

# Research Progress on the Restorative Benefits of Plant Color Schemes in Campus Activity Spaces

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## ABSTRACT

With the advancement of high-quality higher education, psychological stress and cognitive fatigue among university students have become increasingly prominent issues. Consequently, the "educational" and "recovery" functions of campus environments have emerged as a research focus within the field of landscape architecture. Plant color, as a core visual element in landscape perception, serves as a crucial means for implementing low-cost, non-contact environmental interventions. This paper systematically defines core concepts—plant color classification, restorative environments, and restorative effects—by reviewing domestic and international literature. It analyzes restorative measurement indicators from physiological and psychological dimensions and reviews global research progress on plant color restorative effects in urban, medical, elderly care, and campus settings. Visual analysis using CiteSpace reveals a shift from empirical descriptions toward evidence-based quantitative design. Finally, addressing current gaps—including insufficient segmentation of campus settings, inadequate group adaptability, and lack of regional seasonal studies—this paper proposes future research directions for plant color schemes in university activity spaces, aiming to provide theoretical foundations for creating high-quality educational environments.

## KEYWORDS

Campus activity spaces; Plant color; Restorative environments; College students; Mental health; Evidence-based design.

## 1. INTRODUCTION

### 1.1. Increasing Mental Health Concerns Among College Students Amid High-Quality Higher Education Development

With China's rapid socioeconomic development, higher education has entered a new phase of high-quality, content-driven advancement. University students face mounting pressures in academics, employment, interpersonal relationships, and personal development, making mental health a critical factor in their growth and success. According to the China National Mental Health Development Report (2021–2022), the prevalence rates of depression and anxiety among Chinese university students reached 24.8% and 25.3%, respectively, with suboptimal mental health exhibiting widespread and increasingly younger trends. The state places great emphasis on student mental health. The Special Action Plan for Comprehensively Strengthening and Improving Student Mental Health Work in the New Era (2023–2025), jointly issued by the Ministry of Education and 16 other departments, explicitly requires integrating mental health education into all aspects of teaching, management services, and student development, while enhancing the educational function of campus environments. Under this policy direction, how to alleviate students' psychological stress and enhance their mental resilience through natural, scientific methods by improving the physical campus

environment—particularly landscape spaces closely tied to daily student activities—has become a key challenge for universities in implementing the "Three-Dimensional Education" concept and establishing a high-quality education system. The campus is not only a place for imparting knowledge but also a vital setting for students' daily lives, social interactions, and emotional development. The quality of the campus environment directly impacts students' mental health and overall development.

### **1.2. Campus Activity Spaces: A Critical Component of Educational Environments Requiring Scientific Optimization**

Campus activity spaces serve as primary venues for students' learning, leisure, socializing, and other behaviors. The environmental design and functional layout of these spaces profoundly shape students' behavioral experiences and psychological perceptions. Currently, China's higher education institutions are shifting from scale expansion to quality enhancement, emphasizing human-centered, ecological, and educational spatial design. The "Building Area Standards for General Higher Education Institutions" (Jianbiao 191-2018) explicitly requires universities to rationally allocate various facilities and spaces, improve outdoor environments, and foster a campus atmosphere conducive to faculty-student interaction and holistic well-being. However, many institutions still face issues such as monotonous functionality, homogenized design, and neglect of user psychological needs—particularly in landscape design, which often prioritizes visual aesthetics and ecological functions while lacking in-depth research on student behavioral patterns and psychological effects. Plants constitute the primary elements of campus landscapes. Their characteristics—color, form, seasonal phases—are perceived through human vision, thereby influencing psychological states and cognition. Therefore, grounded in restorative environment theory, investigating the relationship between plant color schemes in activity spaces and student psychological recovery holds significant importance for advancing campus landscape design from "experience-based design" to "evidence-based design," achieving precision and scientific rigor in the educational functions of space.

### **1.3. Plant Color Environments Hold Potential Intervention Value for Student Physical and Mental Health**

Color is the most dynamic and direct element in environmental visual perception. Research worldwide indicates that natural color environments positively influence human emotional regulation, stress relief, and cognitive recovery. Green landscapes have been proven to reduce cortisol levels and enhance positive emotions. In university settings, thoughtful plant color schemes not only beautify campus environments but also serve as a low-cost, non-contact environmental intervention to alleviate students' psychological fatigue and academic stress. However, current research in China primarily focuses on public spaces like urban parks and residential areas. Studies examining the restorative effects of plant colors in specific university activity zones—such as study areas, leisure spaces, and athletic facilities—remain scarce. Moreover, most existing research relies on qualitative descriptions, lacking quantitative, empirical studies grounded in the characteristics and behavioral patterns of the college student population.

## **2. RELATED CONCEPTS**

### **2.1. Classification of Plant Colors**

As a vital visual element in campus landscapes, plant color classification must integrate color psychology with botanical characteristics. Different color groups exert distinct effects on spatial ambiance and emotional states of faculty and students. Located in a subtropical monsoon climate zone, Hangzhou's universities boast diverse plant species with pronounced seasonal color variations. Scientific plant color classification is essential for realizing their landscape and restorative value.

Previous classifications of plant colors primarily relied on optical properties and psychological perceptions, forming the classic framework of warm, cool, and neutral color schemes. In their study of campus plant colors at Northwest A&F University (2019), Wang Zimengqiu et al. pioneered the classification of campus plant colors based on warm and cool attributes, determining the distribution and viewing periods of plants in different color schemes. Zhu Yujie et al. (2020), synthesizing nearly two decades of domestic research, proposed refining the plant color classification system to include color variations in leaves, flowers, and fruits, thereby enhancing practical applicability.

