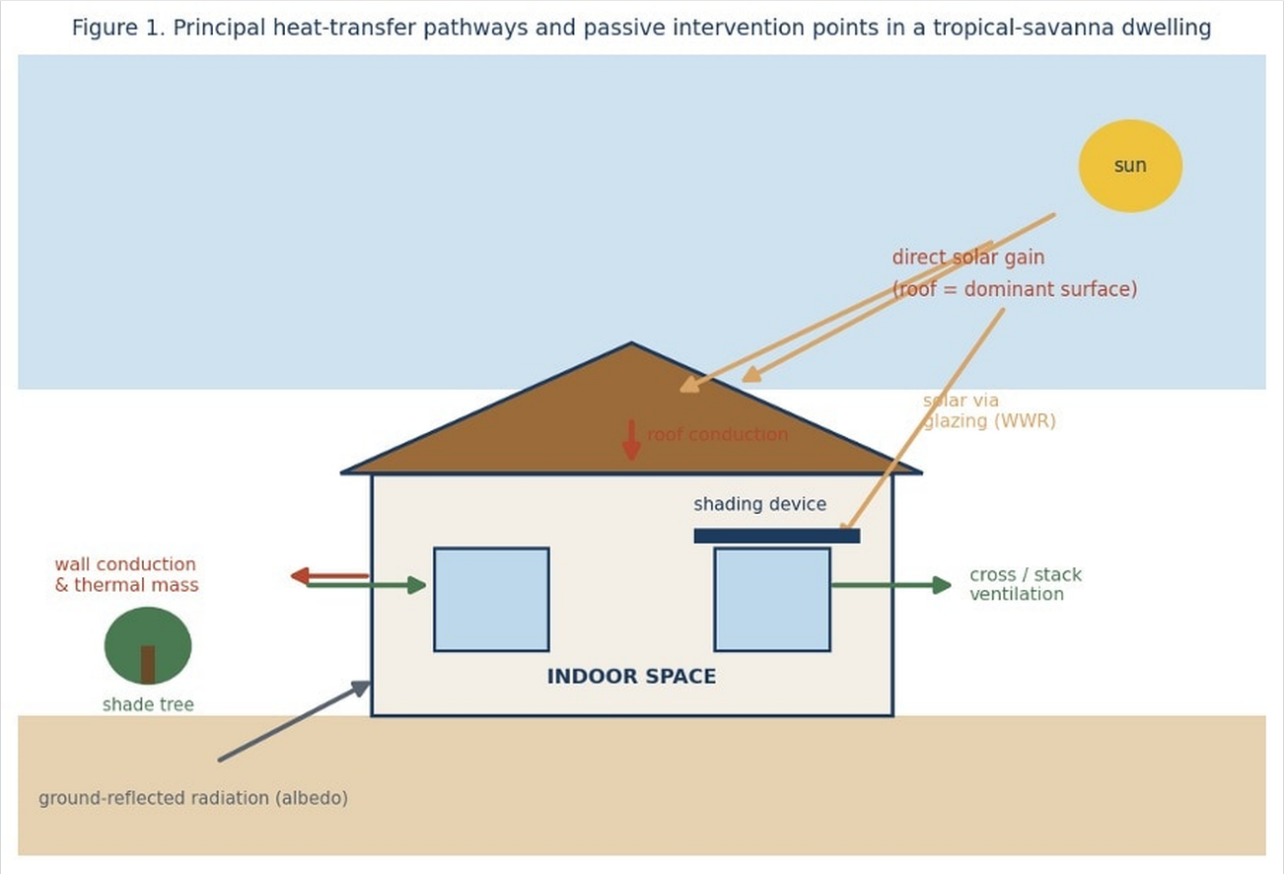

Figure 1. Principal heat-transfer pathways and the corresponding passive intervention points in a tropical-savannah dwelling. The roof is the dominant solar-gain surface, while cross and stack ventilation provide the principal heat-removal mechanism.

2.2. Comfort theory and the case for adaptive models

How comfort is defined determines which design targets are judged adequate. The static, heat-balance approach formalised in the Predicted Mean Vote, and applied in studies such as Abilkhassenova et al. (2023), treats comfort as a narrow band of operative temperature largely independent of occupant adaptation. The adaptive paradigm, by contrast, holds that occupants of naturally ventilated buildings tolerate and indeed prefer a wider, climate-tracking comfort range because they adjust clothing, activity and openings (López-Pérez *et al.* 2019; Aqilah *et al.* 2025). For savannah residential buildings, the great majority of which are naturally ventilated for at least part of the year, the adaptive model is the more defensible baseline, and its use materially enlarges the comfort space that passive design can satisfy. Reviews of naturally ventilated comfort confirm that air movement can extend the acceptable temperature ceiling by several degrees (Abuhussain *et al.* 2024; Aqilah *et al.* 2022). The choice of model is not a technicality: a design judged a failure against a fixed 24 degree set point may be a clear success against an adaptive criterion, and much of the apparent inadequacy of passive buildings in the corpus stems from the use of inappropriately static baselines.

2.3. The seasonal-duality framing

The central analytical lens of this review is what may be termed the savannah seasonal-duality problem. The bioclimatic tradition associated with Olgyay and Givoni treats the building envelope as a filter to be tuned to a prevailing climate, but the savannah does not present one climate; it presents two in annual alternation. A heavyweight envelope with high thermal mass damps the large dry-season diurnal swing and, if coupled with night ventilation, can flush stored heat before dawn. The same mass, however, can trap warmth during humid wet-season nights when outdoor temperatures

no longer fall far enough to discharge it, leaving occupants warmer than a lightweight, well-ventilated alternative would. Figure 4 (Section 5) renders this tension graphically. The implication, developed throughout the analysis, is that the optimal savannah envelope is not a fixed compromise but an adaptive or switchable system whose behaviour changes with the season.

3. Methodology

3.1. Review design and reporting standard

The study is a systematic literature review reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statement. A systematic design was chosen over a narrative one because the research questions require an auditable, reproducible mapping of a dispersed evidence base rather than an illustrative selection. The protocol comprised four stages: identification, screening, eligibility assessment and inclusion, with explicit criteria applied at each transition. The complete flow, with record counts, is presented in Figure 2.

