

Review

Biophilic Design Interventions and Properties: A Scoping Review and Decision-Support Framework for Restorative and Human-Centered Buildings

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Abstract

Humans have an inherent connection to nature, and exposure to natural elements has been shown to reduce stress, improve mood, and support cognitive performance, forming the basis of biophilic design in the built environment. However, existing biophilic design guidance remains largely conceptual and offers limited evidence-based direction on how design properties should be applied. This scoping review addresses this gap by systematically mapping and synthesizing empirical evidence on indoor biophilic design interventions and their properties. Following PRISMA-ScR guidelines, 136 studies published between 2000 and 2025 were reviewed across seven intervention types, including green walls, indoor plants, window views, natural light, natural materials, water features, and nature-inspired visual references. Cross-category analyses identified design properties most consistently associated with restorative outcomes and human cognitive and physiological responses. The findings highlight the importance of moderate greenery levels, high-visibility placement, multi-sensory integration, and the enhanced restorative effects of combining multiple interventions. Contextual factors such as exposure duration and user characteristics were found to influence effectiveness. Based on these findings, the study introduces the Biophilic Intensity Matrix (BIMx), a matrix-based decision-support framework that supports early-stage design by helping designers select biophilic intervention types and compare their relative scale and intensity ranges according to exposure duration.

Keywords: biophilic design; restorative buildings; evidence-based design; decision-support framework; indoor environments



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1. Introduction

Humans have an innate connection to nature, known as biophilia [1]. Two widely cited frameworks, Attention Restoration Theory (ART) [2] and Stress Recovery Theory (SRT) [3] explain this preference. ART emphasizes cognitive recovery through softly fascinating environments, while SRT focuses on affective recovery following exposure to natural stimuli. Empirical evidence shows that contact with natural landscapes from forests and parks to mountains and coastlines reduces stress and supports restoration [4–8]. Despite these benefits, people spend nearly 87% of their time indoors [9], with limited nature contact linked to increased stress, impaired cognition, and lower well-being [10,11]. Biophilic design seeks to bridge this gap by incorporating nature into indoor environments through elements such as plants, daylight, natural materials, and organic forms [12]. Research shows these features lower stress and improves cognition [13,14], aid recovery in healthcare settings [15,16], and enhance learning in schools [17].

Recent work has moved beyond comparing biophilic and non-biophilic spaces, focusing instead on how specific intervention types and design properties influence restorative outcomes. Design attributes such as the degree of greenery coverage, scale, placement, and sensory richness significantly shape physiological and psychological responses [18–24]. However, existing frameworks such as Stephen Kellert’s biophilic design attributes [25], the 14 Patterns of Biophilic Design [12], and certification systems like WELL [26] and LEED [27] offer high-level concepts but lack detailed, evidence-based guidance for optimizing interventions by type, size, or configuration. This gap leaves designers without the tools to select and scale biophilic features for specific contexts or user groups.

To address this need, this study presents a scoping review of seven biophilic interventions, green walls, indoor plants, window views, natural light, natural materials, water features, and nature-inspired visual references, chosen for their prevalence, theoretical grounding, and practical applicability. Following PRISMA-ScR guidelines [28], 136 studies published between 2000 and 2025 were reviewed to classify intervention-specific design properties and link them to human physiological, psychological, cognitive, and behavioral outcomes (Section 3). These findings are synthesized into evidence-based design guidelines (Section 4.1), including the development of the Indoor Green Coverage Ratio (IGCR) as a perceptual metric for operationalizing greenery scale and visibility in interior environments. Together, these evidence-informed properties and metrics underpin the Biophilic Intensity Matrix (BIMx) (Section 4.2), a comparative, early-stage decision-support framework that integrates intervention type and exposure duration to support applied design reasoning in real-world projects.

2. Research Methodology

This study employed a scoping review to systematically map empirical evidence on biophilic design interventions and their properties in relation to human responses in indoor environments. Scoping reviews are well-suited to complex topics with heterogeneous evidence across intervention types, study designs, and outcome measures [29,30]. The review followed the PRISMA Extension for Scoping Reviews (PRISMA-ScR) guidelines [28] to identify, categorize, and synthesize findings for developing restorative design guidelines.

2.1. Scope and Objectives

The review focused on three domains: (1) Biophilic interventions including seven categories: green walls, indoor plants, window views, natural light, natural materials, water features, and nature-inspired visual references; (2) indoor settings containing both real and simulated environments in offices, healthcare, educational, and residential contexts; and (3) human responses covering physiological (e.g., heart rate variability, skin conductance), psychological (e.g., stress, mood, restoration), and cognitive (e.g., attention, cognitive load) dimensions. These domains are aligned with the aim of understanding how intervention types and properties influence human responses indoors.

2.2. Keyword Development and Search Strategy

Search terms were developed for each intervention, including common synonyms (e.g., “living wall,” “vertical garden” for green walls), combined with built-environment terms (e.g., “indoor space,” “office,” “hospital”) and human response terms (e.g., “stress recovery,” “attention,” “HRV”). Boolean logic linked synonyms with OR, and core categories with AND, yielding seven unique search strings. Figure 1 presents the full list of keywords in each category and provides an example for the green wall intervention.

Biophilic Interventions	Keywords
1- Green Wall	"living wall" OR "green wall" OR "vertical garden" OR "vertical greenery" OR "vertical green" OR "plant-covered wall" OR "vegetated wall"
2- Plants	"indoor plants" OR "potted plants" OR "indoor greenery" OR "indoor vegetation" OR "plants in indoor space" OR "green elements" OR "plant decoration"
3- Window View	"window view" OR "view of nature" OR "green view" OR "natural view" OR "view to outside" OR "outdoor view" OR "view to green space"
4- Natural Light	"natural light" OR "daylight" OR "daylighting", "daylight exposure" OR "sunlight penetration" OR "window orientation"
5- Natural Materials	"natural materials" OR "wood interior" OR "wood finishes" OR "timber surfaces" OR "natural stone" OR "bamboo interior" OR "cork panels" OR "natural textures" OR "wooden surfaces" OR "natural interior materials" OR "biophilic materials" OR "nature-inspired materials"
6- Water Feature	"water feature" OR "indoor water feature" OR "water element" OR "fountain" OR "indoor fountain" OR "waterfall" OR "indoor waterfall" OR "aquarium" OR "architectural water" OR "water wall"
7- Symbolic Nature	"nature painting" OR "nature photograph" OR "nature photo" OR "landscape artwork" OR "landscape painting" OR "nature-inspired mural" OR "nature poster" OR "nature-themed wall art" OR "nature imagery" OR "nature artwork" OR "static nature image" OR "nature-based decorative art" OR "biophilic artwork"
Built Environment	
General Terms	"built environment" OR "indoor environment" OR "interior space" OR "architectural space" OR "indoor space design" OR "environmental design" OR "indoor architecture" OR "interior architecture" OR "building design" OR "indoor setting"
Space Types	"workplace" OR "office" OR "work environment" OR "healthcare" OR "hospital" OR "clinic" OR "waiting room" OR "patient room" OR "senior living" OR "education" OR "school" OR "classroom" OR "university" OR "learning environment" OR "residential" OR "home" OR "apartment" OR "housing" OR "commercial" OR "retail environment" OR "shopping mall" OR "commercial interior" OR "lobby"
Virtual/Simulate Environments	"virtual environment" OR "immersive virtual environment" OR "VR" OR "360 degrees video" OR "rendered environment" OR "image-based study" OR "BIM" OR "Building Information Modeling"
Human Responses	
Psychological Responses	"stress recovery" OR "stress reduction" OR "stress recovery" OR "psychological stress" OR "restoration" OR "perceived restorativeness" OR "restoration experience" OR "restorative environment" OR "mood" OR "affective response" OR "emotional response" OR "positive affect" OR "negative affect" OR "well-being" OR "mental health" OR "emotional health" OR "subjective well-being" OR "user preference" OR "environmental preference" OR "design satisfaction"
Cognitive Responses	"attention restoration" OR "attention" OR "focused attention" OR "directed attention" OR "mental fatigue" OR "Cognitive load" OR "cognitive performance" OR "task performance" OR "executive functioning" OR "memory performance" OR "learning outcomes" OR "information processing"
Physiological Responses	"heart activity" OR "heart rate" OR "HR" OR "HRV" OR "heart rate variability" OR "plus rate" OR "skin activity" OR "electrodermal activity" OR "skin conductance" OR "EDA" OR "skin temperature" OR "peripheral temperature" OR "hormonal response" OR "cortisol" OR "salivary cortisol" OR "breathing rate" OR "respiratory rate"
Behavioral Responses	"occupant behavior" OR "spatial behavior" OR "use of space" OR "movement of patters" OR "locomotion" OR "work performance" OR "productivity"
Example	
Green Wall	("living wall" OR "green wall" OR "vertical garden" OR "vertical greenery" OR "vertical green" OR "plant-covered wall" OR "vegetated wall") AND ("built environment" OR "indoor environment" OR "interior space" OR "architectural space" OR "indoor space design" OR "environmental design" OR "indoor architecture" OR "interior architecture" OR "building design" OR "indoor setting" OR "workplace" OR "office" OR "work environment" OR "healthcare" OR "hospital" OR "clinic" OR "waiting room" OR "patient room" OR "senior living" OR "education" OR "school" OR "classroom" OR "university" OR "learning environment" OR "residential" OR "home" OR "apartment" OR "housing" OR "commercial" OR "retail environment" OR "shopping mall" OR "commercial interior" OR "lobby" OR "virtual environment" OR "immersive virtual environment" OR "VR" OR "360 degrees video" OR "rendered environment" OR "image-based study" OR "BIM" OR "Building Information Modeling") AND ("stress recovery" OR "stress reduction" OR "stress recovery" OR "psychological stress" OR "restoration" OR "perceived restorativeness" OR "restoration experience" OR "restorative environment" OR "mood" OR "affective response" OR "emotional response" OR "positive affect" OR "negative affect" OR "well-being" OR "mental health" OR "emotional health" OR "subjective well-being" OR "user preference" OR "environmental preference" OR "design satisfaction" OR "attention restoration" OR "attention" OR "focused attention" OR "directed attention" OR "mental fatigue" OR "Cognitive load" OR "cognitive performance" OR "task performance" OR "executive functioning" OR "memory performance" OR "learning outcomes" OR "information processing" OR "heart activity" OR "heart rate" OR "HR" OR "HRV" OR "heart rate variability" OR "plus rate" OR "skin activity" OR "electrodermal activity" OR "skin conductance" OR "EDA" OR "skin temperature" OR "peripheral temperature" OR "hormonal response" OR "cortisol" OR "salivary cortisol" OR "breathing rate" OR "respiratory rate" OR "occupant behavior" OR "spatial behavior" OR "use of space" OR "movement of patters" OR "locomotion" OR "work performance" OR "productivity")

Figure 1. Keywords' structure showing how intervention-specific, built-environment, and human-response terms were combined using Boolean logic.