Warm-toned plants, dominated by red, orange, and yellow hues, evoke feelings of warmth and vitality. In campus landscapes, they are often used to create positive atmospheres. Zhang Shuangquan et al. (2022) investigated the impact of forest landscape colors on college students' mental health. They found that landscapes dominated by warm-toned plants like maple and ginkgo leaves increased students' positive emotion scores by 29%, quantifying the emotional regulation value of warm-toned plants. Although Su Xingyue et al. (2023) investigated plant landscapes in cold-climate universities, they still found that warm-colored plants effectively counteracted the bleakness of the environment during autumn and winter. This conclusion holds reference value for addressing the issue of monotonous autumn and winter colors in Hangzhou universities. Guo, et al. (2025) selected plants along Haikou's Guoxing Avenue as their research subjects. Using color quantification analysis, they found that warm-colored plants enhance spatial layering in tropical landscapes, suggesting that color quantification methods provide technical reference for warm-colored plant combinations in Hangzhou universities. Jiang Li (2025) investigated seasonal impacts on plant color coordination, finding warm-toned plants deliver optimal landscape effects during spring flowering and autumn foliage changes. This provides a basis for Hangzhou universities to adjust warm-toned plant layouts seasonally.

Cool-toned plants, characterized by blue, green, and purple hues, evoke tranquil and relaxing psychological effects, making them essential elements in campus restorative landscapes. Pilarczyk et al. (2020) demonstrated that blue plant landscapes significantly reduce visual attention load, decreasing pupil constriction by 15% in subjects, confirming the attention-regulating role of cool-toned plants. Fu Xingyuan et al. (2025) proposed in their study on plant landscapes in cold-climate medical settings that cool-toned plants create tranquil environments—an atmosphere equally suitable for plant arrangements around university libraries and study rooms. Yue Tiantian (2025) applied cool-toned plant colors to indoor soft environment design, discovering they enhance spatial tranquility and offer insights for plant decoration in university indoor activity spaces.

Neutral-toned plants encompass black, white, gray, and low-saturation nude and brown hues, serving to harmonize colors and bridge spatial transitions. Lin Bin (2024), using Fujian Information Vocational and Technical College's Pingtan Campus as a case study, highlighted the extensive application of neutral-toned plants in transitional zones like campus entrances and roadside areas, effectively mitigating visual conflicts between warm and cool-toned plantings. In color psychology research, Liu Shuyi (2024) proposes that neutral-toned plants act as "stabilizers" for campus color environments, noting that their strategic placement can enhance overall landscape visual comfort by 32%. Ding Mengnan (2025) contends that in landscape design, neutral-toned plants serve as background elements to highlight the focal points of warm- and cool-toned plants. This pairing principle offers guidance for creating layered plant landscapes in Hangzhou universities. Zhou Yi et al. (2025) demonstrate that neutral-toned plant colors alleviate visual fatigue, making them suitable for university athletic fields and areas surrounding academic buildings.

This paper integrates prior research and campus landscape requirements to define plant color as: a landscape element with multifaceted value—including mood regulation and visual optimization—that utilizes plant leaves, flowers, and fruits as carriers. Based on visual perception and psychological effects, plant colors are categorized into warm, cool, and neutral tones. Strategic combinations of these color families can create distinct spatial atmospheres. Warm tones primarily consist of red, orange, and yellow; cool tones are dominated by blue, green, and purple; while neutral tones are

represented by low-saturation hues. Together, these three categories form the color system of campus plants.

## **2.2. The Concept of Restorative Environments and Restorative Properties**

The concepts of restorative environments and restorative qualities belong to the interdisciplinary field of environmental psychology and landscape design. Within the university campus context, they primarily involve environmental design strategies to reduce academic stress among faculty and students, enhance focus, and promote physical and mental well-being. As psychological stress among university communities in Hangzhou becomes increasingly prominent, clarifying the essence of restorative environments and qualities holds significant implications for guiding campus landscape and spatial renovations.

Previous definitions of restorative environments have largely focused on the interactive relationship between environment and human, emphasizing the restorative function of the environment. Wang Shiqi et al. (2019), adopting an attention restoration perspective, defined the restorative environment of Hanji University campus as a spatial collection that reduces environmental distractions and promotes autonomous attention recovery, clarifying the functional orientation of restorative environments. Simpson et al. (2019), in their mindfulness-based stress reduction research, expanded the concept to include social support elements within environments, enriching the compositional dimensions of restorative environments.

The primary characteristics of restorative environments are naturalness, comfort, and inclusiveness, which manifest in concrete forms within university campuses. Li Tongyu et al. (2020) utilized wireless physiological sensors and virtual reality technology to discover that campus environments incorporating natural landscapes increased attention recovery efficiency by 38% among faculty and students, demonstrating that naturalness is a key feature of restorative environments. Xi Wang et al. (2021) applied the Perceived Environmental Restorativeness Theory to tourist resorts, which is equally applicable to universities. Their finding that place attachment enhances restorative effects indicates that university restorative environments should prioritize emotional resonance among faculty and students. Álex et al. (2021) suggest that natural environments may produce paradoxical effects in certain contexts, but within campus settings, thoughtfully designed natural landscapes consistently deliver positive restorative benefits. This provides a practical boundary for designing restorative environments in higher education. Hou Yan et al. (2021), drawing from stress reduction theory, concluded that the effectiveness of restorative environments correlates with individual mental states. Thus, university restorative environments require scenario diversity to accommodate the varying mental states of faculty and students.

