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Investigating Green Coverage Design Strategies for Enhancing the Environmental Performance of Biophilic Architecture with an Environmental Management Approach

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Abstract

The present study aims to investigate and explain the role of green coverage in enhancing the environmental performance of biophilic architecture through an environmental management approach. The necessity of this research arises from challenges associated with rapid urbanization, increasing energy consumption, and water resource crises across Iran's diverse climates. In this context, the study seeks to identify effective indicators and propose a localized model that clarifies the pathway for integrating natural elements, green technologies, and biophilic design principles. The research adopts a descriptive–analytical approach, combining theoretical studies with the analysis of five domestic and international case studies. The performance indicators of green coverage were examined within four main dimensions: energy and thermal performance, air quality, water management, and human-centered factors. These indicators were then weighted and organized into a conceptual model. The findings indicate that energy reduction and rainwater management have the greatest contribution to improving environmental performance. Moreover, the simultaneous integration of green roofs and green walls can significantly moderate temperature, improve air quality, and enhance thermal comfort. In the final model, the indicators were weighted as follows: 35% for energy, 30% for water, 25% for air quality, and 10% for human-centered factors. This structure creates a dynamic balance between environmental functionality and user well-being, demonstrating that successful green coverage design is achieved when it goes beyond a decorative role and becomes a structural and managerial component of sustainable architecture.

Keywords: Biophilic architecture, Green coverage, Green roof, Green wall, Environmental management, Sustainable development.

1 | Introduction

Rapid urbanization and the excessive consumption of natural resources have disrupted the ecological balance of cities and increased urban ambient temperatures. This phenomenon, commonly referred to as the Urban Heat Island (UHI) Effect, necessitates structural solutions in the design of environmental and built spaces. Under such conditions, architecture, as one of the key factors influencing environmental quality, must move

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beyond its conventional functional role and assume a restorative responsibility toward nature. This paradigm shift has directed increasing attention toward nature-based solutions.

In recent years, the concept of biophilic architecture, which emphasizes the innate human need for connection with nature, has been recognized as an effective approach for improving both psychological well-being and ecological performance [1]. Biophilia, the foundational concept of this approach, is based on the principle that human health and well-being depend on direct and indirect interactions with nature. However, design based on biophilic principles can only achieve its full potential when integrated with real ecological systems such as green infrastructure and environmental management strategies.

In this context, the implementation of green coverage systems in buildings not only enhances energy efficiency and reduces urban pollution but also serves as a means of restoring the human–nature relationship. Green coverage systems, including green roofs and green walls, create a living layer on building structures that moderates heat exchange and improves overall building performance in line with sustainable development objectives. The present study is founded on the assumption that the integration of these three elements, biophilia, green coverage, and environmental management, provides the necessary framework for achieving sustainable architecture in climatically challenging environments.

2 | Problem Statement

In recent years, the application of green coverage systems has gained increasing attention as a significant component of sustainable design. At the international level, this trend has been encouraged through the adoption of various environmental standards and green building certification systems. Nevertheless, in many implemented projects, these systems have been applied superficially and without a comprehensive analysis of local climatic conditions. Such a lack of adaptation has resulted in problems, including the inappropriate selection of plant species requiring excessive irrigation, high water consumption, inadequate drainage design that threatens structural stability, and insufficient maintenance practices. Consequently, the anticipated environmental benefits have often not been fully achieved.

Moreover, within the context of Iranian construction practices, severe water resource limitations and significant seasonal temperature fluctuations have led to the implementation of green coverage systems largely independent of comprehensive urban environmental management policies. This disconnect between the ambitious objectives of green architecture and the realities of local climatic conditions has reduced the long-term effectiveness and durability of implemented projects, preventing them from fully contributing to the goals outlined in sustainable development frameworks.

Therefore, there is a need for comprehensive research aimed at identifying and prioritizing the key indicators influencing the integration of green coverage systems with biophilic design principles and environmental management frameworks within Iran's climatic context. The primary objective of this study is to develop an analytical framework that can support the formulation of a localized and sustainable model, emphasizing the efficient management of internal building resources, particularly water, and the adaptation of architectural solutions to their surrounding environmental conditions.

3 | Theoretical Foundations

3.1 | Biophilic Architecture

Biophilic architecture originates from Wilson's Biophilia hypothesis [2], which defines human affinity for nature as an innate and evolutionary need. This theory encompasses two primary dimensions: direct experiences of nature (such as natural light, air, and water) and indirect experiences of nature (including patterns, forms, and colors inspired by natural environments).

Recent studies [1], [3] have expanded this approach toward the redesign of built environments through nature-inspired patterns and processes. A distinctive characteristic of biophilic architecture is the recreation of natural forms and ecological processes within the spatial, lighting, and functional structures of buildings.

Numerous empirical studies have demonstrated that the presence of natural elements, including daylight, views of green spaces, and natural ventilation, can positively influence building occupants. Research indicates that exposure to natural elements can increase cognitive performance by up to 13% and reduce employee stress levels by approximately 8%.

In the present study, biophilic architecture serves as the theoretical foundation linking humans and the environment. Its role in enhancing the functional efficiency of green architecture is explained through the creation of sensory and perceptual experiences. This dimension ensures that green design strategies function not merely as technical solutions but also as responses to the biological and psychological needs of occupants.

3.2 | Green Coverage in Architecture

Green coverage represents one of the most prominent manifestations of the integration between architectural structures and natural ecological systems, occupying a significant position within both sustainable and biophilic architecture. By introducing living vegetation layers onto horizontal and vertical building surfaces, this technology provides not only aesthetic value but also extensive climatic and ecological benefits. Recent studies indicate that green roofs and green walls contribute significantly to thermal comfort by reducing heat transfer, mitigating air pollution, and improving ambient humidity levels [4], [5]. Consequently, green coverage should be regarded not as a decorative addition but as an integral component of a building's bioclimatic regulation system, actively contributing to the management of heat, light, and air quality.