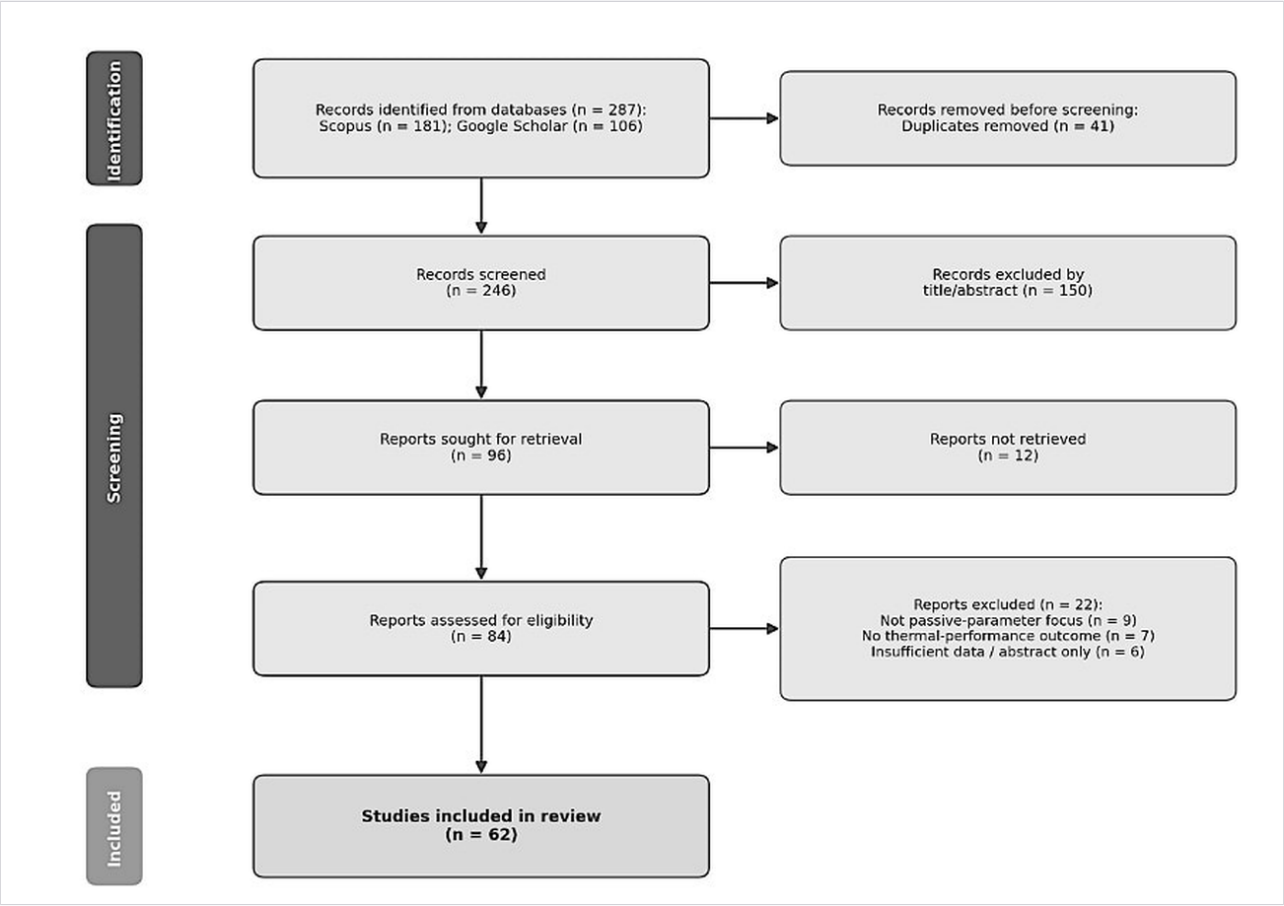

Figure 2. PRISMA 2020 flow diagram of the identification, screening and inclusion process.

3.2. Information sources and search strategy

Two complementary sources were interrogated. Scopus was selected as the primary index for its quality control, structured metadata and reliable Digital Object Identifiers, which support verifiable referencing. Google Scholar was added as a secondary source precisely because of its broader, less filtered coverage, which captures regional Nigerian journals, theses and grey literature that Scopus omits and which are disproportionately important for an under-researched climate zone. The Scopus export was retrieved on 15 June 2026 and returned 181 records; the Google Scholar export returned 106 records, of which 98 carried usable bibliographic metadata. Table 2 sets out the search

architecture, combining concept blocks for passive design, thermal performance, building type and geographic-climatic scope using Boolean operators.

Table 2. Search architecture applied across the two databases.

Concept block	Representative search terms	Operator logic
Passive strategy	"passive design" OR "passive cooling" OR "bioclimatic" OR "natural ventilation" OR "building envelope"	Within-block OR
Thermal outcome	"thermal comfort" OR "thermal performance" OR "indoor temperature" OR "cooling load" OR "energy efficiency"	AND across blocks
Building type	"residential" OR "housing" OR "dwelling" OR "home"	Within-block OR
Geographic / climatic scope	"tropical savanna" OR "savannah" OR "Nigeria" OR "hot-dry" OR "hot-humid" OR "tropical"	Within-block OR

3.3. Eligibility criteria

Inclusion and exclusion criteria, summarised in Table 3, were defined before screening. Studies were eligible if they addressed at least one passive architectural parameter, reported a thermal-performance or comfort outcome, and were relevant to tropical conditions, with priority given to savannah and wider Nigerian residential evidence. Cross-climate and non-residential studies were retained where they carried transferable mechanistic insight, for example envelope or phase-change-material reviews but were weighted accordingly in synthesis (Gupta and Deb 2023; Lamrani *et al.* 2021; Lai *et al.* 2023). Purely materials-science studies with no building-scale outcome, and method-only machine-learning papers without a design-parameter focus, were excluded.

Table 3. Inclusion and exclusion criteria.

Dimension	Included	Excluded
Topic	Passive architectural parameter with a thermal or comfort outcome	Active-only systems; non-thermal outcomes
Building type	Residential primary; other types retained for transferable insight	Industrial or transport enclosures
Climate	Tropical savannah and wider Nigeria prioritised; other tropical retained	Temperate or polar with no transferable mechanism
Document type	Journal articles, reviews, conference papers, book chapters, theses	Editorials; abstract-only records with no extractable data
Language and access	English; retrievable metadata	Non-English; non-retrievable

3.4. Screening, selection and synthesis

The two exports were combined, yielding 287 records. Duplicate detection by title, author and DOI removed 41 records, several of which appeared in both databases, leaving 246 unique records for screening. Title and abstract screening against the eligibility criteria excluded 150 records, predominantly studies set in non-savannah climates, focused on non-residential buildings without transferable value, or confined to materials characterisation. Of the 96 reports sought for full assessment, 12 could not be retrieved or lacked sufficient detail. The remaining 84 underwent full eligibility assessment, from which 22 were excluded for the reasons recorded in Figure 2. Sixty-six studies were retained for synthesis.

Synthesis was thematic rather than meta-analytic, because the heterogeneity of climates, building types, metrics and methods in the corpus precludes statistical pooling. Data were extracted into a

parameter-by-study matrix recording the mechanism examined, the reported direction and where available the magnitude of the thermal effect, the method used, and the climatic setting. Findings were then aggregated by parameter family and interpreted through a structured vote-counting logic that weighted savannah and Nigerian residential evidence most heavily, hot-dry and hot-humid Nigerian evidence next, and transferable cross-climate evidence least. This weighting is the basis of the sensitivity ranking developed in Section 5. The approach has limitations, discussed in Section 7, notably the inclusion of regional grey literature for which DOIs were unavailable, a deliberate trade-off accepted to improve savannah coverage.

4. Passive Design Parameters: A Critical Synthesis

The reviewed evidence is organised below into eight parameter families. For each, the underlying mechanism, the weight of evidence, the savannah-specific nuance and the principal trade-offs are examined. Table 4 consolidates the synthesis into a single matrix, and Figure 3 presents the resulting sensitivity ranking.

Table 4. Synthesis matrix of passive parameters for savannah residential thermal performance.

Parameter family	Primary mechanism	Reported effect	Key evidence	Savannah suitability	Relative cost
Roof (reflectivity, insulation, geometry)	Cuts dominant radiant gain and conductive path	High; majority of fabric gain addressable	Abba (2020); Gupta & Deb (2023); Lapisa et al. (2022); Xi et al. (2025)	Very high (both seasons)	Low–moderate
Natural ventilation	Convective cooling and night purge	High; stabilised peaks near 28 °C	Oforji et al. (2023); Mabdeh et al. (2020); Adaji et al. (2022); Chidiadi & Taki (2025)	High (season-dependent)	Low
External shading	Intercepts solar gain before envelope	Moderate–high; robust across seasons	Onwuzuligbo et al. (2025); Olaniyan et al. (2023)	High	Low–moderate
Fenestration and glazing (WWR)	Controls solar admission, daylight, airflow	Moderate–high; leading load determinant	Gupta & Deb (2023); Olaniyan et al. (2023); Wingrove et al. (2025); (Abdulkareem *et al.* 2018)	High	Moderate
Wall thermal mass and material	Damps diurnal swing; phase lag	Moderate; conditional on season	Muhammed et al. (2024); Jegede & Taki (2022); Okereke & Ike (2025); Okonta (2023)	Conditional (dry-season asset)	Low–moderate
Orientation and built form	Minimises exposed envelope area	Modest but free	Alkali et al. (2021); Nwalusi et al. (2022)	Foundational	Negligible
Phase change materials	Latent storage adds tunable mass	Moderate–high; cost-limited	Bimaganbetova et al. (2020); Nazir et al. (2023); Elenga et al. (2025)	Conditional (budget)	High
Vegetation and surface albedo	Radiant shading; evaporative cooling	Context-dependent; up to ~2.8 °C	Yin et al. (2024); Ji et al. (2024); Bedra & Li (2025)	Context-dependent	Low–high