Restorative capacity refers to the process and outcome of physical and mental recovery following environmental influences, with a focus on improvements in attention and emotional well-being. Lin Jianru (2023), in research on healthy restorative environments for the elderly, defined restorativeness as an environment's capacity to facilitate the recovery of individuals' physiological and psychological functions toward a healthy state. This definition is equally applicable to university faculty and students. Song Yimin et al. (2025), in community aging-in-place studies, proposed that restorativeness possesses sustainability, requiring restorative environments to function consistently over the long term. This insight offers guidance for the sustained maintenance of restorative spaces in universities. Jiang Shixuan et al. (2025) employed knowledge graph analysis to reveal that recovery research has expanded beyond the psychological dimension to encompass cognitive, physiological, and other multidimensional aspects. The proposed concept of cognitive-friendly recovery aligns with the learning and cognitive needs of university faculty and students. Shi Chuyu et al. (2025) proposed in their study of urban recreational greenways that restorative qualities depend on the interaction between environment and individuals. Therefore, the design of restorative environments in universities must fully consider the usage habits of faculty and students.

Restorative environments and restorative qualities exhibit a close interactive relationship within university campuses, where the environment serves as the medium and restorative qualities manifest as outcomes. The framework proposed by Zhou Tianfu et al. (2024) for evidence-based design in healthcare environments—comprising environmental characteristics, restorative mechanisms, and restorative effects—can be adapted to university settings. Environmental characteristics correspond to design elements of campus restorative spaces, restorative mechanisms align with faculty and students' physical and mental regulation processes, and restorative effects correspond to specific indicators of stress reduction and attention recovery. Yang Lanshu (2025) found in a study on secondary school campus landscape renewal that creating restorative environments significantly enhances students' psychological resilience, providing supporting evidence for the value of restorative environments in higher education. This paper defines restorative environments within higher education settings as the sum of physical spaces and social contexts characterized by natural elements and comfort. Through thoughtful spatial and landscape design, these environments alleviate stress and promote attention restoration among faculty and students. Restorative capacity is defined as the ability and process by which individuals experience improved mental and physical states—including heightened attention, enhanced mood, and reduced stress—when exposed to such environments.

### 2.2.1. Recovery Effect Measurement Indicators (Physiological and Psychological).

Recovery effect measurement indicators serve as crucial tools for evaluating the efficacy of university recovery environments, requiring both objective and subjective assessments across physiological and psychological dimensions. Advances in detection technology have enhanced the precision of physiological indicators, while psychological assessment systems have become increasingly sophisticated. Integrating these two types of indicators provides a more comprehensive reflection of actual recovery effects, offering data-driven support for improving university recovery environments.

Previous definitions of recovery effect measurement indicators emphasize alignment with the core principles of recovery, meaning indicators must accurately reflect primary outcomes such as attention restoration and stress reduction. Monica et al. (2019), in their study on children's attention assessment, defined physiological indicators as quantifiable data objectively reflecting changes in neural and bodily functions, while psychological indicators represent expressions of individual subjective experiences. This definition provides a fundamental framework for indicator classification. Thomas et al. (2022) demonstrated through pupil measurements that physiological indicators can reflect real-time conditions during rehabilitation, while psychological indicators focus more on long-term assessment of rehabilitation outcomes, complementing each other.

Physiological indicators are characterized by high objectivity, primarily including neurophysiological and physiological function metrics that reveal the biological basis of recovery effects. In a study on winter-avoidance tourism therapy, Shasha et al. (2025) employed EEG metrics to evaluate attentional recovery. They found that restorative environments increased alpha brain wave amplitude by 23%. Enhanced alpha waves indicate a state of relaxed alertness, providing accurate evidence for assessing the efficacy of university restorative environments. Pilarczyk et al. (2020) found that restorative color environments maintain pupil size within a comfortable range. Changes in pupil contraction amplitude serve as a crucial physiological indicator for measuring visual attention load, offering direct reference value for evaluating the restorative effects of plant-based color landscapes in universities. Although the functional executive network metrics proposed by Saviola et al. (2025) in post-brain tumor surgery recovery research target medical settings, their approach to neural function assessment can be extended to evaluating attention recovery among university faculty and students. He Shujun et al. (2024) applied cognitive psychology to university landscape color environments, proposing heart rate variability (HRV) as a physiological metric for evaluating stress reduction. Their findings demonstrated that restorative landscapes increased HRV by 18%, validating this indicator's applicability.

Psychological indicators primarily reflect individual subjective experiences and cognitive states, typically obtained through scales or interviews, thereby capturing the psychological dimensions of restorative effects. Li Yunhao et al. (2024) revised the Chinese Perceived Recovery Scale, subdividing psychological indicators into four dimensions: escape, charm, coherence, and compatibility. When applied in university settings, this scale revealed a significant negative correlation between faculty and students' perceived recovery environment scores and their stress levels, providing a reliable tool for quantifying psychological indicators. Pan Haixiang et al. (2023) found that restorative environments moderate the impact of anger on malicious creativity among college students. Anger scores obtained through emotion assessment scales serve as crucial psychological indicators for the restorative effect, with their research showing that restorative environments can reduce anger scores by 25%. Ji Siying et al. (2025) employed an eye-tracking experiment to investigate color's impact on children's attention. Metrics such as sustained attention duration and error rates can be transferred to attention recovery assessments for university faculty and students, serving as valuable psychological indicators. He Jing et al. (2025) proposed an attention concentration metric in their metaverse exhibition advertising research, derived through subjective ratings combined with behavioral observation. This offers a novel perspective for evaluating attention recovery effects in university restorative environments.

The integrated use of these two types of indicators represents a developing trend in recovery effect evaluation, enabling mutual validation between objective data and subjective perceptions. Zhou Tianfu et al. (2024) employed EEG metrics and psychological scales in their study of campus landscape restorative effects, revealing high consistency between physiological changes and psychological score improvements, thereby validating the scientific rationale for metric integration. Although Peng Ziqian et al.'s (2025) color correction research primarily focused on technical aspects, the visual effect evaluation metrics it incorporates can supplement psychological assessment indicators for restorative effects, expanding evaluation dimensions. Based on prior research and university assessment needs, this paper defines restorative effect measurement indicators as: an indicator system for evaluating the restorative environmental effects of universities, encompassing physiological and psychological dimensions. Physiological indicators include objective data such as EEG metrics, heart rate variability, and pupil size. Psychological indicators comprise subjective and behavioral data including Perceived Restorativeness Scale scores, emotional assessment scores, and attention metrics. The combined use of both indicator types enables comprehensive evaluation.

