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Evolution And Trends In Landscape Visual Quality Assessment: A Scientometric Analysis Based On Citespace

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Abstract

The visual landscape, shaped by both environmental representation and individual preferences, is a key aspect of the broader landscape. Assessing its characteristics and quality has become essential for landscape management and policy-making. This study analysed 329 publications on landscape visual quality assessment from the Web of Science (WOS) database (January 1989–February 2025) using CiteSpace 6.4 R1 for scientometric analysis. The findings reveal three research phases: cognition, intervention, and exploration of intrinsic mechanisms, marking a shift from aesthetics-focused studies to interdisciplinary approaches. Since 2013, publication volume has surged due to advances in assessment techniques, stabilising after 2021. The expert paradigm and psychophysical paradigm have significantly contributed to the field, yet concerns persist regarding the sustainability of assessment methods given the dynamic nature of environments and audiences. Additionally, the mechanisms underlying visual interactions between individuals and landscapes remain underexplored. By reviewing over three decades of research, this study highlights key trends and research gaps, offering a valuable reference for scholars seeking an overview of the field.

Keywords: *Visual quality; Scientometric analysis; Citespace; Landscape perception; Environmental impact*

1. INTRODUCTION

The landscape presents the visual characteristics of a given area, embodying both physical and perceptual values [1]. Landscape perception refers to how individuals or groups interpret and understand natural or built environments through visual, cognitive, and emotional processes. This concept encompasses how people perceive, experience, and evaluate their surroundings, influenced by cultural background, social values, personal experiences, and ecological conditions [2–4]. While it shares similarities with cognitive landscape studies, their focus differs: landscape perception research primarily examines how individuals experience and assess landscapes through the senses, particularly vision[5], whereas cognitive landscape studies explore how people construct, remember, and utilise landscape information at a cognitive level [6].

The visual landscape is a component of the broader landscape, shaped by the aesthetics of the observed environment and the personal preferences of the observer [7]. Humans rely on vision more than any other sense for learning, reaction, and appreciation. As a result, attention to visual quality has become a public priority [8,9]. The American Society of Landscape Architects (ASLA) asserts that the quality of visual character and scenic resources is essential at local, regional, and national levels. To ensure the conservation and sustainable use of these visual resources, ASLA has established comprehensive public policies[10].

A review of literature from the 1970s to the present reveals that research and applications in landscape perception and visual quality assessment have predominantly focused on three key areas:

The conservation and restoration of natural environments essential for human survival.
The planning, design, construction, maintenance, and management of green built environments that support human life.
The exploration of fundamental principles governing human perceptual responses to landscapes, which influence or determine values, objectives, evaluation criteria, and policy orientations in the first two areas [11].
Early landscape visual assessments emerged as a means to resolve conflicts between forestry operations (such as logging and reforestation) and aesthetic considerations. Over time, as nature reserves, scenic areas, forest parks, and urban planning projects expanded, landscape visual assessments were conducted before and after project implementation to minimise damage to natural and cultural resources while ensuring visual and aesthetic quality [12–14].
Today, the objectives and methodologies of visual landscape assessment have evolved significantly, embracing a more diverse and interdisciplinary approach. This study employs scientometric analysis to provide a comprehensive review of its evolution, current state, and emerging trends. Following a preliminary literature screening, quantitative analysis and knowledge mapping were conducted using CiteSpace 6.4 R1, offering an objective and systematic overview of the field.

2. METHODOLOGY
2.1 Data Sources
The literature analysed in this study was retrieved from the Web of Science (WoS) database. A keyword search was conducted using the following query:
All = (Visual Quality Assessment OR Visual Assessment OR Visual Evaluation OR Visual Quality Evaluation).
This search yielded 33,419 results.
To refine the dataset, the search results were filtered by selecting the Web of Science categories: Architecture, Urban Studies, Environmental Studies, and Art. To ensure the inclusion of high-quality publications, only articles indexed in SCI, SSCI, A&HCI, and ESCI were considered, reducing the dataset to 1,694 records.
The results were then sorted by relevance, and a manual review of titles and abstracts was conducted to exclude publications irrelevant to the research topic. Ultimately, 329 articles were selected for analysis, comprising 301 research articles, 7 early access articles, 8 proceedings papers, 1 editorial material, and 12 review papers.
2.2 Statistical Tools and Methods
Prior to analysis, the plain text files downloaded from WoS were pre-processed to convert formats and remove duplicates. Since the earliest publication in the dataset dates back to 1989, the time period for analysis was set from January 1989 to February 2025, with a time slicing interval of one year [15].
In CiteSpace 6.4 R1, the node types selected for analysis included keywords, authors, institutions, and countries, allowing for the construction of co-occurrence networks, clustering analyses, and collaboration networks in the field of landscape visual quality assessment [16]. Subsequently, Microsoft Excel 2021 was used to statistically process and systematically analyse the data extracted from CiteSpace 6.4 R1.

