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Climate-responsive strategies for sustainable building design: a case study of the Javanese indigenous house in Indonesia

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Abstract. This study investigated climate-responsive strategies for sustainable building through a case study of the Javanese indigenous *Limasan* house in Indonesia. The research analysed how spatial configuration, building materials, and structural systems reflected principles of passive cooling, resource efficiency, and environmental adaptation. Two *Limasan* houses in Pacitan, East Java, one preserved in its traditional form and one modernized, were examined as case samples. Data were collected through field observations, photographic documentation, and semi-structured interviews. The results showed that the preserved *Limasan* house inherently integrated sustainability features, such as optimized natural ventilation, effective rainwater harvesting, and the use of renewable local materials. By contrast, the modernized version employed more durable but less climate-responsive materials, which strengthened structural resilience but reduced ecological performance. Interestingly, the comparative findings highlighted the challenges and opportunities of adapting indigenous housing concepts for contemporary sustainable building practices. This study implied that indigenous knowledge provides valuable references for sustainable housing design, cultural continuity, and climate adaptation policies.

1. Introduction

In the last decade, climate change has intensified as a global crisis, characterized by rising average temperatures, more frequent extreme weather events, and increasing greenhouse gas (GHG) concentrations in the atmosphere [1]. According to the Intergovernmental Panel on Climate Change [2], this trend poses significant risks to ecosystems, human health [3,4], and socio-economic stability worldwide [5]. The construction sector is one of the largest contributors to global carbon emissions [6,7]. In Southeast Asia, energy demand for buildings has increased by about 5% per year since 2000. This rise is driven by rapid urbanization and growing cooling needs in tropical climates [8]. The building sector in Indonesia accounted for around 32% of the country's total final energy consumption in 2017, and it was projected to increase significantly in line with rapid urbanization and the rising demand for cooling [9]. It is also aligned with

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Indonesia's commitment in the Enhanced Nationally Determined Contribution (NDC) 2022, which targeted a reduction in greenhouse gas emissions of 31.89% unconditionally and up to 43.20% with international support by 2030, with the building sector identified as one of the priority areas [10].

Various green building assessment frameworks have been developed globally [11,12]. Green Star in Australia assesses site development, water efficiency, transportation, ecology, materials, and emissions [13]. LEED (Leadership in Energy and Environmental Design) in the United States focuses on energy efficiency, indoor air quality, water conservation, and design innovation while BREEAM (Building Research Establishment Environmental Assessment Method) in the United Kingdom evaluates performance across management, health, energy, transport, materials, waste, and pollution [14]. These frameworks have been effective in reducing emissions and improving resource efficiency in modern construction projects [15,16], However, they have rarely been integrated with practices rooted in indigenous knowledge [17], even though cross-regional studies demonstrated that Passive strategies in traditional vernacular architecture significantly reduce indoor temperature and improve thermal comfort without mechanical systems [18,19].

In Indonesia, various traditional housing types have developed in response to local ecological and cultural conditions [20]. In the southern regions of Java, for instance, the *Limasan* house has endured for decades, even centuries, by utilizing renewable local materials and incorporating systems adaptive to the tropical climate [21–23]. These characteristics indicate that the *Limasan* house has long embodied climate-responsive design principles, well before the emergence of modern sustainable architecture discourses [24]. Nevertheless, most studies on the *Limasan* house have remained culturally oriented and descriptive, without systematically mapping its architectural elements against the technical indicators of contemporary green building frameworks [25]. This research gap is significant, as there is a growing need to formulate a hybrid model that integrates international certification frameworks with ecologically proven indigenous practices [25]. This study aimed to: (1) analyze the environmental practices embedded in the *Limasan* house within the framework of climate-responsive design; (2) map its architectural elements against modern sustainability indicators; and (3) identify adaptive principles relevant for integration into contemporary sustainable architecture in tropical regions.

2. Method

2.1 Research context

This research employed a qualitative case study approach with a comparative sustainability assessment, examining the Javanese Limasan house as a representative example of indigenous climate-responsive architecture. This study was conducted in Pacitan Regency, East Java, Indonesia (Figure 1), selected through purposive sampling. The regency was chosen because it remains one of the regions where *Limasan* houses are relatively well-preserved, both in their original form and in modernized versions. According to the Central Bureau of Statistics of Pacitan, more than 50% of households in several villages still occupy *Limasan*-type houses, making the area an appropriate setting to examine both the sustainability and adaptation of indigenous environmental practices. Geographically, Pacitan covers an area of 1,389.92 km^2 (7°92'–8°29' South Latitude and 110°90'–111°43' East Longitude) and has a tropical climate characterized by high rainfall and significant humidity. These climatic conditions pose challenges for building performance, particularly in terms of ventilation, thermal comfort, and water management, factors that are closely aligned with the Green Star Site Development criteria. The prevalence of

Limasan houses in Pacitan thus provides a valuable opportunity to investigate how vernacular design strategies respond to these environmental demands.