From a technical perspective, green roofs are generally classified into two major categories based on substrate depth and moisture retention capacity: extensive and intensive systems. Extensive green roofs, characterized by shallow soil depths (5–15 cm) and drought-resistant vegetation, are suitable for buildings with structural load limitations. Intensive green roofs, with deeper growing media (20–100 cm), support shrubs, communal spaces, and enhanced biodiversity [6]. In parallel, green walls are typically implemented as either living walls or climbing green facades, each exhibiting different impacts on indoor and outdoor air quality depending on drainage systems and installation methods [7]. Analysis of these categories suggests that each contributes uniquely to climatic performance and that their strategic integration can yield more effective thermal and ecological outcomes.

From an environmental performance perspective, recent urban-scale studies have demonstrated that green coverage systems can reduce rooftop surface temperatures by 10–25°C and decrease atmospheric carbon dioxide concentrations by approximately 0.3–0.5% [5]. This phenomenon results from the combined effects of solar radiation absorption and plant evapotranspiration and may be expressed through the following relationship:

ΔTsurface=α×(Tbare−Tgreen)\Delta T_{surface}=\alpha\times(T_{bare}-T_{green})ΔTsurface=α×(Tbare−Tgreen),

where α represents the thermal reduction coefficient, which depends on vegetation type and moisture conditions and generally ranges between 0.4 and 0.6 [8].

Studies of indigenous projects in northern Iranian cities such as Rasht and Tonekabon have shown that the use of native species such as Tradescantia pallida and Sedum spurium can increase system durability by up to 40% while reducing water consumption by approximately 30% compared with non-native species. These findings highlight the importance of ecological adaptation in design and demonstrate that vegetation selection in Iran should be based not only on aesthetics and livability but also on ecological compatibility with local environmental conditions.

At a broader scale, green coverage systems not only reduce surface temperatures and cooling loads but also contribute significantly to urban ecosystem health by capturing Particulate Matter (PM2.5) and enhancing urban biodiversity [9]. Even in arid climates, such systems can be adapted through the use of lightweight substrates and smart drip-irrigation technologies. Therefore, green coverage should be viewed not merely as a technical intervention but as a practical component of environmental management, capable of transforming building surfaces from passive energy consumers into active regulators of energy and moisture. This perspective elevates green coverage from an architectural form to an ecological performance system, where biophilic architecture converges with environmental sciences and sustainable environmental management becomes embodied within the built environment.

3.3 | Green Walls and Their Performance Indicators

Green walls represent one of the most effective nature-based technologies in biophilic architecture. By creating living envelopes on vertical building surfaces, they regulate temperature, mitigate pollution, and enhance urban livability. Through the integration of vegetation, drainage layers, growth media, and automated irrigation systems, green walls establish a dynamic interface between the building structure and the surrounding ecosystem. In doing so, they transform a “passive facade” into an “active and living envelope,” elevating biophilic architecture from a purely aesthetic concept to a functional environmental strategy.

Studies conducted between 2019 and 2024 generally classify green walls into two categories:

Green facades: Systems in which climbing plants grow from ground level or planters with the support of trellises or structural frameworks.

Living walls (modular green walls): Systems where planting media are incorporated into modules directly attached to the building structure.

The first category is generally more economical and suitable for traditional or humid environments, whereas the second provides greater control over moisture, temperature, and species selection. In Iran’s climatic conditions, living wall systems often demonstrate superior performance due to their adaptability to intense solar radiation and their compatibility with drought-tolerant native species such as Rosmarinus officinalis and Sedum acre. Consequently, the selection between these systems depends primarily on a combined assessment of energy–climate performance and long-term maintenance capacity.

From a thermal perspective, the performance of green walls in reducing surface temperatures and cooling energy demand is well documented. Du et al. [8] reported average temperature differences of 5–9°C between vegetated facades and conventional building surfaces, represented by the relationship:

ΔTsurface=α(Tbare−Tgreen)\Delta T_{surface}=\alpha(T_{bare}-T_{green})ΔTsurface =α(Tbare−Tgreen),

where α ranges from approximately 0.6 to 0.8 for densely vegetated systems. In hot-arid climates, this effect may reduce cooling energy demand by up to 12%, whereas in humid northern cities, its primary role lies in moderating moisture fluctuations within the building envelope. Collectively, these outcomes support contemporary climatic architecture theories that regard living elements as biological energy regulators rather than visual ornaments.

In terms of air quality, studies conducted between 2022 and 2023 indicate that each square meter of green wall can capture approximately 2–3 grams of PM10 per day and remove up to 0.5 mg/m^2 of nitrogen oxides from the atmosphere. Plant species with rough leaf textures, such as Hedera helix and Ficus pumila, exhibit particularly high pollutant absorption capacities. Research conducted by the University of Tehran on projects along Enghelab Street and Niavaran reported an average reduction of 45% in particulate concentrations at the pedestrian level, demonstrating the policy relevance of green walls in high-traffic urban areas. Consequently, the local pollution absorption capacity can be considered a key indicator for quantifying ecological performance within a localized Iranian framework.

From the perspective of water consumption and recycling, recent technological developments increasingly rely on greywater recirculation systems. Masi et al. [10] demonstrated that the integration of linear pumping systems and treated wastewater storage can improve water-use efficiency by up to 72%. Similar approaches tested in Tehranpars have resulted in significant reductions in maintenance costs. Aligning such technologies with environmental management systems such as ISO 14001 enables green walls to evolve from facade elements into resource-management modules, representing a point of convergence between sustainable design and environmental management.

From an aesthetic and social standpoint, green walls function not merely as decorative features but as psychological mediators between people and space. Studies by Yin et al. [11] and Jiang et al. [12] in residential projects across Asia and Europe revealed that 70–80% of residents in buildings with green walls reported higher levels of environmental satisfaction and perceived quality. Domestic field studies in Isfahan and Shiraz similarly identified a direct relationship between vegetation density and environmental satisfaction. These findings confirm that green walls extend beyond physical performance and constitute an essential component of the biophilic mechanism that fosters a sense of place attachment.

