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ORIGINAL

Bioclimatic Design in Modern Architecture: Towards a Greener. More Resilient Future

El Diseño Bioclimático en la Arquitectura Moderna: Hacia un Futuro Más Verde y Resiliente

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ABSTRACT

Objective: was to explore the theories and practices of bioclimatic architecture, highlighting its potential to mitigate environmental impact and improve quality of life through sustainable building design, and as a consequence, to investigate how bioclimatic architecture and energy efficiency can contribute to sustainable development and the reduction of the environmental impact of buildings.
Method: an empirical and conceptual literature review on bioclimatic architecture was carried out, based on academic references and relevant documents to provide an overview of current research on the topic. Academic databases such as Scopus, Science Direct and Google Scholar were searched using terms related to bioclimatic architecture and sustainability. A total of 118 articles were analyzed, of which 14 were selected as relevant.
Results: it was found that bioclimatic architecture focuses on the design of built spaces that integrate with the natural environment, optimizing the use of resources and prioritizing thermal and sensory comfort. Tactics such as bioclimatic ventilation and the use of sustainable materials were identified, as well as the need for adaptable solutions in different socioeconomic contexts, especially in Peru where the adoption of these practices is limited.
Conclusions: bioclimatic architecture is crucial to address contemporary environmental and energy challenges by promoting design that aligns with the natural and climatic environment. This approach not only seeks the comfort of users, but also aims to significantly reduce the carbon footprint of buildings. It is highlighted that the recovery of cultural strategies, such as courtyards, can be a key to a more bioclimatic architecture.

Keywords: Bioclimatic Design; Modern Architecture; Green Future; Resilient Future.

RESUMEN

Objetivo: fue explorar las teorías y prácticas de la arquitectura bioclimática, destacando su potencial para mitigar el impacto ambiental y mejorar la calidad de vida a través del diseño sostenible de edificios, y como consecuencia, investigar cómo la arquitectura bioclimática y la eficiencia energética pueden contribuir a un desarrollo sostenible y a la reducción del impacto ambiental de los edificios.
Método: se llevó a cabo una revisión de literatura empírica y conceptual sobre la arquitectura bioclimática, basándose en referencias académicas y documentos relevantes para proporcionar un panorama de las investigaciones actuales sobre el tema. Se realizaron búsquedas en bases de datos académicas como Scopus, Science Direct y Google Académico, utilizando términos relacionados con la arquitectura bioclimática y la sostenibilidad. Se analizaron un total de 118 artículos, de los cuales 14 fueron seleccionados como relevantes.
Resultados: se encontró que la arquitectura bioclimática se centra en el diseño de espacios construidos que se integren al entorno natural, optimizando el uso de recursos y priorizando el confort térmico y sensorial.

Se identificaron tácticas como la ventilación bioclimática y el uso de materiales sostenibles, así como la necesidad de soluciones adaptables en diferentes contextos socioeconómicos, especialmente en Perú donde la adopción de estas prácticas es limitada.
Conclusiones: la arquitectura bioclimática es crucial para enfrentar desafíos ambientales y energéticos contemporáneos, promoviendo un diseño que se alinee con el medio ambiente natural y climático. Este enfoque no solo busca el confort de los usuarios, sino que también pretende reducir significativamente la huella de carbono de los edificios. Se destaca que la recuperación de estrategias culturales, como los patios, puede ser una clave para una arquitectura más bioclimática.

Palabras clave: Diseño Bioclimático; Arquitectura Moderna; Futuro Verde; Futuro Resiliente.

INTRODUCTION

Bioclimatic architecture (BA) and energy efficiency have emerged as responses to the need to build sustainably, considering both the environmental impact and energy performance of buildings.[1,2,3,4] These concepts have evolved over time as new techniques and technologies have been introduced.[5,6,7] This is where BA focuses on designing spaces that integrate, adapt, and respond to their climatic and natural surroundings.[8,9] The goal is to use the natural resources available in the environment in a respectful way, minimizing their impact on the environment. Its main characteristics are to achieve thermal and sensory comfort with a design that generates well-being for its users. Its strategic foundations include taking advantage of the climate, passive design, the use of appropriate materials, and their harmonious integration into the environment.[1,2] It can therefore be said that AB focuses on self-consumption, minimizing energy use by taking advantage of already available natural resources.[10]

