Re-reading Malay Vernacular: Climate-Responsive Principles in Rumah Panggung for Contemporary Housing

Cut Nuraini, Muhammad Sofyan, Luga Alexander Pakpahan

Abstract

This paper re-reads Malay vernacular architecture to extract climate-responsive principles from the *Rumah Panggung* (stilt house) and translate them into actionable guidelines for contemporary housing in humid-tropical contexts. Combining typological analysis with field documentation in Binjai, North Sumatra, the study revisits key spatial, material, and construction logics elevated floors with ventilated undercroft, deep eaves and high-pitched roofs, porous wall assemblies, shaded verandas, and lightweight, reconfigurable partitions. Situated within Binjai's hot-humid conditions and recurrent pluvial and fluvial flood risks, the case study examines representative neighborhoods and conducts performance-oriented reasoning informed by passive design theory (cross-ventilation paths, stack-effect cooling, solar control, and moisture management). The findings show how the *Rumah Panggung*'s coupled strategies raising habitable floors, creating thermal buffer zones, and grading façade permeability enhance thermal comfort and hydrological resilience while supporting incremental growth and easy repair. These logics are then reformulated as design rules compatible with current construction practice in Binjai: orientation and massing for prevailing breezes, vented high roofs, modular shaded outdoor rooms, raised structures and flood-tolerant ground layers, and hybrid material systems pairing locally available components with durable contemporary products. Scenario prototyping demonstrates the potential to reduce reliance on mechanical cooling and to improve comfort hours across typical dwelling layouts. By reframing the *Rumah Panggung* as climate intelligence rather than style, and grounding the argument in Binjai's urban and environmental realities, the study advances a pragmatic path for affordable, sustainable, and culturally resonant housing delivery today.

Keywords: Binjai; North Sumatra; Malay Vernacular; Rumah Panggung; Passive Design; Tropical Housing; Flood Resilience; Contemporary Adaptation

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Introduction

In hot humid Southeast Asia, residential energy demand is driven largely by cooling loads and moisture management; passive strategies remain the most robust first line of defence against heat stress and high humidity [13], [4]. Indonesia's western islands, including North Sumatra, fall within an Af (tropical rainforest) Köppen climate zone with year-round warmth and high relative humidity, which prioritises shade, ventilation, and rain protection over envelope insulation [5], [9]. In this climatic regime, vernacular precedents such as the Malay Rumah Panggung (stilt house) embed performance logics elevated floors, deep eaves and steep roofs, porous façades, and verandas as thermal buffers that facilitate cross-ventilation, stack-effect cooling, and flood tolerance [7], [8], [10], [11].

Binjai an independent city within Greater Medan sits at low elevation and is intersected by the Bingai, Mencirim, and Bangkatan rivers, experiencing frequent rainy-season flooding [15], [6]. Disaster briefs and news coverage repeatedly document overflow events along these rivers, underscoring the need for hydrologically resilient housing [1], [2], [12]. Local weather observations also confirm persistently high humidity and frequent wet days through much of the year [3], [14].

Despite the existence of context-attuned vernacular knowledge, many contemporary low- to middle-income houses in Indonesian cities adopt generic, sealed envelopes with limited shading and poorly arranged openings, increasing reliance on mechanical cooling and creating moisture problems. Empirical assessments of Malay traditional houses demonstrate how appropriately scaled openings, roof forms, and raised floors can moderate peak indoor temperatures and improve comfort via natural ventilation capabilities that are often absent in current developer housing [7], [10]. In Binjai, where pluvial and fluvial flooding recur, at-grade construction further exposes homes to water damage and displacement [1], [2], [6]. There is thus a dual gap: contemporary housing underperforms thermally in a hot humid climate and lacks flood-risk responsiveness, while vernacular principles remain under-translated into modern, code-compliant construction systems [13], [9].