2.3. Search Process and Inclusion/Exclusion Criteria

Searches were conducted in the Dimensions database [31] for publications from 2000–2025, including research articles, reviews, and conference papers. Filters were applied for relevant disciplines such as Architecture, Built Environment, Environmental Sciences, Human Society, yielding 1520 records. To refine results, each category set was imported

into Landscape & Discovery, an AI-based semantic mapping tool to visualize conceptual clusters [32]. In these visualizations, each cluster is represented as a node where the size reflects the relative volume of publications and the distance and connecting lines represent conceptual relatedness. Larger, closely linked clusters indicate dominant and overlapping research directions, while smaller or isolated clusters reflect less relevant themes. Clusters aligned with human well-being outcomes were prioritized, while unrelated themes (e.g., energy performance, plant maintenance) were excluded. Manual screening removed studies focusing solely on outdoor environments, non-human outcomes, or lacking experimental or quasi-experimental design. Through this process, 121 studies identified via Dimensions met the inclusion criteria and were included in the scoping review.

In addition to database searching, 15 further publications were identified through authors' prior knowledge and domain expertise, including familiarity with key research groups and foundational studies in biophilic design and related fields that were not consistently indexed in Dimensions (e.g., identified via Google Scholar and reference checking). These publications were manually screened using the same inclusion and exclusion criteria and were fully reviewed as part of the scoping review process. The full list of these additional publications is provided in Appendix A (Table A1). In total, 136 publications were reviewed in this scoping review (Figure 2, PRISMA flow).

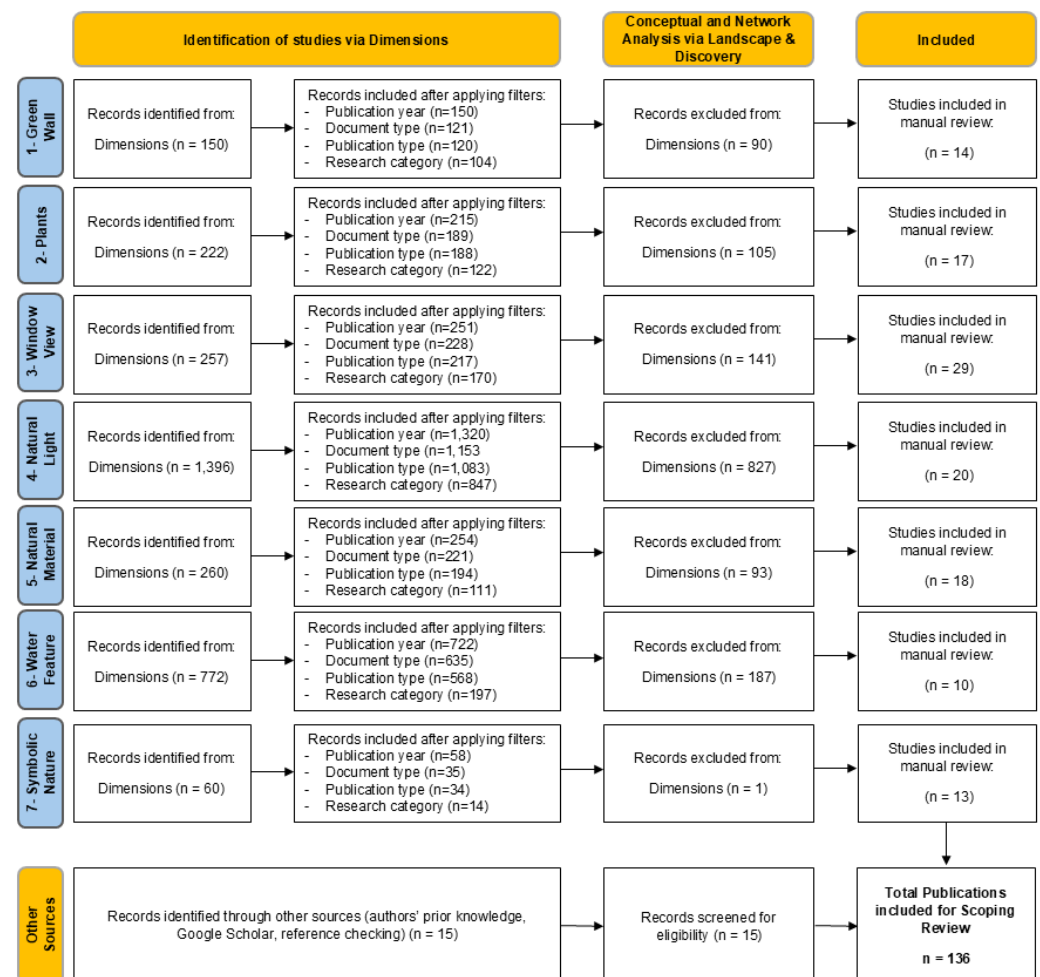


Figure 2. PRISMA 2020 flow diagram summarizing the number of records identified, screened, excluded, and included across all stages of the review.

2.4. Data Extraction and Analysis Framework

For each study, data on intervention type, design properties (e.g., color, size, placement), setting, human outcomes, and methodological details (e.g., sample size, measures) were extracted. Analysis proceeded in two stages:

1. **Within-category** analysis identified recurring design properties and associated human responses for each intervention type, informing preliminary guidelines.
2. **Cross-category** analysis examined studies comparing multiple interventions or combining them, highlighting relative restorative potential and synergistic effects.

3. Results

The following sections present the results of the reviewed publications, organized by each biophilic intervention category, along with cross-category comparisons.

3.1. Within-Category Analysis

3.1.1. Green Wall

Green walls, classified under the “direct experience of nature” domain, provide immediate visual and sometimes tactile engagement with living vegetation [12]. Their vertical form and visual richness make them effective restorative features in varied settings such as workplaces, healthcare facilities, schools, and residences [18,20,22,33,34]. Of the 104 publications initially retrieved, concept network analysis via the Landscape & Discovery platform identified thematic clusters (e.g., “design,” “greenery,” “biophilic design,” “indoor environment”) relevant to human responses. Non-relevant clusters (e.g., “air quality,” “roof,” “energy performance”) were excluded. As shown in Figure 3, larger clusters represent research areas with greater publication volume, while the proximity and connections between clusters reflect the strength of their conceptual relationships. This allowed us to focus on the most thematically relevant directions in the literature for subsequent analysis.

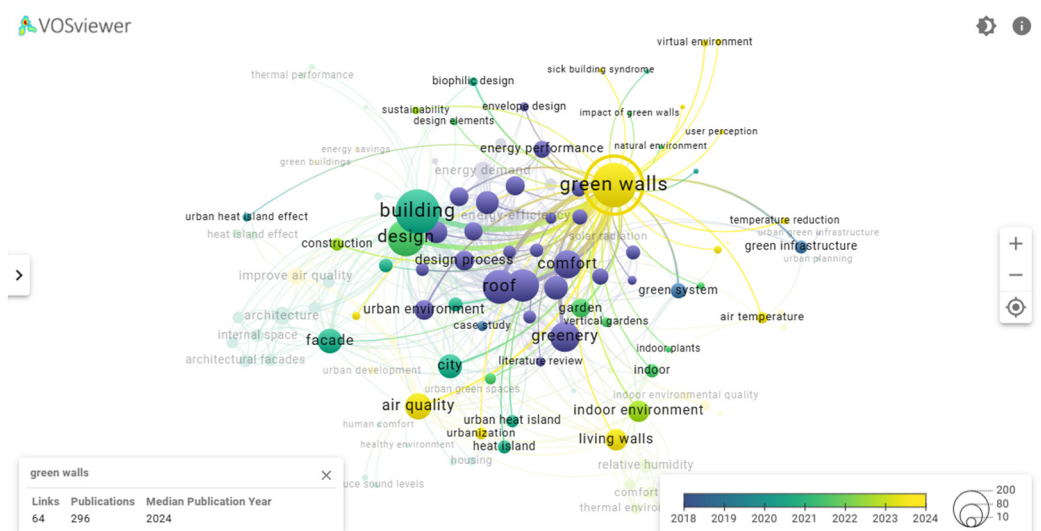


Figure 3. Concept network for the green wall category.

Following screening, 14 publications were retained for full data extraction, focusing on design properties such as size, greenery percentage, plant type, and integration with architecture. Figure 4 summarizes key findings, linking human responses to specific green wall properties with design guidelines.

Design Property	Human Response Impact	Design Insight / Guideline	Publication (Author-Year)
Size	Psychological relaxation	Half-size green walls are more effective than full-size in reducing negative affect	Li et al., 2022; Yeom et al., 2022; Sedghikhanshir et al., 2024
Greenery Dose	Reduces physiological stress (e.g., BP, HR)	80% greenery yields optimal balance: low dose ineffective	Li et al., 2022
Number of Green Walls	Decrease in negative emotions	Greater number of walls associated with stronger emotional benefits	Li et al., 2022; Yeom et al., 2022
Plant Type	Increased emotional comfort	Vine plants or those with textured foliage are preferred	Wang et al., 2024; Sultan, 2019
Color & Texture	Increased engagement	Natural variation in color and texture enhances attentional restoration	Sultan, 2019
Placement	Increased restoration, preference	Central, visible locations (e.g., lobby, hallways) yield higher restorative value	Yang & Cho, 2013; Kim & Ahn, 2015
Structural Form	Indirect, improves usability and adoption	Modular and self-sustaining systems preferred for ease of maintenance and integration	Rahmey et al., 2022; Li et al., 2022
Integration with Space	Perceived naturalness	Green walls that visually blend with surrounding architecture enhance effect	Yang & Cho, 2013; Aymen et al., 2024
User Engagement	Mixed: engagement may vary by context	Interactive or parametric walls can draw attention but may not always lead to restoration	Aymen et al., 2024; Sedghikhanshir et al., 2024; Sedghikhanshir et al., 2025
Functionality	Comfort, satisfaction	Dual-use walls (e.g., dividers or acoustic panels) amplify perceived value and comfort	Yang & Cho, 2013; Rahmey et al., 2022

Figure 4. Design properties and their effects on human responses for green walls (Li et al., 2022; Yeom et al., 2022; Sedghikhanshir et al., 2024; Wang et al., 2024; Sultan, 2019; Yang & Cho, 2013; Kim & Ahn, 2015; Rahmey et al., 2022; Aymen et al., 2024; Sedghikhanshir et al., 2025).

Across studies, several design properties consistently influenced restorative outcomes. Moderate size and coverage, specifically half-sized walls with approximately 80% greenery were most effective for reducing negative effects and physiological stress markers, particularly in small- to mid-sized rooms [20–22]. Plant type was also important; vine-like species or plants with rich textural foliage elicited higher emotional comfort [35,36]. Placement in central, highly visible locations such as lobbies or hallways enhanced visual accessibility and psychological benefits [37,38], while architectural integration or functional uses (e.g., as room dividers or acoustic panels) improved user satisfaction and perceived value [37,39]. Interactive or parametric designs could draw attention but were only beneficial when maintaining a naturalistic appearance [22,40,41].

Synthesizing these findings, effective green wall design should prioritize moderate scale, dense greenery coverage (~80%), species with visually engaging textures, and central, high-visibility placement. Integration into architectural or functional features is encouraged, while purely decorative or disproportionately large installations, particularly in confined spaces, should be avoided. Broader limitations regarding study duration, participant diversity, and contextual applicability are addressed in Section 5.

3.1.2. Indoor Plants

Indoor plants, classified under the “direct experience of nature,” provide sensory engagement through living vegetation in architectural spaces [12,42,43]. From 119 initially retrieved publications, concept network analysis (Figure 5) identified clusters focused on the design properties of indoor plants and their impact on human responses. After excluding irrelevant topics (e.g., air quality, urban development), 17 studies were retained for full data extraction (Figure 6).