Around the world, BA has become one of the most promising approaches to improving the energy efficiency of buildings. However, the effectiveness of these strategies in reducing the energy consumption and carbon footprint of buildings depends largely on how well the building design is adapted to local climatic conditions.[9]

In this context, in Asia, understanding bioclimatic ventilation is considered essential, taking vernacular architecture as a model. This topic has attracted growing interest among researchers, although reviews of natural ventilation in vernacular architecture have been limited. Some of these reviews integrate natural ventilation with other passive design strategies.[4]

In Europe, the European Green Deal established legislation that rigorously regulates the energy performance of buildings, with the aim of reducing CO2 emissions by 55 % by 2030 and achieving carbon neutrality by 20513.[8] Given the need to create strategies that help free users from their dependence on energy to meet their comfort needs according to their context, AB has become important.[7] For his part [2] focuses on the "patio" as a bioclimatic strategy to consider because it helps regulate temperature, providing shade in hot areas, interrupting wind continuity in cold areas to create microclimates, and facilitating cross ventilation in humid areas, which contributes to energy savings. Soust et al.[13] emphasize that students should design homes that integrate carbon footprint assessment through life cycle analysis (LCA) using technological tools, promoting good decisions in architectural design and fostering sustainability.

On the other hand, in Africa, BA is essential for developing countries, especially in this region where the climatic and socioeconomic context demands sustainable design solutions that are adaptable to their context. Thus, through BA, it is possible to improve quality of life and promote energy efficiency.[3]

In South America, there is currently a wide variety of research on bioclimatic design, which shows that there are few structures focused on BA, making it essential and fundamental in today's context.[5] In Mexico [11] argues that immersive technologies make it possible to validate the criteria used in architectural designs, both in terms of energy and thermal comfort. This makes them fundamental in the creation of functional and sustainable spaces.[12,13]

In Peru, despite the efforts made, AB has not been consolidated because buildings are constructed without planning and using inefficient methods, without taking into account climatic and environmental factors.[14] There are several ways to evaluate thermal comfort, but in Peru, the adoption of AB is limited. Today, there are only a few building projects that meet these AB characteristics, which makes it fundamental for sustainable development.[5]

This narrative review article aims to explore the main theories, approaches, and related practices for mitigating the environmental impact of buildings using AB. Through an analysis, the benefits and implementations in different contexts were reviewed. In addition, it addresses how AB can contribute to global sustainability, thereby improving people's quality of life and promoting energy efficiency in buildings.

METHOD

A comprehensive narrative review aimed to describe bioclimatic architecture's empirical and conceptual

output (BA), using empirical references and academic documents to provide an overview of current research on the topic. The search was conducted in the Scopus, ScienceDirect, and Google Scholar databases using a refined search with terms in English, such as “bioclimatic architecture,” “sustainability,” “design,” “efficiency,” and in Spanish such as “diseño bioclimático,” “Arquitectura bioclimática,” “confort térmico,” “sostenibilidad + arquitectura,” and “eficiencia energética” in the defined area of architecture and the environment. More information was found by searching in English; however, articles from before 2022 were found to be relevant but were discarded due to their age.

The search period covered the entire month of September 2024, considering articles published between 2022 and 2024 and one from 2020 due to its importance. There were no language restrictions, provided they were open access. After reviewing 118 articles, 74 were discarded, selecting 14 final relevant articles. The following graphs show the search methods, classification, and characteristics of the articles analyzed.