3. THE EVOLUTION AND CURRENT STATE OF LANDSCAPE VISUAL QUALITY ASSESSMENT
3.1 Evolution and Keyword Burst Analysis
In the 1970s, environmental psychologists explored human preferences for landscape features through visual assessment, emphasising people' s visual perception of landscape resources and proposing some of the earliest theories in visual evaluation research [17–20]. By analysing both external physical elements and intrinsic aesthetic qualities[21], these studies contributed to the creation of visually appealing environments and spaces. However, due to the subjectivity of human perception, early assessment methods lacked scientific rigour and practical applicability, making them difficult for institutions to adopt widely. This led to the emergence and further development of landscape aesthetics research.
With growing concerns about environmental protection, research in this field expanded and deepened, attracting experts from various disciplines. Several subjective evaluation methods were developed, including the Scenic Beauty Estimation (SBE) [22], the Semantic Differential (SD) [23], and the Law of Comparative Judgement (LCJ) [24].
As information technology advanced, landscape visual research increasingly integrated remote sensing and computer-assisted analysis to establish more scientific evaluation systems [25,26]. Over time, research on landscape visual assessment

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has gained momentum, with a notable increase in publication volume in recent years.

Before 2000, annual publication output was relatively low, as the field remained in an exploratory phase. From 2000 to 2020, publication volume gradually increased as research methods matured, enhancing the scientific credibility of findings. The growing body of literature and increasing international recognition suggest that research in this area has gained broader academic acceptance.

A significant milestone in 2009 was the development of a database simulating landscape visual characteristics to assess the impact of landscape elements and their visual features on residential property values. This study represented an early application of streetscape visual assessment in practice [27].

From 2021 onwards, research in this field has experienced explosive growth. As illustrated in FIG, the most frequently emerging keywords during this period include performance, model, and view, reflecting the impact of new technologies on the discipline. Many researchers have begun leveraging online street-view images instead of on-site image collection to improve efficiency [28–30]. Similarly, deep learning models have been introduced to landscape visual quality assessment, with a strong focus on model performance [31,32].

At the same time, visual comfort has garnered increasing academic attention. Researchers have examined lighting levels, contrast, glare control, colour temperature, and spatial layout to assess the visual quality of spaces [33]. In architecture and design, the importance of visual comfort is now widely recognised [34]. Ensuring visually comfortable environments is crucial for creating spaces that support prolonged occupancy, allowing individuals to carry out various tasks effectively without experiencing visual discomfort [35].