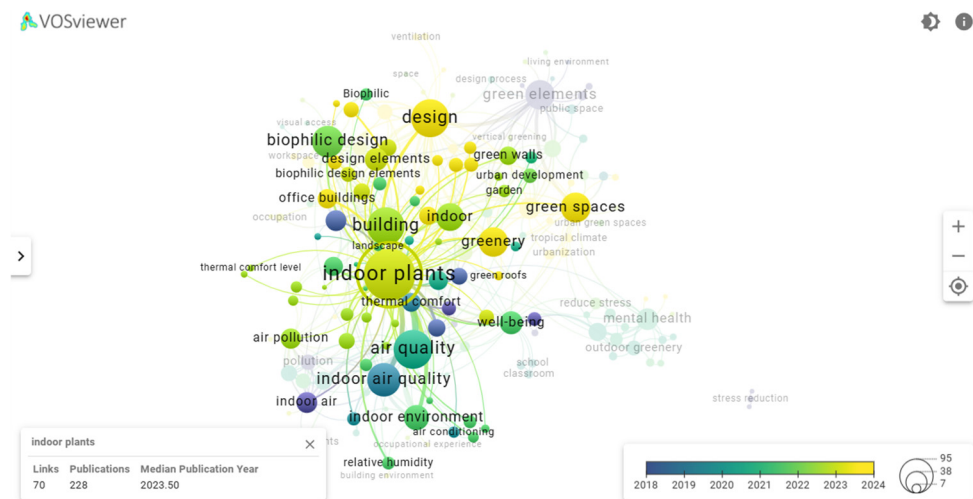


Figure 5. Concept network for the indoor plants category.

Design Property	Human Response Impact	Design Insight / Guideline	Publication (Author-Year)
Green Coverage Ratio (GCR)+Distance	Higher well-being and psychological responses	High greenery + farther distance → highest well-being	Welagedara et al., 2023; Han, 2019
Number of Plants	Large number = tension/tiredness	Too many → tiredness or stress; moderate → preferred	Selim et al., 2020; Han, 2019
Plant Type	Higher comfort, EEG, mood	Real > photo or artificial for comfort and EEG activation	Oh et al. 2019
Placement	Improved attention/mood	Front placement > side; male participants more responsive	Shibata & Suzuki, 2002
Exposure Conditions	Task-dependent outcomes	Positive effects in active working areas (office), not in passive (break rooms)	Hahn et al. 2021
Species	Psychological comfort, aesthetic preference	Orchid, Kamquat, Cactus, frequently preferred	Abbasoğlu & Kahramanoğlu, 2025; Selim et al., 2020
Color/Fractal Complexity	Visual stimulation, attention	Fractal color patterns > basic green surfaces	Shibata et al. 2024
Flowering Plants	Affective response	May reduce pain/anxiety in hospitals	Park & Mattson 2008

Figure 6. Design properties and their effects on human responses for indoor plants (Lanka et al., 2023; Han, 2019; Selim et al., 2020; Oh et al., 2019; Shibata & Suzuki, 2002; Hahn et al., 2021; Abbasoğlu & Kahramanoğlu, 2025; Shibata et al., 2024; Park & Mattson, 2008).

The green coverage ratio (GCR), the proportion of floor area covered by the vertical projection of plants, emerged as a critical design variable [44,45]. Higher GCR combined with greater viewing distance significantly enhanced psychological responses such as preference and pleasure [44], whereas proximity to dense vegetation sometimes reduced comfort due to increased localized CO₂ [46]. Moderate numbers of plants were preferred; excessive quantities, especially in confined spaces, increased tension or fatigue [45,46]. Real plants consistently outperformed artificial or photographic alternatives in eliciting stronger physiological and affective responses, including improved comfort, EEG activation, and mood [47]. Placement also influenced outcomes, plants in frontal, direct sightlines improved mood and attention, particularly for male participants [48]. Effects were stronger in task-oriented settings (e.g., offices) than in passive zones (e.g., break rooms), suggesting that environmental context modulates restorative potential [49]. Certain species, such as orchids, kumquats, and cacti, were favored for both aesthetics and psychological comfort [46,50,51], and flowering plants showed potential to reduce pain and anxiety in healthcare contexts [52].

To maximize benefits, designers should prioritize real potted plants with moderate GCR, visually appealing species, and frontal placement in high-engagement spaces, ensuring visibility without overcrowding. Broader limitations regarding study duration, participant diversity, and contextual applicability are addressed in Section 5.

3.1.3. Window View

Window views connect occupants to outdoor natural elements such as vegetation, sky, and daylight [53,54]. The concept network generated in Landscape & Discovery (Figure 7) revealed relevant clusters such as “window views,” “well-being,” and “green spaces,” which were prioritized for screening, while unrelated clusters (e.g., “facade,” “urbanization”) were excluded. Publications from the relevant clusters were then manually reviewed to finalize the dataset, and from 166 publications, 29 experimental studies met the inclusion criteria (Figure 8).

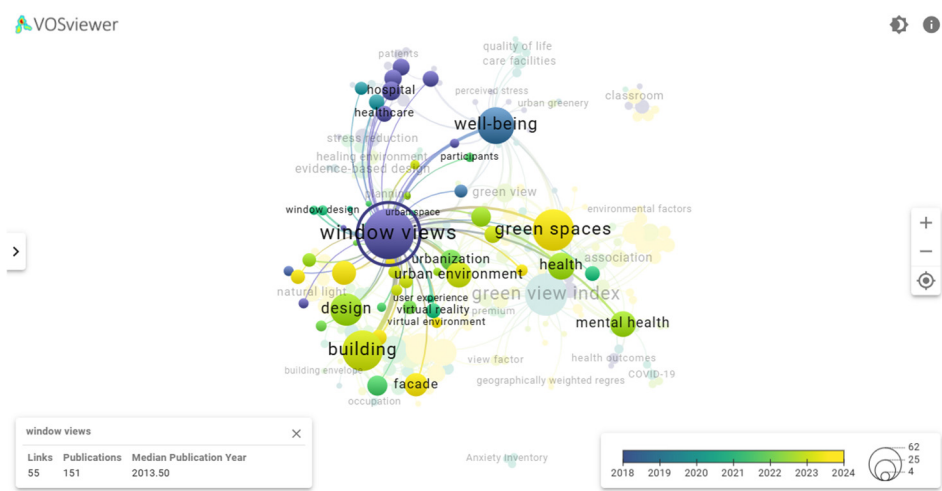


Figure 7. Concept network for the window view category.

Design Property	Human Response Impact	Design Insight / Guideline	Publication (Author-Year)
View Content	Reduced stress, lower anxiety level, increased attention, increased parasympathetic activity, increased visual comfort and preference	Nature view Green space Green space + water Green space + sky Green space + sky + buildings Daylight	Sharam et al., 2023; Oh et al., 2025; Elsadek et al., 2020; Fikfak et al., 2022; Zbařnik-Senegaćnik & Koprivec, 2022; Elsadek et al., 2024; Masoudinejad & Hartig, 2020; Yao et al., 2024; Wang et al., 2019
View Access	Stronger physiological effect Increased restoration, engagement	Near greenery preferred Closer distance (0.8–2.15 m) yields better responses than >5 m	Oh et al., 2025; Abd-Alhamid et al., 2020
View Clarity	Mental health improvement EEG changes, reduced EDA	Panoramic views preferred; blocked views associated with negative effect Clear views from high-rise	Raanaas et al. 2011 Elsadek et al. 2020
Window-to-Wall Ratio (WWR)	Reduced stress, better perception Reduced oppressiveness	25% minimum recommended; above 65% WWR associated with high satisfaction Increasing WWR	Ko et al. 2023 Wang & Munakata 2024
Height-to-Width Ratio (HWR)	Increased oppressiveness	Higher HWR	Wang & Munakata 2024
Horizontal View Angle	Visual comfort	Minimum 35° horizontal viewing angle beneficial for satisfaction	Ko et al. 2023
Artificial vs Real Views	Applicable in windowless settings	High-quality artificial views can match or exceed real ones for comfort, memory, creativity	Liu et al. 2025

Figure 8. Design properties and their effects on human responses for window view (Sharam et al., 2023; Oh et al., 2025; Elsadek et al., 2020; Fikfak et al., 2022; Zbařnik-Senegaćnik & Koprivec, 2022; Elsadek et al., 2024; Masoudinejad & Hartig, 2020; Yao et al., 2024; Wang et al., 2019; Abd-Alhamid et al., 2020; Raanaas et al., 2011; Ko et al., 2023; Wang & Munakata, 2024; Liu et al., 2025).

Findings are clustered into three aspects associated with view quality:

- View content: Natural scenes combining greenery, sky, and water consistently reduced stress, improved mood, and enhanced attention, with richer combinations and daylight producing stronger restorative benefits [55–63].
- View access: Proximity influenced outcomes, with nearby greenery (0.8–2.15 m) yielding stronger physiological and psychological responses than distant or obstructed views [56,64].
- View clarity: Panoramic, unobstructed views improved EEG patterns, reduced electrodermal activity (EDA), and enhanced mental well-being, whereas blurred or narrow views increased visual fatigue and negative effect [57,65].

Additional variables included window geometry: a window-to-wall ratio (WWR) of 25–65% optimized satisfaction [66,67], while excessive height-to-width ratios increased oppressiveness [67], and horizontal view angles $\geq 35^\circ$ improved visual comfort [68]. In windowless settings, high-quality artificial or virtual views could match or exceed real views for comfort, mood, and creativity [69].

Overall, these findings highlight the importance of not only providing access to nature through windows but also optimizing how those views are composed, perceived, and positioned to maximize restorative benefits.

3.1.4. Natural Light

Natural light is a core element of biophilic design, supporting circadian regulation, mood, sleep quality, and cognitive performance [70,71], with benefits reported across offices, classrooms, hospitals, and residential settings [72–74]. From 816 retrieved records, the Landscape & Discovery concept network (Figure 9) highlighted relevant clusters such as “design,” “design principles,” and “architecture,” while excluding unrelated ones (e.g., “façade,” “energy consumption,” “air quality”). Screening the relevant clusters yielded 20 publications meeting inclusion criteria (Figure 10), each assessing at least one measurable human response to natural light properties.

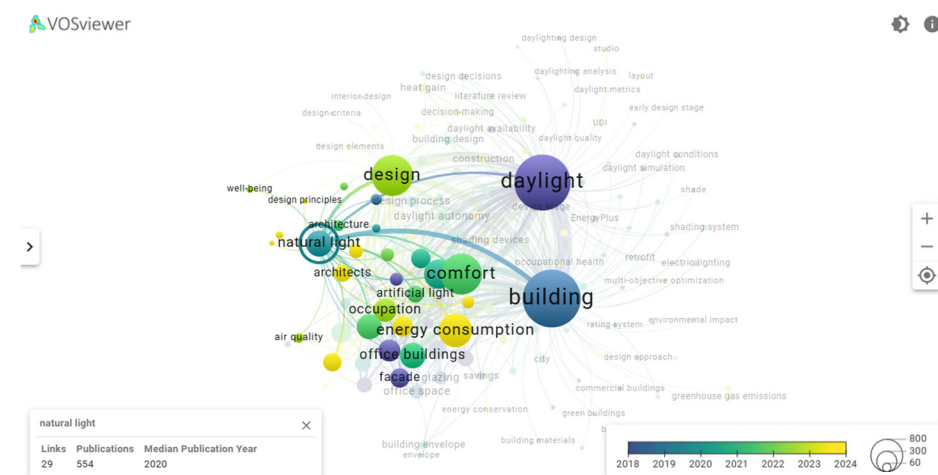


Figure 9. Concept network for the natural light category.