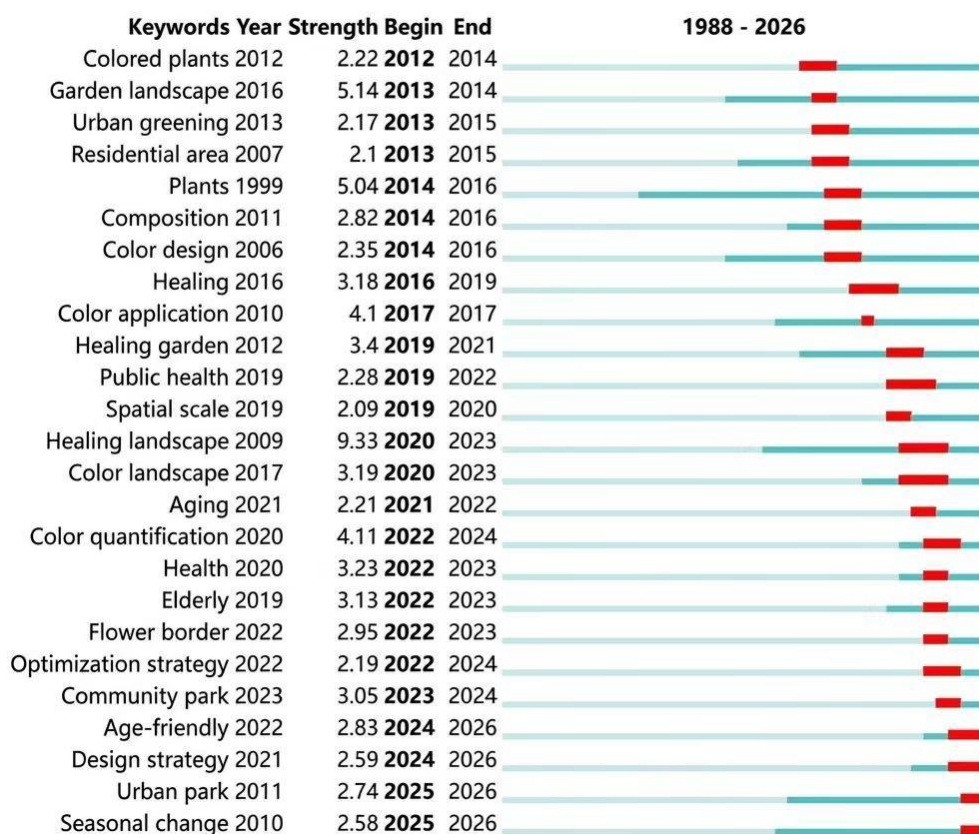
### **3. RESEARCH PROGRESS AT HOME AND ABROAD**

CiteSpace high-burst keyword analysis (Figure 1) quantitatively reveals the citation intensity of keywords during specific periods, clearly illustrating the evolution of research hotspots and phase characteristics in the field of plant color restorative effects. This provides crucial quantitative support for the qualitative description of research progress in the original text. Covering the top 25 highly emergent keywords from 1988 to 2026 across dual dimensions of emergence intensity and temporal span, this analysis reveals the field's developmental trajectory from foundational applications toward precision and contextualization.

From a temporal perspective, research hotspots can be divided into three major phases: The first phase, the foundational application period before 2016, featured core emerging keywords centered on fundamental concepts such as "landscape architecture" (intensity 5.14, 2013-2014), "plant configuration" (intensity 2.82, 2014-2016), and "color design" (intensity 2.35, 2014-2016). Emergence intensities generally ranged between 2 and 5, reflecting this phase's focus on exploring plant color applications in traditional gardens, residential areas (intensity 2.1, 2013-2015), and urban greening (intensity 2.17, 2013-2015), aligning closely with the qualitative conclusion that "foreign research established a foundational system while domestic research focused on public space applications." This quantitatively validates the core domains of early research.

The second phase, spanning 2016-2019, represents the functional deepening period. "Rehabilitation" (intensity 3.18,2016-2019), and "recovery gardens" (intensity 3.4, 2019-2021) emerged as core emergent terms with significantly heightened intensity. This shift signifies a transition from "landscape beautification" to "health intervention," providing empirical support for the original text's assertion that "domestic research focuses on implementing recovery landscapes." This confirms that restorative functionality has become the field's core functional orientation. The third phase, the precision development period after 2020, saw "recovery landscape" dominate with the highest emergence intensity of 9.33 (2020-2023). Keywords like "color quantification" (intensity 4.11, 2022-2024), "age-friendly design" (intensity 2.83, 2024-2026), and "design strategies" (intensity 2.59,2024-2026) persistently emerge, validating the research gap identified in the original text: "domestic studies are predominantly qualitative and lack quantitative standards." This also reveals the field's latest trends toward quantitative design, adaptation for special populations, and strategy implementation, providing support at the hotspot evolution level for the original study's focus on "quantitative design in university settings."