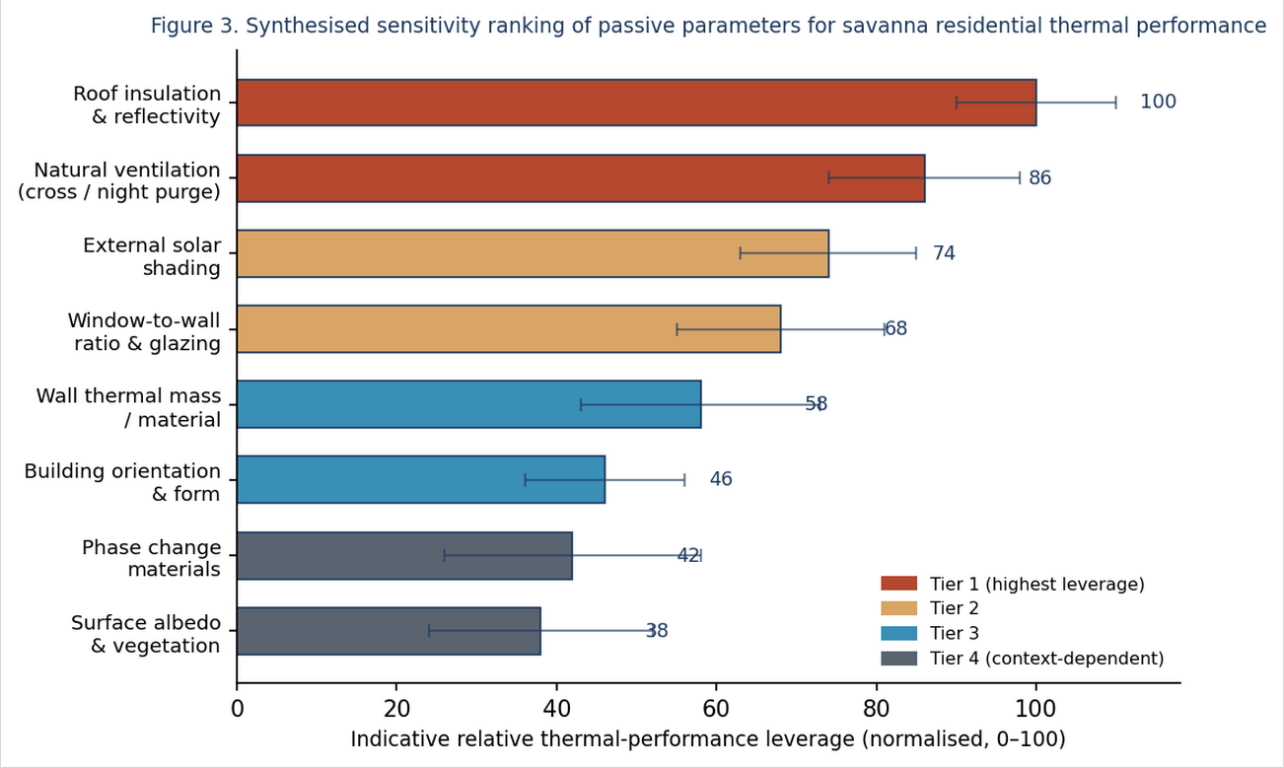

Figure 3. Synthesised sensitivity ranking of passive parameters. Bars show indicative relative leverage and whiskers the spread of reported effects across the corpus; the ranking weights savannah and Nigerian residential evidence most heavily.

4.1. Site, orientation and built form

Orientation and form are the cheapest of all passive measures because they are decided at the sketch stage and cost nothing to implement, yet their leverage is bounded. In the savannah the design objective is to minimise the area of envelope, especially glazing, exposed to the low-angle morning and afternoon sun on the east and west elevations, while presenting longer faces to the north and south where overhangs can exclude high-angle radiation. Simulation of residential orientation in north-eastern Nigeria found measurable cooling-load reductions from re-orienting the long axis, although the gains were modest relative to fabric measures (Alkali *et al.* 2021). Work on contemporary low-rise housing in tropical Enugu reaches a similar conclusion from the opposite climate zone, treating orientation and form as the foundational layer of a climate-responsive strategy rather than as a substitute for fabric measures (Nwalusi *et al.* 2022). Built form interacts with this: a compact plan with a low surface-to-volume ratio reduces total heat exchange, but compactness conflicts with the deep cross-ventilation that the wet season demands. This early tension foreshadows the duality problem and explains why orientation, though foundational, ranks below the fabric and ventilation measures that follow.

4.2. The building envelope: walls, thermal mass and materials

Wall performance in the savannah is governed less by steady-state U-value than by thermal mass and its phasing relative to the diurnal cycle. The ubiquitous sandcrete hollow block, assessed as a walling material in tropical Nigeria, performs poorly in isolation because its moderate mass and conductivity allow daytime heat to reach the interior with little useful delay (Muhammed *et al.* 2024). Indigenous and stabilised-earth alternatives consistently outperform it. Optimisation of residential envelopes using indigenous materials delivered both improved comfort and construction-cost savings (Jegede and Taki 2022), and comparative testing of stabilised latscrete against sandcrete blocks confirmed the thermal advantage of the earth-based option (Okereke and Ike 2025). Material reviews extend the logic to agro-industrial wastes and unfired earth blocks (Jannat *et al.* 2020) and to rice-husk-ash

masonry, which improved building energy performance (Onyenokporo *et al.* 2024a). Investigations of the relationship between building materials and indoor cooling in Nigerian homes reinforce that material selection is among the most consequential envelope decisions (Okonta 2023; Egbum *et al.* 2023).

The critical qualification is seasonal. High mass is an asset in the dry season, when large night-time temperature drops allow stored heat to be purged, but a liability in the humid wet season, when night temperatures stay high and the same mass re-radiates warmth indoors. Studies of traditional versus modern dwellings capture this ambivalence, finding heavyweight traditional construction superior under some conditions but not universally (Okafor *et al.* 2022). The envelope conclusion is therefore conditional rather than absolute: mass should be specified for the dry-season-dominant interior cities and moderated, or paired with assured night ventilation, where the wet season governs comfort.

4.3. The roof: the dominant gain surface

If a single surface deserves design priority in savannah housing it is the roof. Because solar radiation is near-vertical for much of the day, the roof intercepts the largest radiant load, and savannah measurement attributes the majority of fabric heat gain to it (Abba 2020). Three roof parameters are actionable. Reflectivity, achieved through light-coloured or specially coated surfaces, reduces absorbed radiation at source and is among the most cost-effective single interventions. Insulation interrupts the conductive path to the ceiling and is repeatedly identified as the highest-impact envelope measure in tropical reviews (Gupta and Deb 2023); Nigerian assessment of aerogel indicates the upper bound of what high-performance insulation can deliver, while illustrating the cost barrier that limits its residential use (Bashir and Leite 2022). Geometry and ventilated cavities matter too: numerical analysis of roof slope shows that pitch and the provision of a ventilated attic alter both gain and the need for high-performance roofing materials (Lapisa *et al.* 2022). The combined deployment of reflective and insulated roofing with mechanical ventilation was central to the savannah-specific optimisation of Xi et al. (2025), which targeted Kaduna directly. The roof thus offers the rare combination of high leverage and comparatively low cost that places it at the top of the sensitivity ranking.

4.4. Fenestration and glazing

Windows are simultaneously the route for solar gain and the means of ventilation and daylight, which makes their design a balancing act rather than a minimisation. The window-to-wall ratio is the master variable: tropical envelope reviews identify it, alongside glazing properties, as a leading determinant of cooling load (Gupta and Deb 2023). Glazing selection compounds the effect, and Nigerian simulation of window glass thermal properties combined with fixed external shading demonstrates that material choice can meaningfully reduce indoor solar penetration (Olaniyan *et al.* 2023). Façade-level remodelling in Abuja's low-income housing shows that window size, position and shading act as a coupled system, improving daylight while lowering indoor thermal stress (Abdulkareem *et al.* 2018). The most striking finding in this family, however, is behavioural rather than technical. Examining the prevalence of climatically appropriate glazing in practice, Wingrove et al. (2025) document a sustained disconnect between passive-solar theory and what is actually built, with glazing routinely sized and oriented without regard to climate. This gap, revisited in Section 5, signals that the binding constraint on fenestration performance is not knowledge but its application.

4.5. Solar shading

Shading addresses the gain that orientation and glazing cannot eliminate, and it does so before radiation strikes the building. External devices, overhangs, fins, verandahs and screens, are markedly more effective than internal blinds because they intercept radiation outside the thermal envelope. A scoping review of external shading optimisation for residential buildings in Nigeria sets

out the geometric and material considerations and stresses context-specific calibration to local sun paths (Onwuzuligbo *et al.* 2025), while the coupling of fixed shading with appropriate glazing has been shown to suppress indoor temperatures in Nigerian conditions (Olaniyan *et al.* 2023). The deep verandah, a recurring feature of indigenous Nigerian housing, is in effect a vernacular shading and buffer space whose logic modern practice has too often abandoned (Oluwarotimi 2026). Shading ranks highly because it is climatically robust across both seasons and moderate in cost, although its benefit is contingent on correct geometric design for the specific latitude and elevation.

4.6. Natural ventilation

Ventilation is the principal heat-removal mechanism available to a passive building, and in the savannah it carries a double role: convective cooling of occupants and, through night purging, discharge of heat stored in the fabric. Effective cross-ventilation depends on the placement, size and rhythm of openings as much as on their total area. Experimental work in low-rise Nigerian housing demonstrates that the rhythm and arrangement of window openings materially shape the indoor airflow pattern, not merely its volume (Oforji *et al.* 2023). Low-cost strategies to enhance natural ventilation can improve indoor environmental quality without capital-intensive plant (Mabdeh *et al.* 2020), and field study of overheating in low-income Abuja dwellings found that passive measures, ventilation prominent among them, stabilised peak indoor temperatures around 28 degrees Celsius (Adaji *et al.* 2022). The courtyard, examined across hot-dry and humid settings, is a powerful ventilation and micro-climate device whose multilevel variants enhance stack-driven airflow (Chidiadi and Taki 2025). Ventilation does, however, expose the duality directly: night purging is highly effective in the dry season but far less so in the humid wet season, when the outdoor air is itself warm and moist, and security and dust concerns frequently lead occupants to keep openings closed, negating the design intent.