Human access to natural light is strongly shaped by window design, particularly size. A window-to-façade ratio of 20–30% offers optimal daylight for psychological and cognitive comfort, while ratios above 40% risk glare and overheating [75]. Adjustable shading or blinds increase user satisfaction by providing ease and autonomy [76,77]. Dynamic lighting systems that mimic daylight movement improve mood, alertness, and circadian alignment, proving especially valuable in spaces with limited direct light [78,79]. A balanced mix of daylight and localized task lighting reduces eye strain and increases comfort compared to relying on a single source [80].

Design Property	Human Response Impact	Design Insight / Guideline	Publication (Author-Year)
Opening size on facade (Window Size)	Visual Comfort, perception, performance	10% of facade = insufficient 20–30% = optimal 40%+ = minimal added value	Acosta et al. 2023
Shade & Lighting Control	Choice, comfort, attention	Preference for natural light when controllable shade is available	Heydarian et al., 2015; Kim & Casement, 2024
Dynamic Lighting	Positive for mental health and cognitive tasks	Mimics circadian patterns, improves mood and well-being	Schöllhorn et al., 2023; Turley et al., 2024
Light Source Mix	Balance reduces sleep disruption	Using daylight with screen/task light = improved comfort and reduced eye strain	McKee & Hedge 2022
Natural Light + Views	Increased mood and cognitive performance	Combination of daylight and nature views increases restorative effects	Amleh et al., 2025; Timmermann et al., 2015; Boubekri et al., 2020
Light Spectrum, Intensity, and Color	Affects melatonin, sleep, reaction time, attention, cognitive performance	Blue-enriched light = more stimulating; warm light = preferred for comfort; higher intensity = increased attention	Acosta et al., 2023; Golmohammadi et al., 2021; Gagné et al., 2024
Virtual Light and Sky	Patient experience and orientation Some perceptual and cognitive effects	Virtual windows Virtual sky: dynamic clouds > static skies in EEG activation and engagement and lower tension	Keschner et al., 2022; Schöllhorn et al., 2023

Figure 10. Design properties and their effects on human responses for natural light (Acosta et al., 2023; Heydarian et al., 2015; Kim & Casement, 2024; Schöllhorn et al., 2023; Turley et al., 2024; McKee & Hedge, 2022; Amleh et al., 2025; Timmermann et al., 2015; Boubekri et al., 2020; Golmohammadi et al., 2021; Gagné et al., 2024; Keschner et al., 2022).

Combining natural light with nature views produces synergistic benefits for mood, stress recovery, and perceived restoration [81–83]. Light spectrum and color temperature also influence responses: blue-enriched light supports attention in task-driven contexts, whereas warm light is preferred for relaxation [75,84,85], with both affecting hormonal regulation, including melatonin and sleep quality. In windowless settings, virtual skylights and circadian-tuned LEDs, especially with dynamic cloud simulations, can replicate many of these benefits, enhancing patient experience and engagement [78,86].

3.1.5. Natural Materials

Natural materials, particularly wood and stone, are central to the “indirect experience of nature” in biophilic design, providing sensory and symbolic connections through texture, color, and form [87]. The concept network (Figure 11) highlighted relevant clusters such as “natural materials,” “interior design,” and “biophilic design,” while excluding irrelevant ones (e.g., material durability, energy performance). From this, 18 publications were selected for in-depth review, spanning controlled laboratory studies to post-occupancy evaluations, all examining how material ratio, distribution, finish, and integration affect psychological and physiological outcomes. Key findings are summarized in Figure 12.

Wood was the most frequently studied natural material, consistently linked to comfort, perceived naturalness, satisfaction, and overall psychological health [88–91]. When paired with stone or used as cladding for walls and floors, these materials further supported psychological well-being [92,93]. Locally sourced options such as bamboo and adobe also enhanced cultural and emotional resonance [94]. The wood ratio percentage of wall, floor, and ceiling surfaces significantly shaped responses: around 45–50% coverage produced the most favorable psychological outcomes, whereas 90% coverage yielded physiological benefits (e.g., reduced blood pressure) but also signs of overstimulation, including elevated pulse rate and reduced brain activity [88–90].

Form and finish played a critical role. Natural curves with wood finishes promoted stronger restoration than neutral or angular forms [95], and warm-toned woods (yellowish hues) were preferred over cooler tones, improving visual warmth and perceived safety [96,97]. Wood’s restorative potential was greatest when integrated with other biophilic elements (e.g., green walls, views, or patterns), as isolated use had limited effect [95]. Additional benefits included improved acoustic and lighting comfort, particularly in offices

and classrooms [91]. Spaces combining wood in both furniture and wall elements were rated more positively than those with singular applications [92].

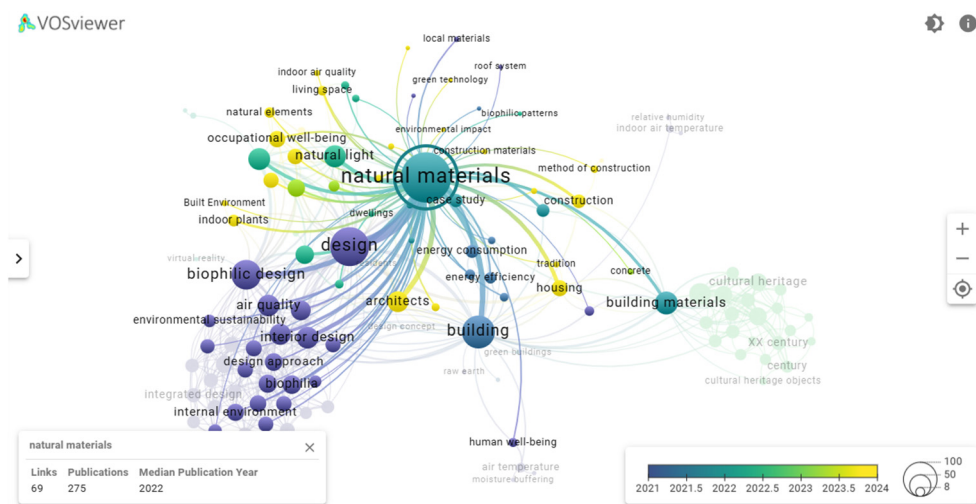


Figure 11. Concept network for the natural materials category.

Design Property	Human Response Impact	Design Insight / Guideline	Publication (Author-Year)
Material Type	Comfort, perceived naturalness, satisfaction psychological and general health	Wood Wood and stone Wood in floors and wall cladding local natural materials like bamboo, wood, and adobe	Tsunetsugu et al., 2007; McCunn & Fell, 2025; Muilu-Mäkelä et al., 2025; Watchman et al., 2017; Peters & D’Penna, 2020; Al-Muslimi, 2021; Tang, 2012
Wood Ratio in Room	Lower anxiety, reduced blood pressure, and improved visual comfort Positive emotion Pleasant and warm	45% wood → strongest psychological response 90% wood → decrease in brain activity and an increase in pulse rate Moderate amount of wood → most positive response Room: 50% covered with pine wood → more pleasant, warm, beautiful, interesting, and natura	Tsunetsugu et al., 2007; McCunn & Fell, 2025; Muilu-Mäkelä et al., 2025
Form and Style	Restoration	Natural (curve) forms paired with natural finishes	Sornubol & Lekagul, 2024
Finishing and Color Temperature	Visual warmth, perceived psychological safety Improved health and comfort	Warm wood tones (yellowish) > cool (bluish); associated with higher comfort Natural colors → promoting health and comfortable working environment	Watchman et al., 2016; Al-Muslimi, 2021; Putra, 2024
Integration with Nature Analogues	Material alone ≠ enough; must connect to broader biophilic cues	Natural finishes without biophilic patterning had limited impact	Sornubol & Lekagul, 2024
Noise & Light Comfort	Satisfaction, task comfort	Wood finishes improve acoustic and lighting comfort in shared spaces	Watchman et al., 2017
Furniture vs. Surfaces	Stronger effect when distributed	Visible wood in furniture and walls	Peters & D’Penna, 2020

Figure 12. Design properties and their effects on human responses for natural materials (Tsunetsugu et al., 2007; McCunn & Fell, 2025; Muilu-Mäkelä et al., 2025; Watchman et al., 2017; Peters & D’Penna, 2020; Al-Muslimi, 2021; Tang, 2012; Sornubol & Lekagul, 2024; Watchman et al., 2016; Putra, 2024).

3.1.6. Water Features

Water features provide multisensory biophilic engagement through visual and auditory cues, with evidence supporting their restorative potential in healthcare, workplace, and virtual settings [98,99]. Following the same analytical process, relevant studies were identified in Dimensions and refined using the Landscape & Discovery platform (Figure 13). Concept clusters directly related to human-centered outcomes such as “biophilic design,” “landscape design,” “green spaces,” and “well-being” were prioritized, while unrelated clusters (e.g., “urban environment,” “source pollution,” “water management”) were ex-

cluded. Manual screening then focused on studies addressing indoor water features and their design properties, including both physical and virtual applications such as aquariums, interior waterscapes, and digital simulations. Key findings and design guidelines are summarized in Figure 14.

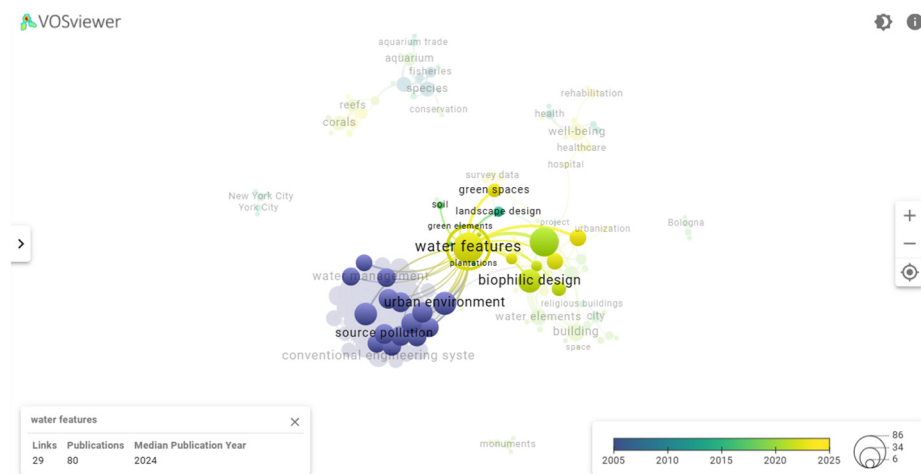


Figure 13. Concept network for the water features category.

Design Property	Human Response Impact	Design Insight / Guideline	Publication (Author-Year)
Aquariums	Patients' psychological state, blood pressure, heart rate, anxiety, or mood Reduction in blood pressure	No impact on patients in waiting room with aquariums with or without fish Aquariums and animal/bird videos in waiting room	Lundberg & Srinivasan, 2021 Lundberg et al., 2024
Waterscapes (lakes, waterfalls)	Effective for stress reduction and salivary cortisol levels	Both slow-moving and fast-moving water visuals reduced stress; no significant difference between types	Lin et al., 2024
VR Water Environments	Stream landscapes especially effective for depression	Simulations of streams, waterfalls, beach scenes produced mood elevation and stress reduction	Lee et al., 2025
Digital Blue Spaces	Useful in virtual or hybrid environments	Effective substitutes when physical water features are not feasible	Lee et al., 2025

Figure 14. Design properties and their effects on human responses for water features (Lundberg & Srinivasan, 2021; Lundberg et al., 2024; Lin et al., 2024; Lee et al., 2025).

