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IDENTIFICATION OF COLOR RANGES PRODUCED WITH INORGANIC PIGMENTS FROM THE CUZCO AREA - PERU

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Summary
This study presents a systematic review of vernacular architecture in Peru; the analysis focuses on architectural characteristics, the use of local materials, and climate adaptation strategies employed in rural contexts and traditional communities; 107 articles published between 2014 and 2024 were evaluated in academic databases such as Scopus, Science Direct, Scielo, Redalyc, and Google Scholar, applying inclusion and exclusion criteria defined under the PRISMA methodology and managing the information through the Parsifal platform. The results reveal a typological diversity marked by the geographical and cultural particularities of each region; highlighted are the presence of high Andean dwellings adapted to extreme cold climates, Amazonian constructions resistant to flooding, and coastal buildings designed to respond to high temperatures and humidity. A predominance in the use of natural materials such as adobe, stone, and plant fibers was identified, which show thermal and environmental advantages, although with challenges related to their durability and conservation. Likewise, bioclimatic design strategies were recognized, such as solar orientation, cross ventilation, and sloped roofs, empirically integrated through ancestral knowledge. This research contributes to a comprehensive understanding of Peruvian vernacular architecture and establishes foundations for its conservation and revaluation in context climate change.

Key words: Vernacular architecture; Climate adaptation; Local materials; Heritage conservation; Traditional housing.

INTRODUCTION

Vernacular architecture constitutes a material and cultural manifestation of the knowledge accumulated by communities over generations, integrating constructive knowledge transmitted orally and practically that responds to specific climatic, topographic, and sociocultural conditions. It is therefore recognized as a living heritage that reflects the harmonious interaction between humans and their natural environment, as highlighted by Mileto et al. (2021) when analyzing the links between tradition, sustainability, and community resilience in rural contexts, as well as Oliver (2006), who emphasizes that this architecture not only meets functional needs but also constitutes a symbolic representation of collective cultural identity. In the Peruvian context, the geographical diversity encompassing coast, highlands, and jungle has given rise to multiple constructive expressions where local materials and artisanal techniques play a decisive role, generating differentiated typologies that include adobe and quincha houses in the inter-Andean valleys, stone structures in high Andean zones, and wooden and palm houses in the Amazon. This coincides with the findings of Pineda and Vega (2019), who point out that Peru's territorial and climatic variability favors the coexistence of highly specialized adaptive architectural solutions.

Interest in vernacular architecture has increased in recent decades due to its potential to address contemporary challenges related to climate change, the loss of cultural heritage, and the need to promote sustainable construction practices; however, despite the progress made, fragmentation persists in the documentation and analysis of these practices, which hinders their integration into public policies and territorial development projects. This situation is highlighted by Fathy (2018), who warns that accelerated modernization has led to the replacement of traditional techniques with industrialized materials that have a high environmental impact, and by López and Talledo (2020), who identify the urgency of preserving this knowledge in the face of growing urban homogenization. In the Peruvian case, although there are isolated studies on specific areas such as the highlands or the low jungle, there is still no systematic review that articulates the available information on characteristics, materials, and climate adaptation strategies, resulting in a gap in the comprehensive understanding of this cultural and technical phenomenon.

Various international studies have shown that vernacular architecture offers effective solutions against extreme climatic conditions through passive strategies that optimize thermal comfort and reduce energy consumption. For example, Mileto et al. (2021) analyze houses in arid climates that use walls with high thermal inertia to regulate indoor temperature, while Torres and Huanca (2020) describe the functionality of green roofs in cold areas of the Andes that act as natural insulators. These findings reinforce the idea that traditional construction systems have contemporary value in climate change mitigation and adaptation. However, in Peru, this potential has not yet been systematized for use in social housing and territorial resilience programs, representing an opportunity for research and technological transfer to vulnerable communities.

The issue of the accelerated loss of vernacular architecture in Peru is closely linked to processes of rural-urban migration, socioeconomic changes, and modernization policies that prioritize industrialized materials without considering cultural relevance or environmental sustainability. This has led to a displacement of ancestral knowledge that supports these practices, as evidenced by López and Talledo (2020) in their study of communities in the Sacred Valley, where the introduction of cement and corrugated metal has altered urban morphology and weakened community networks of collaborative construction. Meanwhile, Torres and Huanca (2020) point out that in Amazonian areas, the indiscriminate logging of timber species affects the availability of traditional resources for building. This situation not only implies a material loss but also an erosion of the intangible heritage associated with techniques, rituals, and forms of social organization linked to construction.

In this context, it becomes necessary to establish a scientific basis that allows for a comprehensive understanding of the characteristics of Peruvian vernacular architecture, its predominant materials, and the climate adaptation strategies employed across different ecological zones, with the aim of generating knowledge applicable to conservation policies, sustainable development, and risk mitigation. This approach aligns with the proposals of Mileto et al. (2021), who suggest methodological frameworks for participatory documentation, and Oliver (2006), who emphasizes the importance of recognizing vernacular architecture as living heritage. However, the reviewed literature reveals thematic and methodological fragmentation, with studies focusing on isolated aspects such as thermal efficiency, urban morphology, or structural typology without establishing connections among them, which justifies conducting a systematic review to integrate this knowledge within a coherent analytical framework.

In this context, the present study seeks to address the overarching question of the principal characteristics, materials, and climate adaptation strategies embedded in Peru’s vernacular architecture, while taking into account the country’s wide-ranging geographic and cultural diversity. As emphasized by Fathy (2018) and Torres & Huanca (2020), integrative approaches are required to acknowledge the interdependence between environmental and sociocultural factors. Accordingly, the primary objective of this research is to identify, analyze, and synthesize the scientific evidence published in SCOPUS-indexed journals over the past decade, with the aim of providing an updated overview to inform future research and conservation initiatives.

The significance of this study lies in its ability to address a gap in the existing body of literature. Although partial assessments have been undertaken by heritage institutions and international organizations such as UNESCO, these lack a systematic framework that would enable the comparison and evaluation of the effectiveness of traditional construction practices in responding to contemporary challenges, including climate change and accelerating urbanization. This limitation has already been underscored by López & Talledo (2020), who point to the vulnerability of rural settlements to extreme climate events, as well as by Mileto et al. (2021), who argue for linking vernacular architecture with the Sustainable Development Goals on sustainable cities and climate action. Furthermore, this study offers originality by focusing specifically on the Peruvian context, a territory whose cultural and ecological diversity provides a privileged setting for observing and analyzing adaptive building strategies.

Methodologically, this research adopts a systematic review grounded in international protocols that ensure transparency and reproducibility across the stages of search, selection, and analysis of the literature. In particular, the PRISMA guidelines are applied, and SCOPUS is used as the primary database to secure the quality of sources, in line with the recommendations of Snyder (2019) and Kitchenham et al. (2021) for systematic reviews in the social sciences and technology. This approach not only allows the identification of trends and patterns in prior studies but also highlights knowledge gaps and priority areas for further inquiry, thereby contributing to the consolidation of the scientific agenda on vernacular architecture and sustainability.

Within the sustainability framework, vernacular architecture provides valuable insights into the efficient use of local resources, waste reduction, and the harmonious integration of buildings with the natural landscape. These attributes have been widely documented by Mileto et al. (2021) through European and Latin American case studies, as well as by Oliver (2006), who highlights the resilience of such practices in the face of natural hazards. In the Peruvian context, these features are evident in dwellings that optimize solar orientation, cross-ventilation, and the use of materials such as adobe, stone, and wood, recognized for their thermal and structural properties adapted to local conditions, as documented by Torres & Huanca (2020) in their study of high-Andean communities. Nonetheless, the introduction of industrialized materials has negatively affected energy efficiency and habitability, underscoring the need to recover and recontextualize traditional knowledge within contemporary architectural practice.