4.7. Phase change materials and advanced thermal storage

Phase change materials (PCMs) extend the thermal-mass principle by storing and releasing latent heat at a chosen transition temperature, in effect adding tunable mass to a lightweight fabric. The corpus on PCMs is large and methodologically mature (Lamrani *et al.* 2021; Zhang *et al.* 2025; Yang *et al.* 2023), and includes work calibrated explicitly to the tropical-savannah climate. Bimaganbetova et al. (2020) identify a narrow band of PCMs suitable across savannah cities worldwide, and savannah-focused energy prediction has been built on PCM-integrated simulation (Nazir *et al.* 2023). Envelope-integration studies in tropical and semi-arid settings report meaningful reductions in cooling demand and improvements in comfort (Elenga *et al.* 2025; Laasri *et al.* 2024; Al-Yasiri and Szabó 2022; Kulumkanov *et al.* 2024). The decisive constraints for savannah housing are economic and practical rather than physical: PCMs remain costly, depend on correct selection of melting range for the local climate, and require supply chains and installation expertise that are not yet widespread in Nigeria. Recent synthesis of PCM integration within building elements reaches the same conclusion, identifying cost, selection and installation capacity rather than thermal performance as the limiting factors (Mohan *et al.* 2026). They are therefore positioned in this review as a high-potential but conditional measure, appropriate where budgets allow and where the transition temperature is matched to local conditions.

4.8. Vegetation, green infrastructure and surface albedo

The final family acts partly at the building scale and partly at the scale of the immediate micro-climate. Shade trees, green roofs and vertical greenery reduce radiant loads and evaporatively cool surrounding air, and systematic reviews confirm the cooling benefit of urban tree canopy and green infrastructure (Yin *et al.* 2024; Ji *et al.* 2024). Surface albedo is a related lever: high-reflectance finishes reduce absorbed radiation, although savannah-specific simulation finds the effect uneven, with wall albedo reducing the Universal Thermal Climate Index by up to 2.8 degrees Celsius while ground

albedo had a minimal effect and can in some configurations worsen outdoor comfort by reflecting radiation onto occupants (Bedra and Li 2025). This nuance, that a measure can help or harm depending on geometry, mirrors the conditional character of thermal mass and reinforces the review's central message that savannah passive design rewards calibration over the uncritical application of generic prescriptions. Vegetation and albedo measures rank lower in the hierarchy not because they are ineffective but because their benefit is the most context-dependent and the slowest to establish.

5. Discussion

5.1. An evidence-weighted sensitivity hierarchy

Aggregating the parameter analysis produces a clear ordering of design priorities for savannah residential buildings, presented in Figure 3. The roof occupies the top tier because it combines the largest addressable load with low to moderate cost. Natural ventilation follows, both for its direct convective effect and for its role in unlocking the benefit of thermal mass through night purging. External shading and the management of glazing and window-to-wall ratio form the next tier, being climatically robust and moderate in cost. Wall mass, orientation, phase change materials and vegetation occupy the lower tiers, not because they lack effect but because their benefit is either modest, conditional on season or budget, or highly sensitive to context. This hierarchy is the review's first contribution: it replaces the undifferentiated lists of strategies common in the literature with a prioritised sequence that tells a designer where to spend the first and most consequential decisions. Sensitivity-based evaluation of passive approaches for Nigerian residential buildings provides methodological precedent for this kind of ranking and arrives at a broadly comparable ordering of envelope priorities (Tambaya 2023). Parallel work on hot-arid Saudi housing likewise finds roof and glazing measures to dominate achievable cooling-demand reductions (Rodrigues *et al.* 2025).

5.2. The seasonal-duality problem and the case for adaptive envelopes

The hierarchy is necessary but not sufficient, because the savannah does not present a stable target. Figure 4 illustrates why. During the dry season the wide gap between daily maximum and minimum temperatures rewards thermal mass and night ventilation, which together shift the indoor peak away from the hottest hours and discharge stored heat before dawn. During the wet season the diurnal range collapses, night temperatures remain elevated and humidity rises, so that the same mass becomes a heat reservoir that cannot discharge, and the design priority shifts decisively towards maximised airflow and moisture control. A single fixed envelope optimised for one season is therefore necessarily suboptimal for the other.

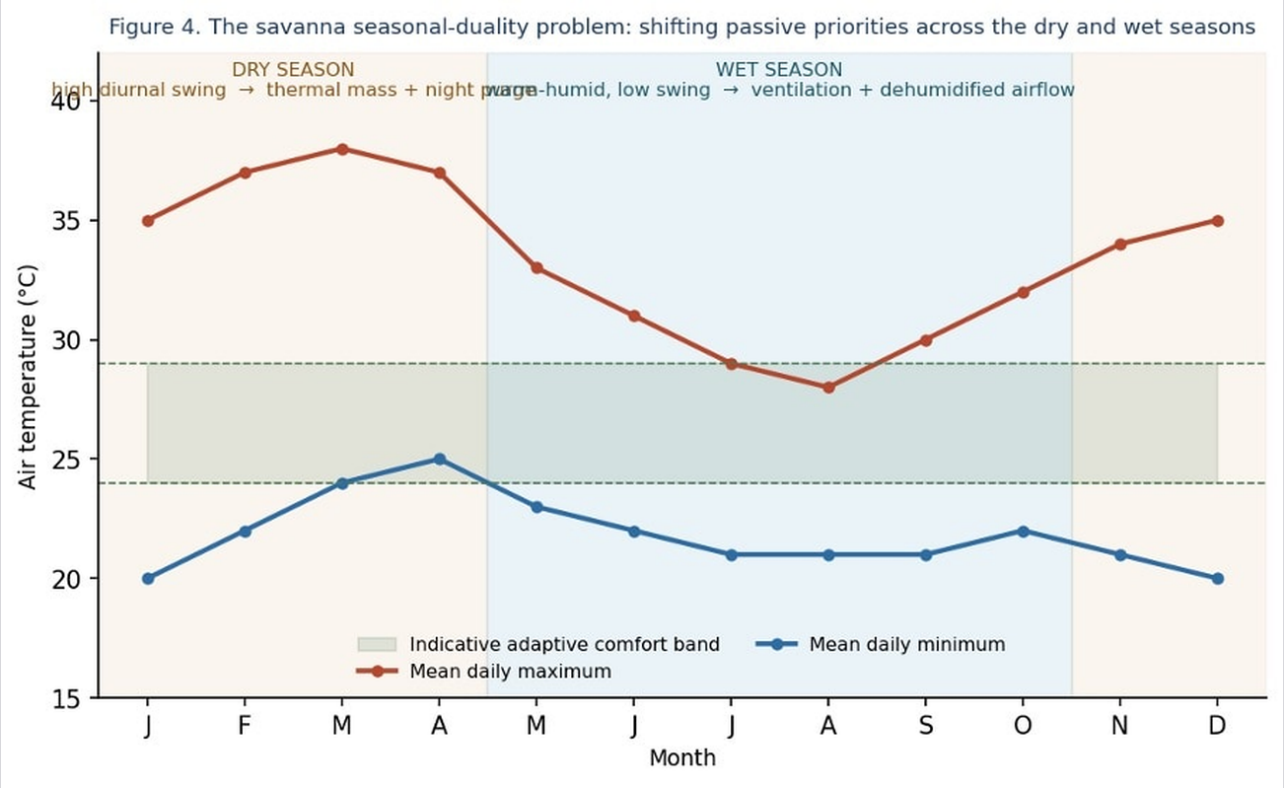

Figure 4. The savannah seasonal-duality problem. The collapse of the diurnal range between the dry and wet seasons inverts the relative value of thermal mass and ventilation, motivating adaptive rather than fixed envelopes.

The constructive implication is that savannah residential design should favour adaptive or hybrid solutions over single strategies: moderate rather than maximal mass, paired with generous and secure openings that allow occupants to switch behaviour between seasons, and resilient measures such as roof performance and shading that pay off in both regimes. This reframing explains several apparently contradictory findings in the corpus, in which heavyweight construction outperforms lightweight in one study and underperforms in another (Okafor *et al.* 2022; Muhammed *et al.* 2024); the contradiction dissolves once the governing season is specified. The seasonal-duality framing is the review's second contribution and a corrective to the climate-as-singular assumption embedded in conventional bioclimatic prescription.