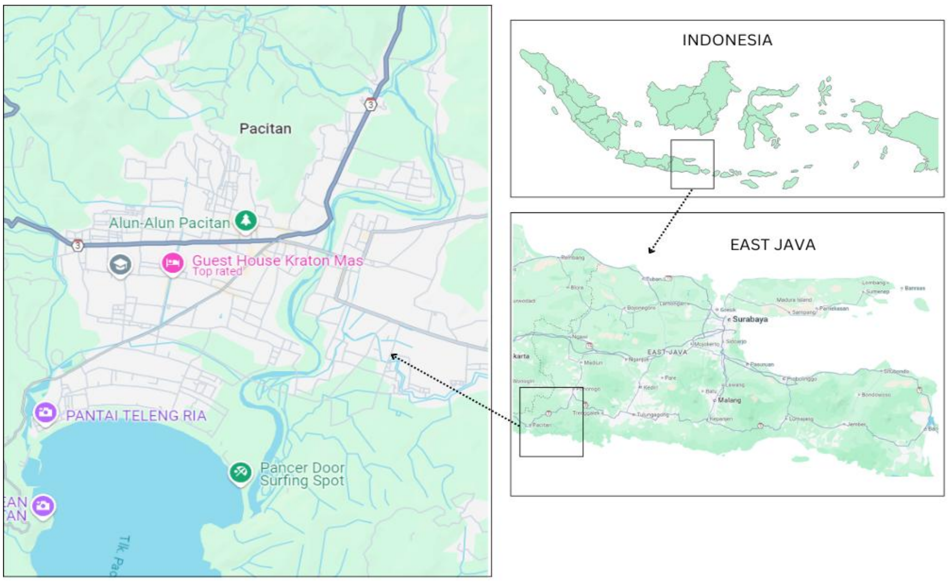

Figure 1. Case study research location.

Two *Limasan* houses (Figure 2) were purposively selected as case samples. The first is a traditional *Limasan* house, preserved since 1920, which has largely maintained its original form with only minor material replacements due to deterioration. The second is a modernized *Limasan* house, in which several traditional elements have been adapted to meet contemporary functional needs. The contrast between these two cases enables a comparative assessment of the extent to which vernacular architectural strategies align with or diverge from Green Star indicators for sustainable site development.

(a) (b)

Figure 2. Sample of traditional houses: (a)Preserved in original form, (b) Modernized

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2.2 Data collection

This study employed three primary techniques for data collection: participatory observation, in-depth interviews, and documentation. Participatory observation was conducted to directly examine the physical conditions and functions of *Limasan* houses, including those preserved in their original form and those that had been modernized. The observation framework was adapted from the Green Building Index [26] (see Table 1 for details), which offers sustainability indicators relevant to tropical Asian contexts. To strengthen international comparability, the six GBI aspects were further mapped against three international frameworks: LEED (US), BREEAM (UK), and Green Star (Australia). This mapping ensured international comparability and highlighted overlaps as well as gaps in the assessment of vernacular sustainability practices (see Appendix Table A1).

Table 1. Aspects of sustainability design in the participatory observation instrument for *Limasan* house

No.	Aspect	Observation Indicators
1.	Spatial Layout	Accessibility and circulation within the house
2.	Use of Building Materials	Types of materials used (Durability and environmental friendliness)
3.	Energy and Resource Efficiency	Utilization of natural lighting Ventilation is designed to ensure proper air circulation without artificial cooling.
4.	Water and Waste Management	Rainwater management system Household waste is managed sustainably, such as through composting or recycling systems.
5.	Integration with the Environment	House orientation to wind and sunlight Gardens, courtyards, or trees that are part of the house design to support the local ecosystem are observed.
6.	Modernization Changes in the House	Structural or layout modifications for modern needs The use of modern materials is assessed for whether they maintain or reduce sustainability principles.