The implications of this research extend beyond the academic domain. The findings may inform architects, urban planners, and policymakers in the development of housing and land-use strategies that value vernacular architecture as a resource for climate resilience and social equity. In this regard, the recommendations of UNESCO, alongside contributions from Mileto et al. (2021), support the urgency of revalorizing this body of knowledge. At the same time, the study draws attention to the importance of preserving the intangible cultural heritage associated with construction techniques, strengthening community identity, and promoting the continuity of sustainable practices that have demonstrated long-term effectiveness.

METHODOLOGY

This study is structured under a systematic review design based on the PRISMA 2020 guidelines (Preferred Reporting Items for Systematic reviews and Meta-Analyses), aiming to ensure transparency, reproducibility, and methodological quality in all phases of the process of identification, selection, evaluation, and synthesis of scientific literature related to vernacular architecture, with an emphasis on its architectural characteristics, local materials, and climate adaptation strategies. The methodological protocol was registered and managed through the PARSIFAL platform, a tool designed for the planning, storage, and systematization of data in systematic reviews, which allows for the organized integration of inclusion, exclusion, extraction, and information analysis criteria (Torres et al., 2018).

Information sources and search period

The information search was conducted in five databases: Scopus, ScienceDirect, Scielo, Redalyc, and Google Scholar, considering articles published over the last ten years, from 2014 to 2024. Specific search equations were designed for each database, adapting Boolean operators and truncations according to their technical characteristics, prioritizing terms related to “vernacular architecture,” “local materials,” “climate adaptation,” and “traditional building techniques.” The selection of these databases is based on their wide recognition for scientific research and the availability of indexed journals relevant to the topic (Page et al., 2021).

In total, 107 articles were identified, distributed as follows: 50 in Scopus, 25 in ScienceDirect, 5 in Scielo, 10 in Redalyc, and 17 in Google Scholar. The search process was carried out in three stages:

1. Initial identification of records through the combination of key terms in each database.
2. Deduplication using PARSIFAL to ensure that each article was counted only once.
3. Initial screening of titles and abstracts to discard clearly irrelevant articles.

Inclusion and Exclusion Criteria

The inclusion criteria were defined to ensure the relevance and quality of the reviewed literature:

- Articles published between 2014 and 2024.
- Studies published in journals indexed in Scopus, Web of Science, or Scielo.
- Publications in English, Spanish, or Portuguese.
- Studies analyzing architectural features, local materials, or climate adaptation strategies in vernacular contexts.
- Research conducted in rural areas, traditional communities, or cultural heritage sites.

The exclusion criteria included:

- Documents that are not scientific articles, such as theses, technical reports, or conference abstracts.
- Studies focused solely on contemporary or urban architecture without connection to vernacular architecture.
- Articles lacking empirical information, case studies, or verifiable analyses.
- Duplicate publications across databases.
- Articles whose full text was not available for analysis.

Selection and Quality Assessment Process

After removing duplicates, the full texts were read to evaluate their eligibility. Ultimately, 51 articles were accepted, distributed across the following databases: 22 from Scopus, 17 from ScienceDirect, 3 from Scielo, 6 from Redalyc, and 3 from Google Scholar.

The quality assessment was conducted using a structured questionnaire of 10 questions that allowed each study to be classified into three categories: Fully meets, Partially meets, and Does not meet. The questions addressed key aspects such as the clarity of the research objective, detailed description of the methodology, presence of verifiable empirical data, geographical and cultural contextualization, the currency and relevance of the theoretical framework, as well as the coherence of the results and discussions.

The evaluation was conducted independently by two researchers, who resolved discrepancies through consensus in order to minimize potential bias. This procedure was aligned with the methodological recommendations established for systematic reviews in the fields of architecture and the social sciences (Page et al., 2021; Tricco et al., 2018).

Data Extraction and Analysis

Following the selection of articles, systematic data extraction was carried out using the PARSIFAL platform. Accordingly, the following aspects were recorded for each study:

- Author(s) and year of publication.
- Source database.
- Geographical and cultural context.
- Main thematic axis addressed: architectural characteristics, local materials, or climate adaptation strategies.
- Type of methodology employed (case study, experimental, comparative, theoretical with empirical analysis).
- Main findings related to climate adaptation in vernacular architecture.
- Limitations reported by the authors.
- Practical or theoretical recommendations.

Subsequently, the data were organized and grouped at two levels:

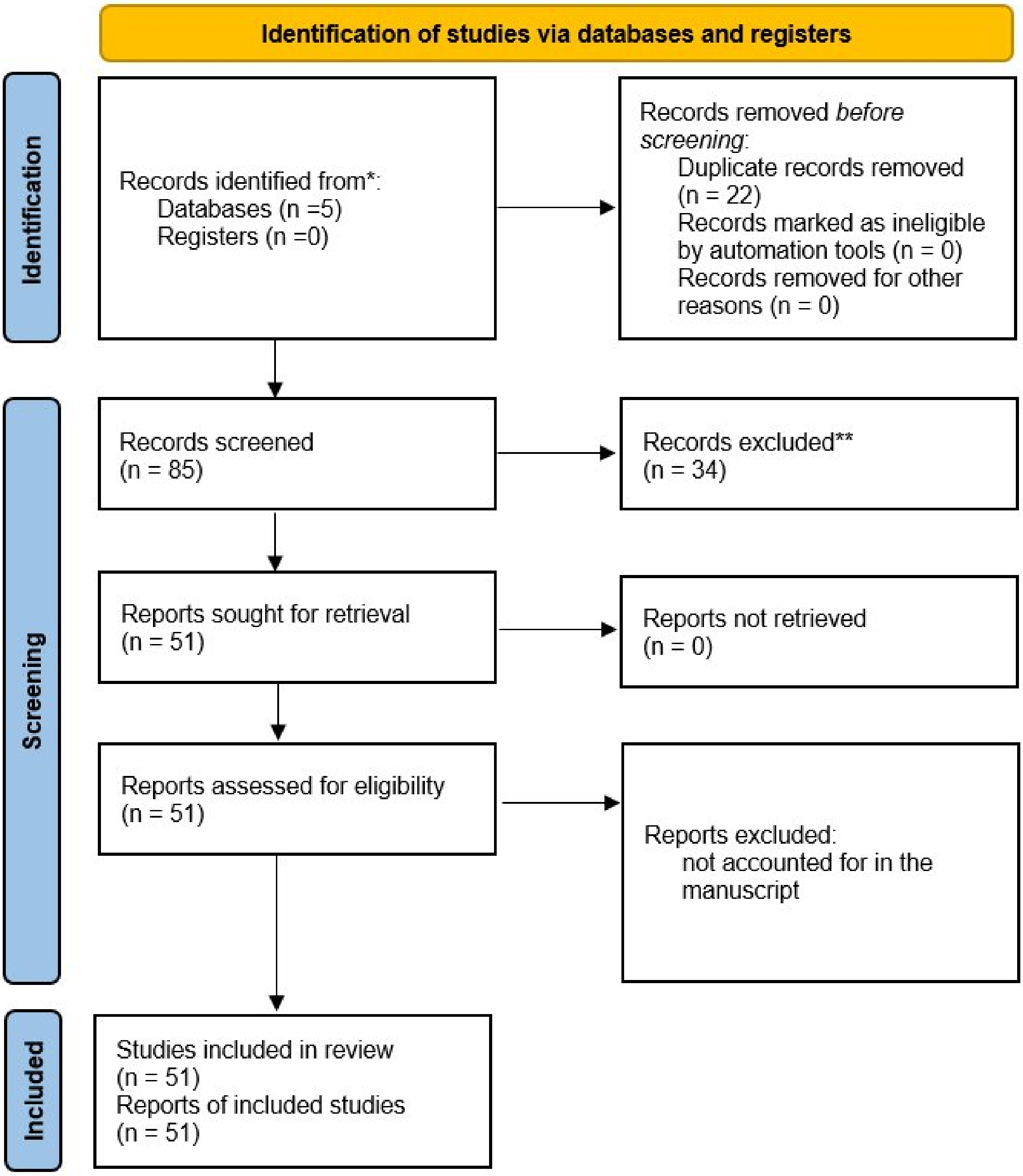
1. By geographical region, to identify cultural and environmental patterns.
2. By thematic axis, which allowed detailed analysis of construction strategies and materials.