5.3. The evidence-to-practice-and-policy gap

The most sobering theme across the corpus is that robust evidence has not translated into practice. In a study of high-rise residential buildings in Lagos, only 28.6 per cent of cases had adopted passive design strategies despite their documented benefit (Dimuna *et al.* 2025). Wingrove et al. (2025) demonstrate a systematic disconnect between passive-solar theory and built glazing practice, and surveys of office and residential adoption in Nigeria report only moderate awareness among the property owners and managers who commission and operate buildings (Adegoke *et al.* 2025; Oluwatayo and Miracle 2025). A structured review of the motivators and challenges of passive design extracted far more barriers than drivers in hot, dry and humid developing-country contexts (Juffle and Rahman 2023). The same asymmetry appears at continental scale, where feasibility assessments of passive systems across African countries identify cost, capacity and regulatory constraints rather than technical limits as the binding obstacles (Lazaro and Li 2025).The barriers are familiar: weak enforcement of building energy codes, a construction culture habituated to sandcrete and air-conditioning, the low first-cost priorities of a housing market facing a deficit exceeding seventeen million units (Oluwarotimi 2026), and a shortage of designers trained in climate-responsive method.

The gap is not evidential but institutional, which means it will not close through more simulation studies alone.

5.4. A methodological critique of the field

The corpus also reveals weaknesses in how savannah passive design is studied. There is a heavy dependence on building simulation, valuable for its control but only as reliable as its weather files and calibration, set against a relative scarcity of longitudinal field measurement in occupied savannah dwellings; the field studies that do exist, such as those in Abuja classrooms and low-income housing, are notable partly for their rarity (Mustapha 2023; Adaji *et al.* 2022). Comfort baselines are inconsistently defined, with static and adaptive models used interchangeably and few studies adopting a Nigeria-specific adaptive standard. Sampling is frequently small and convenience-based (Oluwatayo and Miracle 2025), limiting generalisation. Future-climate testing is uncommon, even though warming will intensify the cooling task (Aloshan 2026; Lee and Ng 2025a). And the residential focus is thin: a substantial share of Nigerian passive-design evidence is drawn from classrooms, offices, libraries and places of worship (Mohammadpourkarbasi *et al.* 2022; James *et al.* 2022), from which residential inferences must be drawn cautiously. These weaknesses define the research agenda set out in Section 7.

5.5. Equity, affordability and the low-income imperative

Finally, the savannah passive-design problem is inseparable from an equity problem. The households least able to afford continuous mechanical cooling are those most exposed to overheating, and social and low-cost housing is repeatedly shown to perform poorly in use (Simões *et al.* 2021; Callejas *et al.* 2023; Lee and Ng 2025b). Passive design is, in this light, not merely an energy strategy but a public-health and affordability strategy, and the measures that matter most for low-income housing, roof performance, ventilation, shading and locally available materials, are precisely those at the top of the sensitivity hierarchy and the bottom of the cost scale. Retrofit packages developed for existing Nigerian housing demonstrate that meaningful improvement is achievable within tight budgets (Onyenokporo and Ochedi 2019; Chung-Camargo *et al.* 2024; Adaji and Adekunle 2025), and upcycled and waste-derived materials extend that reach further (Onyenokporo *et al.* 2024b). Aligning the design hierarchy with the affordability constraint is thus not a compromise but a convergence.

6. Practical Guidelines and Decision Framework

The preceding analysis converts into actionable guidance through two devices: a staged decision framework (Figure 5) and a tiered specification table (Table 5). The framework sequences design decisions by leverage and embeds the seasonal-duality judgement as an explicit branch, so that practitioners resolve form and the high-impact fabric measures first, then calibrate mass and ventilation to the dominant local season, and only then consider advanced or optional measures. This sequencing is deliberate: it ensures that the cheapest, highest-leverage decisions are not foreclosed by later ones.

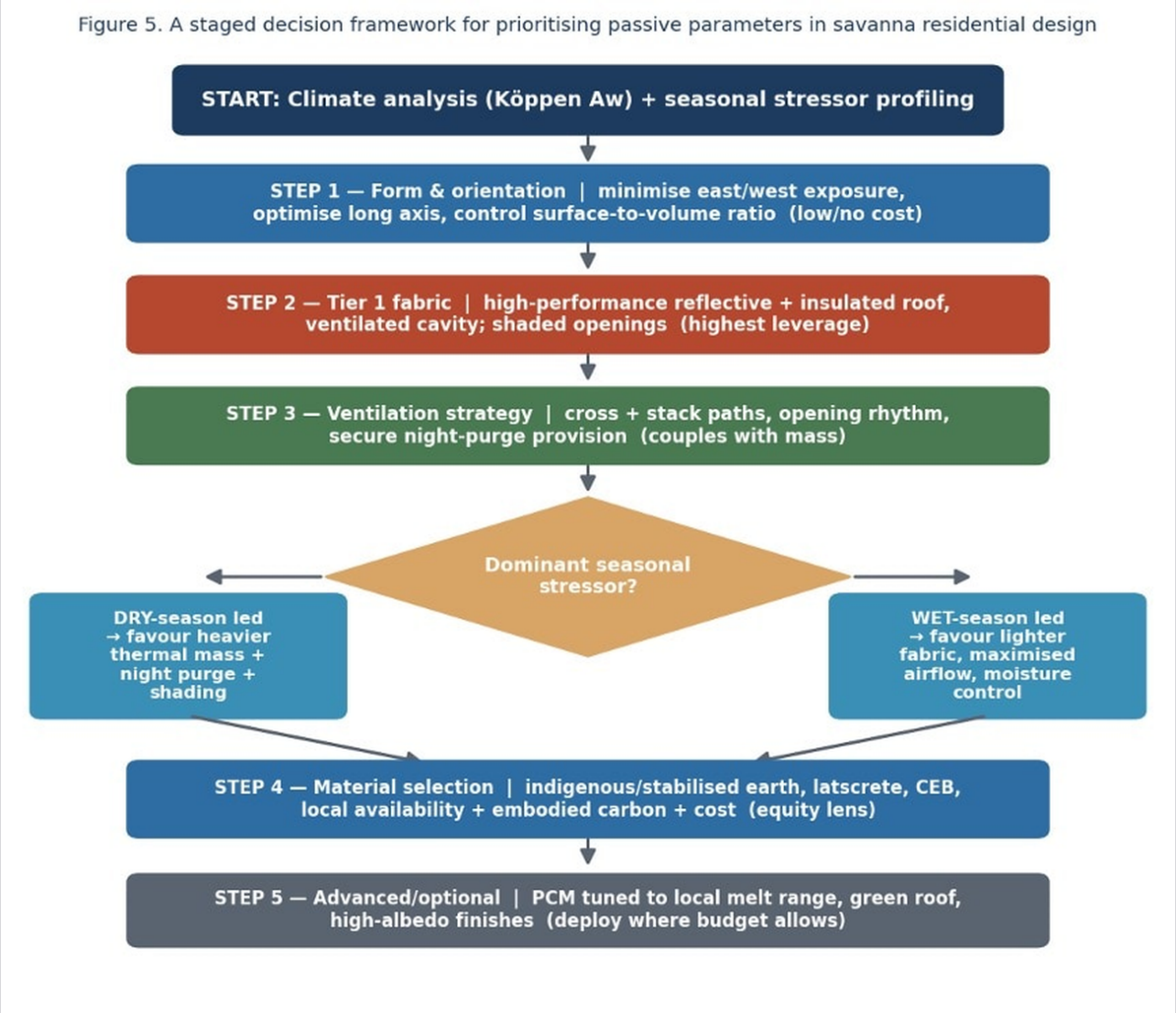

Figure 5. A staged decision framework for prioritising passive parameters in savannah residential design, with the seasonal-duality judgement embedded as an explicit branch.

Table 5. Tiered practical design guidelines for tropical-savannah residential buildings.