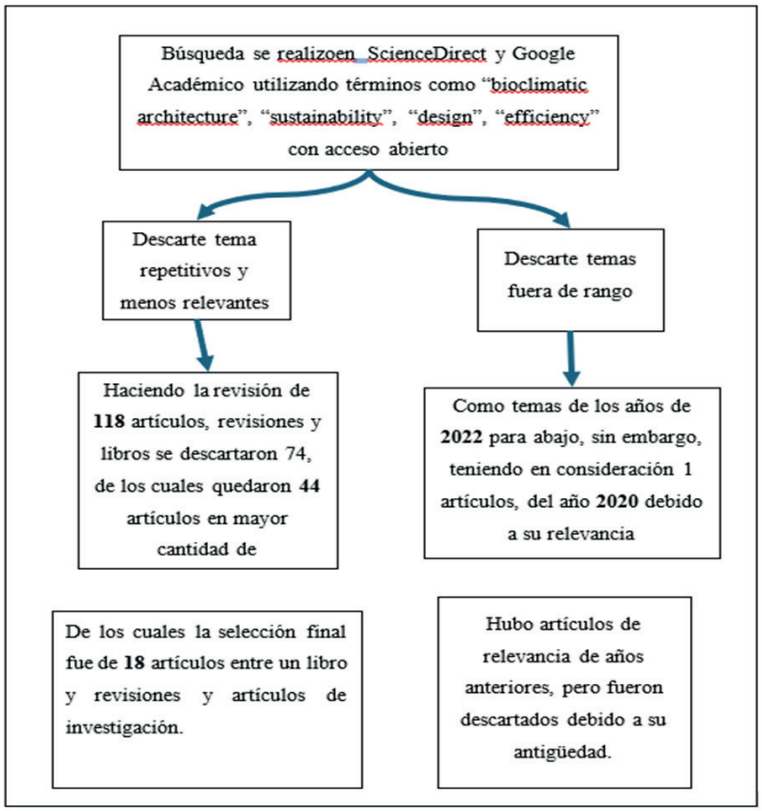

Figure 1. Flowchart of the literature review search

RESULTS

Tabla 1. Datos

Author(s)	Title	Year	URL/doi	Summary
(1)	Bioclimatic architecture	2020	https://dialnet.unirioja.es/servlet/articulo?codigo=7398396	Bioclimatic architecture seeks to design buildings adapted to the climate and natural environment, using resources sustainably. Its goal is to achieve thermal comfort, use smart materials, and take advantage of the local climate to reduce environmental impact, preserving ecosystems and minimizing pollution in the construction process.
(2)	Examples of bioclimatic architecture that contribute to the health of inhabitants and the planet.	2023	https://ri.conicet.gov.ar/handle/11336/219632	Bioclimatic architecture optimizes environmental quality and energy efficiency by taking advantage of natural resources. Gauzin-Müller (2002) highlights the importance of an environmental approach to design and management. In La Pampa, examples such as two schools show remarkable energy savings, highlighting the feasibility of reducing consumption and climate impact.

(3)	Architecture trends and challenges in sub-Saharan Africa's construction industry: A theoretical guideline of a bioclimatic architecture evolution based on the multi-scale approach and circular economy	2023	https://www.sciencedirect.com/science/article/pii/S1364032123004501	Architecture, which began with vernacular design, influenced later concepts. In sub-Saharan Africa, interest in bioclimatic design is growing but faces obstacles to its expansion. This article evaluates the existing literature on bioclimatic design and its challenges and proposes an adaptive approach based on the circular economy to promote sustainable construction practices.
(4)	Natural ventilation in vernacular architecture: A systematic review of bioclimatic ventilation design and its performance evaluation.	2024	https://www.sciencedirect.com/science/article/abs/pii/S0360132324001598	Natural ventilation strategies in vernacular architecture have generated interest due to their bioclimatic and passive approach. Investigating these techniques involves evaluating ventilation designs and their environmental impact. However, the field faces challenges in creating prototypes and implementing appropriate quantitative methods, requiring a thorough review.
(5)	Implementation of bioclimatic design to improve thermal comfort in architectural spaces for young people with intellectual disabilities in El Agustino.	2023	https://repositorio.ucv.edu.pe/handle/20.500.12692/104527	Despite the scarcity of bioclimatic structures, growing awareness of new needs and modalities is promoting their importance for users and the ecosystem. In addition, previous research on intellectual disabilities and specialized articles allow us to define an architectural proposal adapted to these needs.
(6)	Bioclimatic strategies in existing multifamily buildings to achieve cities' decarbonization goals: Potential and relevance for Catalonia climates.	2024	https://acortar.link/GrKLb2	The EU's decarbonization targets require strategies that reduce energy dependence for comfort. Bioclimatic Strategies (BS), adapted to local conditions, support these objectives. However, their success depends on support for project teams and advanced tools to evaluate bioclimatic solutions.
(7)	Innovative solutions in bioclimatic architecture and energy efficiency: building sustainably.	2024	https://acortar.link/AsvvQQ	Bioclimatic architecture and energy efficiency respond to the need to build sustainably, considering the environmental impact and efficiency of buildings. Throughout history, various cultures have applied bioclimatic principles to adapt to the natural environment and take advantage of available resources.
(8)	Beyond passive House: Use of evolutionary algorithms in architectural design.	2023	https://acortar.link/TWsARg	Buildings account for one-fifth of greenhouse gas emissions. Improving their energy efficiency is key to climate neutrality. This study analyzed how to optimize geometric characteristics in single-family homes in southern Brazil, achieving a reduction in energy consumption of between 76 % and 91 % and an increase in thermal comfort.
(9)	Impact of key bioclimatic design strategies on buildings' performance in dominant climates worldwide.	2022	https://acortar.link/cgemtP	Bioclimatic design strategies improve the energy efficiency of buildings, but they depend on climatic conditions. This study investigated the impact of techniques such as green roofs, shading, natural ventilation, and Trombe walls in three global climates. The results showed that the right combination of strategies reduces energy consumption and GHG emissions.
(10)	Bioclimatic architecture. Regulatory analysis and case study	2022	https://riunet.upv.es/handle/10251/181307	This final degree project addresses the key aspects of sustainable architecture, from its history and regulations to equipment and examples of buildings with high energy ratings. It includes a case study on the energy certification of a rural house in Albacete, demonstrating that proper layout and choice of facilities can improve efficiency, even in existing buildings.