In summary, based on the synthesis of international research and Iran's climatic requirements, the principal performance indicators of green walls can be categorized into four major dimensions:

I. Surface temperature reduction (ΔT) as an energy-performance indicator.
II. Removal of PM and gaseous pollutants as an air-quality indicator.
III. Water-use efficiency through recycling systems and reduced evaporative losses as a water-management indicator.
IV. Psychological and aesthetic impacts on occupants as a human-centered performance indicator.

These dimensions provide a comprehensive framework for evaluating the environmental effectiveness of green wall systems within biophilic and sustainable architectural design.

3.4 | Indicators and Criteria for Evaluating Green Coverage Performance

The scientific evaluation of green coverage systems in biophilic architecture requires the identification of indicators capable of simultaneously addressing environmental, energy-related, and human-perception dimensions. These indicators emerge from the convergence of environmental sustainability principles, biophilic design concepts, and environmental management frameworks. Their primary function is to transform green design from a conceptual approach into a measurable and comparable assessment framework. The four main categories of indicators that constitute the international basis for evaluating green coverage performance are listed below [6], [13], [14].

I. Energy and thermal performance indicators.
II. Air quality and microclimate indicators.
III. Water management and resource conservation indicators.
IV. Human-centered and aesthetic indicators.

Within the first category, variables such as surface temperature difference (ΔT), heat flux, and annual energy savings (kWh/m^2) are widely used to assess the ability of green coverage systems to moderate heat transfer and reduce building cooling loads [15]. The second category includes indicators such as PM10 removal, reduction of atmospheric CO_2 concentrations, and mitigation of the UHI effect, all of which are directly associated with urban air quality and public health [6].

The third category focuses on resource efficiency and includes indicators such as the greywater recycling ratio (RWR%), effective evapotranspiration rates, and overall water-use efficiency. According to Al-Jayyousi [16], these indicators represent the most critical determinants of green roof performance in arid and semi-arid climates. Finally, human-centered indicators, including environmental satisfaction, visual connection to nature, and perceived psychological well-being [12], reflect the social and experiential benefits of green coverage systems and highlight their contribution to occupant comfort and quality of life.

From a comparative analysis of the literature, energy-related indicators tend to receive the highest weighting in temperate climates. However, in hot-arid regions such as many parts of Iran, water management and thermal stress reduction become more significant performance criteria [17], [18]. Consequently, each indicator should be evaluated through two complementary dimensions: a global standard framework, which provides universally accepted assessment criteria, and a local adaptation framework, which incorporates the specific climatic and environmental conditions of Iran [19].

This dual-criteria approach enables green coverage design to evolve from a purely imitative model toward an adaptive and context-sensitive strategy that responds effectively to local resource constraints and environmental challenges. Accordingly, the variation in weighting between energy-related and water-related indicators across these two evaluation systems forms the foundation for the climate-based decision-support model developed in the subsequent chapter.

Table 1. Classification of environmental performance indicators of green coverage systems.

Indicator Group	Sub-Indicator	Measurement Criterion (Unit)
Energy and thermal performance	Surface temperature difference (ΔT)	°C reduction compared with a non-vegetated surface
	Annual energy savings	kWh/m² or percentage reduction in energy consumption
Air quality and microclimate	PM10 and CO_2 removal capacity	g/m²·day or reduction in concentration (ppm)
	UHI mitigation	Difference in surrounding ambient temperature (°C)
Water management and resource conservation	Greywater recycling ratio (RWR%)	Percentage of water volume recovered and reused
	Effective evaporative loss reduction	Percentage reduction compared with conventional irrigation systems
Human-centered and aesthetic performance	User environmental satisfaction	Mean questionnaire score (1–5 scale)
	Visual access to greenery	Percentage of spaces with direct views of vegetation

3.4.1 | Interpretation

The indicators presented in *Table 1* provide a comprehensive framework for evaluating the environmental performance of green coverage systems within biophilic architecture. The energy and thermal performance category assesses the effectiveness of green roofs and green walls in reducing heat gain and lowering energy demand. The air quality and microclimate category measures the capacity of vegetation to remove pollutants and mitigate UHI effects. The water management and resource conservation category focuses on water-use efficiency and recycling potential, which are particularly important in water-scarce regions. Finally, the human-centered and aesthetic performance category evaluates the contribution of green coverage to occupants' psychological well-being, environmental satisfaction, and visual connection with nature.

Together, these indicators establish a balanced assessment system that integrates ecological performance, resource efficiency, and human well-being, thereby supporting the implementation of sustainable and climate-responsive biophilic design strategies.

3.5 | Comparative Analysis of Indicators at Global and Local Scales

The dual-dimensional evaluation of green coverage indicators demonstrates that the relative importance of each indicator varies depending on climatic and cultural contexts. In humid and semi-humid countries, energy performance and air quality indicators are prioritized. In contrast, in arid and semi-arid climates such as Iran, water management and passive cooling strategies carry greater weight [1], [18], [20].

This variation stems from differences in the prioritization of critical environmental resources. In regions where water scarcity and high solar radiation are dominant constraints, the focus of design shifts from energy efficiency alone toward hydrological sustainability and thermal resilience. This climatic tension highlights the necessity of adapting imported design models to local ecological conditions and emphasizes the importance of developing an indigenous, context-sensitive framework for green coverage systems.

Accordingly, this divergence between global standards and local requirements underscores the need for a localized model for green coverage management that is both environmentally responsive and climatically adaptive.

Table 2. Comparison of indicator priorities at global and Iranian local scales.