This study seeks to: a) re-read the Malay Rumah Panggung to distil climate-responsive principles relevant to hot humid living (ventilation, solar/rain control, moisture and flood management) through typological and performance-oriented analysis [8], [11]; b) contextualise these principles within Binjai's climatic and hydrological realities to identify constraints and opportunities for application [3], [15], [1], [2]; c) translate vernacular logics into actionable, performance-based guidelines and detail concepts compatible with contemporary materials, construction practices, and regulatory expectations [13], [9]; and d) anticipate performance by outlining comfort and resilience scenarios (cooling load reduction, comfort hours, flood tolerance) for typical Binjai house layouts.

Literature Review

2.1 Malay Vernacular Typology and Climate Logic

Scholarship on Malay vernacular architecture consistently characterizes the Rumah Panggung (stilt house) as a lightweight, highly permeable system optimized for hot humid climates through raised floors, deep eaves, ventilated roof spaces, and verandas that act as thermal buffers. These features work together to limit solar gains, promote cross-ventilation and stack-effect cooling, and provide a hygienic separation from damp ground while accommodating seasonal inundation [22], [11]. Typological and historical readings further show that such climate intelligence persisted even as colonial materials and planning ideas were hybridized with indigenous forms across Malaya and the Indonesian archipelago [11]. In Indonesia and Bangka Island specifically, stage-house variants illustrate how raised construction, porous façades, and lightweight skins were calibrated to monsoonal rainfall and high humidity [8].

2.2 Empirical Evidence on Thermal Performance and Airflow

Field and experimental studies on traditional Malay houses (e.g., Penang; Negeri Sembilan) document measurable indoor temperature moderation and robust cross-ventilation when elevated floors, well-scaled openings, and ventilated high roofs are combined [20], [23]. Temperature and air-speed monitoring, along with airflow visualization, support the proposition that vernacular spatial and envelope logics can deliver comfort hours without mechanical cooling when sited/oriented appropriately [20], [23].

2.3 Passive Design and Adaptive Comfort Frameworks

Handbooks for tropical design prioritize four early-stage levers shading, controlled permeability for ventilation, rain protection, and low thermal mass to curb cooling loads in hot humid regions [13]. In parallel, adaptive comfort theory (and its codification in ASHRAE Standard 55) shows that raising indoor air speed via natural ventilation or fans broadens acceptable operative temperatures in naturally ventilated buildings evidence that aligns with vernacular reliance on moving air and shade rather than insulation [17], [18].

2.4 Indonesian Passive-Cooling Zones and Implications for North Sumatra

Recent national-scale zoning for passive cooling in Indonesia classifies hot humid locales into finer sub-zones and recommends strategy mixes (comfort ventilation, night purging, or combinations) based on temperature, humidity, and wind regimes [9], [24]. For Sumatra including North Sumatra priority tactics include generous, well-oriented openings for cross-ventilation, deep overhangs, and high, vented roofs; night ventilation is beneficial where diurnal swings allow. These mappings provide a contemporary performance frame for translating Rumah Panggung logics to modern housing in cities such as Binjai [9], [24].

2.5 Flood Resilience and Stilted Housing in Humid-Tropical Contexts

Beyond thermal performance, stilt houses historically mitigate fluvial and pluvial flood risks by elevating habitable floors above design flood levels and allowing unhabited undercrofts to flood safely. Comparative and place-specific studies in Southeast Asia (Malaysia, Vietnam, the Philippines, Indonesia) connect such elevation strategies to reduced damage and faster recovery, while noting the need for structural checks against scour and lateral loads [19], [21], [26]. Malaysian guideline reviews highlight the growing push toward flood-resistant detailing (e.g., elevated services and water-resistant materials) and the policy gap in mainstream residential practice [25]. These insights reinforce the dual agenda thermal comfort and hydrological safety embedded in Malay vernacular precedent.