Evidence from the reviewed studies indicates that both real and virtual water features can meaningfully support restoration when thoughtfully integrated into indoor environments [100,101]. Stream-like water scenes, particularly in virtual applications, were most consistently associated with mood enhancement and depression reduction [100]. Simulated beach scenes, waterfalls, and rivers also produced strong emotional and physiological benefits, including stress reduction and improved mood, underscoring the value of digital blue spaces where real water elements are not feasible. In contrast, physical aquariums, regardless of fish presence, showed limited standalone impact on anxiety or mood, especially in healthcare waiting areas [102,103]. Their benefits increased when paired with complementary natural stimuli, such as bird or animal videos, suggesting that passive water features often require multisensory reinforcement. Finally, both slow- and fast-moving waterscapes (e.g., lakes, waterfalls) reduced stress and cortisol levels with no significant difference between movement types [100], implying that the visual presence of water alone may be sufficient to evoke relaxation, reinforcing the broad restorative value of waterscapes.

3.1.7. Nature-Inspired Visual References

This category addresses non-immersive, symbolic biophilic interventions that visually represent nature through static media such as paintings, photographs, murals, and wall

art. Unlike immersive digital environments (e.g., VR or animated videos), these elements evoke natural qualities through artistic or photographic depiction rather than motion or interactivity. Fourteen relevant publications were identified from the Dimensions database and refined through the Landscape & Discovery platform. In the generated concept network (Figure 15), clusters such as “landscape painting,” “painted landscapes,” “photographic stimuli,” and “visual arts” were prioritized for manual screening, while unrelated clusters were excluded to focus on studies assessing restorative and emotional responses in built environments. Results from manual review are summarized in Figure 16.

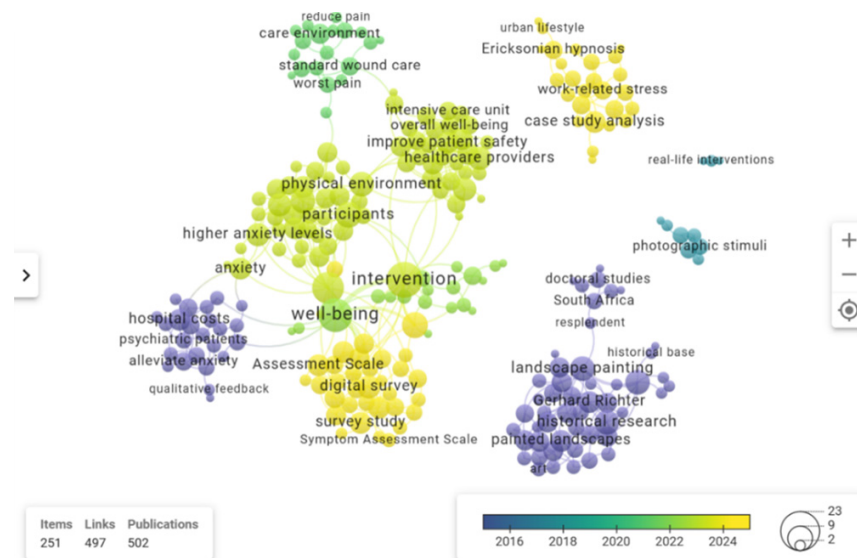


Figure 15. Concept network for nature-inspired visual references category.

Design Property	Human Response Impact	Design Insight / Guideline	Publication (Author-Year)
Type of Visual Content	Preference, restoration stress reduction, mood improvement, reduced anxiety	Images with natural and realistic content are better than colorful or artificial or abstract images	Bogerd et al., 2018; Catissi et al., 2023; Nanda et al., 2011; Yap et al., 2022; Ng et al., 2025
Realistic vs. Abstract Representations	Emotional regulation, reduced anger and agitation	Realistic depiction of nature and avoid abstract art	Nanda et al., 2011; Kweon et al., 2008
Placement and Context of Use	Improved mood and comfort in healthcare; better attention in academic settings	Incorporate nature art in visual fields of high-stress or cognitive demand settings	Goel et al., 2024; Bogerd et al., 2018; Catissi et al., 2023; Nanda et al., 2011; Yap et al., 2022; Kweon et al., 2008; Gao & Zhang, 2021
Comparative Effectiveness of Content Type	Content-specific mood outcomes; positive affect	Select visual themes (e.g., beauty, tranquility) based on context-specific needs	Bogerd et al., 2018; Catissi et al., 2023; Patterson et al., 2023
Integration with Other Biophilic Features	Potential synergistic effects, enhanced restoration	Combine nature-based visual reference with physical greenery where possible	Bogerd et al., 2018; Gao & Zhang, 2021; Gerlach et al., 2023

Figure 16. Design properties and their effects on human responses for nature-inspired visual references (Bogerd et al., 2018; Catissi et al., 2023; Nanda et al., 2011; Yap et al., 2022; Ng et al., 2025; Kweon et al., 2008; Goel et al., 2024; Gao & Zhang, 2021; Patterson et al., 2023; Gerlach et al., 2023).

Content type emerged as the most influential variable, with consistent evidence that realistic depictions of nature, whether photographs, paintings, or videos outperform abstract, non-nature, or purely decorative visuals in eliciting restorative responses [104–108]. Representations of greenery, water, and sky were linked to reduced stress, lower anxiety, improved mood, and higher perceived restorativeness across diverse settings, from psychiatric facilities to university classrooms [105–107,109]. By contrast, abstract art sometimes produced neutral or even adverse reactions, particularly among sensitive groups such as

psychiatric patients [107]. Placement and visibility were also critical: nature-based posters, murals, and wall art were most effective when located in frontal or frequently viewed positions, especially in high-stress or attention-demanding environments like outpatient clinics and educational spaces [104,110,111]. Combining visual references with other biophilic features (e.g., plants, green walls) consistently amplified restorative potential [105]. Even brief exposure such as 12 min of nature videos significantly reduced pain, tiredness, and anxiety in chemotherapy patients [106], underscoring the role of both exposure duration and frequency.

Comparative findings indicate that static nature imagery can match or exceed the benefits of immersive technologies in low-stimulation contexts, offering a durable, low-maintenance alternative. While VR and digital simulations allow personalization and scalability, their effectiveness depends heavily on high-quality, realistic content and user comfort [108,112,113]. Large-format murals and high-resolution photographic prints remain a practical solution for delivering sustained psychological benefits in resource-limited settings.

3.2. Cross-Category Analysis

Biophilic design elements in real-world settings rarely occur in isolation; their restorative impact often depends on interactions with other environmental features. To explore these relationships, the reviewed literature was screened for studies that either (1) directly compared different biophilic interventions in similar contexts or (2) evaluated environments incorporating multiple interventions simultaneously. Comparative studies provide insight into the relative effectiveness of interventions under specific conditions, while combination studies reveal potential synergies when elements are layered, informing strategies for multi-sensory, integrated design.

3.2.1. Comparative Studies

Eleven publications directly compared two or more biophilic intervention types. Findings were synthesized by grouping all pairwise comparisons involving the same primary intervention, with results summarized in Figure 17.

Across comparative studies, real vegetation, whether as green walls or indoor plants generally outperformed symbolic nature references such as posters in delivering restorative benefits [18,19,104,114,115]. Window views often matched or exceeded the restorative potential of vegetation over longer exposure durations, especially when paired with warm interior tones or natural materials for multi-sensory enhancement [18,114,116–118]. Green walls proved highly effective in space-limited environments but achieved more sustained benefits when integrated with daylight or other natural features [18,104,114,115]. Indoor plants were more impactful when combined with window views, rather than used as isolated decorative elements [18,114,119]. Finally, the effectiveness of biophilic content was shaped by contextual familiarity, with users responding more positively to environmental types aligned with their lived experience [120]. These findings underscore the importance of evaluating interventions not only in isolation but also in the context of other environmental features, an approach further explored in the combination studies reviewed below.

3.2.2. Combination Studies

A total of 10 publications examined combinations of biophilic interventions and their collective impact on human responses. To highlight recurring patterns, results were synthesized by grouping studies according to the primary combination theme and identifying common design lessons. The synthesized results and associated guidelines are summarized in Figure 18.

Primary Intervention	Compared With	Relative Findings	Generalized Design Guidance	Publications (Author-Year)
Green Wall	Nature poster, indoor plants, outdoor view, daylight, combination of views, other greenery	Performs better than symbolic images and posters; comparable to plants for short-term recovery; daylight enhances effect; views may surpass green walls over longer exposure; combination with other elements provides balanced benefits	Use green walls as effective substitutes when space limits views; pair with daylight or other natural elements for stronger and longer-lasting benefits; avoid relying solely on green walls for extended exposure scenarios	Bogerd et al., 2018; Gunn et al., 2022; Xiaoxue & Huang, 2024; Parkhomchuk, 2024; Yin et al., 2020
Indoor Plants	Inanimate objects, nature views, green walls	Similar effect to inanimate natural-form objects when used in isolation; more effective when combined with views; generally, less restorative than green walls	Integrate plants with other natural features for better outcomes; avoid stand-alone decorative placement without biophilic context	Gunn et al., 2022; Evensen et al., 2015; Yin et al., 2020
Window View	Green walls, plants, natural materials, daylight, warm-colored walls, artwork	Often more restorative over time than vegetation alone; warm-colored walls enhance benefits; natural materials reduce stress; abstract art less effective	Maximize high-quality views; combine with warm tones or natural materials for multi-sensory benefit	Gunn et al., 2022; Gao & Zhang, 2020; Altaf et al., 2025; Yin et al., 2020; Douglas et al., 2022
Natural Materials	Window views, artwork	Reduce stress and improve environmental satisfaction; comparable to views; more effective than abstract art	Use as complementary feature to other biophilic elements; avoid relying solely on abstract visual cues	Altaf et al., 2025; Douglas et al., 2022
Context-Specific Nature Content	Green spaces, desert views	Restoration depends on environmental familiarity; desert residents benefited more from desert views than green	Match biophilic content to cultural and environmental context of users	Yin et al., 2022

Figure 17. Comparative studies of biophilic interventions and associated design guidelines (Bogerd et al., 2018; Gunn et al., 2022; Xiaoxue & Huang, 2024; Parkhomchuk, 2024; Yin et al., 2020; Evensen et al., 2015; Gao & Zhang, 2020; Altaf et al., 2025; Douglas et al., 2022; Yin et al., 2022).