In-depth interviews were conducted with the two homeowners to explore the intergenerational transformation of *Limasan* houses and to understand how cultural values and modernization influenced functional and design changes (see Table 2 for interview themes). These interviews also revealed how local traditions shaped the structure and spatial organization of *Limasan* houses from their original construction to the present. Documentation, including heritage records and supplementary written materials, was used to strengthen the overall dataset and provide contextual depth. Together, these three techniques created a comprehensive basis for examining the adaptation of vernacular architecture in relation to sustainability and contemporary building standards.

Table 2. Interview aspect and question

No.	Aspect Explored	Interview Questions
1.	History and transformation of the house	When was this house built, and has it undergone any changes since the first generation? What were the main reasons for the changes or renovations made to this house? Were they driven by practical needs or cultural or religious influences?
2.	Influence of culture values	How have local cultural values influenced the design and layout of this house?
3.	Changes in function and design of the house	How has the function of rooms in this house evolved over time? Have any rooms been repurposed to meet modern needs? How has the house's design been adjusted for modern needs, such as privacy, lighting, and ventilation?
4.	Use of building materials	What materials were originally used in this house? Has there been a shift towards modern materials like concrete or steel?
5.	Sustainability and environmental Impact	How has the design of this house adapted to its surroundings? Is there a particular focus on sustainability, such as water and energy management?
6.	Social perspectives	How are social spaces in this house organized to align with social values of the local community?
7.	Challenges of modernization and preservation	What are the main challenges in preserving the traditional design of this house amidst modernization? Has modernization altered the original identity of the *Limasan* house? If so, in what ways?

2.3 *Qualitative data analysis*
The data obtained from observations, interviews, and documentation were analyzed using a descriptive qualitative approach supported by triangulation. The analysis involved three stages: (1) identifying architectural elements of traditional *Limasan* houses with attention to materials, roof structures, and spatial layouts; (2) conducting a comparative assessment between traditional and modernized houses in terms of functionality and sustainability; and (3) evaluating the integration of sustainability principles into vernacular design. This process provided a holistic understanding of how *Limasan* houses balance cultural heritage with contemporary sustainable architectural practices.

3. Result and Discussion

3.1 Architectural and environmental practices in the traditional Limasan house
Field observations and documentation revealed that several architectural elements of the traditional *Limasan* house represented enduring practices of environmental sustainability. On average, *Limasan* houses in Pacitan covered approximately 120 m^2 (12 m in width and 10 m in length) with a principal roof height of up to 5 meters (see Figure 3). The spatial orientation was

typically directed toward the south or east, a positioning that facilitated the entry of prevailing morning and afternoon breezes.

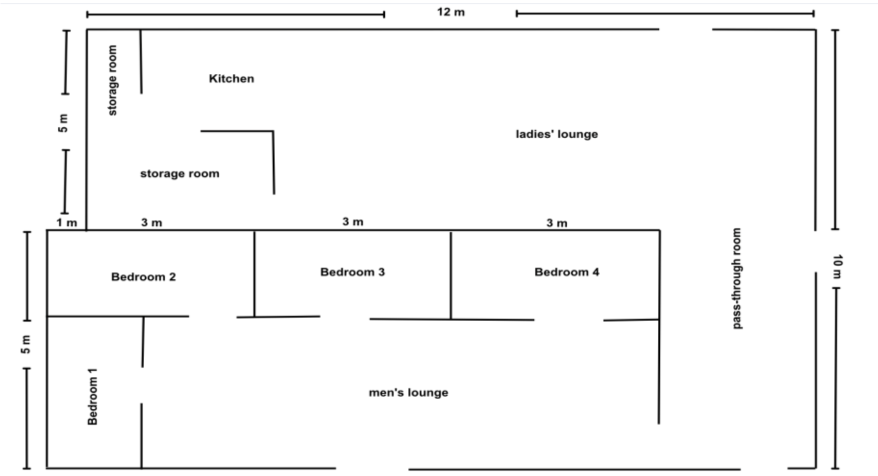

Figure 3. Spacial layout traditional preserved tradisional *Limasan* house

Ethnographic interviews indicated that such orientations were also grounded in Javanese cosmological philosophy: eastward orientation symbolized renewal and blessing as associated with the sunrise, while southward orientation represented cosmological balance and reverence toward the guardian of the southern sea. Oceanographic investigations of the southern coast of Java showed that the southeast monsoon from July to October generated a strong westward South Equatorial Current with surface velocities up to 23 cm/s. From November to June, the current shifted eastward as the Java Coastal Current, reaching peak velocities of 31 cm/s during the northwest monsoon, suggesting that an east-facing orientation could optimize airflow and enhance natural cross-ventilation. Collectively, these findings underscored the integration of cultural belief systems with climate-responsive architectural strategies, illustrating how vernacular design mediated between symbolic meaning and ecological adaptation.