Indicator Group	Sub-Indicator	Global Priority	Local Priority (Iran)	Key References
Energy and thermal performance	Energy consumption reduction/surface ΔT	5	3	[13], [14]
Air quality and microclimate	PM and CO_2 removal/UHI mitigation	4	3	[6], [12]
Water and resources	Rainwater recycling/water-use efficiency	3	5	[10], [16]
Materials and environmental adaptation	Use of local and low-carbon materials	3	4	[9], [21]
Human-centered and aesthetic	User satisfaction/visual connection to nature	3	3	[12]

3.5.1 | Interpretation

The comparative analysis indicates a clear shift in priority between global and local (Iranian) contexts. While global frameworks tend to emphasize energy efficiency and thermal performance, the Iranian context places higher importance on water management and resource conservation due to climatic aridity and water scarcity. Conversely, indicators related to energy and air quality, although still significant, receive relatively lower weighting in the local context. This divergence highlights the necessity of context-sensitive design strategies and supports the development of a localized evaluation model for green coverage systems in biophilic architecture.

4 | Research Type and Approach

This study is applied in nature and follows a descriptive–analytical approach, aiming to develop a localized model for improving the environmental performance of green coverage systems in biophilic architecture. The data were collected through a systematic review of international scientific literature and the analysis of five selected case studies. A combined inductive–deductive methodology, in line with Berndtsson [20] and Zuo and Zhao [21], was employed to align theoretical indicators with Iran's climatic conditions. This structure not only maintains scientific validity but also enables the adaptation of global findings to local data, ultimately transforming theoretical insights into practical, environment-based design guidelines.

4.1 | Research Process

The research process was organized into five sequential stages to ensure methodological coherence in transforming theoretical data into a conceptual model. These stages were structured by integrating the PRISMA framework used in sustainable design studies [24] with comparative analytical logic.

At each stage, a combination of qualitative methods (literature review and conceptual synthesis) and quantitative methods (indicator weighting) was applied to ensure that the findings are reproducible and transferable to other climatic contexts. The final outcome of this process is a structured model that systematically clarifies the relationship between green coverage systems, biophilic architecture, and environmental management.

Table 3. Research implementation stages and content of each step.

Stage	Key Activity	Main Output
Literature review and indicator identification	Review of 52 international sources (2019–2024) and extraction of performance variables	Preliminary list of environmental and biophilic indicators
Development of a classification framework	Grouping indicators into four main dimensions	Multidimensional evaluation framework
Global–local comparative analysis	Comparison of indicator priorities in global literature and Iran's climatic data	Indicator comparison matrix
Weighting and prioritization	Determining the relative importance of indicators using a qualitative pairwise comparison model (AHP)	Final weighted indicator table
Conceptual model development	Integration of results into a four-dimensional analytical structure	Final conceptual research model

The continuity of the five-stage process has transformed the research workflow, from data extraction to final modeling, into a reproducible and context-adaptable framework. In this way, the process can serve as a foundation for developing hybrid models in the field of environmental design within similar climatic contexts.

4.2 | Selection and Analysis of Case Studies

In this section, in order to empirically validate the indicators extracted from the theoretical framework, a set of prominent international and national projects recognized for their application of green coverage in biophilic architecture has been selected for comparative analysis. These case studies were chosen with the aim of demonstrating diversity in climatic conditions, implementation technologies, and the level of integration between green coverage systems and architectural structures, thereby enabling an assessment of their compatibility with the proposed Iranian contextual model.

The comparative analysis of each case's characteristics and performance indicators not only reveals the environmental and human-related potentials of green coverage systems but also provides a theoretical and empirical foundation for the development of the study's conceptual model. *Table 4* presents the main specifications of the selected projects, including climate type, type of green system, dominant performance indicator, and key biophilic features, in order to ensure a structured, evidence-based, and comparable analysis for subsequent stages of the research.

Table 4. Specifications and characteristics of selected case studies on green coverage in biophilic architecture.

No.	Project Name	Location	Climate Type	Type of Green Coverage	Main Performance Indicator	Key Biophilic Feature
1	Bosco Verticale	Milan, Italy	Temperate Mediterranean	Vertical green facade	CO_2 absorption ~30 tons/year	Over 900 trees used for natural cooling
2	One Central Park	Sydney, Australia	Hot and humid	Combined green roof and green wall	25% energy savings	Ken Yeang's design with heliostat mirrors reflecting sunlight
3	CaixaForum Madrid	Madrid, Spain	Mediterranean	Intensive green wall	70% reduction in runoff	Patrick Blanc's design with ~15,000 plant species
4	ACROS Fukuoka Building	Fukuoka, Japan	Semi-humid Asian	Stepped green roof	4–6°C temperature reduction	Integration with urban topography and landscape continuity
5	Parkroyal on Pickering	Singapore	Hot and humid	Green roofs and sky gardens	25% water consumption reduction	15,000 m² biophilic hanging gardens
6	Iran Mall Green Tower	Tehran, Iran	Semi-arid	Extensive green roof	18% energy reduction	Use of native plants and a smart irrigation system

The analysis of the projects presented in *Table 4* indicates that variations in climate, construction technology, and the type of green coverage system directly influence environmental performance patterns. Projects implemented in hot and arid regions such as Tehran and Dubai primarily focus on irrigation efficiency, the selection of native plant species, and evapotranspiration control. In contrast, case studies located in humid climates such as Singapore and Sydney place greater emphasis on optimizing natural ventilation and humidity regulation.

Furthermore, the performance analysis reveals that the level of integration between the primary building structure and the green system is a critical factor in thermal stability and energy efficiency. Buildings such as Bosco Verticale and the ACROS Fukuoka Building, where vegetation is structurally embedded within the architectural design, demonstrate superior performance in terms of energy consumption reduction and surface temperature mitigation.

The findings suggest that integrating indigenous climatic strategies with advanced green coverage technologies can provide a viable pathway toward achieving efficient biophilic architecture in Iran. These results form the basis for the extraction of key indicators and the development of the study's conceptual model.