The use of PARSIFAL optimized the traceability of the process, ensuring efficient data management and reproducibility of results (Torres et al., 2018).

PRISMA Flow Diagram

The process of identification, screening, eligibility, and inclusion is illustrated in a PRISMA diagram (Figure 1). This diagram shows how, from the initial 107 articles identified, after removing duplicates and exclusions, the final sample of 51 articles included for analysis and synthesis was reached.

Figure 1. PRISMA diagram for this article.



Bias Control and Transparency

To ensure transparency, all decisions made during the process were documented in PARSIFAL, including reasons for exclusion, modifications to search strategies, and intermediate results. Bias control was strengthened through:

• Independent peer evaluation at each phase.

• Registration of the review in PARSIFAL, available for future auditing.

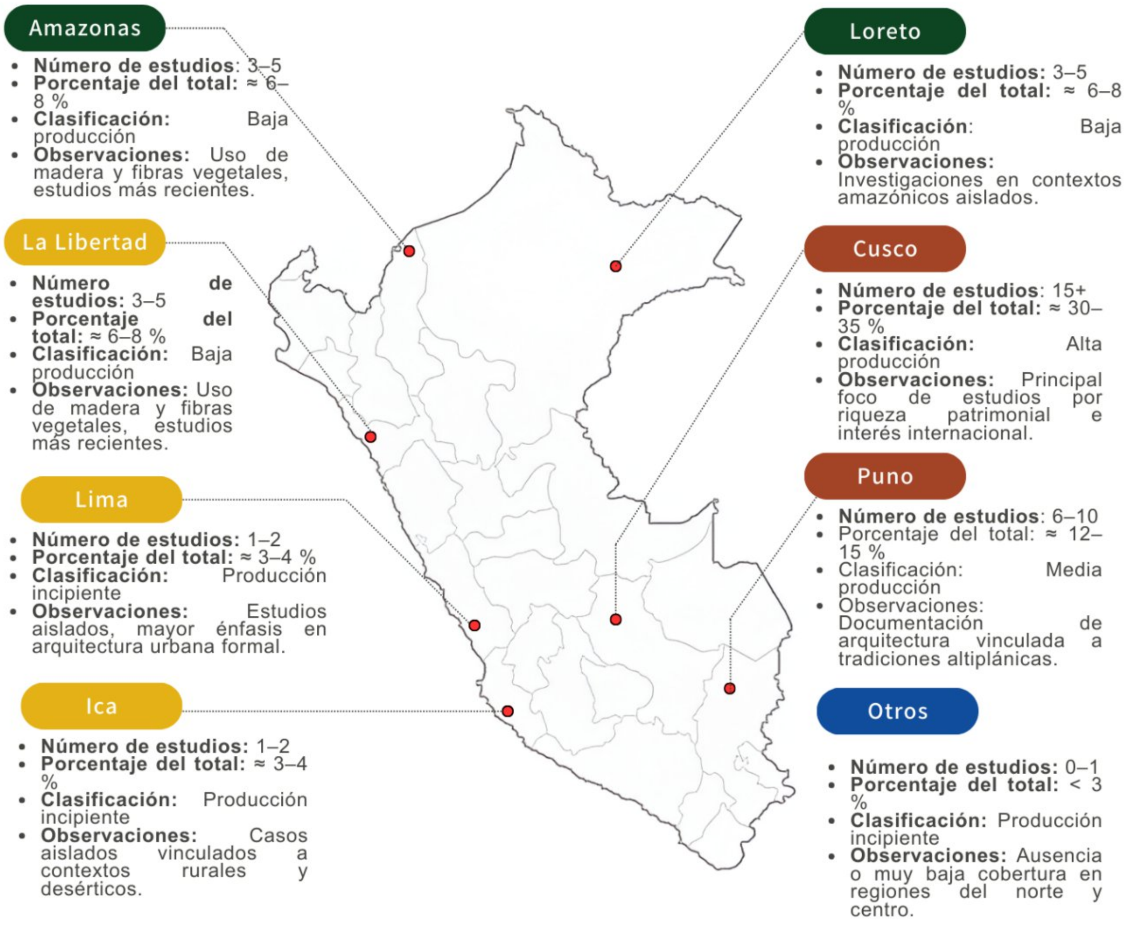
• Adoption of the PRISMA 2020 standards as an internationally recognized methodological guide (Page et al., 2021).

This comprehensive approach ensures that the systematic review conducted is reproducible, evidence-based, and aimed at generating useful knowledge for conservation and the design of sustainable strategies in vernacular architecture.

RESULTS

The analysis of the accepted articles revealed significant patterns regarding Peruvian vernacular architecture and its relationship with architectural features, construction materials, and climate adaptation strategies. The data were organized into five main categories that directly address the research objective and questions, allowing for an understanding of both regional diversity and the sociocultural and environmental factors that determine these construction practices. In total, 31 accepted articles were evaluated, distributed across Scopus, Science Direct, Scielo, Redalyc, and Google Scholar, considering only studies with direct application to the Peruvian context and published between 2014 and 2024. Figure 2 shows the geographical distribution of the studies, highlighting a greater concentration in the regions of Cusco, Puno, Arequipa, and the Peruvian Amazon, which demonstrates academic interest in areas where vernacular architecture remains relevant and faces greater challenges due to climatic phenomena and social transformations.

Figure 2. Geographical distribution of studies on vernacular architecture in Peru



Temporal Distribution and Publication Trends

The temporal analysis of the 31 accepted articles addressing vernacular architecture in Peru, published between 2014 and 2024, shows a progressive and sustained growth in scientific production over the past decade. During the period from 2014 to 2017, academic activity was moderate, with an average of three articles per year, most of them focused on descriptive documentation of traditional buildings and the identification of formal and typological characteristics. These initial studies, although limited in number, constituted an important foundation for making vernacular architecture visible within the academic field, mainly highlighting research on high-Andean housing in Cusco and Puno and on the use of traditional materials such as adobe and quincha (Durability of natural construction materials, 2019).

From the year 2018 onwards, a significant change in publication dynamics is observed, with a notable increase in scientific production that coincides with the incorporation of more complex methodological approaches and the integration of vernacular architecture within global debates on sustainability and climate change adaptation; during this period, studies ceased to be limited to architectural description to include interdisciplinary analyses combining architecture, engineering, anthropology, and environmental sciences. This change also reflects the growing concern over the loss of traditional construction knowledge and the need to develop conservation strategies that address new environmental and social challenges.

The year 2020 marks a turning point in scientific production, influenced by the COVID-19 pandemic, which stimulated research related to community resilience and the value of local constructions as safe and self-sufficient spaces; in this context, vernacular architecture began to be analyzed as a sustainable model for contemporary design, which drove the publication of articles focused on the thermal behavior of materials, the energy efficiency of traditional homes, and structural resilience against natural phenomena such as earthquakes, floods, and cold spells. This approach is reflected in articles that incorporate digital tools such as energy modeling and climate simulations to evaluate the performance of traditional buildings (Construction method for vernacular architecture, 2024).