(a) (b) (c) (d)

Figure 4. Architectural features of preserved traditional *Limasan* house (a) lowered front veranda, (b) bedroom with bamboo partition, (c) circulation space connecting to the kitchen, and (d) jointing system between structural columns.

The first climate-responsive strategy identified in the traditional *Limasan* house is the predominant use of locally sourced materials, including bamboo for partition walls, teakwood for the main structural frame, and clay tiles for roofing (Figure 4b–d). These materials contribute to thermal comfort in the indoor environment. Temperature measurements conducted at 01:00 PM local time indicated that indoor temperatures were on average 2–3 °C lower than outdoor temperatures, even in the absence of mechanical cooling (see Figure 5 for comparative results). This finding aligns with studies of tropical vernacular architecture, which demonstrate the role of organic local materials in moderating indoor thermal extremes in climates with high diurnal temperature variations [22,27]. Thermal balance in the *Limasan* house is further supported by the design of the veranda roof, which is set 1.52 m lower than the main roof (Figure 4a).

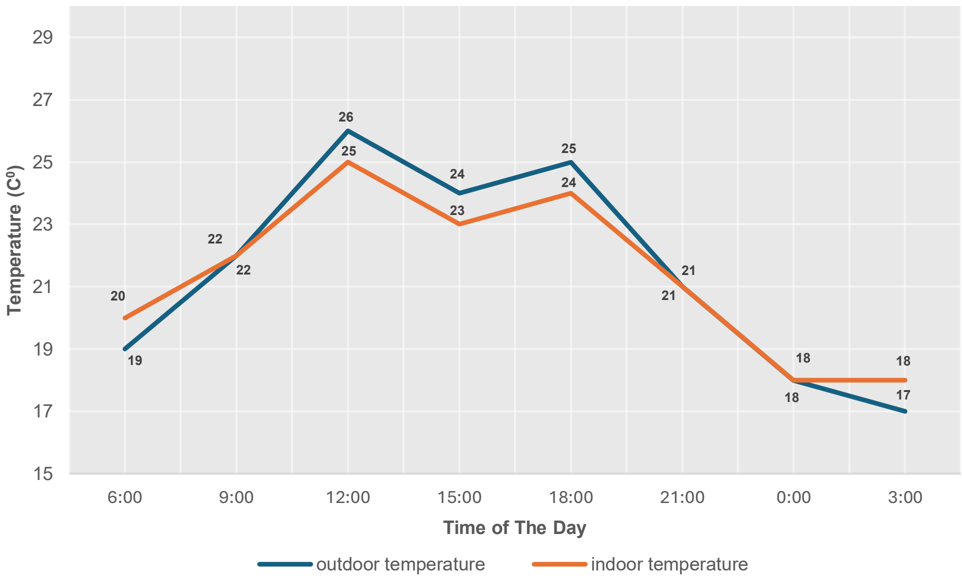

Figure 5. Graph of diurnal variation of outdoor and indoor temperatures

Ethnographic interviews revealed that this architectural feature carries cultural significance, as the lower height obliges visitors to bow slightly as a gesture of respect toward the homeowner. Functionally, however, it mitigates solar radiation and rainfall exposure. Simple measurements showed that shaded veranda areas were 1–2 °C cooler than adjacent open courtyards at midday. As one homeowner explained, 'without this veranda, the afternoon sun would directly penetrate the living room, making it uncomfortably hot' (Interview, July 12, 2024). These results corroborate broader findings in tropical vernacular studies, which highlight the effectiveness of deep verandas and roof overhangs as passive shading strategies that also enhance natural ventilation [28]. Bioclimatic design principles (integrating shading, ventilation, and thermal insulation) are increasingly reinterpreted in contemporary sustainable architecture to address current climatic challenges [29]. Next prominent climate-responsive strategy observed in the *Limasan* house is the use of column-to-column joinery designed without rigid fasteners or nails (Figure 4d). Structural connections are implemented through traditional wooden pegging and mortise–tenon techniques. This construction principle aligns with tropical vernacular architecture, which emphasizes structural flexibility and 'thermal breathing' as mechanisms to enhance indoor thermal comfort and extend the building's lifespan [28,29].

(a) (b)

Figure 6. Rainwater management system in the traditional *Limasan* house: (a) Integrated gutter positioned between roof tiles to channel rainwater; (b) Water collection at the roof's end for reuse in domestic purposes, reflecting sustainability practices through the utilization of natural resources.