(12)	Microclimatic resilience of the Mediterranean courtyard: evaluation of thermal comfort and energy savings associated with the use of passive strategies in courtyard design.	2023	https://dialnet.unirioja.es/servlet/tesis?codigo=322582	Rising global temperatures, urban heat islands, and dependence on fossil fuels present significant technological challenges. Concerns about thermal comfort and energy consumption in buildings highlight the crucial role of architecture in this context. The recovery of spaces such as courtyards, characteristic of our cultural environment, is presented as a key bioclimatic strategy.
(13)	Calculating the carbon footprint in digital design tools: reflections on teaching experiences.	2023	https://revistes.upc.edu/index.php/JIDA/article/view/12371	This teaching experience addresses collective housing projects, evaluating their carbon footprint using digital tools and the Life Cycle Assessment (LCA) methodology. The aim is to raise awareness of the impacts of systems, materials, and architectural design, promoting the optimization and selection of materials to reduce the carbon footprint.
(11)	Immersive technologies as a tool for architectural design: literature review.	2024	https://acortar.link/kXzJRZ	Immersive technologies allow us to experience virtual spaces, integrating color, sound, light, and form, which makes them valuable in architecture. This study reviews the application of virtual, augmented, and mixed realities in architectural design, highlighting their relevance in validating design criteria and improving user understanding.
(14)	Design proposal for a bioclimatic house to reduce energy consumption in the San Juan Bautista-Iquitos district.	2024	https://repositorio.urp.edu.pe/handle}/20.500.14138/7506	The city of Iquitos faces problems of disorderly settlements and housing built without consideration for the climate, soil, and local materials. This research proposes a bioclimatic housing design in San Juan Bautista to reduce energy consumption. Using the E.050 standard, bibliographic research, and Revit software, current characteristics, construction criteria, and the subsoil are analyzed to propose an efficient design.

CONCLUSIONS

Bioclimatic architecture plays an essential role in sustainability and energy efficiency in building design, especially in a global context where environmental and energy challenges are becoming increasingly urgent. This approach seeks to create buildings that provide comfort to users and reduce environmental impact by promoting the responsible use of available natural resources. Through design principles that integrate the natural and climatic environment, bioclimatic architecture optimizes the use of sunlight, natural ventilation, and thermal insulation, reducing energy demand and, therefore, greenhouse gas emissions.

One key to bioclimatic architecture is its ability to adapt to local characteristics, both climatic and cultural. A notable example is the recovery of traditional cultural strategies, such as courtyards, which have been used for generations in different cultures to provide shade, promote air circulation, and create pleasant microclimates within buildings. These open spaces allow maximum use of natural light without overheating interiors, promoting cross ventilation and contributing to a healthier, more energy-efficient indoor environment.

Furthermore, including cultural elements in bioclimatic design improves the energy performance of buildings and enriches users' sense of identity and belonging. By incorporating traditional elements such as courtyards, architecture can link past and future generations while adapting to modern sustainability needs. Therefore, the recovery of cultural strategies, such as courtyards, presents itself as a practical and symbolic solution in the transition towards a more bioclimatic architecture capable of facing the challenges of climate change without losing sight of local history and culture.

In conclusion, bioclimatic architecture not only has the potential to transform the way we design and build but also connects us with traditions and cultural heritage, demonstrating that the old and the new can coexist harmoniously in the search for sustainable and efficient solutions.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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