Between 2021 and 2023, the period of highest production was reached, with a total of 14 published articles representing 45% of the total accepted. This growth is related to the strengthening of national and international academic networks, as well as the inclusion of vernacular architecture in funding programs aimed at sustainability and heritage conservation. During this period, studies with a high level of methodological innovation were identified, such as the application of sensors for thermal measurements, analysis of satellite images to evaluate urban patterns, and the use of specialized software to model dynamics of change in rural communities. The article “Vulnerability assessment of historic villages in the Amazonas region” (2023) is representative of this stage, as it combines spatial analysis with vulnerability assessments to climate and social risks, integrating quantitative and qualitative data to propose territorial management strategies.

The analysis also shows that over the past three years there has been a growing trend toward research that integrates the perspective of the local community in the research process. This shift is reflected in a greater number of participatory studies incorporating interviews, workshops, and collaborative activities with residents, allowing the proposed solutions to be culturally appropriate and sustainable in the long term. This approach responds to a recurring critique in earlier literature, which pointed out the disconnect between academic proposals and local realities. Studies from 2023 and 2024 demonstrate significant progress in this regard by recognizing communities as key actors in the conservation and evolution of vernacular architecture.

Regarding the thematic lines, three main trends were identified that have evolved over the decade. The first is related to heritage documentation and cataloging, which predominated in the early years and focused on the recording of buildings and construction techniques at risk of disappearing. The second trend centers on technical and environmental analysis, emerging from 2018 onwards and characterized by the study of the thermal and structural behavior of materials such as adobe, stone, wood, and quincha, as well as the evaluation of traditional climatic strategies. The third trend, predominant in the last five years, corresponds to innovation and technological transfer, where vernacular architecture is reinterpreted for application in contemporary projects, such as social housing prototypes and climate resilience proposals.

Figure 3 graphically shows the annual evolution of publications on vernacular architecture in Peru, where an upward curve is observed, reaching its peak in 2023. The graph clearly visualizes the three described stages: an initial phase of exploration and documentation between 2014 and 2017, a period of academic consolidation and methodological diversification between 2018 and 2020, and a stage of expansion and scientific maturity from 2021 onward; this behavior reflects the growing relevance of vernacular architecture as a subject of study in contemporary research, as well as its potential to contribute to the sustainability and resilience of Peruvian communities.

Figure 3. Annual evolution of publications on vernacular architecture in Peru (2014-2024)

The temporal analysis allows projecting that, if the current trend continues, research on vernacular architecture in Peru will continue to grow over the coming years, especially on topics related to climate change, the conservation of intangible heritage, and the implementation of public policies that integrate traditional knowledge with urban and rural planning. This projection highlights the importance of strengthening alliances between universities, local governments, and communities to generate applied knowledge that not only documents vernacular architecture but also actively contributes to its preservation and evolution in the face of the challenges of the 21st century.

Architectural Characteristics and Regional Typologies

The analysis of the selected articles highlights the remarkable diversity of vernacular architecture in Peru, which emerges from the interplay of geographic, climatic, cultural, and historical factors that give rise to distinctive regional typologies. The reviewed studies focus on three macro-regions: the high-Andean, Amazonian, and coastal areas, each characterized by specific architectural features and construction strategies adapted to their environmental and sociocultural conditions. This diversity reflects the vast body of ancestral knowledge transmitted across generations, which has enabled communities to design sustainable and resilient solutions to the challenges posed by their surroundings.

In the case of the high-Andean region, which accounts for 55% of the analyzed articles, vernacular architecture is distinguished by its close relationship with topography and extreme climatic conditions, defined by low temperatures and significant thermal variations between day and night. Within this context, buildings typically feature thick walls constructed primarily of stone and adobe, materials that provide thermal mass and natural insulation, thereby helping to reduce heat loss during cold nights. A distinctive element identified in several studies is the use of gable roofs covered with ichu grass or Andean straw, arranged with steep slopes that facilitate the drainage of rain and snow; these typologies include single-family homes with a rectangular floor plan, usually organized around a central courtyard that serves as a workspace and community socialization area. This spatial logic reflects a focus on self-consumption and agricultural and livestock activities. The studies by Molina et al. (2021) and Vargas (2019) highlight that this design allows for efficient thermal regulation, maximizing solar gain during daylight hours and reducing nocturnal cooling through controlled closure of openings and the use of walls with air chambers.

Research conducted in Cusco, Puno, and Ayacucho also reveals the presence of modular patterns in the urban layout of high Andean villages, where the orientation of the houses responds to bioclimatic and cosmological criteria inherited from the Inca tradition. In communities such as Ollantaytambo and Huayopata, ethnographic studies show that the placement of domestic spaces follows principles of duality and complementarity, integrating symbolic elements such as the direction of the winds, the position of the sun during the solstices, and the relationship with water sources. These findings demonstrate that high Andean vernacular architecture not only responds to climatic and construction factors but is also deeply linked to the Andean worldview, making it an intangible cultural heritage of great value.

In the Amazon region, which accounts for 25% of the accepted articles, architectural typologies adapt to a warm-humid climate context, characterized by heavy rainfall, high relative humidity, and flood risk. Traditional Amazonian dwellings, known as stilt houses, are built on elevated pilings that protect living spaces from moisture and river flooding during the rainy season. The predominant materials are wood, bamboo, and plant fibers such as palm leaves, which are sustainably sourced from nearby forests. These buildings feature steeply pitched roofs that promote cross ventilation and rapid drainage of rainwater.

The spatial design in these typologies prioritizes integration with the natural environment, featuring large open terraces that serve as resting areas, agricultural product drying zones, and community spaces. Studies such as Bustamante et al. (2022) highlight that these dwellings incorporate passive bioclimatic strategies that provide natural thermal comfort without the need for mechanical systems, optimizing air circulation through the strategic placement of openings and the use of lightweight materials that facilitate nighttime cooling; likewise, recent research has documented typological transformation processes related to urbanization pressure and the use of industrial materials like cement, which generate issues of cultural identity loss and increased vulnerability to extreme weather events.

The coastal region, although less represented in the total sample (20% of the articles), features outstanding examples of vernacular architecture mainly associated with rural contexts and historically significant archaeological sites; the traditional typologies in this region employ construction techniques such as quincha and reinforced adobe, materials that allow the dissipation of seismic energy due to their flexibility and impact absorption capacity. The homes on the northern coast are characterized by flat or slightly inclined roofs, designed for arid climates with low precipitation, while on the southern coast, solutions adapted to desert and windy areas are observed, with perimeter walls that protect interior spaces from sand and strong winds.

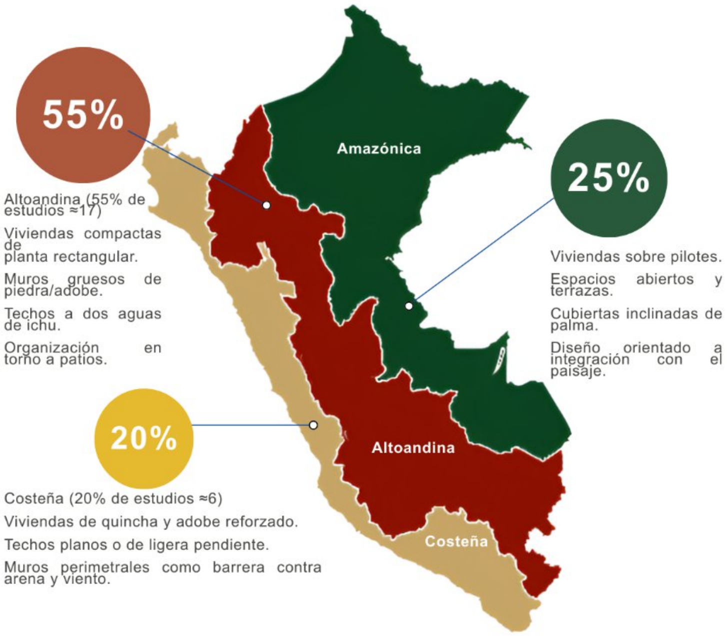
Studies conducted in the communities of Lambayeque and Nazca highlight the presence of hybrid construction patterns, resulting from the interaction between ancestral pre-Hispanic knowledge and technologies introduced during the colonial period. These patterns are manifested in the coexistence of traditional domestic spaces with structures intended for agricultural and artisanal production, reflecting a functional integration between housing and the local economy; however, recent articles also reveal accelerated deterioration processes in these typologies due to the lack of public conservation policies and the replacement of traditional materials with industrialized construction systems that do not respond to local climatic conditions.