Primary Combination	Interventions Combined	Key Findings	Generalized Design Guidance	Publications (Author-Year)
Natural Light + Views	Windows, daylight, views of nature	Enhances restorative effects, circadian regulation, and mood; benefits for healthcare and workplace settings	Combine natural light with high-quality views where possible; design to optimize both daylight penetration and visual access	Zadeh et al., 2014; Timmermann et al., 2015
Greenery + Daylight	Indoor plants, green walls, daylight	Improves well-being, creativity, and health; greenery more effective when well-lit	Pair vegetation with daylight to amplify restorative potential; avoid placing greenery in poorly lit areas	Sanchez et al., 2018
Views + Greenery	Houseplants, green views, vegetation	Reduces anxiety and improves mood in residential and office settings	Integrate both near greenery and distant views for balanced visual stimulation	Zhang et al., 2023; Khanzadeh, 2024
Views + Natural Materials	Nature views, wood, stone, evolving materials	Promotes productivity and occupant health; strengthens environmental connection	Use natural materials alongside views to enhance multi-sensory engagement	Demirkol & Önaç, 2024; Elantary, 2024
Multi-Element Environments	Vegetation, natural light, water features, natural materials, sound	Broad benefits for well-being, satisfaction, and sustainability; more effective than single features	Layer multiple biophilic elements for cumulative effect; design for sensory diversity	Emami et al., 2024; Elantary, 2024; Abubakr & Kim, 2024

Figure 18. Combination studies of biophilic interventions and associated design guidelines (Zadeh et al., 2014; Timmermann et al., 2015; Sanchez et al., 2018; Zhang et al., 2023; Khanzadeh, 2024; Demirkol & Önaç, 2024; Elantary, 2024; Emami et al., 2024; Abubakr & Kim, 2024).

Across studies, combinations of biophilic elements consistently outperformed single interventions, with the most effective pairings including natural light with high-quality views [82,121] and greenery with daylight [122]. These combinations leverage both visual access and sensory quality, enhancing mood, reducing stress, and improving cognitive performance. Views paired with greenery [123,124] or natural materials [14,125] further strengthen restorative effects through balanced visual stimulation and tactile–visual synergy. The most immersive benefits were observed in multi-element environments that blend vegetation, daylight,

water features, natural materials, and sound [14,126,127], creating cumulative, multi-sensory engagement. Designers should aim to layer interventions so that combined features are spatially and functionally integrated, rather than simply co-located, to maximize restorative potential.

4. Discussions

This discussion addresses two objectives: (1) synthesizing results from within- and cross-category analyses to extract general design guidelines for biophilic interventions, emphasizing properties such as greenery dose, spatial configuration, and sensory qualities most influential in promoting restoration and stress recovery; (2) introducing the Biophilic Intensity Matrix (BIMx), an applied framework for structuring and comparing biophilic intervention strategies in indoor environments through informed selection, relative scaling, and integration of natural elements.

4.1. General Design Guidelines for Biophilic Interventions

Findings across intervention categories reveal recurring design properties that consistently shape restorative outcomes. While interventions differed in form from green walls and window views to water features and natural materials, their impact was mediated by context, user characteristics, and integration strategy. Effective designs balanced scale and intensity with spatial and functional constraints, leveraged multi-sensory engagement where possible, and aligned with occupants' environmental familiarity. These insights underscore that successful biophilic design depends not only on *what* elements are included, but *how* they are positioned, combined, and scaled to evoke restoration.

4.1.1. Indoor Green Coverage Ratio (IGCR)

Across the reviewed literature, the size and density of green elements emerged as one of the strongest determinants of restorative outcomes, directly influencing the intensity of the biophilic stimulus and the degree of visual access to greenery. A relevant measure, the Green Coverage Ratio (GCR), the proportion of floor area covered by the vertical projection of plants [45], has been adapted to define the Indoor Green Coverage Ratio (IGCR). In this study, IGCR is defined as a dimensionless ratio representing the proportion of visually accessible interior surface area occupied by vegetation. IGCR standardizes the quantification of vegetation intensity within interiors by accounting for both proportion and spatial distribution of greenery across visible surfaces (walls, ceiling, and floor). This provides a consistent metric linking vegetation coverage to restorative design potential and offering a shared language for research and practice.

Operationally, IGCR is calculated as the total projected area of visible vegetation divided by the total visually accessible interior surface area. The numerator includes the cumulative projected area of all visible plant elements (e.g., green walls, planters, suspended greenery), regardless of rooting location, as perceived within space. The denominator includes walls, ceiling, and floor surfaces that fall within typical occupant fields of view, excluding visually inaccessible or concealed surfaces. All areas are measured in square meters, and IGCR is expressed as a percentage or decimal value.

It is important to note that IGCR is intended as a perceptual and spatial indicator reflecting the extent of visually accessible greenery experienced by occupants, rather than as a measure of biological or environmental remediation performance. While vegetation-specific physiological functions such as biomass accumulation, oxygen release, and volatile organic compound absorption are critical for indoor environmental quality, these characteristics were not consistently reported or evaluated in the reviewed restorative and psychophysiological studies and therefore fall outside the scope of this metric. Accordingly, IGCR

should be understood as complementary to plant-species-specific or engineering-based performance indicators rather than a replacement for them.

Findings from reviewed studies such as the higher efficiency of half-sized green walls [20–22], moderate amounts of indoor plants [45,46], and window-to-wall ratios supporting greenery and daylight of 20–30% [75] or up to 65% [66,67], indicate that moderate greenery access is most effective. These results align with research suggesting a preference for ~50% GCR in indoor settings [45] and with outdoor studies linking at least 20% vegetation cover to stress and depression reduction, 30% to anxiety reduction, and $\geq 41\%$ tree cover density to improved mood and recovery [128,129]. Medium greenery levels appear to balance visual salience with comfort, avoiding both the under-stimulation of sparse vegetation and the overstimulation or spatial dominance of excessive coverage.

Although measurement methods varied, including use of outdoor vegetation indices such as NDVI (Normalized Difference Vegetation Index) [130], the overall pattern points to medium vegetation levels as optimal. Based on the synthesis, an IGCR of 40–60%, with ~50% as an initial benchmark, is suggested as an evidence-informed reference range for restorative-focused design contexts. However, this range is primarily supported by controlled laboratory and virtual environment studies where the restorative stimulus was isolated, absent the spatial, operational, and functional constraints of real-world interiors. In practice, particularly in workplaces, classrooms, or healthcare settings achieving 40–60% IGCR often requires extensive vertical greenery or large-scale plant groupings, which may be constrained by floor area, lighting, maintenance, and competing functions.

A context-calibrated approach is therefore recommended:

- 20–30% IGCR: In most interiors; already yields strong restorative effects.
- 30–40% IGCR: For relaxation- or restoration-focused spaces (e.g., lounges, wellness rooms, green atriums).
- >40% IGCR: For specialty immersive spaces (e.g., botanical centers, exhibitions) and generally impractical for everyday environments.

Further applied research in real-world contexts is needed to refine these thresholds and validate IGCR across building types, user groups, and cultural settings.

4.1.2. Color, Pattern and Texture

Beyond the quantity of greenery, the visual properties of biophilic elements, including color, pattern, and texture, emerged as key determinants of restorative potential. Across studies, green hues closely matching natural foliage were linked to higher preference, greater psychological comfort, and improved physiological indicators such as reduced heart rate and electrodermal activity [36,85,96]. Natural tonal variation within the green spectrum outperformed flat, monochromatic surfaces [36,52]. Texture also mattered, vine leaves, textured bark, and warm wood grain elicited stronger engagement and emotional comfort [33,96]. Natural patterns such as fractals, branching forms, and foliage clustering supported sustained attention and aesthetic preference [52]. These features align with ART, which emphasizes “soft fascination” that holds attention without mental fatigue [2].

From a visual perception standpoint, Feature Integration Theory (FIT) [131] explains how features like color and texture are processed pre-attentively before forming a coherent focus. Thus, green walls with high contrast against neutral backdrops or plants with varied textures are more likely to draw attention. In restorative design, such salience can be achieved through deliberate framing or patterned leaf arrangements. However, as SSRT notes [3], attention capture alone is insufficient; stimuli must be positively appraised to promote restoration. Overly high-contrast colors or artificial textures can overstimulate or reduce authenticity. The evidence supports color palettes and patterns that are both salient and ecologically congruent, reinforcing positive natural associations.

Accordingly, the following design recommendations were proposed:

- Use naturalistic green hues with tonal variation to mimic real foliage.
- Incorporate organic textures (wood grain, leaf veins, stone surfaces) to enhance engagement.
- Integrate fractal or branching patterns for visual complexity without overload.
- Leverage contrasts strategically, placing natural elements against neutral/complementary backgrounds.
- Avoid flat, uniform surfaces or unnatural colors that reduce fascination.

When applied intentionally, color, texture, and pattern act as perceptual tools to direct attention and shape positive emotional responses. Integrating these principles ensures natural elements are optimally perceived and engaged with, advancing the goals of restorative design.

4.1.3. Spatial Composition and Location

The spatial arrangement and placement of biophilic elements strongly influence their restorative potential. Central or high-visibility placement (e.g., green walls in lobbies, plants in direct sightlines) consistently produced stronger psychological and physiological benefits than peripheral or obstructed positioning [37,38,48,56,64]. This aligns with environmental visibility principles, where prominent features are more likely to be engaged with and integrated into spatial perception. Spatial composition, the configuration and distribution of interventions also play a critical role. Studies show that diverse presentation (e.g., plants distributed across surfaces and heights) often yield greater restoration than singular, monolithic interventions like a single large green wall [8,44,46]. From the perspective of Attention Restoration Theory, variety fosters “soft fascination” by providing multiple low-effort stimuli rather than one static focal object.

Comparisons of indoor plants and green walls illustrate that distributed plants present multiple small-scale stimuli that sustain novelty and engagement, while large green walls offer strong initial impact but may lead to stimulus habituation [132]. Additionally, distributed arrangements naturally create multiple salient cues, capture and sustained engagement according to the Feature Integration Theory [131]. Accordingly, single stimuli should be paired with secondary distributed elements to maintain interest, and using perceptual contrast (e.g., green against a neutral wall) further enhances visibility and restorative impact.

Accordingly, the following design recommendations were proposed:

- Prioritize high-visibility, direct-sightline locations in primary activity areas.
- Use diverse but coherent arrangements instead of uniform placement.
- Pair large features with smaller distributed elements.
- Integrate interventions functionally (e.g., green partitions, planter-benches).
- Place in high-dwell areas for maximum exposure.
- Apply perceptual contrast to boost salience and attention capture.

In short, spatial strategy determines whether nature is merely present or actively experienced in daily life, making composition and location as important as the intervention type itself.

4.1.4. Combination of Biophilic Interventions

The reviewed literature consistently shows that combination of biophilic environments outperform single-intervention designs for promoting psychological restoration, stress recovery, and overall well-being [120–127]. These additive benefits are supported by ART, where layered stimuli provide richer “soft fascination” that sustains engagement, and by SRT, where multiple congruent natural cues enhance the perception of comfort [3,4].

The most effective combinations integrated visual access (e.g., views or greenery) with sensory enhancers such as daylight, tactile natural materials, or water sounds [120,122,125]. These designs engage both bottom-up perceptual systems, which respond to salient features like color and movement, and top-down cognitive appraisal systems, which assign restorative meaning [24]. Daylight, for example, was found to amplify the positive effects of greenery [122], while natural materials deepened the benefits of nature views [125]. When combining biophilic interventions, it is essential that the design principles and performance constraints of each intervention are considered in relation to one another, rather than applied independently. For example, daylight should be integrated in a way that enhances visual connection to nature while simultaneously addressing glare control, visual comfort, and thermal implications through appropriate shading and façade strategies [133].