4.3 | Conceptual Model of the Research

Based on the findings and case study analyses, the conceptual model of this research was developed to explain the role of green coverage in enhancing the environmental performance of biophilic architecture. The model is structured around three main pillars: biophilic principles, green coverage technologies, and environmental management. The interaction among these three pillars leads to reduced energy consumption, improved air quality, effective water management, and enhanced user comfort.

Using the Analytical Hierarchy Process (AHP), the relative importance of the indicators was determined as follows: energy (35%), water (30%), air quality (25%), and human-centered factors (10%). The integration of these weighted factors results in a localized and efficient model that serves as a foundation for the sustainable integration of green coverage systems in biophilic architecture.

In this model, inputs include climatic conditions, the type of green coverage system (green roof, green wall, or hybrid systems), and the selection of native plant species. These inputs are processed through the regulating mechanisms of green coverage systems, such as evapotranspiration, shading, pollutant absorption, and water retention, resulting in outputs such as reduced energy consumption, improved air quality, efficient water resource management, and enhanced thermal and psychological comfort for users.

A key feature of this model is the dynamic interaction among indicators, where improvement in one component (e.g., water management) can have synergistic effects on other components, such as energy performance and air quality. This structure demonstrates that the success of green coverage in biophilic architecture depends on its functional integration as a comprehensive environmental management system, rather than as an isolated or purely decorative element.

Fig. 1 illustrates the conceptual structure of the study, in which "environmental management," as a macro-level layer, through "green cover design strategies" and with the mediation of "biophilic architecture principles," influences the four main dimensions of environmental performance, including energy, water, air quality, and human-centered factors. Ultimately, this leads to the improvement of the building's environmental performance and the achievement of sustainable development.

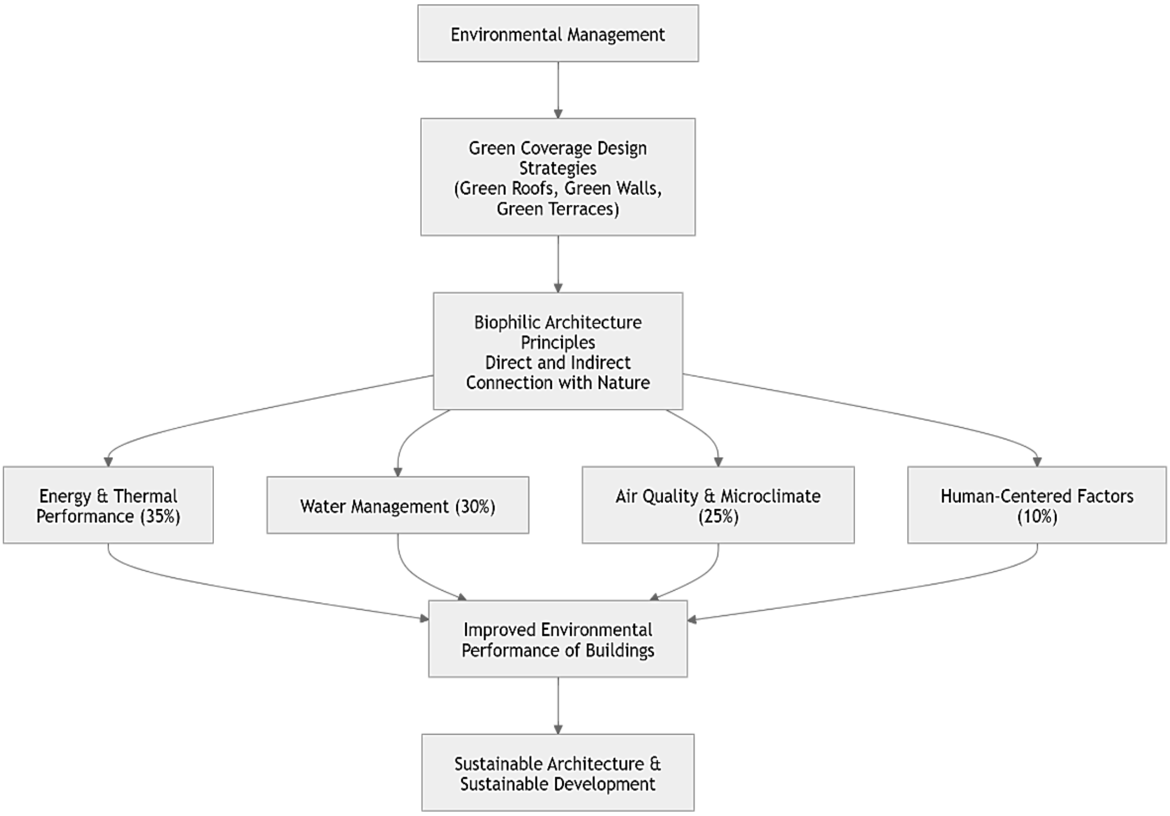

Fig. 1. Conceptual model of the research explaining the role of green cover in enhancing the environmental performance of Biophilic architecture.