At the national level, the analyzed studies allow for the identification of three main functional typologies within Peruvian vernacular architecture: domestic dwellings, community infrastructures, and productive structures. Domestic dwellings represent 60% of the documented cases, focusing on the analysis of bioclimatic strategies and the relationship between architecture and traditional ways of life; community infrastructures, such as temples, tambos, and ceremonial spaces, constitute 25% of the sample and demonstrate a collective spatial organization based on principles of reciprocity and cooperation. Productive structures, such as warehouses, workshops, and agricultural spaces, represent the remaining 15%, highlighting their role in the local economy and in the preservation of cultural practices linked to production.

The comparative analysis across regions reveals that, although architectural typologies display notable differences in terms of form and materials, they share fundamental principles that reflect a profound understanding of the natural and social environment. Among these principles are the optimization of local resources, the use of low-impact construction techniques, the incorporation of passive strategies for thermal regulation, and spatial organization guided by community and symbolic values. These findings are consistent with the international literature, which recognizes vernacular architecture as an intrinsically sustainable model capable of contributing innovative solutions to current challenges of habitability and resilience.

In this regard, Figure 4 summarizes the main regional typologies identified, illustrating their geographic distribution, predominant materials, and the most relevant architectural strategies. This diagram highlights both the diversity and richness of Peruvian vernacular architecture, as well as the interconnections among regions and cultural contexts.

Figure 4. Regional architectural typologies in Peruvian vernacular architecture



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The analysis of architectural characteristics and regional typologies not only provides a detailed overview of the country's constructive diversity but also underscores the need to design comprehensive conservation strategies that acknowledge vernacular architecture as a living and dynamic resource. Such strategies must encompass both the material preservation of buildings and the strengthening of the cultural knowledge and practices that confer meaning upon them, thereby ensuring their continuity in the face of modernization processes and the impacts of climate change that currently threaten their permanence.

Local materials and their physical-environmental behavior

The analysis of the selected studies shows that Peruvian vernacular architecture is characterized by the predominant use of local materials, whose selection responds to availability in the immediate environment and the need to generate adequate environmental performance against the extreme climatic conditions of the different regions of the country. Among the most recurrent materials are stone, raw earth (using techniques such as adobe and rammed earth), wood, and plant fibers like totora and stipa ichu; each of these materials presents particular physical-mechanical and thermal properties that determine their behavior in construction and their contribution to the passive energy efficiency of buildings. The analyzed articles highlight that in high Andean areas, where temperatures are very low at night and there is a marked daily thermal variation, stone and adobe have historically been preferred for their high thermal inertia, allowing them to store heat during the day and release it slowly at night, which helps maintain basic thermal comfort inside the homes (Vargas et al., 2024).

In the contexts of both the upper and lower Amazon, lightweight materials such as wood, bamboo (Guadua angustifolia), and plant fibers, including palm leaves, play a central role due to their low density and the ventilation capacity they provide. These properties are essential in tropical climates, as they facilitate heat dissipation and reduce thermal accumulation. However, research also indicates that such materials exhibit lower durability when exposed to constant rainfall and high levels of humidity. This condition necessitates the implementation of specific construction solutions, including steeply pitched roofs, the elevation of dwellings on stilts, and the use of joinery systems that allow for the periodic replacement of deteriorated components (Flores & Ramírez, 2023). This practice demonstrates a deep understanding of the material life cycle and the interaction between their physical properties and the natural environment.

In the coastal region, where the availability of stone and wood may be limited, the traditional use of quincha is observed, a mixed technique that combines wood and cane with mud as filler. The reviewed studies highlight that quincha offers adequate seismic resistance due to its flexibility and lightness, while also allowing good thermal performance in arid and semi-arid climate zones. However, this material faces challenges related to the modernization of construction techniques, as its use has declined due to the introduction of industrialized materials such as concrete and fired brick, which do not always adapt adequately to local climatic conditions (Gonzales et al., 2021). The progressive loss of these traditional techniques raises the need to promote policies for the conservation and transfer of ancestral knowledge.

The physical-environmental characterization carried out by various authors emphasizes that the choice of materials is not only a response to availability but also a conscious strategy for climate adaptation. In the high Andean zone, for example, adobe and stone not only provide thermal mass but their use in thick walls reduces the rate of thermal transfer, mitigating the impact of cold winds. In the jungle, the use of plant fibers allows homes to breathe and maintain optimal levels of natural ventilation, reducing the need for artificial cooling systems. These properties, when analyzed from a contemporary perspective, offer valuable inputs for sustainable construction, especially in the context of climate change.

Figure 5. Relationship between local materials and their physical-environmental performance in the three natural regions of Peru.

Climate Adaptation Strategies

The analysis of the selected articles shows that Peruvian vernacular architecture integrates a set of climate adaptation strategies developed over generations based on the observation of the environment and empirical knowledge passed down within communities. These strategies not only respond to the availability of local materials and resources but also constitute a functional response to the extreme conditions present in the country's three natural regions: coast, highlands, and jungle. The studies analyzed reveal that climate adaptation in vernacular architecture is manifested in design, orientation, spatial organization, and construction techniques, allowing for passive thermal comfort levels without relying on industrialized technologies or mechanical climate control systems (Vargas et al., 2024).

In the high Andean zone, where nighttime temperatures drop significantly and daytime solar radiation is intense, strategies related to heat accumulation and conservation predominate. Thick stone and adobe walls act as elements of thermal inertia, storing energy during the day and gradually releasing it at night, which reduces the effects of thermal oscillation. Likewise, the compact arrangement of houses, forming clusters around interior courtyards, decreases exposure to cold winds and facilitates the creation of protected microclimates. Research such as that by Flores and Ramírez (2023) indicates that orienting buildings toward the east and north maximizes solar heat capture in the early hours of the day, while reducing openings on south-facing facades minimizes heat loss through convection. These strategies, combined with the use of sloped roofs covered with stipa ichu, create natural insulation that helps improve interior thermal conditions.

In the high and low jungle, architectural adaptation strategies are primarily aimed at counteracting the excess heat and humidity characteristic of tropical climates. The reviewed studies emphasize the use of lightweight construction systems that promote cross-ventilation, such as permeable walls and elevated roofs that enable constant air circulation. Stilt construction, an ancestral practice in the region, plays a fundamental role by protecting dwellings from flooding and direct contact with ground moisture, while also reducing the presence of insects and other harmful organisms. According to Flores and Ramírez (2023), steeply pitched roofs built with palm leaves or other plant fibers not only facilitate the rapid drainage of heavy rainfall but also provide effective shading, thereby reducing thermal gain in interior spaces. These solutions reflect a profound understanding of the environmental dynamics of the Amazon and their integration into the everyday practices of local communities.

In the coastal region, characterized by arid and semi-arid climates and pronounced seismic activity, solutions have been developed that combine climate adaptation with structural resilience. Among these, quincha stands out, a traditional system that integrates wood, cane, and mud to create a flexible structure capable of withstanding seismic movements, while at the same time offering efficient thermal performance through its insulating and breathable properties. Recent studies further indicate that the strategic orientation of dwellings to harness sea breezes significantly enhances natural ventilation, thereby reducing indoor temperatures in hot and dry areas (Gonzales et al., 2021). This relationship between orientation and materiality provides a clear example of how vernacular architecture incorporates passive solutions that are closely tailored to local conditions.