2.6 From Precedent to Contemporary Guidelines: Opportunities and Constraints

Translating vernacular principles into contemporary housing demands reconciling passive design intent with structural robustness, material durability, and code compliance. Recent structural evaluations of traditional Malay houses identify vulnerabilities to lateral forces, sliding, and differential settlement especially under scour while confirming adequate gravity capacity in primary members; this points to the need for engineered foundations, lateral systems, and durable hybrid materials when re-adapting raised typologies today [16]. Synthesis papers and practice-oriented texts therefore argue for performance-based "rules of thumb" (e.g., orientation windows for prevailing breezes, verifiable opening areas/WWR, minimum overhang depths, vented ridge specifications, flood-tolerant ground layers) to bridge vernacular climate intelligence with modern delivery systems [10], [13], [22].

Synthesis and gap. Taken together, the literature affirms that Rumah Panggung embodies a coherent, climate-responsive system with concurrent flood resilience. Yet, few works operationalize these logics as quantified, transferable guidelines packaged for today's small-plot, developer-led housing in secondary Indonesian cities. This paper addresses that gap by reframing Malay vernacular strategies as measurable design principles, then testing their applicability in Binjai's hot-humid and flood-prone context.

Research Methodology

The study adopts a mixed-methods design combining (i) typological analysis of representative housing in Binjai, North Sumatra, and (ii) a rule-based performance audit operationalized through measurable indicators derived from passive design, adaptive comfort theory, and flood-resilience literature (e.g., ASHRAE 55; UN-Habitat tropical design guidance; Indonesian passive-cooling zoning) [9], [13], [17], [24]. The goal is to translate vernacular climate logics into verifiable criteria for contemporary small-plot housing.

Three prevalent plot/house types are specified to reflect Binjai's urban fabric and hydrological exposure, can be seen in figure 1:

a. T1 Stilted (or stilt-ready) row house (≈ 6 × 15 m plot). Party walls on two sides; single-aspect rooms common.
b. T2 Corner-lot duplex (≈ 8 10 m frontage). Dual-aspect rooms; greater shading opportunities.
c. T3 Infill on flood-susceptible streets. At-grade slabs are typical; intervention emphasizes elevated floors and floodable ground layers.

Figure 1. Three prevalent plot/house types

Orientation is recorded to prevailing wind and solar paths; local flood design levels (DFL) are noted from available municipal/hazard sources.

A purposive sampling frame of 12 18 dwellings (4 6 per typology) is used to capture variation in orientation, envelope configuration, and flood exposure. Primary data comprise on-site geometric measurements of openings, overhangs, stilt/plinth heights, veranda depth, and roof vent areas, complemented by photographic documentation and rapid mapping of space use. A monitored subset (n = 6) is instrumented with temperature humidity loggers (≥10-min intervals) and low-velocity anemometers at 1.1 m (seated level), with spot globe temperature where feasible, while hourly weather, wind rose data, and flood heights from the nearest station and local reports provide the climatic and hydrological context for adaptive-comfort baselines and flood design levels [1] [3], [5], [6], [14].

Indicators are computed at façade/space level and aggregated to the dwelling to form a composite resilience index (CRI). Thresholds and targets are grounded in hot humid passive design guidance and adaptive comfort theory, covering cross-ventilation potential, effective opening ratios, window-to-wall ratios, shading performance, roof venting, freeboard and service elevation, night-vent readiness, semi-outdoor buffers, envelope thermal capacity, and detailing robustness [9], [13], [17], [18], [24]. Each indicator is normalized to [0,1] using target-based linear ramps, with hard non-compliances (e.g., finished floor level below design flood level) clamped to 0, and weighted to reflect the relative importance of ventilation, shading, and flood protection in Binjai's context. Analysis proceeds via descriptive typology profiles (T1 T3), between-typology comparisons (one-way ANOVA or Kruskal Wallis on CRI and key indicators), sensitivity checks on weights (±25%), and qualitative triangulation between measured air speeds/comfort observations and adaptive-comfort bands [17], [18]. Scenario prototyping then develops "minimum-moves" retrofit/new-build schemes per typology to achieve CRI ≥ 0.75, focusing on strategic additions to openings, shading, roof venting, and elevation strategies.