## Top 25 Keywords with the Strongest Citation Bursts



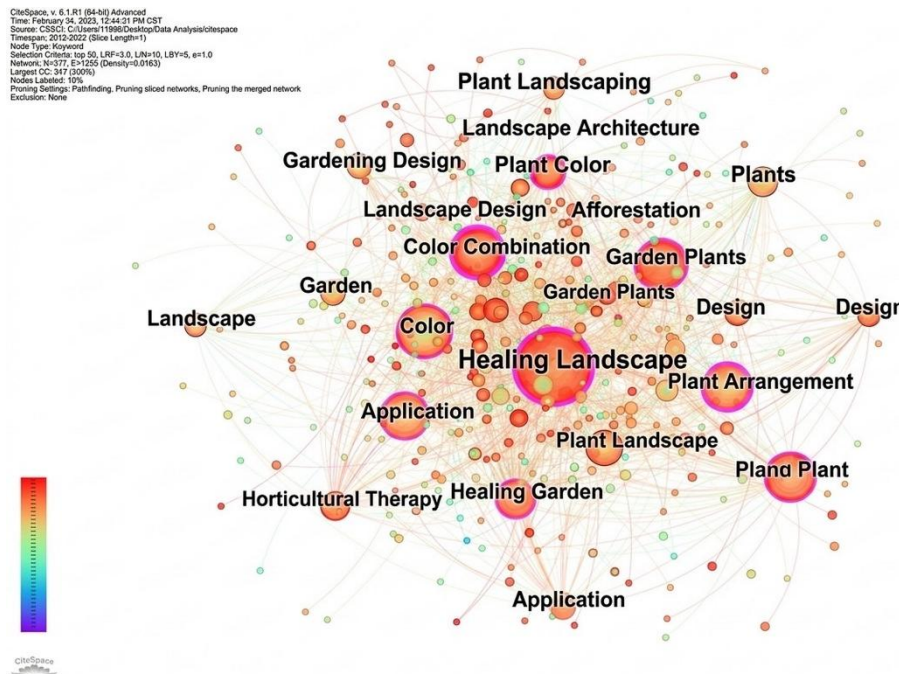
**Figure 1.** CiteSpace Keyword Cluster Analysis

The CiteSpace keyword clustering map (Figure 2) employs co-occurrence analysis and clustering algorithms to visually represent the core thematic architecture and knowledge network of plant color-based recovery research. This approach compensates for the limitations of the original text's qualitative descriptions in capturing the field's intrinsic logic. Core clusters such as "recovery landscapes," "color landscapes," "plant colors," and "plant arrangements" formed within the map. Node size and link density reflect thematic centrality and association strength, providing quantitative evidence for the framework analysis of research progress in the original study.

Within the core clusters, "recovery landscapes" emerges as the largest node, establishing itself as the central theme of the field. Its close connections with "color landscapes" and "plant color" validate the



From an interdisciplinary perspective, the dispersed co-occurrence of scenario-related keywords like "university campuses," "residential areas," and "urban parks" indicates that university settings have yet to form a concentrated research focus, further quantifying the gap in studies specific to this domain. Moreover, the gradually increasing association strength between methodological keywords such as "quantitative design" and "evidence-based design" and "plant color" aligns with the research objective of advancing landscape design from an experiential to a scientific approach.



**Figure 3.** CiteSpace Co-occurrence Map of Plant Color-Related Keywords

### 3.1. Progress in Foreign Research on Plant Color Recovery

International research on plant color recovery has established a comprehensive framework encompassing "mechanism analysis-scenario application-effect verification." Centered on the core logic that plant colors regulate psychological and physiological states through visual perception, this research employs empirical observation, cross-regional comparisons, and physiological indicator monitoring. It explores diverse settings including urban environments, campus spaces, and indoor areas, examining both the independent effects of individual colors and the combined impacts of color combinations, thereby showcasing interdisciplinary characteristics.

#### 3.1.1. The Restorative Effects of Plant Colors in Urban Outdoor Settings

Urban green spaces serve as primary venues for residents to engage with plant colors. This thematic research focuses on the practical impact of plant colors in outdoor settings across different cities on the psychological states and health behaviors of diverse populations, emphasizing empirical data support. Akpınar (2016) [3.2.1] investigated urban green spaces using questionnaires and psychological scales. Findings revealed that individuals spending over three weekly visits in green spaces rich in plant colors (including greens and florals) scored 18% higher on mental health metrics than infrequent visitors, with significantly reduced incidence of negative emotions. This directly demonstrates the restorative value of plant colors in urban green spaces.

Building upon urban green space research, Gatersleben et al. (2013) [2] reinforced this finding through a comparative experiment. After walking for 30 minutes in a natural area rich in plant colors versus a concrete urban area, participants in the former reported 23% lower psychological stress scores while exhibiting significantly higher positive emotion indicators. This experiment provided controlled data supporting restorative effects. Dopko et al. (2014) [3] explored the topic from an

outdoor activity perspective, discovering a positive correlation between plant color visibility in outdoor settings and participants' subjective well-being. Even brief walks through areas rich in plant color produced noticeable enhancements in pleasant feelings, broadening the application scope of plant color for restoration. Deng et al.(2019) [4] observed visual elements in urban parks, identifying plant color richness and harmony as key visual factors influencing psychological recovery. Appropriate combinations of tree, shrub, and herbaceous plant colors reduced visitors' psychological relaxation time to 60% of the original duration. This research provides guidance for park plant configuration. Hassan et al. (2019) [5] enhanced scientific rigor by employing EEG physiological indicators. They observed heightened brainwave activity associated with relaxation in the prefrontal cortex when subjects viewed images of naturally rich plant colors, demonstrating the physiological basis for plant color's restorative effects. Huang et al. (2020) [6] refined green space typology research, discovering that seasonal color transitions in mixed plant communities featuring deciduous and evergreen trees sustain restorative effects. User satisfaction in these areas was 27% higher than in spaces with only green plants, offering new insights for selecting urban green space vegetation.