In addition, more is not always better. Redundancy, such as multiple green elements with minimal variation, can reduce restorative potential, while poorly integrated features risk sensory clutter [126]. Evidence suggests that diversity of form and sensory mode, rather than sheer number of interventions, drives combined effectiveness.

It is important to note that although multisensory combinations are frequently reported as beneficial, the reviewed studies, particularly controlled laboratory and VR-based experiments did not explicitly examine potential cognitive load, sensory redundancy, or attentional competition across sensory pathways. Most multisensory conditions were evaluated as integrated design scenarios rather than through systematic manipulation of cross-modal interactions or nonlinear effects between visual, auditory, and tactile stimuli. Accordingly, reported synergistic benefits should be interpreted as outcome-based observations rather than evidence of optimized multisensory balance. Designers should prioritize synergistic layering (e.g., greenery + daylight + tactile natural materials) to ensure complementary rather than competing stimuli.

4.1.5. Virtual Biophilic Design

Virtual biophilic environments (VBEs) have emerged as an alternative or supplement to physical interventions, offering scalability, customization, and feasibility in settings with spatial or budget constraints [86,112,113]. When designed with high sensory fidelity including realistic textures, accurate spatial scaling, and congruent auditory cues VBEs can elicit physiological and psychological benefits comparable to real nature exposure [86,112]. From a theoretical perspective, presence theory explains why high-fidelity VR can match real environments by providing immersive cues associated with the sense of “being there,” enhancing engagement [134]. However, the biophilic hypothesis suggests that innate evolutionary connections to real nature may still make physical interventions superior over repeated or long-term exposures. Studies highlight that visual realism, natural motion (e.g., dynamic clouds, moving foliage), and multisensory congruence are critical for restorative effects [86,113]. Conversely, low-resolution graphics, mismatched soundscapes, or unnatural lighting can undermine benefits and even cause discomfort.

Thus, VBEs should not be considered a one-to-one replacement for real nature but rather a strategic complement effective for temporary exposure, space-limited environments, or personalization (e.g., patient-selected scenes in healthcare).

4.1.6. Duration of Exposure

The reviewed studies revealed a clear distinction in exposure duration patterns depending on the research setting, the mode of presentation, and the context of use. In laboratory-based VR experiments, participants were typically exposed to a controlled, high-intensity biophilic stimulus for a relatively short, fixed period, often between 5 and 12 min [20,106,112]. These interventions were carefully designed to maximize restorative potential within a con-

strained time frame, using large visual fields, high greenery coverage, or immersive visual and auditory cues. The aim in such settings was to elicit measurable physiological and psychological effects quickly, aligning with the demands of controlled experimental protocols.

By contrast, field studies in real environments such as offices, hospitals, or educational settings often involved longer, naturally occurring exposure periods [46,66,81], even when these were not explicitly manipulated as a variable. In these contexts, the intensity of the stimulus (e.g., size, greenery coverage, or sensory richness) was typically lower and less controlled, with restorative effects accruing gradually over sustained or repeated exposure. Here, exposure time was more dependent on observer goals and environmental function: for example, the way a person interacts with a green wall in a break room (brief, incidental exposure) differs from their engagement with plants or views in their personal office (continuous, background exposure).

From a theoretical standpoint, this relationship between presentation mode and exposure time reflects the interaction of Stimulus Intensity and Temporal Engagement in restorative environments. ART suggests that environments with strong “soft fascination” cues such as high-contrast greenery, complex textures, or flowing water can more rapidly draw attention and support cognitive recovery. SRT further indicates that physiological stress markers may respond quickly to salient stimuli but may require prolonged exposure for full normalization. In controlled, high-intensity presentations (e.g., immersive VR nature scenes), rapid engagement and measurable short-term recovery are more likely. In contrast, in realistic, multi-purpose environments where stimuli are less concentrated, longer exposure durations integrated into daily routines are essential for sustained benefits.

This suggests a practical implication for design:

- Short, intense exposures (e.g., VR relaxation rooms, waiting areas) should maximize sensory richness, spatial prominence, and visual accessibility of biophilic features.
- Longer, ambient exposures (e.g., offices, classrooms, hospital wards) should focus on integrating natural elements into the user’s visual and functional field over time, considering their goals and activities.

4.1.7. Demographic Variability

User characteristics including age, gender, cultural background, and environmental familiarity modulate responses to biophilic design [44,46,120]. For instance, male participants showed stronger mood improvements from frontal plant placement, while females demonstrated higher restoration from certain view compositions [44]. Cultural and environmental familiarity also shaped outcomes; desert residents exhibited better stress recovery when viewing desert landscapes compared to green spaces [120]. These differences can be understood through cultural schema theory, which emphasizes that prior experiences influence how environments are perceived and evaluated. The person–environment fit model also explains that restorative benefits are maximized when environmental features align with individual needs, preferences, and familiarity [135].

For designers, this underscores the importance of inclusive and context-sensitive biophilic design selecting content, scale, and placement of interventions based not only on generic evidence but also on the specific demographic and cultural profile of occupants. Strategies may include offering choice and personalization (e.g., varied visual themes, adjustable lighting, or mixed vegetation types) to accommodate diverse restorative needs.

Taken together, the evidence-based design properties outlined in Sections 4.1.1–4.1.7 provide a foundation for translating biophilic research into applied design support. While these guidelines identify key properties that shape restorative outcomes, their implementation in practice requires tools that can account for variation in intervention type, exposure duration, and contextual constraints. As an initial application of these guidelines, the

following section introduces the Biophilic Intensity Matrix (BIMx), a comparative decision-support framework that integrates intervention type and exposure duration to support early-stage design reasoning (Section 4.2).

4.2. Biophilic Intensity Matrix (BIMx)

The findings from the review were synthesized into the Biophilic Intensity Matrix (BIMx), a matrix-based decision-support framework developed to support early-stage design by helping designers compare biophilic intervention types and reason about their relative intensity ranges in relation to exposure duration. Rather than prescribing exact dimensions, quantities, or performance thresholds, the BIMx translates empirical evidence on human cognitive and physiological responses into a structured, comparative framework that supports contextual calibration of biophilic interventions for restorative design. The BIMx does not prescribe dimensions, quantities, or performance targets; instead, it supports comparative reasoning about biophilic strategies across different exposure contexts. Importantly, the BIMx is not intended as a predictive or mathematically validated model, but as a qualitative synthesis of recurring empirical patterns observed across heterogeneous study designs and research settings, including both virtual and physical environments.

As illustrated in Figure 19, the vertical axis of the matrix represents biophilic intervention types, organized along a nature-compression gradient. At the top of this axis are interventions involving direct and minimally altered integration of nature, such as outdoor views, living vegetation, water, daylight, and natural sounds, which tend to provide higher restorative richness. Practical constraints related to space, lighting, maintenance, or programmatic requirements often necessitate more mediated forms of nature integration. Below this level are multi-element combinations, where two or more biophilic features such as greenery, daylight, and natural materials are layered to trigger restorative effects. Further down are single-element interventions, such as a green wall or indoor plants used in isolation without additional sensory reinforcement. At the lowest level are visual- or property-based interventions, which reference nature through color, pattern, or texture without incorporating living or multisensory components. As interventions move downward along this axis, greater prominence, coverage, salience, or sensory complexity is generally required to achieve comparable restorative potential.

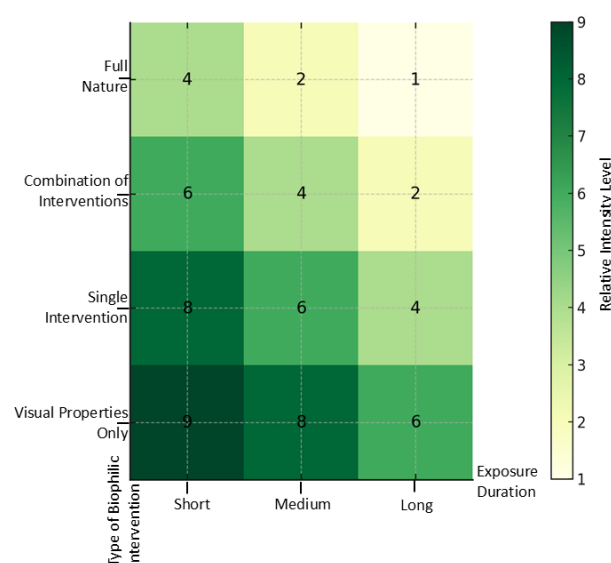


Figure 19. Biophilic Intensity Matrix (BIMx) illustrates the relationship between biophilic intervention type and exposure duration. The matrix provides conceptual and comparative relative intensity ranges to support early-stage design reasoning rather than prescribing exact dimensions or performance values.

The horizontal axis represents exposure duration and frequency over time. The reviewed literature generally indicates an inverse relationship between exposure duration and the level of intervention intensity required to elicit restorative responses. Short-duration contexts such as waiting areas, transitional spaces, or brief restorative experiences tend to benefit from more prominent or immersive biophilic interventions to produce perceptible effects within limited timeframes. In contrast, long-duration context such as offices, classrooms, or patient rooms can support restorative outcomes through more modest interventions when exposure is continuous and embedded within daily routines. This inverse relationship reflects a synthesis of empirical trends rather than a mathematically derived function and should be interpreted as conceptual rather than quantitative. This relationship is mediated by attentional engagement and contextual conditions. In short-duration laboratory or virtual reality studies, participants are typically exposed to biophilic stimuli for only a few minutes within highly controlled and visually simplified environments, requiring higher stimulus salience or intensity to capture attention and elicit measurable restorative responses. Conversely, in real-world settings where exposure duration is substantially longer but attentional engagement is more diffuse and intermittent, cumulative exposure over time can compensate for lower momentary attention, allowing more moderate or integrated interventions to support restoration.

At the same time, virtual and simulated environments differ from physical settings in key environmental variables including depth perception, color fidelity, material reflectance, airflow, and other ambient physical properties which may influence the magnitude and nature of restorative responses. As such, findings from virtual environments should be interpreted as controlled experimental proxies rather than direct equivalents of real-world biophilic conditions.

The intersection of intervention type and exposure duration within the BIMx indicates a relative intensity range appropriate for a given design scenario. The numeric values shown in the matrix represent ordinal, comparative intensity levels intended for conceptual guidance rather than measured or calibrated quantities. Ordinal levels are assigned based on relative differences observed in the literature within and across intervention categories, considering factors such as visual prominence, spatial dominance, sensory richness, and degree of immersion required to elicit restorative responses under comparable exposure conditions. Higher values indicate greater relative intensity within a given intervention type, but do not imply linear scaling, equal intervals, or predictive thresholds.

For example, a single-element intervention in a short-exposure environment may require greater visual prominence or sensory reinforcement, whereas in long-exposure settings, layered combinations of moderate greenery, daylight, and natural materials may achieve sustained restorative benefits at smaller scales. As a worked illustration, a green wall used in a short duration waiting area would typically need to be larger, centrally located, and visually dominant to capture attention and elicit measurable effects, placing it at a higher ordinal intensity level. The same green wall integrated into an office or classroom, where exposure is continuous and embedded in daily routines, can support restoration at a lower ordinal level due to cumulative exposure over time. These examples are illustrative rather than prescriptive and are intended to support comparative reasoning rather than define exact design solutions.