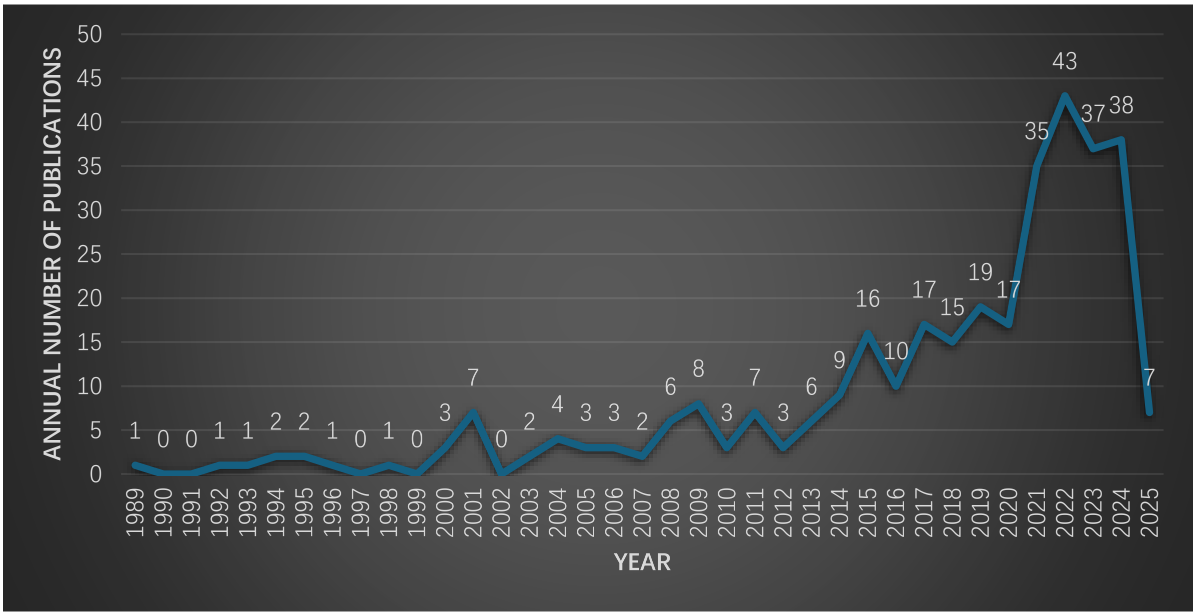

Figure 1. Annual publication count on landscape visual quality assessment

Figure 2. Top 17 keywords with the strongest citation bursts

3.2 Keyword Co-occurrence Analysis

CiteSpace was used to generate keyword co-occurrence and clustering knowledge maps, enabling a comprehensive examination of research trends through count, centrality, burst strength, and starting year statistics [36]. To minimise statistical bias, keywords were manually deduplicated and merged, and redundant terms overlapping with the search formula were removed. The statistical results are presented in Table 1, Figure 3 and Figure 4.

No.	Key Words	Count	Centrality	Year	No.	Key Words	Count	Centrality	Year
1	Perception	67	0.23	1995	16	Forest	9	0.03	2001
2	Quality	54	0.2	2000	17	Visual Impact	9	0.03	2004
3	Preference	44	0.09	2001	18	Model	9	0.06	2016
4	Scenic Beauty	30	0.1	2000	19	Space	8	0.05	2006
5	Impact	25	0.08	2014	20	View	8	0.02	2005
6	Aesthetic	27	0.11	2001	21	Indicators	8	0.04	2011
7	Design	18	0.11	2010	22	Visualization	8	0.04	2004
8	Landscape Environment	27	0.09	1994	23	Agroindustrial Buildings	8	0.02	2009
9	Performance	11	0.02	2014	24	Attributes	8	0.03	2006
10	Management	11	0.02	2001	25	Built Environment	7	0.03	2013
11	Visual Assessment	11	0.05	1994	26	Visual Impact Assessment	7	0	2022
12	Health	10	0.01	2015	27	GIS	7	0.04	2005
13	Buildings	10	0.1	2017	28	Visibility	6	0.04	2005
14	Photographs	10	0.06	2001	29	Eye Tracking	6	0.01	2015
15	Urban	9	0.02	2019	30	Visual Comfort	6	0.01	2022

Table 1. Frequency and centrality of the top 30 keywords

Centrality is a key indicator for assessing the importance of keywords (Table 1). A centrality value above 0.1 indicates that a keyword is a central node, suggesting its significance and influence within the field [36]. Among the keywords, perception ranks highly in both count and centrality, demonstrating its fundamental role in landscape visual quality research. Since 2001, the keyword preference has gained increasing attention, indicating a shift in scholarly focus from unidimensional landscape perception to the broader concept of landscape experience, which encompasses interactions between people and their environment [37]. This interaction can represent both the ideal vision of an observer and the design intent of a landscape architect [38].

While landscape and forest had already appeared in publications by 1994, keywords such as urban and building only gained increased academic attention after 2017. This trend aligns with citation bursts (figure 2), which indicate a shift in research focus from forests, suburban areas, and scenic spots towards high-density urban environments during this period.

To further clarify the research domains associated with key topics in landscape visual quality assessment, an LLR (log-likelihood ratio) algorithm was applied to the CiteSpace-generated keyword co-occurrence map to extract clustering labels. The maximum number of clusters was set to 12 to meet research needs. The effectiveness of the clustering map was evaluated using Modularity (Q) and Silhouette (S) indices. The Q value, ranging from 0 to 1, indicates the structural significance of the network, with $Q > 0.3$ suggesting a meaningful cluster structure, while a higher Q value reflects stronger clustering performance. The S value measures network homogeneity, where $S > 0.5$ indicates reasonable clustering, and $S > 0.7$ suggests highly reliable clustering [39]. In this study, the Q value was 0.5336 and the S value was 0.639, indicating

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well-defined and reliable clusters (Figure 3).
Based on the clustering results, research themes can be categorised into three major domains:
Understanding and evaluating the environment [27,40,41];
Modifying and managing the environment [12,13,42];
Exploring the interactions between the environment and human perception and behaviour [43–46].
The timeline-based cluster map (Figure 4) further reveals a developmental trajectory that can be summarised into three progressive stages: understanding, intervention, and exploration of underlying mechanisms.