Tier	Parameter	Recommended specification (savannah residential)	Rationale
1	Roof	Reflective, light-coloured finish over an insulated deck with a ventilated attic cavity	Addresses the dominant radiant load at lowest cost; effective in both seasons
1	Ventilation	Designed cross- and stack-ventilation paths; secure, operable, insect- and dust-screened openings for night purging	Primary heat-removal route; unlocks the benefit of thermal mass
2	Shading	External overhangs and fins sized to the local sun path; deep verandahs on east and west	Intercepts gain before the envelope; climatically robust
2	Glazing / WWR	Moderate window-to-wall ratio with climate-appropriate glazing; avoid large unshaded east/west glazing	Controls solar admission without sacrificing daylight or airflow
3	Walls / mass	Moderate mass tuned to season: higher mass where dry season governs, lighter and ventilated where wet season governs; favour stabilised earth or latscrete	Resolves the seasonal-duality tension; uses local materials

Table 5. (continued)

Tier	Parameter	Recommended specification (savannah residential)	Rationale
3	Orientation / form	Long axis east-west; minimise east/west exposure; balance compactness against ventilation depth	Free at design stage; foundational but bounded
4	PCM / vegetation / albedo	Deploy where budget allows, with melting range and albedo calibrated locally	High potential but conditional and context-sensitive

For policymakers the implications are equally concrete. Because the gap is institutional, the highest-value interventions are regulatory and educational rather than technical. Priorities include mandatory minimum roof and glazing performance within an enforced building energy code, the development and dissemination of savannah-specific weather files and a Nigeria-specific adaptive comfort standard, incentives for locally produced low-carbon walling materials, and the embedding of climate-responsive design in architectural and engineering curricula and continuing professional development. Without enforcement and capacity-building, the evidence synthesised here will continue to outpace its application.

7. Limitations and Future Research

Three limitations bound this review. First, the savannah-specific residential evidence remains thin, so several conclusions rest partly on transferable cross-climate and non-residential studies; the sensitivity ranking should be read as an evidence-weighted hypothesis to be tested rather than a settled measurement. Second, the corpus is dominated by simulation, and the synthesis inherits the uncertainty of those models, particularly where weather files or calibration are not savannah-specific. Third, the inclusion of regional grey literature without DOIs, accepted to widen savannah coverage, introduces variable quality control. The corresponding research agenda is clear: longitudinal field measurement in occupied savannah dwellings across both seasons; the establishment of a Nigeria-specific adaptive comfort baseline; controlled comparison of fixed versus adaptive envelopes under the seasonal-duality lens; whole-life cost and embodied-carbon analysis of the recommended measures (Addy *et al.* 2024); future-climate stress testing; and implementation research into the institutional barriers that the evidence-to-practice gap has exposed.

8. Conclusion

The tropical-savannah belt of Nigeria poses a thermal-design problem that is neither that of the humid coast nor that of the arid north, but a seasonal alternation between the two, and it is precisely this duality that conventional, single-climate passive-design prescriptions fail to capture. Synthesising sixty-six studies, this review has shown that savannah residential comfort is, for the most part, achievable through the fabric and the openings rather than through machinery: get the roof right, let the building breathe, shade what the form cannot, and the largest share of the cooling task is solved before an air-conditioner is switched on. Its three contributions follow from that finding. The evidence-weighted sensitivity hierarchy tells designers where the first and most consequential decisions lie. The seasonal-duality framing explains why a fixed envelope can never be optimal and makes the case for adaptive, calibrated solutions, reconciling the contradictory results that have long unsettled the field. And the staged framework and tiered guidelines translate both into guidance that an architect can use on a drawing board and a policymaker can write into a code.

The harder truth is that the binding constraint is no longer knowledge. The evidence that passive design works in the savannah is now strong enough to act upon; what is missing is enforcement, training and a construction culture willing to trade the false economy of cheap blockwork and standby generators for the durable comfort of a well-conceived envelope. For a country building into

a housing deficit of seventeen million units under a warming sky, the choice is consequential. Each dwelling raised without these principles locks in decades of avoidable heat, cost and carbon; each one raised with them is a small, cumulative act of climate adaptation. The savannah has, in effect, been offering the same instruction through its indigenous architecture for centuries. This review's final argument is simply that it is time, with the evidence now assembled, to listen and to build accordingly.

Declarations

Author contributions. Benjamin Moral: Conceptualization, methodology, investigation, writing—original draft and writing—review & editing.

Funding. This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors.

Conflicts of interest. The author declares no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data availability. The datasets generated in the course of this research are available from the author upon reasonable request.

Acknowledgements. The author wishes to acknowledge the entire staff of the Faculty of Architecture, Bingham University for their guidance and support through the PhD program, as this is an outcome of my PhD Thesis.

References

Abba, H.Y (2020) 'thermal performance in tropical savannah climate of Nigeria, Journal of Xi'.

Abdulkareem, Mahmood; Al-Maiyah, Sura; Cook, Malcolm (2018) 'Remodelling façade design for improving daylighting and the thermal environment in Abuja's low-income housing', *Renewable and Sustainable Energy Reviews*, 82, pp. 2820-2833. Available at: https://doi.org/10.1016/j.rser.2017.10.010

Abilkhassenova, Zhansaya; Memon, Shazim Ali; Ahmad, Abrar; Saurbayeva, Assemgul; Kim, Jong (2023) 'Utilizing the Fanger thermal comfort model to evaluate the thermal, energy, economic, and environmental performance of PCM-integrated buildings in various climate zones worldwide', *Energy and Buildings*, 297, pp. 113479. Available at: https://doi.org/10.1016/j.enbuild.2023.113479

Abuhussain, Mohammed Awad; Alotaibi, Badr Saad; Suru, Ikram Bello; Dodo, Yakubu Aminu; Alshenaifi, Mohammad Abdullah; Aliero, Muhammad Saidu (2024) 'Bibliometric analysis and literature review of occupant thermal comfort in naturally ventilated buildings (1995–2021)', *Environmental Science and Pollution Research*, 31(46), pp. 56983-57001. Available at: https://doi.org/10.1007/s11356-023-31053-y

Adaji, Michael U.; Adekunle, Timothy O.; Watkins, Richard (2022) 'Overheating and passive cooling strategies in low-income residential buildings in Abuja, Nigeria', *Routledge Handbook of Resilient Thermal Comfort*. Routledge, pp. 159-174. Available at: https://doi.org/10.4324/9781003244929-14

Adaji, M.U. and Adekunle, T.O (2025) 'Enhancing healthy indoor thermal environment of low-income households in a hot humid climate through passive cooling interventions: a case of Abuja, Nigeria, Healthy Buildings Europe 2025 – Proceeding'.

Addy, Michael Nii; Ateko, Bright; Roberts, Ben M.; Opoku, Desmond; Aigbavboa, Clinton; Kwofie, Titus Ebenezer (2024) 'Design optimisation for embodied carbon and thermal performance of a courtyard house in the warm–humid climate of Ghana', *Architectural Engineering and Design Management*, pp. 1-22. Available at: https://doi.org/10.1080/17452007.2024.2442979

Adegoke, Ayodele Samuel; Abidoye, Rotimi Boluwatife; Sunindijo, Riza Yosia (2025) 'Stakeholders' Awareness of the Benefits of Passive Retrofit in Nigeria's Residential Building Sector', *Sustainability*, 17(14), pp. 6582. Available at: https://doi.org/10.3390/su17146582

Al-Yasiri, Qudama; Szabó, Márta (2022) 'Energetic and thermal comfort assessment of phase change material passively incorporated building envelope in severe hot Climate: An experimental study', *Applied Energy*, 314, pp. 118957. Available at: https://doi.org/10.1016/j.apenergy.2022.118957

Alkali, M A; Jie, Liu; Dalibi, S G; Danja, I I; Nasir, M.H.; Inuwa Labaran, Usman; Umar, Abdullahi M.; Adamu, Kabiru (2021) 'Optimizing Building Orientation for Reduced Cooling Load in Northeast Nigeria's Residential Architecture', *IOP Conference Series: Earth and Environmental Science*, 793(1), pp. 012028. Available at: https://doi.org/10.1088/1755-1315/793/1/012028

Aloshan, Mohammed A. (2026) 'Evaluating the effects of climate change on energy use and cooling demands in mid-aged residential buildings in Saudi Arabia', *Energy Reports*, 15, pp. 109106. Available at: https://doi.org/10.1016/j.egyr.2026.109106

Aqilah, Naja; Rijal, Hom Bahadur; Zaki, Sheikh Ahmad (2022) 'A Review of Thermal Comfort in Residential Buildings: Comfort Threads and Energy Saving Potential', *Energies*, 15(23), pp. 9012. Available at: https://doi.org/10.3390/en15239012

Aqilah, Naja; Rijal, Hom Bahadur; Zaki, S.A. (2025) 'Indoor thermal environment and effect of air movement on comfort temperature in Malaysian naturally ventilated dwellings', *Journal of Building Engineering*, 104, pp. 112151. Available at: https://doi.org/10.1016/j.jobe.2025.112151

Bashir, Aminu Wali; Leite, Brenda Chaves Coelho (2022) 'Performance of aerogel as a thermal insulation material towards a sustainable design of residential buildings for tropical climates in Nigeria', *Energy and Built Environment*, 3(3), pp. 291-315. Available at: https://doi.org/10.1016/j.enbenv.2021.02.003