Data quality is supported through dual-observer measurements on a 25% subsample and pre/post calibration checks of monitoring devices. Construct validity is anchored in direct mapping of indicators to mechanisms widely recognized in the literature cross-ventilation, shading efficacy, attic venting, flood freeboard, and lightweight envelopes [13], [17] [19]. Ethical procedures include informed consent for access and brief interviews and anonymized reporting. The audit is explicitly bounded to first-order passive and flood measures; it is not a substitute for detailed thermal airflow simulation or structural design, and the modest monitoring periods imply that seasonal replication would be required to fully capture inter-seasonal variability.

Results

4.1 Typological Re-Reading: Distilled Climate-Responsive Principles

The re-reading of Malay *Rumah Panggung* yields a coherent system of climate strategies rather than discrete images. Across documented precedents, five principle-sets recur: (i) elevation + floodable ground (hydrological resilience); (ii) shading + buffered semi-outdoors (solar/rain control with verandas); (iii) graded permeability (operable louvers, aligned openings, transoms); (iv) vented high roof (stack-effect exhaust and attic heat relief); and (v) lightweight, reparable skins (reduced thermal lag, rapid drying). These principles are mutually reinforcing e.g., verandas and deep eaves enable large openings to work without glare or rain ingress, while a vented roof improves pressure differentials that drive cross-ventilation.

4.2 Binjai Case: Climatic and Hydrological Constraints as Design Drivers

Site appraisal in Binjai (humid-tropical, frequent wet days, and recurrent pluvial/fluvial events) foregrounds dual performance targets: thermal comfort without continuous mechanical cooling and flood-aware ground treatment. Typical small-plot houses observed in newer estates show limited eave depth, sealed façades, and at-grade slabs configurations that underdeliver on both targets. Consequently, design translation prioritizes (a) fully shading principal apertures; (b) establishing continuous inlet outlet paths; (c) venting roof spaces; and (d) elevating the habitable floor while keeping the ground layer explicitly floodable and easy to clean.

4.3 Rule-Based Performance Assessment (Qualitative)

Applying the comparison rules to common Binjai plot types (row house ~6×15 m; corner lot; infill on flood-susceptible street) indicates the following directional outcomes:

1. Ventilation potential. Aligning apertures on opposing façades, restoring high-low opening pairs (e.g., operable clerestory/transoms), and specifying ridge venting systematically increase pressure differentials and internal air movement, enabling comfort in naturally ventilated mode for longer daily periods.
2. Solar and rain control. Overhangs sized to keep direct sun off glazing during peak hours allow larger opening areas without overheating or water ingress; wrap-around verandas function as primary thermal buffers and social space.
3. Moisture management. Elevated floors, breathable wall assemblies, and ventilated roof spaces reduce surface condensation risk and drying times after wet episodes.
4. Hydrological resilience. A floodable, unoccupied undercroft with washable finishes, elevated services, and sacrificial skirtings localizes damage and shortens recovery following shallow inundation events.

These outcomes are consistent across prototypes when rules are applied as a set; partial adoption (e.g., adding large openings without shading) undermines performance.

4.4 Design Prototypes and Implementation Readiness

Three prototypes were developed to demonstrate transferability:

1. Stilted row-house on 6×15 m plot. A continuous veranda along the long façade, paired with operable louvers and transoms, establishes cross-ventilation through living spaces; the floor is raised above the local design flood with diagonally braced short piles. Roof ventilation is ensured by a vented ridge and screened gables.
2. Corner-lot duplex with wrap-around veranda. Dual-aspect rooms exploit prevailing breezes; deep eaves and corner verandas shade two façades; a service spine is elevated and consolidated for rapid inspection.
3. Infill house on flood-susceptible street. A taller plinth and fully floodable ground layer are combined with washable ground-contact surfaces and elevated electrical distribution; front and rear openings are balanced despite privacy constraints via high-level louvers and perforated screens.

Across prototypes, material palettes pair durable frames (treated timber, steel, or engineered bamboo) with lightweight, repairable claddings, and use locally serviceable roofing with reflective underlay. Detailing prioritizes continuous flashings, drip edges, screened vents, and insect-proof night ventilation panels.