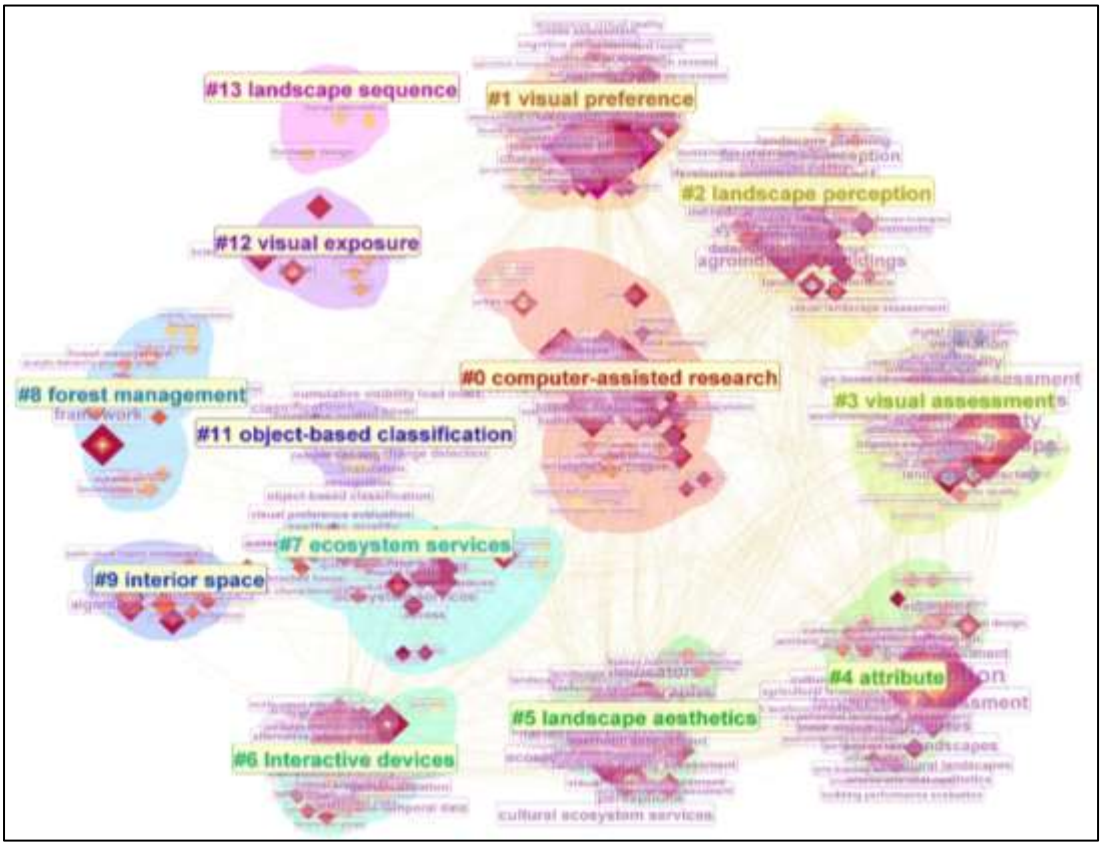

Figure 3. Keyword co-occurrence map

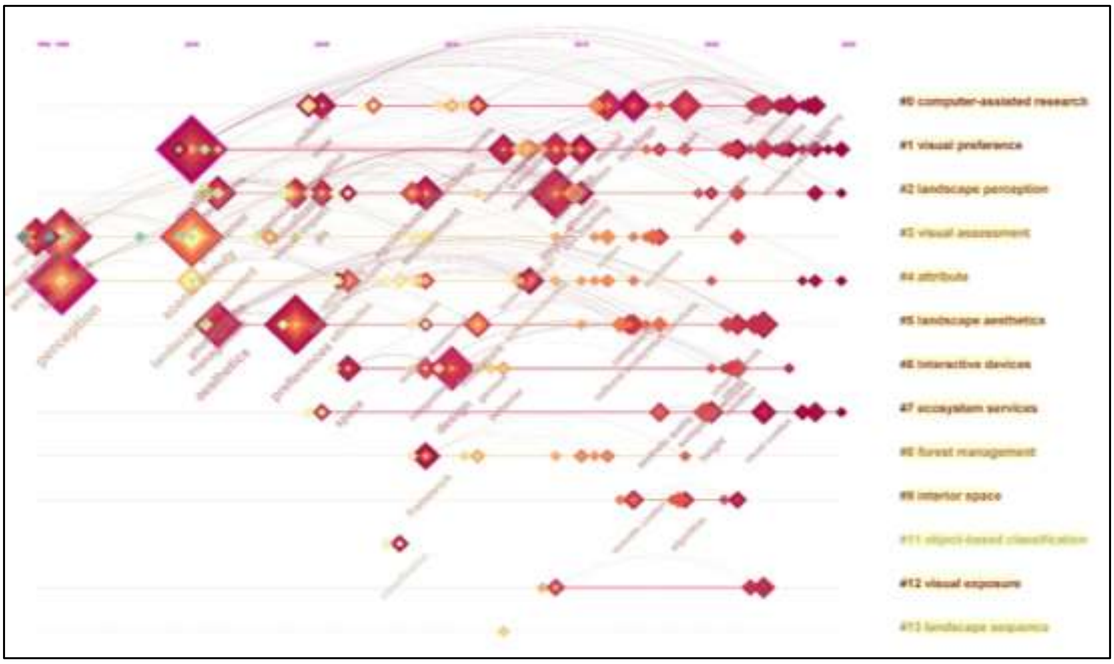

Figure 4. Timeline-based cluster map

3.3 Analysis of Author, Institution, and National Collaboration Networks

In terms of citation frequency, T.C. Daniel is the most highly cited author, with 78 citations. His research emphasises a human-centred approach to design, focusing on how spatial environments influence human interaction and emotional experiences. He argues that landscapes are not merely physical spaces but also serve as cultural, emotional, and social conduits [47]. Over the years, he has provided periodic reviews of landscape visual assessment methods and trends [22,22,48,49].

In this analysis, J.F. Palmer is the second most cited author, with 56 citations. His perspectives align closely with those of Daniel, with the distinction that Palmer, through experimental and field studies, demonstrated that specific landscape forms and natural elements-such as greenery, open spaces, and water bodies-can evoke positive emotional responses and enhance quality of life [50]. He also contributed to the identification and classification of visible landscape attributes [51].

R. Kaplan is recognised for his major academic contribution to restorative environment theory, which posits that restorative environments should encompass four key characteristics: predictability, complexity, opportunities for exploration that meet individual needs, and engagement with natural elements [52].