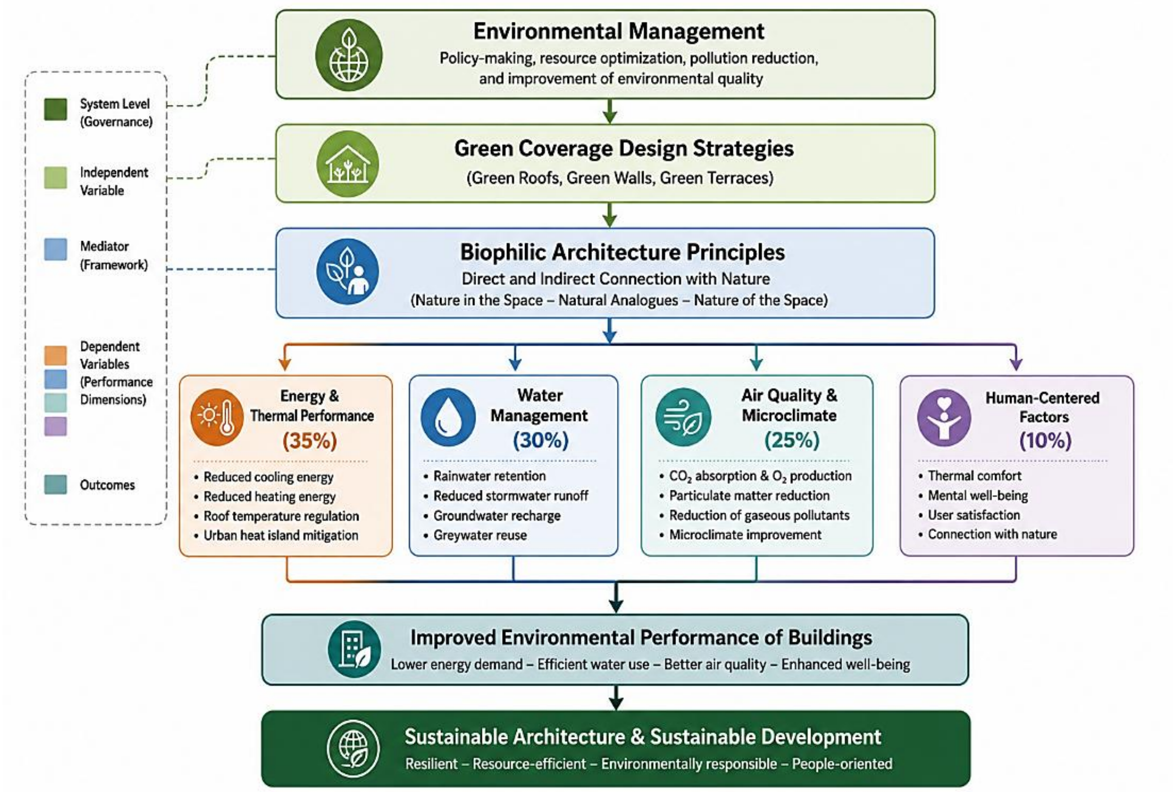

Fig. 2. Integrated model of the environmental performance of green cover within the framework of Biophilic architecture and environmental management.

5 | Explanation of Model Components

5.1 | Environmental Management

Environmental management is positioned at the highest level of the model, acting as the policy-making and guiding framework. This approach includes:

I. Optimization of resource consumption.

II. Reduction of environmental impacts of buildings.

III. Energy management.

IV. Water management.

V. Reduction of pollutant emissions.

VI. Improvement of environmental quality.

Environmental management provides a framework ensuring that green coverage is not merely an aesthetic element, but an integrated part of the building's management system.

5.2 | Green Coverage Design Strategies (Main Independent Variable)

This section represents the main independent variable of the study and includes:

5.2.1 | Green roof

I. Reduction of solar heat gain.

II. Increased thermal insulation.

III. Storage and control of stormwater runoff.

IV. Reduction of the UHI effect.

5.2.2 | Green wall

I. Improvement of air quality.

II. Absorption of airborne particulates.

III. Reduction of cooling loads.

IV. Increase in urban biodiversity.

5.2.3 | Green terraces and green facades

I. Expansion of vegetated surface areas.

II. Creation of semi-open natural spaces.

III. Enhancement of user comfort.

5.3 | Biophilic Architecture Principles (Mediating Variable)

This component acts as a mediating variable in the model. Biophilic architecture seeks to restore the relationship between humans and nature in the built environment. Its main principles include:

Direct connection with nature: Living plants, natural light, air flow, water.

Indirect connection with nature: Natural patterns, natural materials, nature-inspired colors.

Spatial and experiential qualities: Sense of refuge, natural views, sense of place attachment.

Role of green coverage: Green coverage implements these principles within the architectural body and strengthens the human–nature connection.

5.4 | Environmental Performance Evaluation Dimensions

5.4.1 | Energy and thermal performance (35%)

The most significant category in the model includes:

I. Reduction of cooling energy demand.
II. Reduction of heating energy demand.
III. Surface temperature moderation.
IV. Reduction of the UHI effect.

Role of green coverage: Vegetation and substrate layers act as natural insulation, reducing heat transfer.

5.4.2 | Water management (30%)

I. Rainwater harvesting.
II. Reduction of surface runoff.
III. Groundwater recharge.
IV. Greywater reuse.

Role of green coverage: Green roofs and walls absorb and store part of the rainfall, reducing pressure on urban drainage systems.

5.4.3 | Air quality (25%)

I. CO_2 absorption.
II. Oxygen production.
III. Reduction of PM.
IV. Reduction of gaseous pollutants.

Role of green coverage: Vegetation acts as a natural filter, improving the surrounding air quality.

5.4.4 | Human-centered factors (10%)

I. Thermal comfort.
II. Psychological well-being.
III. User satisfaction.
IV. Increased interaction with nature.

Role of green coverage: The presence of natural elements reduces stress, enhances concentration, and improves overall quality of life.

6 | Proposed Mathematical Model

The overall environmental performance index can be defined as

EP=0.35E+0.30W+0.25A+0.10HEP = 0.35E + 0.30W + 0.25A + 0.10HEP=0.35E+0.30W+0.25A+0.10H,

where:

EP: Overall environmental performance.

E: Energy and thermal indicator.

W: Water management indicator.

A: Air quality indicator.

H: Human-centered indicators.

6.1 | Model Interpretation

The model demonstrates that green coverage design strategies, through strengthening biophilic architecture principles and within the framework of environmental management, enhance four main dimensions of environmental performance. The most significant impacts are associated with reductions in energy consumption and improvements in water resource management, while air quality enhancement and user well-being play complementary roles. Accordingly, green coverage is not merely a decorative element but an ecological and managerial infrastructure for achieving sustainable architecture.