4.5 Limitations and Next Steps

Results are rule-based and typologically grounded; they do not substitute for full simulation or code-level structural design. Future work should (i) quantify comfort hours and cooling-energy reduction via coupled thermal airflow simulation; (ii) calibrate overhang depth and opening schedules to Binjai's diurnal/seasonal solar geometry; and (iii) test foundation/bracing strategies against local scour and lateral loads. Stakeholder co-design with local builders and residents is recommended to align rules with procurement realities and maintenance cultures.

Discussion

5.1 Interpreting The Results Through Adaptive Comfort Theory

The rule-based prototypes for Binjai substantiate an adaptive comfort pathway whereby increased air movement and behavioural choices expand acceptable operative temperatures in naturally ventilated dwellings [18], [17]. In practice, the combined use of opposed openings, high low vent pairs (e.g., transoms with ridge vents), and veranda buffers raises indoor air speed while decoupling primary living spaces from peak solar gains. This aligns with empirical findings from traditional Malay houses where elevated floors and ventilated roofs moderated indoor temperatures relative to outdoors [20], [23]. Our results therefore support the proposition that Rumah Panggung logics remain effective when reframed as measurable design rules rather than stylistic motifs.

5.2 Synergy Of Passive Design Strategies In A Hot Humid Zone

Consistent with tropical design guidance, performance gains arise from strategy coupling rather than single measures [13]. Deep eaves and verandas enable larger, more permeable façades without rain ingress; elevated, lightweight floors reduce thermal lag and drying time after wet episodes; and vented high roofs create a stack-effect exhaust that stabilizes cross-ventilation. The prototypes thus operationalize a graded-permeability envelope with shading and roof venting as first-order levers precisely the mix recommended for Indonesia's hot humid sub-zones in which Binjai is situated [9], [24]. Partial adoption (e.g., enlarging openings without shading) weakens this synergy, helping to explain the underperformance of many contemporary small-plot houses that imitate cross-ventilation visually but not thermodynamically.

5.3 Hydrological Resilience: Elevating Habitability Rather Than Defending Ground

In Binjai's pluvial/fluvial hazard context, the prototypes shift emphasis from defending at-grade slabs to elevating the habitable layer and designing a floodable ground storey. This approach mirrors long-standing vernacular risk management and recent resilience literature that ties stilted construction to reduced damage and faster recovery provided that foundations and lateral systems are engineered for scour and horizontal loads [19], [26]. Our translation embeds washable finishes, elevated services, backflow prevention, and sacrificial skirtings to confine loss to low-value layers, bridging vernacular intent with contemporary maintenance and safety expectations.

5.4 Structural And Durability Considerations In Re-Adapting Stilted Typologies

While gravity capacity of primary members in traditional houses is often adequate, vulnerabilities to lateral actions and differential settlement require engineered upgrades when redeploying stilted forms in urban settings [16]. The results therefore recommend short, braced piles or piers, continuous load paths, and moisture-robust connection detailing paired with repairable lightweight cladding. This hybrid logic preserves the low thermal capacitance and reparability emphasized in vernacular practice while addressing durability and code compliance [11], [8].

5.5 From Precedent To Implementable Rules For Developer Housing

The comparison table translates precedent into actionable rules that can be specified in briefs and checked in design reviews: (i) ensure opposed openings of balanced area; (ii) size overhangs/verandas to fully shade principal glazing during peak sun; (iii) provide vented ridges and screened high low vents; (iv) maintain a floodable, uninhabited ground layer with elevated MEP; and (v) adopt lightweight, repairable skins over durable frames. Such rules respond to barriers identified in the literature namely, that implementation failures are often managerial and regulatory rather than purely technical [10], [13]. By packaging the rules as verifiable criteria, the approach facilitates uptake by municipal reviewers and volume builders.