Bedra, Komi Bernard; Li, Jiayu (2025) 'Relevance of Ground and Wall Albedo for Outdoor Thermal Comfort in Tropical Savanna Climates: Evidence from Parametric Simulations', *Sustainability*, 17(14), pp. 6303. Available at: https://doi.org/10.3390/su17146303

Bimaganbetova, Madina; Memon, Shazim Ali; Sheriyev, Almas (2020) 'Performance evaluation of phase change materials suitable for cities representing the whole tropical savanna climate region', *Renewable Energy*, 148, pp. 402-416. Available at: https://doi.org/10.1016/j.renene.2019.10.046

Callejas, Ivan Julio Apolonio; Guarda, Emeli Lalesca Aparecida da; Durante, Luciane Cleonice (2023) 'Constructive Measures to Counterbalance Climate Change Impacts on Low-Income Housing in the Brazilian Savannah Climate', *Green Energy and Technology*. Springer International Publishing, pp. 371-385. Available at: https://doi.org/10.1007/978-3-031-24208-3_26

Chidiadi, Eleazar; Taki, Ahmad (2025) 'Examining the Impact of Multilevel Courtyards in Hot-Dry and Humid Climates', *Energies*, 18(10), pp. 2425. Available at: https://doi.org/10.3390/en18102425

Chung-Camargo, Katherine; González, Jinela; Chen Austin, Miguel; Carpino, Cristina; Mora, Dafni; Arcuri, Natale (2024) 'Advances in Retrofitting Strategies for Energy Efficiency in Tropical Climates: A Systematic Review and Analysis', *Buildings*, 14(6), pp. 1633. Available at: https://doi.org/10.3390/buildings14061633

Dimuna, Kingsley O.; Ekhaese, Eghosa N.; Mercy, Oizuanjemen; Akinola, Adedotun; Ndimako, Onyedikachukwu O. (2025) 'Enhancing Thermal Comfort in High-Rise Condominiums Through Passive Design Strategies in Lagos, Nigeria', *International Journal of Sustainable Development and Planning*, 20(5), pp. 1797-1811. Available at: https://doi.org/10.18280/ijsdp.200501

Egbum, P.S., Anaebo, C., David, C. and Barnaby, J (2023) 'Exploring the use of indigenous building materials to achieve thermal comfort in a hot, humid climate: the case of South Eastern Nigeria, African Journal of Educational Management, Teaching and Entrep'.

Elenga, Rolains Golchimard; Zhu, Li; Defilla, Steivan (2025) 'Performance evaluation of different building envelopes integrated with phase change materials in tropical climates', *Energy and Built Environment*, 6(2), pp. 332-346. Available at: https://doi.org/10.1016/j.enbenv.2023.11.008

Gupta, V.; Deb, C. (2023) 'Envelope design for low-energy buildings in the tropics: A review', *Renewable and Sustainable Energy Reviews*, 186, pp. 113650. Available at: https://doi.org/10.1016/j.rser.2023.113650

James, M. E.; Fulani, O. A.; Azoji, C. F. (2022) 'Application of Passive Cooling Principles in Selected Hotel Buildings in Southwest Nigeria', *IOP Conference Series: Earth and Environmental Science*, 1054(1), pp. 012032. Available at: https://doi.org/10.1088/1755-1315/1054/1/012032

Jannat, Nusrat; Hussien, Aseel; Abdullah, Badr; Cotgrave, Alison (2020) 'Application of agro and non-agro waste materials for unfired earth blocks construction: A review', *Construction and Building Materials*, 254, pp. 119346. Available at: https://doi.org/10.1016/j.conbuildmat.2020.119346

Jegede, Olumide Ebenezer; Taki, Ahmad (2022) 'Optimization of building envelopes using indigenous materials to achieve thermal comfort and affordable housing in Abuja, Nigeria', *International Journal of Building Pathology and Adaptation*, 40(2), pp. 219-247. Available at: https://doi.org/10.1108/IJBPA-01-2021-0009

Ji, Lili; Shu, Chang; Gaur, Abhishek; Wang, Lin; Lacasse, Michael (2024) 'A state-of-the-art review of studies on urban green infrastructure for thermal resilient communities', *Building and Environment*, 257, pp. 111524. Available at: https://doi.org/10.1016/j.buildenv.2024.111524

Juffle, Nor Aqilah Haji; Rahman, Md Motiar (2023) 'An overview of motivators and challenges of passive design strategies', *IOP Conference Series: Earth and Environmental Science*, 1195(1), pp. 012039. Available at: https://doi.org/10.1088/1755-1315/1195/1/012039

Kulumkanov, Nursat; Memon, Shazim Ali; Khawaja, Saleh Ali (2024) 'Evaluating future building energy efficiency and environmental sustainability with PCM integration in building envelope', *Journal of Building Engineering*, 93, pp. 109413. Available at: https://doi.org/10.1016/j.jobe.2024.109413

Kwag, Byung Chang; Adamu, Babayo Mohammed; Krarti, Moncef (2019) 'Analysis of high-energy performance residences in Nigeria', *Energy Efficiency*, 12(3), pp. 681-695. Available at: https://doi.org/10.1007/s12053-018-9675-z

Laasri, Imad Ait; Charai, Mouatassim; Es-sakali, Niima; Mghazli, Mohamed Oualid; Outzourhit, Abdelkader (2024) 'Evaluating passive PCM performance in building envelopes for semi-arid climate: Experimental and numerical insights on hysteresis, sub-cooling, and energy savings', *Journal of Building Engineering*, 98, pp. 111161. Available at: https://doi.org/10.1016/j.jobe.2024.111161

Lai, Fei; Zhou, Jinzhi; Lu, Lin; Hasanuzzaman, M.; Yuan, Yanping (2023) 'Green building technologies in Southeast Asia: A review', *Sustainable Energy Technologies and Assessments*, 55, pp. 102946. Available at: https://doi.org/10.1016/j.seta.2022.102946

Lamrani, B.; Johannes, K.; Kuznik, F. (2021) 'Phase change materials integrated into building walls: An updated review', *Renewable and Sustainable Energy Reviews*, 140, pp. 110751. Available at: https://doi.org/10.1016/j.rser.2021.110751

Lapisa, Remon; Arwizet, -; Krismadinata, -; Arafat, Andril; Saputra, Aprizal; Romani, Zaid (2022) 'Numerical Analysis of the Roof Slope Effect on the Building Thermal Comfort and the Need for Roofing Materials in Tropical Area', *International Journal on Advanced Science, Engineering and Information Technology*, 12(6), pp. 2556-2562. Available at: https://doi.org/10.18517/ijaseit.12.6.16283

Lazaro, Samuel Aires Master; Li, Xiangyu (2025) 'Evaluating the feasibility and challenges of using passive solar systems for achieving thermal comfort in African countries: a review', *International Journal of Building Pathology and Adaptation*, 44(2), pp. 515-535. Available at: https://doi.org/10.1108/IJBPA-05-2024-0109

Lee, Yilin; Ng, Edward (2025a) 'An adaptable framework for resilient subtropical low-income housing under future climate and predicted lifestyles: a Hong Kong case study', *Energy and Buildings*, 348, pp. 116412. Available at: https://doi.org/10.1016/j.enbuild.2025.116412

Lee, Yilin; Ng, Edward (2025b) 'Enhancing thermal performance of subtropical low-income housing through passive and behaviour-guided adaptive design', *Building and Environment*, 285, pp. 113542. Available at: https://doi.org/10.1016/j.buildenv.2025.113542

López-Pérez, L.A.; Flores-Prieto, J.J.; Ríos-Rojas, C. (2019) 'Adaptive thermal comfort model for educational buildings in a hot-humid climate', *Building and Environment*, 150, pp. 181-194. Available at: https://doi.org/10.1016/j.buildenv.2018.12.011

Mabdeh, S., Ahmad, S., Alradaideh, T. and Bataineh, A (2020) 'Low-cost ventilation strategies to improve the indoor environmental quality by enhancing the natural ventilation in multistory residential buildings, Periodicals of Engineering and Natural Sciences, 8'.

Mohammadpourkarbasi, Haniyeh; Jackson, Iain; Nukpezah, Daniel; Appeaning Addo, Irene; Assasie Oppong, Rexford (2022) 'Evaluation of thermal comfort in library buildings in the tropical climate of Kumasi, Ghana', *Energy and Buildings*, 268, pp. 112210. Available at: https://doi.org/10.1016/j.enbuild.2022.112210

Mohan, Man; Dewangan, Sheetal Kumar; Soni, Sourabh Kumar; Kalbande, Vednath P.; Choudhari, Manoj S.; Jain, Reliance; Chinnasamy, Veerakumar; Sharma, Vinod Kumar; Krishnan, S.R. Akhil; Ahn, Byungmin (2026) 'Building thermal comfort and energy savings: A review of performance, challenges, opportunities, and recommendations in phase change material integration within building elements', *Applied Thermal Engineering*, 300, pp. 131105. Available at: https://doi.org/10.1016/j.applthermaleng.2026.131105

Muhammed, Adamu; Folorunso, Clement Oluwole; Fadairo, Gabriel (2024) 'Assessment of sandcrete hollow blocks' thermal performance as a walling material for tropical buildings in Lokoja, Nigeria', *International Journal of Building Pathology and Adaptation*, 42(4), pp. 653-671. Available at: https://doi.org/10.1108/IJBPA-07-2021-0096

Mustapha, T.D (2023) 'Assessment of thermal comfort in naturally ventilated classrooms in the tropical savanna climate of Nigeria', *Unpublished manuscript*.