6.2 | Conceptual Research Hypothesis

The integrated use of green roofs, green walls, and other vegetated design strategies within the framework of biophilic architecture and environmental management leads to a significant improvement in the environmental performance of buildings through the enhancement of energy efficiency, water management, air quality, and human well-being indicators.

7 | Findings

The analysis of data derived from theoretical studies and case study investigations reveals several key findings:

First, among the examined indicators, energy consumption reduction and stormwater management have the greatest impact on the environmental performance of buildings. This issue is particularly significant in Iran's arid and semi-arid climates, where limited water resources and high solar radiation intensity necessitate integrated design strategies.

Second, the results indicate that the simultaneous integration of green roofs and green walls performs better than the use of either system alone in terms of temperature regulation, heat load reduction, and air quality improvement. This combination enhances bioclimatic interaction and strengthens synergistic environmental effects.

Third, in terms of air quality, green coverage systems demonstrate a considerable capacity for PM absorption and pollutant reduction, which plays an important role in improving environmental health in dense urban areas.

Fourth, the findings show that the use of native plant species not only reduces water consumption but also increases system durability and decreases maintenance costs. This issue confirms the importance of localization in design strategies.

Finally, although human-centered indicators carry the lowest weight in the model, their role in improving user satisfaction, reducing stress, and enhancing spatial perception remains essential and complementary to the technical performance of the system.

8 | Discussion

The results of this study indicate that green coverage design within the framework of biophilic architecture leads to meaningful environmental performance improvement only when it is considered as an integrated and management-oriented system. In many implemented projects, a purely decorative approach has reduced system efficiency, whereas the findings of this research emphasize the necessity of a shift toward a systemic perspective.

From an analytical standpoint, the higher weighting of energy and water indicators reflects the fact that environmental sustainability in Iran is primarily dependent on the management of basic natural resources. This finding differs from global studies, where energy is often the dominant priority; however, in Iran, water scarcity is a more critical determining factor. Therefore, design models must move away from imported frameworks toward localized and climate-responsive solutions.

Moreover, case study analysis demonstrates that successful projects are those in which green coverage is integrated into the architectural structure, rather than being added as a superficial element. This integration enhances thermal efficiency, reduces energy consumption, and improves spatial environmental quality.

At the applied level, the following conclusions can be drawn:

I. The simultaneous use of green roofs and green walls should be considered a core design strategy.

II. Plant species selection must be based on local climatic conditions and water availability.

III. Smart irrigation and water recycling systems should be an integral part of the design.

IV. Green coverage must be defined within urban environmental management policies.

In conclusion, the future of sustainable architecture in climates such as Iran lies in the transition from symbolic design approaches to performance-based and bioclimatic architecture, where green coverage is not a decorative feature but a core ecological infrastructure. The proposed conceptual model can serve as a decision-support tool for designers and urban managers in developing sustainable biophilic projects.

9 | Conclusion

The findings of this study indicate that green coverage design within biophilic architecture leads to significant environmental performance improvement only when treated as an integrated and management-oriented system. In many practical projects, a decorative approach to green coverage has reduced its efficiency, whereas this study emphasizes the need for a shift toward a systemic perspective.

Analytically, the higher weighting of energy and water indicators demonstrates that environmental sustainability in Iran depends primarily on resource management. This finding differs from global frameworks where energy is the dominant priority, while in Iran, water scarcity is the key determinant. Therefore, design models must shift from imported approaches toward localized and climate-based strategies.

Case studies further show that successful projects are those in which green coverage is integrated into the architectural structure rather than applied as an external addition. This integration improves thermal performance, reduces energy consumption, and enhances environmental quality.

At the practical level, the following recommendations are highlighted:

I. Combined use of green roofs and green walls as a core design strategy.

II. Selection of plant species based on local climate and water availability.

III. Integration of smart irrigation and water recycling systems.

IV. Inclusion of green coverage within urban environmental management frameworks.

In summary, the future of sustainable architecture in climates such as Iran depends on a shift from symbolic design toward performance-driven bioclimatic architecture, where green coverage is considered an ecological infrastructure rather than a decorative element. The proposed conceptual model can serve as a decision-support tool for designers and urban planners.

9.1 | Research Limitations

Although the findings provide a relatively comprehensive model for green coverage design in biophilic architecture, several limitations should be acknowledged.

First, the lack of accurate and comparable statistical data from domestic projects limited the quantitative evaluation of indicators. Many existing projects lacked consistent documentation regarding energy performance, irrigation systems, or air quality monitoring.

Second, the wide climatic diversity of Iran and the absence of a unified classification system for thermal conditions limited the generalizability of the results. Although the proposed model is adaptable, it requires parameter adjustment for different climatic zones.

Third, time and financial constraints in field data collection and limited access to some international projects resulted in reliance on secondary data sources, making parts of the analysis descriptive rather than experimental.

Finally, since the study primarily focused on environmental and design aspects of biophilic architecture, economic and social dimensions were not examined in depth. These aspects require further complementary research.

9.2 | Suggestions for Future Research

Based on the findings and limitations of this study, several directions for future research are proposed.

First, long-term field studies are needed to monitor the real performance of green roofs and green walls in different climatic regions of Iran in order to generate more accurate quantitative validation data.

Second, research on the economic dimension and life-cycle assessment of green coverage systems can provide a more comprehensive understanding of financial sustainability and cost–benefit analysis.

Third, future studies should focus on integrating green coverage with advanced smart technologies such as moisture sensors, automated irrigation systems, and bio-active materials, which can optimize performance and reduce maintenance requirements.

Fourth, from a social and cultural perspective, investigating the impact of green coverage on user behavior and residential patterns in Iranian urban contexts can deepen understanding of human-centered aspects of biophilic architecture.

Finally, it is recommended that academic institutions, professional organizations, municipalities, and environmental agencies collaborate to develop localized guidelines for the design and maintenance of green coverage systems and incorporate them into national building regulations. This step would contribute to the formation of a future architecture that grows with nature rather than against it.