In practice, the BIMx is intended for use during early and conceptual design phases, when decisions about spatial organization, programmatic priorities, and environmental intent are being established but detailed dimensions and specifications have not yet been fixed. Designers can use the matrix by first identifying the primary function of a space and the expected exposure duration of occupants and then comparing different biophilic intervention types and combinations that may be appropriate within those conditions. By

situating potential strategies within the matrix, designers can reason about the relative prominence, sensory richness, and layering required to support restorative outcomes without committing prematurely to specific sizes or materials.

The matrix also supports iterative scenario testing, allowing designers to explore trade-offs between alternative biophilic approaches. For instance, it can help assess whether layering multiple lower-intensity interventions such as moderate greenery, daylight access, and natural materials may provide comparable restorative potential to a single, more visually dominant feature. This comparative logic is particularly valuable in projects constrained by space, budget, maintenance capacity, or regulatory requirements, where direct or large-scale integration of nature may not be feasible.

Beyond guiding individual design decisions, the BIMx provides a shared conceptual language that facilitates communication among multidisciplinary stakeholders, including architects, interior designers, engineers, owners, and facility managers. By framing biophilic design in terms of relative intensity, exposure duration, and intervention type, the matrix helps clarify design intent and expected experiential outcomes early in the process. This supports more informed discussions about feasibility, cost, maintenance implications, and integration with building systems such as lighting, ventilation, and façade design. In this way, the BIMx functions not only as a design-support tool but also as a boundary object that bridges empirical research, design intent, and technical coordination, enabling more coherent and transparent integration of biophilic strategies within complex building projects.

While the BIMx is intentionally presented as a qualitative and comparative framework, it also offers a structured foundation for the development of future quantitative biophilic design guidelines. The matrix can inform controlled laboratory and field-based studies by systematically guiding the selection of intervention types and relative intensity ranges to be tested across different exposure durations. Such studies represent a necessary next step toward mathematical validation, enabling the derivation of calibrated thresholds, conversion coefficients, and dose–response relationships for specific spatial types and biophilic modalities. In parallel, future work should establish calibration mechanisms that relate restorative responses observed in virtual environments to those measured in physical settings, explicitly accounting for differences in perceptual fidelity and environmental physics.

Furthermore, while demographic and cultural variables clearly moderate restorative responses, the reviewed studies do not provide sufficient consistency or resolution to encode these factors as independent structural dimensions within a comparative design framework. Instead, such variables function as contextual modifiers that should inform how the BIMx and associated design guidelines are interpreted and applied for specific user groups, rather than as primary axes for early-stage decision-making. In this way, the BIMx functions as an adaptive reference that supports the progressive translation of qualitative design knowledge into validated quantitative frameworks, while maintaining sensitivity to contextual and experiential variability.

5. Limitations and Future Research

While this review provides a comprehensive synthesis of empirical evidence on biophilic design interventions, several limitations should be acknowledged. Much of the available evidence is derived from short-term laboratory or controlled studies with limited demographic diversity, which constrains generalization to long-term, real-world, and culturally diverse contexts. In addition, many studies examine biophilic interventions in isolation, often without accounting for spatial, operational, or maintenance constraints that influence feasibility in practice, particularly in multi-use or space-limited environments. These limitations also highlight opportunities for advancing biophilic design research through more ecologically valid and interdisciplinary approaches.

The role of contextual modifiers such as exposure duration, user characteristics, cultural background, and environmental familiarity remains underexplored, despite general indications that these factors shape restorative responses. Moreover, the existing evidence base is geographically concentrated, with a large proportion of studies conducted in Western, East Asian, or high-income urban contexts, limiting insight into cultural variability and transferability across climatic, social, and economic settings. Similarly, relatively few studies examine the system-level implications of biophilic features, including their interactions with lighting, HVAC, and acoustic systems. In addition, this review introduces visually grounded metrics such as the IGCR to support comparative analysis of restorative exposure, vegetation-specific physiological functions such as biomass accumulation, oxygen release, and volatile organic compound absorption were not consistently reported in the reviewed studies. Integrating perceptual biophilic metrics with plant-species-specific and building-performance indicators therefore represents an important future direction.

An additional limitation concerns the use of different window-size metrics across the reviewed literature. Studies focusing on perceptual and view-related outcomes commonly employ window-to-wall ratio (WWR), defined relative to interior wall surfaces, whereas studies examining daylight availability, glare, and thermal performance typically use window-to-façade ratio, defined relative to the overall building envelope. Although both metrics describe window size, they are referenced to different spatial boundaries and analytical objectives, limiting direct comparison across view- and light-focused studies. Future research should explicitly examine the relationships between these metrics and develop integrated or translatable definitions that link window size to both visual experience and daylight performance.

Moreover, differences between virtual and physical environments including depth perception, color accuracy, material properties, and ambient air conditions, were rarely examined explicitly, raising challenges in directly translating laboratory or VR-based findings to real-world settings where sensory complexity, behavioral adaptation, and competing stimuli are present. This underscores the need for calibration between simulated and real-world restorative outcomes. Future research should therefore prioritize longitudinal and field-based investigations that integrate psychological, physiological, and building-performance metrics, enabling a more holistic understanding of how intervention type, relative intensity ranges, and environmental conditions interact over time.

The Biophilic Intensity Matrix (BIMx) introduced in this study is intentionally positioned as a comparative and qualitative decision-support framework rather than a prescriptive or predictive tool. As such, future research is needed to progressively test and refine the relationships represented in the matrix across diverse building types, functions, climates, and user groups. Controlled laboratory studies and in situ experiments can use the BIMx to systematically vary intervention types and relative intensity ranges across different exposure durations, with empirical outcomes mapped back onto the matrix. A critical next step is the mathematical validation of these relationships, including the development of calibrated intensity coefficients, spatially specific thresholds, and dose–response functions that move beyond ordinal comparison. Such studies may also explicitly examine attentional engagement, sensory adaptation, cognitive load, sensory redundancy, and nonlinear multisensory interactions, and calibration between virtual and physical environmental conditions helping to clarify attenuation or enhancement patterns observed between short-term experimental settings and long-term real-world environments.

Further research could also explore the integration of the BIMx into digital design and decision-support environments, linking its comparative logic with simulation-based performance modeling, post-occupancy evaluation, and human-response data. In particular, evidence-based design guidelines and the BIMx could be embedded within digital simulation workflows and parametric design platforms, enabling systematic testing of

biophilic intervention types and relative intensity ranges across different spatial and exposure scenarios. Emerging approaches such as image-based analysis, computer vision, and AI/ML techniques may further support the automated assessment of visual greenery, daylight distribution, and spatial composition, allowing empirical outcomes to iteratively refine design recommendations. Such developments would support evidence-informed and performance-driven design workflows, facilitate communication between designers, engineers, and owners, and strengthen the practical translation of biophilic and neuroarchitectural principles within intelligent building contexts.

6. Conclusions

This scoping review synthesized findings from 136 empirical studies examining biophilic design interventions and their properties in relation to human physiological, psychological, cognitive, and behavioral responses. The results indicate that restorative potential is strongly influenced by the type of intervention, its spatial integration, visual prominence, and sensory richness, rather than the mere presence of natural elements. Across intervention categories, design characteristics such as visual quality (e.g., color, texture, and pattern), high-visibility placement, spatial composition, and the layering of multiple biophilic features were consistently associated with more robust restorative outcomes.

Evidence from controlled studies suggests that indoor greenery coverage is an important design variable, and the proposed Indoor Green Coverage Ratio (IGCR) offers a structured way to describe and compare greenery levels across studies. While experimental findings often indicate higher restorative responses at moderate-to-high coverage levels, practical constraints in real-world settings frequently necessitate lower or more distributed applications. These results underscore the need to interpret quantitative indicators such as IGCR contextually, rather than as fixed targets.

The review further highlights the interactive role of exposure duration, demonstrating that short-term environments often require more prominent or immersive interventions, whereas long-term settings can support restoration through more modest but continuously accessible biophilic features. Virtual or simulated nature may provide partial benefits when direct integration is not feasible, though effectiveness depends on realism, user comfort, and contextual appropriateness.

To translate these findings into design practice, this study introduced the Biophilic Intensity Matrix (BIMx), a comparative decision-support framework that relates biophilic intervention types to exposure duration through relative intensity ranges. Rather than prescribing dimensions or performance thresholds, the BIMx offers a conceptual structure to support early-stage design reasoning, scenario comparison, and interdisciplinary communication.

Despite the growing evidence base, significant gaps remain, particularly regarding long-term effects, responses across diverse populations and cultural contexts, seasonal variability, and operational considerations such as maintenance. Much of the existing literature relies on short-term laboratory studies with inconsistent reporting of design properties. Future research should prioritize longitudinal and field-based investigations, standardized reporting of biophilic characteristics, and systematic testing of intervention types and relative intensity ranges. Together, the IGCR and BIMx provide complementary foundations for progressively advancing evidence-based, human-centered, and performance-informed biophilic design within intelligent building contexts.

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Conflicts of Interest: Authors Alireza Sedghikhanshir and Raffaella Montelli were employed by the company Stantec during the course of this research. The authors declare that there are no other financial or non-financial interests that could be perceived as influencing the research outcomes.

Appendix A

Table A1. Additional publications reviewed based on authors' prior knowledge.

Author(s), Year	Shortened Title	Journal, Link (All Accessed on 25 July 2025)
Altaf et al., 2025	Impact of Windows, Materials, and Nature Representations on Well-Being	https://doi.org/10.1016/j.buildenv.2025.113147
Yin et al., 2020	Effects of Biophilic Indoor Environments on Stress and Anxiety Recovery	https://doi.org/10.1016/j.envint.2019.105427
Holland et al., 2021	Measuring Nature Contact: A Narrative Review	https://doi.org/10.3390/ijerph18084092
Yin et al., 2022	Stress Recovery in Virtual Desert and Green Environments	https://doi.org/10.1016/j.jenvp.2022.101775
Cox et al., 2017	Neighborhood Nature Exposure and Mental Health Benefits	https://doi.org/10.1093/biosci/biw173
Jiang et al., 2015	Tree Cover Density and Landscape Preference	https://doi.org/10.1016/j.landurbplan.2015.02.018
Douglas et al., 2022	Built Environment Features and Human Well-Being: A Mixed-Methods Study	https://doi.org/10.1016/j.buildenv.2022.109516
Kort et al., 2006	Restorative Effects of Virtual Trees	https://doi.org/10.1016/j.jenvp.2006.09.001
Altaf et al., 2022	Crowdsourced Studies of Architectural Design and Well-Being	https://doi.org/10.3389/frsc.2022.780376
Bianchi et al., 2023	Indoor Nature, Solidarity, and Group Identity in Remote Work	https://doi.org/10.1016/j.buildenv.2023.110909
Yin et al., 2018	Physiological and Cognitive Responses to Biophilic Indoor Environments	https://doi.org/10.1016/j.buildenv.2018.01.006
Jiang et al., 2014	A dose of nature: Tree cover, stress reduction, and gender differences	https://doi.org/10.1016/j.landurbplan.2014.08.005
Ramanpong et al., 2024	Effects of Forest Density on Physiological and Psychological Responses	https://doi.org/10.1016/j.tfp.2024.100551
Sun et al., 2024	Effects of Classroom Color Tones on Student Emotions	https://doi.org/10.3390/buildings14103309
Choi et al., 2016	Physiological and Psychological Responses to Indoor Greenness	https://doi.org/10.1016/j.ctim.2016.08.002

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