The findings indicated that a key climate-responsive practice in the traditional *Limasan* house was the implementation of a water management system. Integrated gutters were installed between roof tiles (Figure 6a) to channel rainwater directly, enabling rainwater harvesting without the need for additional infrastructure. The collected water was stored in traditional clay jars (Figure 6b) that functioned as domestic reservoirs. This strategy demonstrated the adaptive capacity of the *Limasan* house to local climatic conditions while simultaneously reflecting embedded cultural values. Such vernacular design principles provided an empirical foundation for the development of sustainable architecture rooted in traditional ecological knowledge.

3.2 Comparative assessment: traditional vs. modernized Limasan house

Furthermore, this study conducted a comparative analysis of modern adaptations of the *Limasan* house to examine how climate-responsive design principles had been modified or adjusted. The modern *Limasan* house featured a more compact spatial layout of approximately 80 m^2 (Figure 7), primarily due to limited land availability.

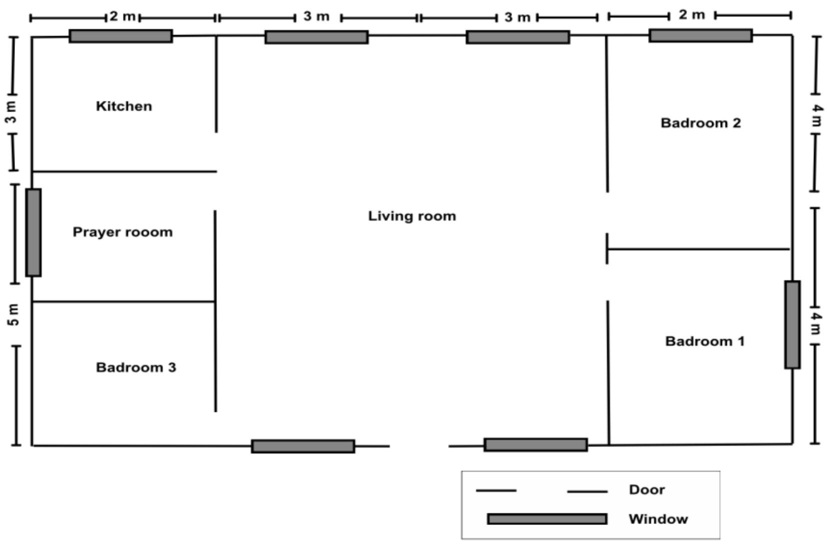

Figure 7. Spacial layout traditional modernized *Limasan* house

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Observations revealed that modernized *Limasan* houses tended to replace organic materials such as bamboo and teakwood with concrete, brick, and lightweight steel (Figure 8). Unlike traditional houses, which employed non-rigid foundations using timber beams and river stones as flexible supports, modern adaptations utilized reinforced concrete strip footings that rigidly bound walls and columns. According to homeowner interviews, this substitution aimed to improve structural durability and reduce routine maintenance requirements.

Preserve house with oven bamboo wall (a)

Modern house with brick wall (b)

Figure 8. Comparison of wall materials between traditional and modern *Limasan* houses.

However, the shift in materials diminished the building's capacity to maintain passive thermal comfort, as modern construction Temperature measurements conducted in the living rooms of both traditional and modern *Limasan* houses over a 24-hour cycle showed distinct thermal performance differences. The traditional house maintained a negative indoor–outdoor temperature differential with an average ΔT = –0.375 °C, indicating a consistent passive cooling effect throughout the day. In contrast, the modern house exhibited a positive differential with an average ΔT = +0.4375 °C, suggesting that indoor spaces tended to be warmer than the outdoor environment for most of the day. A detailed account of the diurnal indoor–outdoor temperature variations in both traditional and modern *Limasan* houses is presented in Table 3.