Meanwhile, I.D. Bishop highlights that landscape assessment should consider not only aesthetics but also social needs. In the context of urbanisation, he explores how landscape design can enhance the usability and accessibility of public spaces. He pioneered the application of various computer-aided techniques to conduct quantitative research in this field [53–55].

No.	Author	Count	No.	Author	Count
1	DANIEL T.C.	78	11	DUPONT L.	26
2	PALMER J.F.	56	12	ARRIAZA M.	25
3	KAPLAN R.	46	13	APPLETON J.	24
4	BISHOP I.D.	42	14	SMARDON R.C.	23
5	STAMPS A.E.	42	15	TVEIT M.	22
6	ULRICH R.S.	37	16	VAN DENBERGAE	21
7	GOBSTER P.H.	35	17	LYNCH K.	21
8	ZUBE E.H.	35	18	HULL R.B.	18
9	KAPLAN S.	35	19	SHEPPARD S.R.J.	17
10	LOTHIAN A.	27	20	SHAFER E.L.	15

TABLE 2. Statistics of the top 20 most cited authors

In Figure 5, the concentric rings within each node represent the time periods in which publications were produced, while the radius of each node indicates the volume of publications. As shown in Figure 5 and Table 3, China has been the leading country in terms of publication output over the past 30 years, followed by the United States, the United Kingdom, and Italy. In terms of publication timeline, Spain and Malaysia are also among the first-tier countries, having initiated relevant research relatively early.

The connecting lines in Figure 5 illustrate international collaboration networks. While Malaysia has been an early contributor to the field and has produced a significant number of publications, it has not emerged as a central node in international research collaboration.