5.6 Policy And Code Implications

The findings suggest three regulatory levers for hot humid, flood-prone cities such as Binjai:

1. Development control standards that reward verified cross-ventilation paths, minimum shading depths, and roof-vent provisions as compliance options parallel to mechanical cooling [9], [13], [17].
2. Flood-resilient housing guidelines that normalize elevated finished floors, floodable ground layers, and service elevation consistent with emerging guidance reviews and regional risk studies [25], [19].
3. Materials and detailing protocols emphasizing two-stage weather seals, continuous flashings, and locally serviceable components, reflecting the maintainability logic in vernacular and contemporary practice [13], [22].

5.7 Cultural Continuity And Contemporary Habitability

The prototypes preserve behavioural affordances semi-outdoor verandas, shaded work bays, modular growth identified as culturally embedded in Malay houses, while adapting them to small plots and privacy norms of contemporary estates [11]. Rather than reproducing historic images, the approach recontextualizes climate intelligence, supporting culturally legible yet performative housing.

5.8 Limitations And Research Agenda

The results are qualitative and typologically grounded. Future work should integrate coupled thermal airflow simulation to quantify comfort hours and cooling-energy reduction; conduct parametric shading studies tied to Binjai's solar geometry; and test foundation/bracing under site-specific geotechnical conditions [17], [18], [19]. Post-occupancy studies are recommended to evaluate adaptive behaviours and maintenance practices, extending empirical lines opened by previous monitoring of traditional Malay houses [20], [23].

Suggestions

6.1 For design practice

Rule-based briefs and reviews. Require, at minimum: (i) opposed openings of balanced effective area; (ii) overhangs/verandas sized to eliminate direct sun on principal glazing during 10:00 15:00; (iii) vented ridges plus screened high low openings; (iv) finished floor level set above local design flood level (DFL), with a floodable, uninhabited ground layer and elevated MEP. Early performance checks. Conduct quick airflow/comfort assessments (adaptive-comfort compliance and cross-vent path verification) and solar-shading studies prior to detailed design; iterate plan depth, opening placement, and veranda geometry accordingly. Envelope detailing. Specify two-stage weather seals, continuous flashings/drip edges, insect-proof night-vent panels, reflective roof underlays that maintain airflow, and repairable cladding modules over durable frames.

6.2 For Policy And Code (Binjai And Similar Hot Humid, Flood-Prone Cities)

Alternative compliance path. Recognize naturally ventilated dwellings that document cross-vent paths, minimum shading depths, and roof-vent provisions as a code-compliant route alongside mechanical cooling. Flood-resilient housing provisions. Normalize elevated floors, floodable ground layers, elevated services, and backflow protection in mapped hazard zones; allow height/setback accommodations for verandas and raised plinths. Approval and incentives. Fast-track permits and provide fee reductions or density/coverage bonuses for verified passive designs meeting adaptive-comfort and flood-resilience criteria.

6.3 For Implementation in Binjai

Pilot projects. Deliver three demonstration houses (row, corner, flood-street infill) to validate constructability, costs, and user acceptance; monitor comfort, humidity, and recovery after heavy rain. Capacity building. Issue a municipal pattern book (detail sheets for overhangs, ridge vents, screened louvers, floodable finishes) and train local builders on foundations/bracing for raised floors. Supply-chain alignment. Pre-qualify locally serviceable components (louvers, screens, flashing systems, reflective underlays) to reduce maintenance friction.

6.4 For research

Quantification. Simulate comfort hours and cooling-energy reduction via coupled thermal airflow models; run parametric studies for overhang depth, opening schedules, and roof vent sizing under Binjai's solar/meteorological data. Structural and geotechnical testing. Evaluate scour-resistant foundations and lateral systems for short-pile/short-pier solutions typical of small plots. Post-occupancy evaluation. Track adaptive behaviors, indoor humidity/mould risk, and maintenance cycles; assess long-term durability and lifecycle costs.

6.5 For Education and Community Engagement

Homeowner guidance. Produce simple decision aids (orientation, aperture pairing, veranda layouts, flood-ready finishes). Studio/technical curricula. Integrate the rule set into local architecture and construction programs to mainstream climate-responsive, flood-aware housing.

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