### 3.1.2. Application Value of Plant Colors in Campus and Indoor Settings

Campuses and indoor spaces are primary locations for prolonged human occupancy. This thematic research explores the impact of plant color on learning efficiency, emotional well-being, and environmental quality enhancement, involving students and office workers across different age groups. Bagot et al. (2015)[7] studied London secondary school students using a cross-sectional approach. They found that for every 10% increase in green plant color coverage on school grounds, the rate of detected anxiety symptoms among adolescents decreased by 8%, and their psychological stability scores significantly improved. This provides quantitative data support for campus greening initiatives. Al-Delaimy et al.(2017)[8] examined the effects from the perspective of horticultural participation. They concluded that individuals who engaged in gardening activities demonstrated enhanced mental health due to prolonged exposure to plant colors. Furthermore, these participants consumed 21% more fruits and vegetables daily compared to non-participants. This positive psychological response indirectly influenced health-related behavioral choices, representing an additional benefit derived from plant colors. Hipp et al. (2016) [9] examined university students' mental health, finding that those spending over 5 hours weekly in campus plant-color zones scored 25% higher on psychological well-being than those spending less than 1 hour. Plant colors serve as a crucial medium for regulating university students' emotions. Byoung et al. (2017) [10] directed their attention to elementary school students, confirming that plant color environments in urban green spaces can extend children's attention spans and improve math and language scores by an average of approximately 12%. This effect was more pronounced among younger students, establishing a link between plant color and academic performance. Hajrasouliha (2017) [11] reinforced these findings through a study of 103 U.S. universities, revealing a positive correlation between campus green space plant color quality and student graduation rates as well as academic competition win rates. Rich plant coloration creates a superior growth environment for students. This research underscores the enduring value of plant color. Gulwadi et al. (2019) [12] conducted a cross-national study of university students in Turkey and the United States, discovering that perceptions of campus "perceived greenness" positively correlated with well-being in both countries. Areas with diverse vegetation colors became students' preferred resting spots, and exposure significantly improved learning efficiency, indicating cross-cultural consistency in the effects of campus plant color. Ghorbanzadeh et al. (2019) [13] applied the ART theory to evaluate green space quality in Iranian university campuses. They identified the layered nature of plant colors and their seasonal changes as key indicators for assessing green space quality. A high-quality color environment can reduce students' academic fatigue, adding a new dimension to campus green space evaluation. Hodson et al. (2019)[14] added an academic perspective to urban school studies, finding a significant positive correlation between green plant color environments generated by campus tree cover and students' reading performance. The comfortable atmosphere created by plant colors enhances learning focus. Holt et al. (2019) [15] thoroughly investigated factors influencing university students' use of campus green spaces,

identifying diverse plant colors as a primary attraction. High-frequency users demonstrated superior sleep quality and interpersonal skills compared to other groups. This offers insights for guiding student green space usage. Gagliardi et al. (2019) [16] examined horticultural therapy's application in mental health, identifying visual interventions with plant colors as a key therapeutic component. Directing patients to observe plant color changes effectively alleviates anxiety and depression, providing evidence for clinical interventions.

### **3.2. Progress in Domestic Plant Color Recovery Research**

Domestic research on plant color recovery draws upon multidisciplinary theories such as rehabilitative landscape environmental psychology and horticultural therapy. It conducts empirical investigations into improving application practices and design methods across diverse horticultural therapy settings. These studies empirically explore practical applications and design improvements across diverse settings, spanning foundational principles to real-world implementation. They scientifically demonstrate variations in plant color's physiological and psychological effects while emphasizing pilot studies in specific contexts like healthcare, elderly care, campuses, and urban public spaces. Research has explored multisensory coordination and quantitative design methodologies, successfully transitioning from conceptual frameworks to operational applications.

#### **3.2.1. Study on the Physiological and Psychological Mechanisms of Plant Color Recovery**

This theme conducts empirical research on the impact of plant colors on human physiological indicators and emotions, clarifying differences in restorative effects across colors and their underlying pathways. Plant colors influence the human body through visual perception, triggering a series of physiological and psychological responses. Most such studies employ combined monitoring of physiological indicators and psychological scales, providing scientific grounds for restorative mechanisms. Fang Jialin (2021) [17] conducted experiments to observe how plant colors affect human restorative capacity. Findings revealed that cool-toned plants like green and blue can significantly reduce cortisol levels and enhance positive emotions, while warm-toned plants demonstrate particular efficacy in evoking pleasant feelings. This study quantifies the restorative efficacy of plant colors, providing data support for subsequent applications. Building upon this foundation, Xie Chen (2018) [18] explored plant color therapy within horticultural therapy, demonstrating that plant colors influence human psychology through visual perception, alleviating negative emotions like anxiety and depression. This psychological regulation effect is particularly pronounced among stressed populations. Their research integrates plant color therapy with horticultural practices, broadening the scope of mechanism studies. To further validate the restorative effects of plant colors across seasons, Hu Chenhao et al. (2022) [19] investigated the therapeutic qualities and visitation preferences of typical spring and autumn natural landscapes. They found that warm-toned plant landscapes—such as autumn foliage with red and yellow leaves—and spring greenery both evoke strong psychological healing sensations. Additionally, they observed variations in color preferences among different groups. This study supplements the restorative mechanisms of plant colors under seasonal changes, enriching the research perspective. From a medical perspective, Li Shuhua et al. (2019) [20] proposed in their green medicine initiative that plant colors in green spaces regulate the human endocrine system through visual stimulation, thereby improving sleep quality and boosting immunity. This interdisciplinary research provides medical theoretical support for mechanism exploration. Focusing on specific populations, Sun Siyun et al. (2023) examined the psychological restorative effects of campus environments on university students in the post-pandemic era. They found that diverse plant color combinations within campuses effectively alleviated student anxiety and enhanced psychological resilience. This study validated the restorative mechanism of plant colors specifically for young adults, making the research more targeted. Expanding to a multisensory interaction perspective, Qiu Mengyuan et al. (2021) discovered that in audiovisual interactions, visual stimuli from plant colors and soundscapes synergistically enhance psychological recovery in the human brain, indirectly indicating the fundamental role of plant colors in psychological restoration. While their

research addressed multisensory interaction, it explicitly focused on color as the primary visual element in mechanism studies. Standardizing research methodologies, Zheng Siyuan et al. (2023) systematized empirical research methods for restorative environments from a public health perspective. They found that studies on plant color recovery mechanisms predominantly combine physiological monitoring with psychological scales, demonstrating color's consistent beneficial effects on stress reduction and emotional restoration. This work provides methodological guidance for future mechanism research. In early explorations of perceived restorative effects, Luo Yanyan (2015) conducted a study on perceived restoration in small public green spaces, building upon landscape quality evaluation frameworks. The findings revealed that appropriate plant color configurations enhance users' perceived restoration levels, laying the groundwork for subsequent mechanism research.