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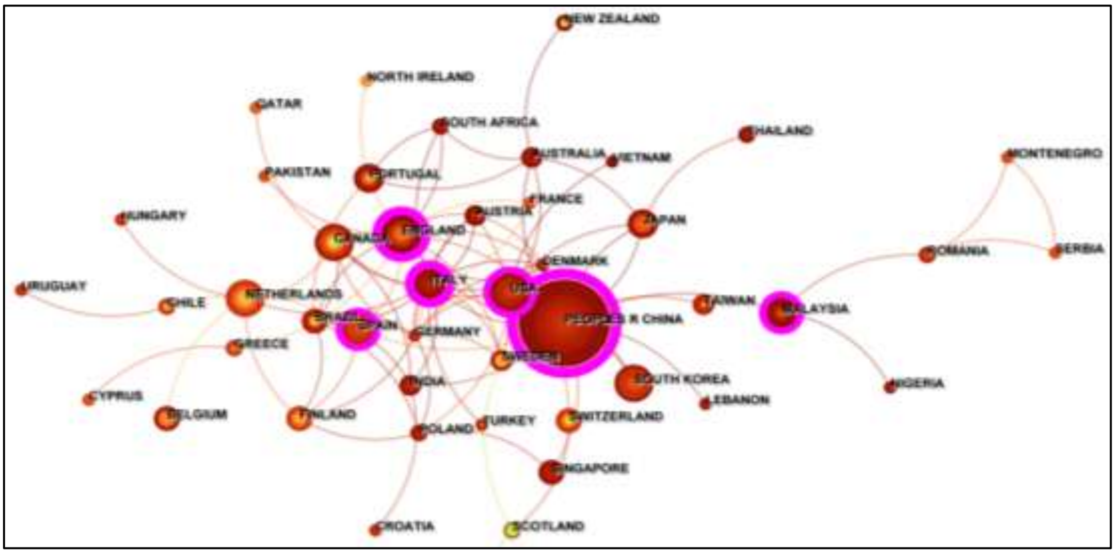

Figure 5 Network map of national collaborations

No.	Institution	Count	No.	Institution	Count
1	China University of Mining & Technology	8	16	City University of Hong Kong	3
2	National University of Singapore	5	17	Chinese Academy of Sciences	3
3	Harbin Institute of Technology	5	18	Hanyang University	3
4	Nanjing Forestry University	5	19	RWTH Aachen University	3
5	Swiss Federal Institutes of Technology Domain	5	20	Istanbul Technical University	2
6	Tongji University	4	21	Harvard University	2
7	Delft University of Technology	4	22	McGill University	2
8	Cornell University	4	23	California Polytechnic State University San Luis Obispo	2
9	Ghent University	4	24	Universidad Politecnica de Madrid	2
10	Universidad de Extremadura	4	25	Universidad de Malaga	2
11	Technion Israel Institute of Technology	4	26	TJ Boyle Associates	2
12	ETH Zurich	4	27	Jiangsu Normal University	2
13	University of Sheffield	4	28	University of Arizona	2
14	University of Melbourne	3	29	AGH University of Krakow	2
15	California State University System	3	30	Yildiz Technical University	2

Table 3 Statistics of the Top 30 Most Cited Institutions

4. THE MAIN PARADIGMS AND METHODOLOGIES OF LANDSCAPE VISUAL QUALITY ASSESSMENT

4.1 Three Stages of Methodological Development

Between the 1970s and 1990s, various academic schools worldwide began integrating and refining landscape visual assessment methods. Humanistic, socio-economic, and ecological indicators were progressively incorporated into evaluation frameworks, leading to a shift towards comprehensive and diversified assessment systems. During this period, two key landscape evaluation models emerged: the preference model[56,57] and the surrogate component model [58]. These models laid the foundation for four widely recognised paradigms in landscape visual assessment: the expert paradigm [59], the psychophysical paradigm [60,61], the cognitive paradigm [61], and the experimental paradigm [62], among which the expert paradigm and psychophysical paradigm have been the most extensively applied.

The expert paradigm is exemplified by methodologies such as VMS (Visual Management System), VRM (Visual Resource Management), and LRM (Landscape Resource Management) in the United States. In contrast, the psychophysical paradigm advocates using the general public's aesthetic preferences as a benchmark for evaluating landscape visual quality. Representative methods within this paradigm include the Semantic Differential (SD) method, the Scenic Beauty Estimation (SBE) method, and the Balanced Incomplete Block-Law of Comparative Judgement (BIB-LCJ) method.