Table 3. Comparative diurnal variation of outdoor and indoor temperatures in tradisional and modernized *Limasan* house

Time	Tradisional House		ΔT (Indoor – Outdoor) (^{0}C)	Modern House		ΔT (Indoor – Outdoor) (^{0}C)
	outdoor temperature (^{0}C)	indoor temperature (^{0}C)		outdoor temperature (^{0}C)	indoor temperature (^{0}C)	
6:00 AM	19	20	1	19	20	1
9:00 AM	22	22	0	22	22	0
12:00 PM	26	25	-1	26	26.50	0.5
3:00 PM	24	23	-1	25	24.5	-0.5
6:00 PM	25	24	-1	25	25.5	0.5
9:00 PM	21	21	0	20	21.5	1.5
12:00 AM	18	18	0	18	18.5	0.5
3:00 AM	17	18	1	18	18	0

Observations revealed that modern *Limasan* houses tended to employ large glass windows and solid brick walls as replacements for traditional wooden or bamboo walls. According to homeowner interviews, this shift was primarily driven by the rising cost of high-quality timber, and the relatively high maintenance demands of organic materials. Glass and brick were considered more economical in terms of both construction and long-term upkeep, although thermally they exhibited greater heat absorption compared to traditional materials. A comparative analysis was therefore conducted to identify fundamental differences in climate-responsive elements and spatial organization between traditional and modern *Limasan* houses. This comparison, which was based on six indicators adapted from the Green Building Index [26](see Table 4), demonstrated that modernization not only altered the visual character of the *Limasan* house but also significantly transformed its climate-responsive design principles.

Table 4. Comparative analysis of climate-responsive elements and spatial layouts in traditional and modern *Limasan* houses

No.	Aspect	Traditional *Limasan* house	Modernized *Limasan* house	Empirical indicators
1.	Spatial Layout	8 rooms: Pendopo (1), Pringgitan (1), Dalem (1), Bedrooms (3), Kitchen/Pawon (1), Gandok/Granary (1); Total area ±120 m^2.	6 rooms: Pendopo (1), Pringgitan (1), Dalem (1), Bedrooms (2), Kitchen/Pawon (1), Gandok/Granary (0); Total area ±80 m^2.	Number of rooms, total floor area, percentage reduction of space (25%).
2.	Use of Building Materials	Bamboo & teak wood walls, stone foundation, clay roof tiles; mortise-tenon joints without nails.	Bricks, concrete, light steel; reinforced concrete foundation.	Material type, thermal capacity, joint system.
3.	Energy & Resource Efficiency	High ceiling ±5 m, roof cavity ±1.2 m^3; natural ventilation through bamboo lattices & roof gaps; average ΔT -0.375 °C.	Ceiling ±3.8 m, roof cavity ±0.5 m^3; limited ventilation; average ΔT +0.4375 °C.	Temperature measurements, ventilation design, roof cavity capacity.
4.	Water & Waste Management	Bamboo rainwater channels, natural soil infiltration; household waste collected for organic fertilizer (based on interviews).	PVC gutters; most waste discharged into public channels without further management.	Type of drainage system, presence of waste management.
5.	Integration with the Environment	East/south orientation (90%); front yard with shading trees; wide terrace ±1.5 m.	Orientation depends on land availability; fewer shading trees; terrace ±0.8–1 m. | House orientation, shading vegetation, terrace width.	House orientation, shading vegetation, terrace width.
6.	Modernization Changes in the House	Predominantly traditional elements; minor modifications (e.g., paint or small glass panes).	Predominantly modern materials; simplified spatial layout; some Javanese cosmological elements removed.	Percentage of structural, material, and spatial modifications.

Although modernized, several vernacular architectural elements were retained in the adapted *Limasan* houses. However, the climate-responsive functions of these elements were reduced in effectiveness due to the use of modern materials and the downsizing of certain dimensions. This indicates an effort to preserve the identity of traditional architecture while simultaneously adapting to contemporary material preferences, albeit with compromises in thermal comfort and energy efficiency. A detailed description of the vernacular elements preserved in modern *Limasan* adaptations is presented in Table 5.

Table 5. Climate-responsive elements retained in modernized *Limasan* houses

No.	Element	Traditional house	Modern house	Change in effectiveness
1.	*Limasan* Roof Form	High (±5 m) with large roof cavity, maximizing hot air circulation.	Roof form retained, but roof cavity smaller and ceiling lower.	Passive cooling capacity reduced by ±15–25% (estimated based on average ΔT difference).
2.	Building Orientation	Generally east, south-facing; supports morning and afternoon airflow and aligns with cultural philosophy.	Orientation depends on land availability	Effectiveness remains, but reduced if large glass windows are frequently closed
3.	Overhang	Width ±1.5 m; functions as shading and reduces direct solar radiation.	Smaller dimension (±0.8–1.0 m); partially replaced with metal/glass canopy.	Shading effectiveness reduced by ±20–30% during daytime (based on ΔT difference).