Nazir, Kashif; Memon, Shazim Ali; Saurbayeva, Assemgul; Ahmad, Abrar (2023) 'Energy consumption predictions by genetic programming methods for PCM integrated building in the tropical savanna climate zone', *Journal of Building Engineering*, 68, pp. 106115. Available at: https://doi.org/10.1016/j.jobe.2023.106115

Nwalusi, Dickson M.; Obi, Nicholas I.; Chendo, Ikebueze G.; Okeke, Francis O. (2022) 'Climate Responsive Design Strategies for Contemporary Low-rise Residential Buildings in Tropical Environment of Enugu, Nigeria', *IOP Conference Series: Earth and Environmental Science*, 1054(1), pp. 012052. Available at: https://doi.org/10.1088/1755-1315/1054/1/012052

Oforji, Peter I.; Mba, Emeka J.; Okeke, Francis O. (2023) 'The Effects of Rhythm on Building Openings and Fenestrations on Airflow Pattern in Tropical Low-Rise Residential Buildings', *Civil Engineering Journal*, 9(8), pp. 2062-2084. Available at: https://doi.org/10.28991/CEJ-2023-09-08-016

Okafor, Marcellinus U.; Awuzie, Bankole Osita; Otasowie, Kenneth; Marcel-Okafor, Udochukwu; Aigbavboa, Clinton (2022) 'Evaluation of Indoor Thermal Comfort Conditions of Residential Traditional and Modern Buildings in a Warm-Humid Climate', *Sustainability*, 14(19), pp. 12138. Available at: https://doi.org/10.3390/su141912138

Okanlawon, S.A (2025) 'Climate-responsive architecture in South-Western Nigeria: a case study of climate analysis and design adaptation in a selected town, Journal of Environmental Management and Construction Research (JEMC'.

Okereke, Agha-Ejimole; Ike, Felix (2025) 'Indoor thermal comfort comparison of stabilised latscrete and sandcrete blocks as walling materials in buildings in Port Harcourt Metropolis, Nigeria', *Acta Structilia*, 32(1), pp. 171-198. Available at: https://doi.org/10.38140/as.v32i1.8604

Okonta, Donatus Ebere (2023) 'Investigating the impact of building materials on energy efficiency and indoor cooling in Nigerian homes', *Heliyon*, 9(9), pp. e20316. Available at: https://doi.org/10.1016/j.heliyon.2023.e20316

Olaniyan, S., Yunus, S. and Onigbogi, O (2023) 'Towards sustainable indoor thermal comfort in the tropical building design: comparative performance analysis of fixed external shading elements and differential window glass thermal properties, Uniosu'.

Oluwarotimi, Y.I (2026) 'Pathway to passive design for energy-efficient residential buildings in Nigeria (blending tradition and modernity)', *Doctoral thesis*.

Oluwatayo, Adedapo A.; Miracle, Nduka D. (2025) 'Investigating the Adoption of Passive Cooling Strategies in Selected Office Buildings in Abuja, Nigeria', *IOP Conference Series: Earth and Environmental Science*, 1492(1), pp. 012019. Available at: https://doi.org/10.1088/1755-1315/1492/1/012019

Onwuzuligbo, Chijioke Chinyere; Uzoagba, Chidiebele Ejikeme Joseph; Umeora, Chukwunonso Obiefuna; Mmonwuba, Nwanneka Chibuzo (2025) 'Geometrical and Material Considerations for External Shading Optimisation of Residential Buildings in Southeastern Nigeria: A Systematic Review', *IPS Journal of Physical Sciences*, 2(1), pp. 20-26. Available at: https://doi.org/10.54117/ijps.v2i1.5

Onyenokporo, Nwakaego Chikaodinaka; Ochedi, Ekele Thompson (2019) 'Low-cost retrofit packages for residential buildings in hot-humid Lagos, Nigeria', *International Journal of Building Pathology and Adaptation*, 37(3), pp. 250-272. Available at: https://doi.org/10.1108/IJBPA-01-2018-0010

Onyenokporo, Nwakaego C.; Taki, Ahmad; Montalvo, Luis Zapata; Oyinlola, Muyiwa A. (2024a) 'Exploring the Impact of Rice Husk Ash Masonry Blocks on Building Energy Performance', *Buildings*, 14(5), pp. 1290. Available at: https://doi.org/10.3390/buildings14051290

Onyenokporo, Nwakaego C.; Beizaee, Arash; Adekeye, Olutola F.; Oyinlola, Muyiwa A. (2024b) 'The Bottle House: Upcycling Plastic Bottles to Improve the Thermal Performance of Low-Cost Homes', *Sustainability*, 16(4), pp. 1360. Available at: https://doi.org/10.3390/su16041360

Rodrigues, Lucelia; Cherian, Benjamin Abraham; Tokbolat, Serik (2025) 'Reducing Cooling Energy Demand in Saudi Arabian Residential Buildings Using Passive Design Approaches', *Buildings*, 15(11), pp. 1895. Available at: https://doi.org/10.3390/buildings15111895

Santos, Michael M.; Ferreira, Ana Vaz; Lanzinha, João C. G. (2022) 'Passive Solar Systems for the Promotion of Thermal Comfort in African Countries: A Review', *Energies*, 15(23), pp. 9167. Available at: https://doi.org/10.3390/en15239167

Simões, Gianna Monteiro Farias; Leder, Solange Maria; Labaki, Lucila Chebel (2021) 'How uncomfortable and unhealthy can social (low-cost) housing in Brazil become with use?', *Building and Environment*, 205, pp. 108218. Available at: https://doi.org/10.1016/j.buildenv.2021.108218

Tambaya, I (2023) 'Combining Building Simulation and Sensitivity Analysis for the Evaluation of Passive Design Approaches for Residential Buildings in Nigeria', *Journal of Sustainability Research*, 5(2). Available at: https://doi.org/10.20900/jsr20230007

Wingrove, Katherine; Heffernan, Emma; Daly, Daniel; Ambrose, Michael (2025) 'Passive-solar design: Evidence of the disconnect between theory, policy and practice in the glazing design of contemporary Australian homes', *Energy and Buildings*, 345, pp. 116104. Available at: https://doi.org/10.1016/j.enbuild.2025.116104

Xi, Tianyu; Sa'ad, Salanke Umar; Liu, Xinyu; Sun, Haibo; Wang, Ming; Guo, Fei (2025) 'Optimization of Residential Indoor Thermal Environment by Passive Design and Mechanical Ventilation in Tropical Savanna Climate Zone in Nigeria, Africa', *Energies*, 18(3), pp. 450. Available at: https://doi.org/10.3390/en18030450

Yang, Tingting; Ding, Yong; Li, Baizhan; Athienitis, Andreas K. (2023) 'A review of climate adaptation of phase change material incorporated in building envelopes for passive energy conservation', *Building and Environment*, 244, pp. 110711. Available at: https://doi.org/10.1016/j.buildenv.2023.110711

Yin, Yihan; Li, Song; Xing, Xiaoyi; Zhou, Xinyi; Kang, Yujie; Hu, Qi; Li, Yanjing (2024) 'Cooling Benefits of Urban Tree Canopy: A Systematic Review', *Sustainability*, 16(12), pp. 4955. Available at: https://doi.org/10.3390/su16124955

Zhang, Aitonglu; Xiong, Yaxuan; Zhao, Yanqi; Wu, Yuting; Xu, Qian; Ding, Yulong (2025) 'A review of passive building thermal management with phase-change materials', *Renewable and Sustainable Energy Reviews*, 211, pp. 115334. Available at: https://doi.org/10.1016/j.rser.2025.115334

HOW TO CITE THIS ARTICLE

Moral, B. (2026). Passive Architectural Design Parameters for Indoor Thermal Performance in Tropical Savannah, Nigeria: A Review of Residential Buildings. *Research and Reviews in Sustainability*, 2, 317-336. https://doi.org/10.65582/rrs.2026.017

COPYRIGHT AND LICENCE

© 2026 The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution (CC BY 4.0) licence, which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.