Authors' Contributions

All aspects of the research and manuscript preparation were carried out by the author. The author has read and approved the final version of the manuscript.

Data Availability

All data supporting the reported findings in this research paper are provided within the manuscript.

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References

[1] Kellert, S. R., Heerwagen, J., & Mador, M. (2013). *Biophilic design: The theory, science and practice of bringing buildings to life*. John Wiley & Sons. https://www.amazon.com/Biophilic-Design-Practice-Bringing-Buildings/dp/0470163348

[2] Wilson, E. O. (2017). Biophilia and the conservation ethic. In *Evolutionary perspectives on environmental problems* (pp. 250–258). Routledge. https://www.taylorfrancis.com/chapters/edit/10.4324/9780203792650-18/biophilia-conservation-ethic-edward-wilson

[3] Yeang, K. (2019). *Saving the planet by design: Reinventing our world through ecomimesis*. Routledge. https://doi.org/10.4324/9781315712727

[4] Joshi, M. Y., & Teller, J. (2021). Urban integration of green roofs: Current challenges and perspectives. *Sustainability*, *13*(22), 12378. https://doi.org/10.3390/su132212378

[5] Shafique, M., Azam, A., Rafiq, M., Ateeq, M., & Luo, X. (2020). An overview of life cycle assessment of green roofs. *Journal of cleaner production*, *250*, 119471. https://doi.org/10.1016/j.jclepro.2019.119471

[6] Berardi, U., GhaffarianHoseini, A., & GhaffarianHoseini, A. (2014). State-of-the-art analysis of the environmental benefits of green roofs. *Applied energy*, *115*, 411–428. https://doi.org/10.1016/j.apenergy.2013.10.047

[7] Susca, T., Zanghirella, F., Colasuonno, L., & Del Fatto, V. (2022). Effect of green wall installation on urban heat island and building energy use: A climate-informed systematic literature review. *Renewable and sustainable energy reviews*, *159*, 112100. https://doi.org/10.1016/j.rser.2022.112100

[8] Du, H., Zhou, F., Cai, W., Cai, Y., & Xu, Y. (2021). Thermal and humidity effect of urban green spaces with different shapes: A case study of Shanghai, China. *International journal of environmental research and public health*, *18*(11), 5941. https://doi.org/10.3390/ijerph18115941

[9] Ying, J., Zhang, X., Zhang, Y., & Bilan, S. (2022). Green infrastructure: Systematic literature review. *Economic research-ekonomska istraživanja*, *35*(1), 343–366. https://www.tandfonline.com/action/showCitFormats?doi=10.1080/1331677X.2021.1893202

[10] Masi, F., Rizzo, A., & Regelsberger, M. (2018). The role of constructed wetlands in a new circular economy, resource oriented, and ecosystem services paradigm. *Journal of environmental management*, *216*, 275–284. https://doi.org/10.1016/j.jenvman.2017.11.086

[11] Yin, J., Zhu, S., MacNaughton, P., Allen, J. G., & Spengler, J. D. (2018). Physiological and cognitive performance of exposure to biophilic indoor environment. *Building and environment*, *132*, 255–262. https://doi.org/10.1016/j.buildenv.2018.01.006

[12] Jiang, B., Li, D., Larsen, L., & Sullivan, W. C. (2016). A dose-response curve describing the relationship between urban tree cover density and self-reported stress recovery. *Environment and behavior*, *48*(4), 607–629. https://doi.org/10.1177/0013916514552321

[13] Kellert, S. R. (2008). Dimensions, elements, and attributes of biophilic design. In *Biophilic design: The theory, science, and practice of bringing buildings to life* (pp. 3–19). Wiley: Hoboken, NJ, USA. file:///C:/Users/Administrator/Desktop/BDCH.pdf

[14] Bustami, R. A., Belusko, M., Ward, J., & Beecham, S. (2018). Vertical greenery systems: A systematic review of research trends. *Building and environment*, *146*, 226–237. https://doi.org/10.1016/j.buildenv.2018.09.045

[15] Manso, M., & Castro-Gomes, J. (2015). Green wall systems: A review of their characteristics. *Renewable and sustainable energy reviews*, *41*, 863–871. https://doi.org/10.1016/j.rser.2014.07.203

[16] Al-Jayyousi, O. R. (2003). Greywater reuse: Towards sustainable water management. *Desalination*, *156*(1–3), 181–192. https://doi.org/10.1016/S0011-9164(03)00340-0

[17] Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and urban planning*, *97*(3), 147–155. https://doi.org/10.1016/j.landurbplan.2010.05.006

[18] Santamouris, M. (2014). Cooling the cities-a review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments. *Solar energy*, *103*, 682–703. https://doi.org/10.1016/j.solener.2012.07.003

[19] Razzaghmanesh, M., Beecham, S., & Kazemi, F. (2014). The growth and survival of plants in urban green roofs in a dry climate. *Science of the total environment*, *476*, 288–297. https://doi.org/10.1016/j.scitotenv.2014.01.014

[20] Berndtsson, J. C. (2010). Green roof performance towards management of runoff water quantity and quality: A review. *Ecological engineering*, *36*(4), 351–360. https://doi.org/10.1016/j.ecoleng.2009.12.014

[21] Zuo, J., & Zhao, Z. Y. (2014). Green building research-current status and future agenda: A review. *Renewable and sustainable energy reviews*, *30*, 271–281. https://doi.org/10.1016/j.rser.2013.10.021

[22] Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage Publications. https://www.ucg.ac.me/skladiste/blog_609332/objava_105202/fajlovi/Creswell.pdf

[23] Yin, R. K. (2017). *Case study research and applications* (Vol. 6). Sage Thousand Oaks, CA. https://www.amazon.com/Case-Study-Research-Applications-Methods/dp/1506336167

[24] Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *International journal of surgery*, *88*, 105906. https://doi.org/10.1136/bmj.n71