The comparative assessment of traditional and modern *Limasan* houses revealed a significant trade-off between modernization and sustainability. This trade-off was also evident in cultural and functional dimensions, where several Javanese cosmological elements and multifunctional communal spaces were either removed or simplified, thereby reducing cultural continuity and social cohesion [21]. These findings demonstrated that while modernization provided practical advantages, it diminished passive energy efficiency, resource management, and cultural sustainability. The results further indicated that the modernization of housing in tropical contexts must consider ecological sustainability as well as cultural values.

3.3 Integration of sustainability principles and contemporary relevance

This analysis identified adaptive principles of the traditional *Limasan* house relevant for sustainable architecture in tropical regions. Challenges include limited urban land and potential conflicts between functionality and tradition, but specific strategies can address these. As shown in Appendix Table A1, most of these features align closely with international sustainability indicators. Conversely, modernization reinforced structural integrity using more durable and safer materials. One of the key challenges, however, lies in the higher cost of natural materials compared to modern options such as reinforced concrete and lightweight steel [30,31]. While organic materials enhance natural ventilation through permeable joints that regulate humidity and indoor thermal comfort, cost-effective solutions can be achieved by combining traditional and modern materials. A hybrid wall system, integrating natural elements with modern materials such as hollow bricks or lightweight concrete blocks, offers both structural strength and opportunities for cross-ventilation [32].

The modernization of the *Limasan* house presented challenges in retaining Javanese cultural values embedded in spatial organization. One of the most significant examples concerns the use of the kitchen, traditionally referred to as *Pawon*. In Javanese culture, *Pawon* functions not only as a kitchen but also as a vital social space, particularly for women. It has historically served as the center of domestic life, a place for family gatherings, collective cooking, and intimate interaction [23]. Beyond its practical role, *Pawon* carries symbolic meaning as a space for storytelling, exchanging ideas, and receiving parental advice. In contemporary housing, however, land constraints have reduced the kitchen to a purely functional area located at the rear of the house, thereby diminishing its social and cultural functions. Within modern *Limasan* adaptations, this concept may be reinterpreted by integrating a secondary access to the kitchen or rear area, thereby preserving Javanese values of privacy and social etiquette. Such a spatial adjustment would also enhance cross-ventilation, improving air circulation throughout the dwelling and supporting energy efficiency and thermal comfort in the tropical climate [33]. As an implication for housing policy, cultural preservation, and sustainable architectural innovation, the adaptive reinterpretation illustrated how traditional principles of the *Limasan* house may inform the formulation of tropical housing design standards that are both climate-responsive and culturally grounded.

4. Conclusion

This study analyzed the adaptation principles of the traditional *Limasan* house for integration into sustainable architecture in tropical regions. The results showed that the traditional *Limasan* house incorporated key sustainability features, including natural ventilation, rainwater management, and the use of local materials that supported energy efficiency. However, modernization employed more durable materials that were less climate-responsive, reducing the effectiveness of passive design in achieving thermal comfort. Nevertheless, adapting traditional design principles with modern materials offered a hybrid solution that combined ecological sustainability and functionality, as well as adjustments for the limited urban context. This study highlighted the importance of preserving cultural continuity and local values in modern architectural design and provided a new contribution to the literature on sustainable architecture, with recommendations for optimizing the integration of traditional design principles in more sustainable urban development.

Disclosure Statement

The authors used of generative AI tools in the preparation of this manuscript. ChatGPT (OpenAI, GPT-5) was used to assist in language editing and refinement of certain sections. All outputs were critically reviewed and edited by the authors to ensure the integrity and accuracy of the final content.

References

[1] World Meteorological Organization (WMO) 2023 *The Global Climate 2011–2020: A Decade of Accelerating Climate Change* (Geneva: WMO)
[2] Intergovernmental Panel on Climate Change (IPCC) 2022 (Cambridge University Press) pp 3–34
[3] Hossain B, Shi G, Ajiang C, Sarker M N I, Sohel M S, Sun Z, Hamza A 2022 *Int. J. Environ. Health Res.* **32** 2359–75