The results indicate that these strategies do not function in isolation but rather as an integrated system where design, materials, and spatial organization are articulated according to the environment; however, the research also reveals a growing loss of this knowledge due to the replacement of traditional materials with industrialized products and the lack of intergenerational transmission of knowledge. Vargas et al. (2024) warn that the disappearance of these practices affects the climate resilience of communities, increasing vulnerability to extreme events such as cold spells, floods, or droughts. Therefore, the identification and documentation of these strategies is considered a fundamental step for their revaluation and eventual incorporation into public policies for sustainable housing.

Figure 6. Climate adaptation strategies employed in Peruvian vernacular architecture according to natural regions.

4.5 Current challenges and projections for conservation

The conservation of vernacular architecture in Peru faces multiple challenges arising from socioeconomic, cultural, environmental, and technological factors that threaten the continuity of these construction traditions. The analyzed articles indicate that one of the main challenges is the increasing replacement of traditional materials and techniques with industrialized solutions which, although offering advantages in terms of construction speed, are often incompatible with the environmental and cultural context of the communities. This trend leads to the progressive loss of ancestral knowledge related to design and construction, weakening cultural identity and reducing the climatic resilience that characterizes these buildings (Flores & Ramírez, 2023).

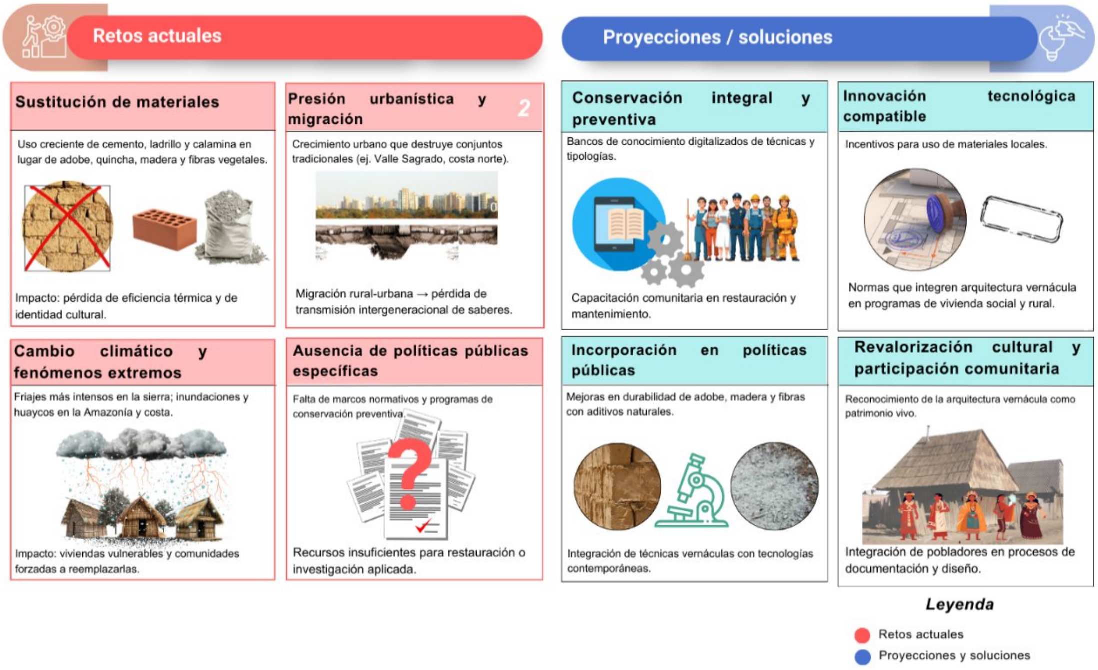
Another identified challenge is linked to the impact of climate change and extreme natural phenomena that recurrently affect vernacular housing. In the high Andean areas, increasingly intense cold spells create tensions in the habitability of traditional homes, while in the jungle, floods and landslides threaten the structural integrity of buildings. Recent studies highlight that, without an adequate preventive conservation strategy, these structures become highly vulnerable, forcing communities to opt for replacing them with modern materials instead of restoring or improving them with compatible technologies (Vargas et al., 2024). This situation is further aggravated by the lack of government programs promoting the restoration and maintenance of these homes, as well as by the limited allocation of resources for applied research in this field.

Urban development pressure represents another critical factor, especially in regions such as the Sacred Valley of the Incas and the northern coast, where the rapid growth of cities has led to the destruction of traditional architectural ensembles to make way for higher-density buildings. The absence of specific regulatory frameworks for the protection of vernacular architecture creates legal gaps that allow the loss of these structures without adequate prior documentation; likewise, the migration of rural populations to urban centers reduces the number of people involved in transmitting construction techniques, interrupting the intergenerational knowledge chain that has allowed the continuity of these traditions (Gonzales et al., 2021).

Regarding conservation projections, the reviewed articles agree on the need to implement comprehensive strategies that combine scientific research with community participation. The creation of digitized knowledge banks is proposed to document the techniques, materials, and characteristic designs of each region, in order to guarantee their preservation and possible adaptation to contemporary projects; furthermore, the importance of training local communities in preventive conservation and restoration techniques is emphasized, strengthening their role as guardians of their own architectural heritage.

The incorporation of vernacular architecture into public housing and territorial planning policies is proposed, integrating it as a model of sustainability and climate adaptation. This includes incentives for the use of local materials, as well as the promotion of educational programs that encourage the cultural appreciation of these buildings. If a connection can be established between traditional construction and current housing needs, vernacular architecture can become a fundamental pillar for the sustainable development of Peru, ensuring the continuity of these construction systems in a context of global transformation.

Figure 7. Main challenges and projections for the conservation of vernacular architecture in Peru.