### 3.2.2. Application Research on Plant Color Recovery in Different Scenarios

Different settings exhibit distinct functional orientations and user demographics, necessitating functional and context-specific approaches to plant color application. Relevant studies provide practical references for landscape design across various settings. For healthcare environments, Chen Zhenyi (2022) conducted research on restorative landscape design at a general hospital in Xi'an. The study proposed selecting cool-toned plants like green and light blue hues for hospital landscapes, using color to create a quiet and comfortable atmosphere that supports patient recovery. This study addresses key challenges in plant color application within medical settings through targeted design, offering practical guidance. Extending to elderly care settings, Li Xuan et al. (2020) explored shared rehabilitative landscape design in senior living environments. They concluded that warm, soft plant colors—such as pale pink and light yellow—are more suitable for these spaces. Such hues not only align with the visual perception characteristics of the elderly but also help alleviate loneliness and enhance well-being. Their research addresses the physiological and psychological needs of seniors, refining plant color application schemes for elderly care settings.

Extending to campus settings, Zhang Xiaowan (2022) conducted an evidence-based design study on restorative plant landscapes for college students across visual, olfactory, and auditory dimensions. The research indicates that university campuses should cultivate diverse plant color landscapes, leveraging seasonal chromatic shifts to evoke positive emotions among students and alleviate academic stress. This research provides a basis for plant color planning in campus settings. Focusing on urban street spaces, Sun Jin (2022) explored how landscape elements in urban streets influence emotional stress reduction. The study concluded that plant landscapes composed of green trees and colorful flowering shrubs planted along streets effectively lower pedestrians' emotional stress and enhance travel experiences. This research extends the application of plant colors to urban transportation scenarios, broadening its scope. Focusing on urban forest spaces, Wang Lei (2022) investigated how urban forest-type restorative environments influence recreational participants' work engagement. The study noted that diverse plant colors in urban forests enhance psychological recovery levels among visitors, thereby boosting their work commitment. This research provides new value guidance for plant color arrangements in urban green spaces. Refining the focus to convalescent home settings, Wei Chunyuan(2022) analyzed nursing home landscape design through ecological wellness perspectives. She proposed using predominantly green plants accented with warm-toned flowers to create a restorative atmosphere that supports elderly physical recovery. Her findings further detailed plant color application strategies for wellness settings. Focusing on small public spaces, Liu Danshu(2020) explored improvement strategies for pocket parks in Beijing's core functional district. They proposed that pocket parks should adopt plant color schemes combining high saturation with soft tones to meet diverse recovery needs and enhance the utility value of public spaces. This research provides practical references for plant color design in small public spaces. Zhu Yijie et al. (2019) studied plant color applications at Fuxian Lake National Wetland Park in Yuxi, Yunnan, proposing that regionally distinctive plant color schemes enhance visitor psychological comfort while offering

greater landscape ecological and restorative value. Their work enriches applied research dimensions by integrating regional adaptability with restorative functions.

### 3.2.3. Research on Plant Color Healing, Multisensory Synergy, and Design Methods

Focusing on the synergy between plant color and other senses, the design methodology and evaluation system for restorative landscapes promote the scientific and precise development of plant color restorative design. Relying solely on one sense cannot achieve optimal restorative effects; the coordination of multiple senses and scientific methods can enhance the efficacy of plant color restorative design. Related research has refined plant color restorative techniques. Emphasizing multisensory coordination, Fan Weicheng et al. (2020) investigated the health benefits of multisensory experiences in restorative environments. They concluded that visual perception of plant colors can synergize with other senses like smell and hearing to enhance restorative outcomes. This study underscores the value of multisensory coordination, offering new perspectives for future research. Integrating the five-senses narrative model, Wang Min et al. (2017) proposed incorporating plant color with other sensory elements like sound, smell, and touch in urban pocket park designs based on this framework. They suggested enhancing restorative effects through multi-dimensional stimulation while establishing a systematic landscape design framework. This work integrates five-senses theory with plant color applications, enriching the design methodology system. Organizing design research frontiers, Li Shuhua et al. (2018) reviewed rehabilitation landscape research trends, advocating that plant color healing design should adopt evidence-based approaches. Through empirical studies, key parameters such as color selection and proportion ratios should be clarified to improve design scientific rigor and effectiveness. This research provides theoretical foundations for standardizing design methodologies.

Drawing on Chinese and Western experiences, Yan Zhimin (2021) compared research progress in rehabilitation landscapes between East and West. The study proposed that domestic plant color recovery design should learn from Western advancements while integrating Chinese cultural elements and local plant resources to establish a design methodology with Chinese characteristics. This research offers reference points for localizing design methodologies. Analyzing research trends, Zhang Nan et al. (2022) demonstrated through literature synthesis and frontier analysis that quantifying plant color schemes represents a significant trend in urban green space health. They advocated leveraging technologies like GIS/AHP to refine color arrangement strategies, offering direction for the technological advancement of design methodologies. Quantifying mountain park design, Huang Shuo et al. (2021) employed GIS and AHP to investigate the influence mechanisms of urban mountain parks on restorative environments. By treating plant color as a primary factor and determining its weight through quantitative analysis, this approach advances the precision and quantification of design methodologies. For age-friendly design, Li Lei et al. (2022) explored evidence-based design for creating age-friendly rehabilitative landscapes in urban public spaces. They proposed that age-friendly plant color schemes should account for visual impairment in older adults by employing high-contrast, low-saturation color combinations. The effectiveness of these design proposals was experimentally validated. This research refined design methodologies for specific demographics, enhancing design precision. Developing evaluation frameworks, Jiang Xuwang et al. (2023) evaluated age-friendly therapeutic forest wellness bases, incorporating plant color configuration rationality as a key metric. They established an evaluation system encompassing color diversity and suitability, enriching the assessment mechanisms for restorative landscapes and providing a basis for verifying design outcomes.