[4] Munslow B and O'Dempsey T 2010 *Third World Q.* **31** 1339–56
[5] Narain U, Margulis S and Essam T 2011 *Clim. Policy* **11** 1001–19
[6] Huang L, Krigsvoll G, Johansen F, Liu Y and Zhang X 2018 *Renew. Sustain. Energy Rev.* **81** 1906–16
[7] Ürge-Vorsatz D, Harvey L D D, Mirasgedis S and Levine M D 2007 *Build. Res. Inf.* **35** 379–98
[8] IEA 2022 *Roadmap for Energy-Efficient Buildings and Construction in ASEAN: Timelines and Actions Towards Net Zero-Carbon Buildings and Construction (Paris: OECD Publishing)*
[9] Climate Transparency 2020 *Indonesia Cooling Plan: National Cooling Action Plan for Indonesia* (Jakarta: Ministry of Energy and Mineral Resources, Republic of Indonesia)
[10] Republic of Indonesia 2022 *Enhanced Nationally Determined Contribution Republic of Indonesia 2022*
[11] Li Y, Rong Y, Ahmad U M *et al* 2021 *Environ. Sci. Pollut. Res.* **28** 46196–46214
[12] Retzlaff R C 2008 *J. Am. Plan. Assoc.* **74** 505–19
[13] Green Building Council of Australia 2022 *Green Star Buildings v1.1 Consultation Paper* (Sydney: Green Building Council of Australia)
[14] Schweber L 2013 *Build. Res. Inf.* **41** 129–45
[15] Crawley D and Aho I 1999 *Build. Res. Inf.* **27** 300–8
[16] Kajikawa Y, Inoue T and Goh T N 2011 *Sustain. Sci.* **6** 233–46
[17] Hafez F S, Sa'di B, Safa-Gamal M, Taufiq-Yap Y H, Alrifaey M, Seyedmahmoudian M, Stojcevski A, Horan B and Mekhilef S 2023 *Energy Strateg. Rev.* **45** 101013
[18] Moscoso-García P and Quesada-Molina F 2023 *Buildings* **13**
[19] Zune M, Rodrigues L and Gillott M 2020 *Sustain. Cities Soc.* **54**
[20] Nursanty E, Cauba A G and Waskito A P 2024 *Place Brand. Public Dipl.* **20** 482–503
[21] Idham N, Numan I and Mohd M 2010 *Open House Int.* **35** 15–26
[22] Muqoffa M, Suyitno, Yaningsih I, Rachmanto R A, Himawan K, Caroko NBasuki 2025 *J. Asian Archit. Build. Eng.*
[23] Weichart G 2020 *Fabrications* **30** 25–43
[24] Sari W E 2020 *Local Wisdom J. Ilm. Kaji. Kearifan Lokal* **12** 1–9
[25] Shankar P 2024 *Potency of the Vernacular Settlements: Recent Scholarships in Vernacular Studies* (Taylor and Francis)
[26] Green Building Index 2023 Green Building Index: Malaysia's International Green Benchmark *Green Build. Index*
[27] Muqoffa M, Himawan K, Juwana W E and Adhi R 2024 *ISVS eJ* ***11*** 60-95
[28] Figueroa-Lopez A, Arias A, Oregi X and Rodríguez I 2021 *J. Build. Eng.* **43**
[29] Couvelas A 2020 *Procedia Manuf.* **44** 326–33
[30] Sari D P, Sudirman M and Chiou Y S 2024 *Archit. Sci. Rev.* **67** 105–19
[31] Vitasurya V R, Hardiman G and Sari S R 2019 *Tataloka* **21** 170
[32] El-Tawil, S., Harries, K. A., Fortney, P. J., Shahrooz, B. M., & Kurama, Y. 2010 *J. Struct. Eng.* **136** 755–69
[33] Ahmed T, Kumar P and Mottet L 2021 *Renew. Sustain. Energy Rev.* **138** 110669

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Appendix

Tabel A1, Mapping of Green Building Index (GBI) Aspects to International Sustainability Frameworks

GBI Aspect	Corresponding LEED Category	Corresponding BREEAM Category	Corresponding Green Star Category
Spatial Layout	Indoor Environmental Quality (ventilation, daylight)	Health & Wellbeing (thermal comfort, visual comfort)	Indoor Environment Quality (ventilation rates, daylight access)
Building Materials	Materials & Resources (sustainable materials, low embodied carbon)	Materials (responsible sourcing, lifecycle impacts)	Materials (life cycle impacts, responsible products)
Energy & Resource Efficiency	Energy & Atmosphere (energy performance, passive design)	Energy (low-energy design, efficiency measures)	Energy + Indoor Environment Quality (ventilation effectiveness)
Water & Waste Management	Water Efficiency (rainwater management, water use reduction) + Materials & Resources (waste reduction)	Water (consumption, rainwater harvesting) + Waste (operational waste)	Water (alternative sources, reduced potable use) + Materials (operational waste)
Integration with Environment	Sustainable Sites (heat island reduction, site ecology)	Land Use & Ecology (biodiversity, ecological value)	Sustainable Sites (ecology, microclimate)