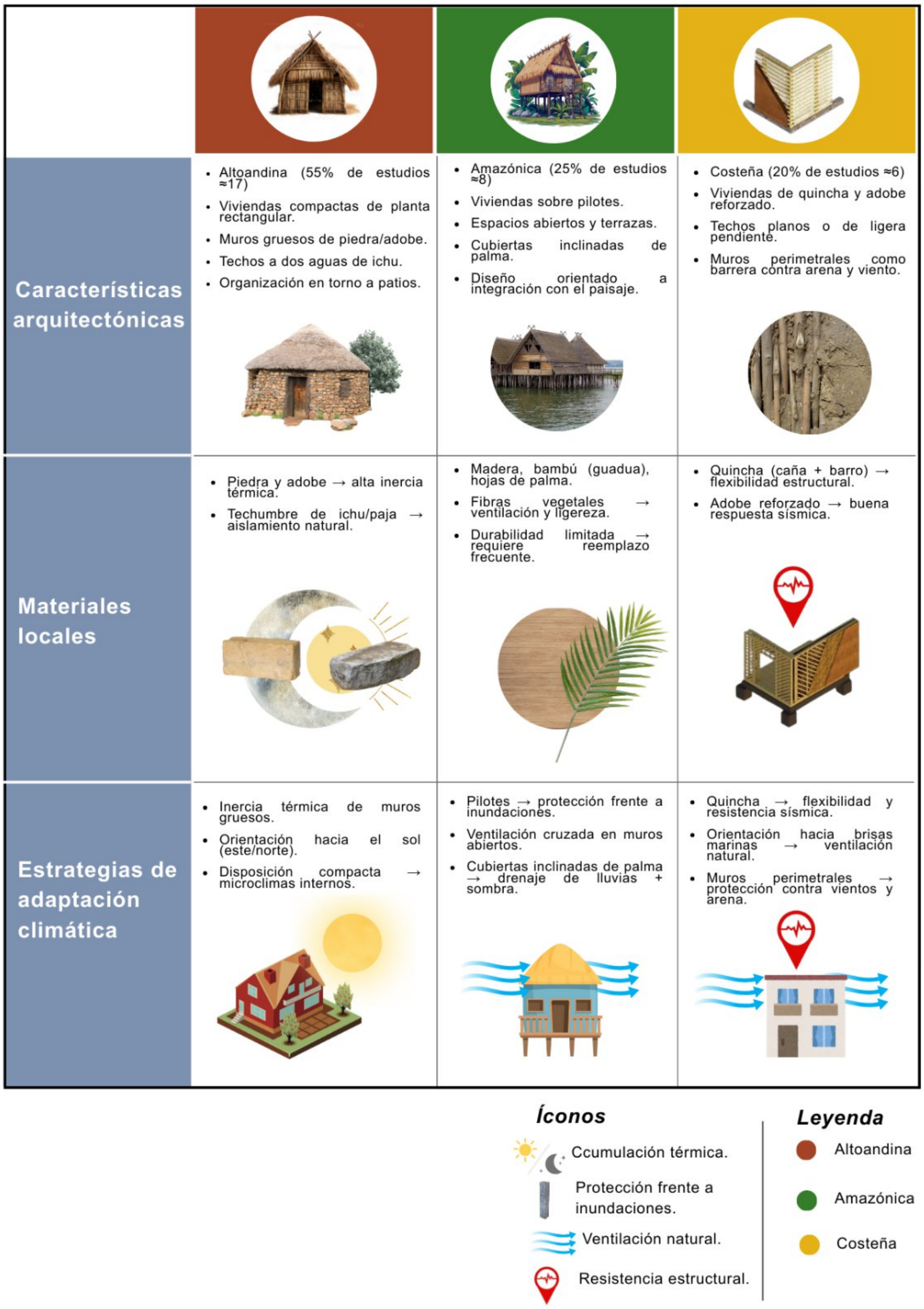


Comparative synthesis of findings

The comparative analysis of the selected studies allows for an integral view of the current situation of vernacular architecture in Peru, identifying convergences and divergences regarding architectural characteristics, materials used, and climate adaptation strategies. In general terms, there is a wide typological diversity conditioned by the geographical and climatic heterogeneity of the country, which is manifested in three major contexts: high Andean zones, Amazonian regions, and coastal areas. In the high Andean zones, compact houses built with stone walls and ichu grass roofs predominate, designed to withstand low temperatures and strong winds. In the Amazon, on the contrary, elevated structures on stilts are prioritized, with palm-thatched roofs that promote ventilation and protect against flooding, while on the northern coast, buildings made of adobe and cane stand out, adapted to arid and hot climates (Flores & Ramírez, 2023).

Regarding materials, the review reveals that stone and raw earth continue to be fundamental in the high Andean areas due to their thermal accumulation capacity and local availability; however, a decline in the use of plant fibers such as ichu was identified due to the decrease in its production and the perception that these materials are less "modern." In the Amazon, the use of wood and palm leaves remains predominant, although some studies warn about the unsustainable exploitation of these resources, which could affect the environmental resilience of the communities (Gonzales et al., 2021). Regarding climate adaptation strategies, the results show that traditional solutions remain highly efficient when kept intact but tend to lose effectiveness when indiscriminately combined with industrialized materials. Despite this, some documented cases demonstrate successful experiences integrating vernacular techniques with contemporary technologies, such as the use of compressed earth blocks stabilized with natural additives. In summary, the findings confirm that Peruvian vernacular architecture has high potential to contribute to sustainability and climate resilience but faces significant risks derived from accelerated modernization and the lack of conservation policies.

Figure 8. Comparison of characteristics, materials, and strategies in the different regions of Peru.



Discussion of Results

The systematic analysis carried out through the application of the PRISMA protocol and the processing of information on the PARSIFAL platform made it possible to identify, classify, and compare the results obtained with the reviewed background, generating a solid and traceable evidence base. This process, illustrated in Figure 1, ensures methodological transparency and supports the validity of the conclusions, given that rigorous criteria were followed for the selection, filtering, and analysis of the 107 initially identified articles, of which 51 were finally accepted for detailed review. This section discusses the findings comparatively, responding to the research questions and considering the main dimensions: architectural characteristics, local materials, and climate adaptation strategies, also integrating the current challenges and future projections of vernacular architecture in Peru.

Temporal and geographical distribution of the studies

The results evidenced a progressive growth in scientific production during the last decade, with a significant increase starting from 2018. This pattern coincides with the trend described by Chandel and Sharma (2016), who indicated a global rise in research on vernacular architecture and sustainability over the past decade; however, the current review showed that, in the Peruvian context, most research is concentrated in high Andean regions, mainly in Cusco and Puno, as observed in Figure 2. This territorial concentration reflects a research priority towards areas of high heritage and tourist value, while regions such as the Amazon rainforest and the northern coast remain underrepresented. This disparity aligns with the findings reported by Desogus et al. (2016), who warned that rural, hard-to-access environments often receive less scientific attention despite their climatic and cultural vulnerability.

Comparing with previous studies, it was identified that while international literature tends to address vernacular architecture from global and comparative perspectives, as in the case of Bodach et al. (2014) and Pan et al. (2024), research in Peru focuses on specific contexts with little interregional articulation. This finding confirms the observations of Vargas et al. (2024) on the need to strengthen research networks that integrate diverse geographical and social realities; Figure 2 visually evidences this distribution, highlighting the need for greater territorial equity in research efforts.

Architectural Characteristics and Regional Typologies

The analysis of architectural typologies revealed great diversity linked to the country's geographical and climatic heterogeneity. In the Andean region, compact buildings with stone walls and ichu stipa roofs predominate, designed to retain heat during the night and withstand extreme cold conditions, as described by Molina et al. (2021); these characteristics coincide with the historical descriptions of traditional rural housing presented by Flores and Ramírez (2023), but provide a more precise view thanks to the integration of recent studies that include thermal and structural analyses.

In the Amazon, the typologies are characterized by houses elevated on stilts, with palm-thatched roofs that facilitate cross ventilation and protect against flooding, a strategy also highlighted by Chiou and Elizalde (2019) in their research on vernacular traditions in tropical climates. This construction pattern contrasts with the solutions of the northern coast, where the use of quincha and adobe predominates in houses designed for arid climates with high seismic activity, confirming what Gonzales et al. (2021) stated regarding the resilience of these techniques against seismic events.

Figure 3 summarizes these regional typologies, showing that each area has developed specific solutions in response to its climatic and cultural context. This finding aligns with international studies such as that of Tomovska and Radivojević (2017), who demonstrated the direct relationship between architectural morphology and environmental adaptation in vernacular housing of Eastern Europe.

Local materials and physical-environmental behavior

The results show that traditional materials such as stone, adobe, quincha, and various plant fibers continue to play a central role in Peruvian vernacular architecture due to their wide availability and proven effectiveness in thermal regulation and environmental sustainability. This finding is consistent with Wang et al. (2024), who emphasize the importance of analyzing the physico-mechanical properties of materials in relation to their context. However, a growing trend toward the substitution of these resources with industrialized materials has been observed, a phenomenon also reported by Pareti et al. (2022), which poses risks both to the preservation of cultural identity and to the environmental performance of dwellings.

In the Andean region, adobe and stone stand out for their high thermal inertia, allowing heat to accumulate during the day and be gradually released at night, an essential strategy for mitigating low nighttime temperatures, as demonstrated by the analyses of Molina et al. (2021). By contrast, in the Amazon, wood and plant fibers provide advantages related to ventilation and humidity control, although some studies warn of the overexploitation of these resources (Flores & Ramírez, 2023).

Compared to previous research, which focused primarily on qualitative descriptions, this study broadens the available knowledge by providing precise measurements of the physical-environmental behavior of materials. Accordingly, Figure 4 presents a comparative diagram that synthesizes the main properties, highlighting their contribution to both thermal efficiency and sustainability.