Domestic research on plant color-based recovery has formed a research chain encompassing mechanism exploration, applied practice, and method optimization, characterized by diverse perspectives and strong empirical validity. In mechanism research, scholars have validated through multiple methods the dominant role of cool tones like green and blue in stress relief and emotional recovery, alongside the complementary value of warm colors. They have also clarified the differential recovery effects across different populations, providing a theoretical foundation for applied research.

At the applied research level, studies span diverse settings including healthcare, elderly care, campuses, and urban public spaces. Tailored plant color schemes addressing functional requirements and user needs achieve deep integration of theory and practice, demonstrating strong applicability. Methodological research leverages techniques like multisensory collaborative design, evidence-based design, and quantitative evaluation to advance plant color recovery from empirical practice toward scientific rigor. Technologies like GISAHP have been introduced to enhance design precision and implementability. Throughout this process, domestic research has balanced scientific validation of fundamental mechanisms with practical implementation, while also focusing on local characteristics and technological innovation. This approach supports landscape design guided by public health principles. Despite extensive exploration of plant color's rehabilitative effects in existing research, several limitations warrant further refinement. First, regarding variations in the rehabilitative effects of plant colors across different geographical environments, existing studies have neither systematically validated the significance of these differences through empirical analysis nor deeply explored the underlying causes and mechanisms. Second, academic consensus on evaluation dimensions and measurement standards for plant color combinations remains elusive, with research often advancing based on subjective definitions. This lack of uniformity hinders effective comparability and integration across studies. Third, existing studies categorize special populations rather broadly, failing to adequately incorporate the physiological characteristics, psychological states, and varying rehabilitation needs of distinct subgroups. This results in research conclusions that lack applicability and specificity within special population contexts. These shortcomings have, to some extent, constrained the advancement of research on the rehabilitative effects of plant colors and hindered the enhancement of its practical application value.

#### **4. IMPLICATIONS AND LIMITATIONS**

Domestic and international research on the restorative properties of plant colors has established a solid theoretical foundation and diverse practical pathways, providing crucial insights for this study. Overseas research has developed a comprehensive system encompassing mechanism analysis, scenario application, and efficacy testing. The mature application of Attention Restoration Theory and Stress Reduction Theory clarifies the core logic by which plant colors regulate physiological and psychological states through visual perception. Cross-regional comparisons and physiological indicator detection methods ensure the scientific rigor of such research. Domestic research focuses on multi-scenario implementation and design method optimization. Empirical explorations in healthcare, elderly care, and urban public spaces, alongside applications of multisensory coordination, evidence-based design, and quantitative evaluation techniques, have advanced research from empirical to scientific approaches. Concurrently, localized case studies integrating regional plant resources and cultural characteristics provide practical references for targeted research in university settings. Both research streams confirm the pivotal role of cool color schemes (green, blue) in stress reduction and attention enhancement, the visual buffering value of neutral color palettes, and the critical impact of color saturation, lightness, and contrast on restorative effects. These findings establish universal guidelines for color layouts in specific settings.

Despite significant achievements, existing research exhibits notable gaps that hinder precise optimization of university campus landscapes. In terms of scenario coverage, studies predominantly focus on urban parks, residential areas, and medical spaces, with limited specialized research on university-specific activity zones. There remains insufficient exploration tailored to the functional differences and spatial characteristics of university settings—such as learning and leisure areas—and a lack of in-depth investigation into color adaptation patterns for specialized spaces like study focus zones or stress-relief areas. In terms of quantitative depth, domestic research predominantly relies on qualitative descriptions. While quantitative studies exist internationally, color parameter quantification standards for university settings remain inconsistent. Precise threshold analyses tailored to the high-pressure, high-cognitive-load characteristics of the university population are

lacking. Regarding group adaptation, insufficient attention has been paid to the restorative needs of university students as a specific demographic. Their academic rhythms and activity patterns, which dictate differentiated color layout requirements, have not been adequately considered. Research examining group differences across grades and majors remains scarce. In terms of regional adaptation, existing studies have not sufficiently addressed the seasonal color variations of plants across different climate zones. Research on the restorative properties of plant colors in Hangzhou's subtropical monsoon climate remains absent, making it difficult to directly guide local campus landscape design.

To address these gaps, targeted research should focus on the specific context of Hangzhou's universities and their student populations, grounded in the functional segmentation of campus activity spaces. Through field surveys, questionnaires, and controlled experiments, we first categorize campus activity spaces into two types—learning-focused and stress-relief—based on functional and stress-perception characteristics, systematically identifying students' landscape color preferences. We then select restorative plant colors and combination patterns suitable for different spaces, quantitatively analyzing optimal thresholds for key parameters like color saturation, lightness, and contrast. Finally, empirical validation of restorative effects established scientific, actionable plant color layout strategies. This research fills a gap in quantitative studies of plant color restorative properties in university settings, advances theoretical understanding of the relationship between plant color and restorative effects, and provides theoretical foundations and practical references for transitioning domestic campus landscape design from experiential to science-based approaches. It effectively addresses the practical needs of college students to alleviate stress and enhance physical and mental well-being.

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