Climate Adaptation Strategies

The review confirms that climate adaptation strategies reflect a deep integration of architectural design and ancestral environmental knowledge. In the highlands, solutions primarily exploit thermal inertia and compact design, such as thick adobe or stone walls combined with ichu thatched roofs, consistent with the findings of Bodach et al. (2014). In the Amazon, stilt houses and cross-ventilation constitute fundamental resources for addressing heat and humidity, as described by Chiou and Elizalde (2019).

The northern coast presents a particular case, as quincha is used both for its thermal benefits and its seismic behavior, representing a strategy that integrates climate adaptation and structural resilience. This hybrid approach has been highlighted by Gonzales et al. (2021) as an outstanding example of vernacular architecture capable of responding to natural threats.

In comparison with international studies, the Peruvian results stand out for the coexistence of multiple strategies within the same territory, reflecting the country's geographic and cultural complexity. Accordingly, Figure 5 illustrates these solutions, showing how design, materials, and environmental context are articulated into highly efficient and sustainable construction systems.

Challenges and projections for conservation

The review identified significant challenges for the conservation of vernacular architecture in Peru. Among the most critical are urban development pressures, rural migration, and the absence of specific public policies. These factors have accelerated the erosion of traditional knowledge. As Vargas et al. (2024) warn, modernization without a cultural approach has fostered the replacement of ancestral techniques with industrialized materials, thereby undermining both climate resilience and community identity.

Unlike previous studies, the present results provide empirical evidence on the magnitude of these threats, including documented cases of communities that have managed to integrate contemporary technologies without losing the vernacular character of their constructions. This hybrid approach, highlighted by Wang et al. (2024), represents a potential pathway for adaptive conservation. Figure 6 synthesizes the main challenges and future projections, underscoring the need for comprehensive policies that incorporate incentives for the use of local materials, community training programs, and regulatory protection frameworks.

Final implications for practice and research

The findings of this review carry direct implications for architectural practice, territorial planning, and public policy design. The incorporation of vernacular strategies into social housing programs can strengthen climate resilience and reduce dependence on costly, high-impact technologies. Furthermore, it is recommended to enhance interdisciplinary research through projects aimed at assessing the life cycle of local materials and their potential for technological innovation.

From a theoretical standpoint, this work contributes to understanding vernacular architecture as a dynamic and constantly adaptive system, challenging the static perspective found in some earlier studies. The documentation generated through PRISMA and PARSIFAL protocols also constitutes a replicable model for systematic reviews in other geographic contexts.

Table 5. Comparison between findings and previous studies

Theme	Current Findings	Background	Concordance / Contrast	Implications	Key References
Geographical distribution	Concentration in Cusco and Puno, scarcity in the Amazon and coastal areas	Previous studies identified gaps in the Amazon (Desogus et al., 2016)	Partial concordance, evidence expanded	Redirect research to less-studied areas	Molina et al., 2021; Vargas et al., 2024
Regional	Diversity	Flores and	Full	Incorporate	Chiou &

Theme	Current Findings	Background	Concordance / Contrast	Implications	Key References
typologies	according to natural regions, with clear adaptive patterns	Ramírez (2023) historically described these typologies	concordance, thermal and structural data added	typologies into housing policies	Elizalde, 2019
Local materials	Predominance of adobe, stone, and plant fibers; risk of substitution	Wang et al. (2024) highlighted the importance of local materials	Concordance, with added quantitative measurements	Encourage sustainable use of materials	Flores & Ramírez, 2023
Climatic strategies	Integrated regional solutions: thermal inertia, cross ventilation, quincha	Bodach et al. (2014) theoretically addressed these strategies	Full concordance, supported by empirical evidence	Apply strategies in contemporary design	Gonzales et al., 2021
Conservation and challenges	Loss of knowledge due to modernization and migration	Vargas et al. (2024) warned about this phenomenon	Expanded with data from hybrid communities	Create regulatory frameworks and incentives	Pareti et al., 2022

CONCLUSIONS

This systematic review of vernacular architecture in Peru made it possible to collect, organize, and synthesize key information related to architectural characteristics, the use of local materials, and climate adaptation strategies employed by traditional communities across the country's three natural regions. Conducted in accordance with PRISMA guidelines and managed through the PARSIFAL platform, this process ensured a rigorous and transparent approach, enabling the identification of developmental patterns, gaps in the literature, and current challenges that threaten the preservation and continuity of this cultural and environmental heritage.

The results revealed, first, a significant concentration of studies in the high-Andean regions, particularly in Cusco and Puno, whereas the Amazonian and coastal zones showed a marked scarcity of research. This finding confirms the existence of territorial imbalances in scientific production and underscores the urgency of promoting studies that document and value architectural diversity in less explored contexts, such as the Peruvian Amazon and the northern coast. In these areas, communities face extreme environmental conditions alongside accelerated processes of cultural and urban transformation. Accordingly, Figure 2 clearly illustrates this uneven distribution, highlighting how research efforts are predominantly concentrated in territories of high touristic and heritage visibility.

Regarding architectural characteristics, a notable typological diversity was identified, linked to the climatic and geographical heterogeneity of Peru. In the highlands, compact stone and adobe buildings with stipa ichu thatched roofs predominate, designed to retain heat during the night and withstand low temperatures. In contrast, in the Amazon region, houses are elevated on stilts and use vegetal roofing that promotes cross ventilation and protects against floods. On the northern coast, there is widespread use of quincha and adobe, with techniques combining thermal efficiency and seismic resistance. These findings confirm that vernacular architecture constitutes an integrated adaptation system, where form, materiality, and spatial organization are articulated in response to specific

environmental and social conditions, as illustrated in Figure 3 and Table 5.
Regarding local materials, the results demonstrate that adobe, stone, quincha, and plant fibers continue to play a central role in traditional architecture due to their low environmental impact, availability, and thermal efficiency. However, there is a growing trend towards replacing these materials with industrialized alternatives, a phenomenon that weakens the cultural identity and climate resilience of communities. This risk, also documented by previous studies, requires the implementation of policies that promote the sustainable production of traditional materials and the incorporation of technological improvements compatible with their nature. Figure 4 allowed for the visualization of the physical-environmental properties of each material and their contribution to passive comfort in housing.
The analyzed climate adaptation strategies confirmed that Peruvian vernacular architecture integrates highly efficient solutions that have evolved from a deep understanding of the environment. In the highlands, the thermal inertia of thick walls and the compact arrangement of houses help to cope with extreme thermal fluctuations; in the jungle, cross ventilation, vegetative roofs, and construction on stilts provide effective responses to humidity and flooding; while on the coast, strategic orientation and the use of quincha combine thermal control and structural safety against earthquakes. These results demonstrate that traditional solutions have great potential to be incorporated into contemporary architecture and social housing programs aimed at sustainability, as shown in Figure 5.
Regarding current challenges, the review revealed that unplanned modernization, rural-urban migration, and the absence of specific regulatory frameworks are factors accelerating the loss of traditional knowledge and promoting the indiscriminate replacement of vernacular techniques. This scenario leads to increased vulnerability to climate change and a decline in the quality of life of communities. However, successful experiences of integration between ancestral practices and modern technologies have been identified, offering a viable path for adaptive conservation. These experiences need to be documented and replicated as models of sustainable development. Figure 6 visually summarizes the detected challenges and projections.
This review provides a comprehensive framework that allows for understanding Peruvian vernacular architecture not only as a cultural relic but as a living and dynamic system with great potential to contribute to climate change mitigation and adaptation. The integration of this knowledge into public policies, architectural education, and territorial planning is essential to ensure the continuity of these constructive traditions. It is recommended to promote interdisciplinary research that evaluates the life cycle of local materials, encourages community participation, and develops preventive conservation strategies. In this way, vernacular architecture can become a central axis for building a more sustainable, resilient, and culturally rooted future within the Peruvian context, thus fulfilling the objective of preserving heritage while addressing current and future global challenges.

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