Building on these paradigms, four additional evaluation models were developed: the ecological model, the formal aesthetic model, the psychological model, and the phenomenological model[63]. The ecological and formal aesthetic models primarily focus on expert-driven or design-based evaluation, while the psychological and phenomenological models emphasise public perception and behavioural responses.

In these models, psychophysical and surrogate component models can be classified as quantitative synthesis approaches, integrating subjective and objective methods while emphasising the stimulus-response process. Each paradigm, grounded in distinct theoretical foundations, applies different evaluation methods and perspectives to assess specific landscape elements and environmental contexts.

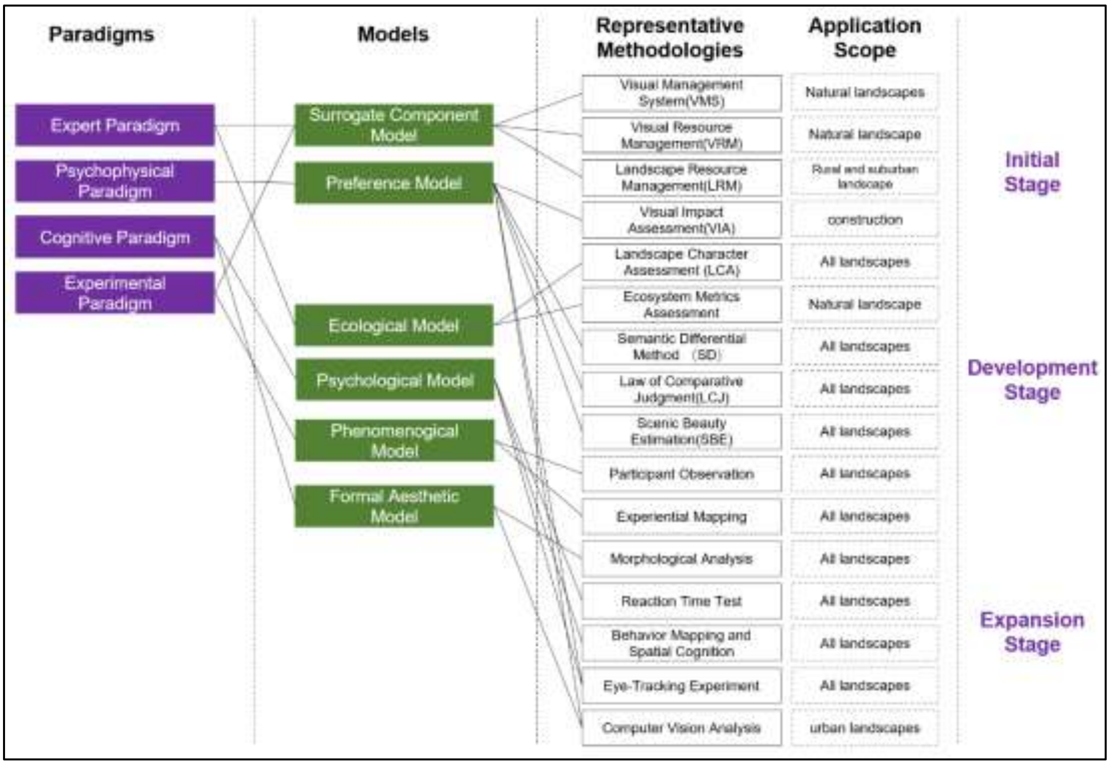

Figure 6 Main research paradigms and methodologies in landscape visual quality assessment

4.2 Comparison of Landscape Visual Quality Assessment Paradigms

The four primary paradigms for assessing landscape visual quality each have distinct characteristics and applications.

a. Expert Paradigm

This paradigm relies on trained professionals to evaluate landscapes based on aesthetic principles and regulations, guiding planning and management [59]. While ensuring standardised assessments, it may overlook public perception. It includes the Morphometric Paradigm, which quantifies landscape characteristics, and the Ecological Paradigm, which integrates aesthetics with ecological principles [49].

b. Psychophysical Paradigm

Rooted in experimental psychology, the Psychophysical Paradigm conceptualises landscape aesthetics as a stimulus-response mechanism, employing mathematical models to quantify visual quality [64]. Two prominent methods within this paradigm are Scenic Beauty Estimation (SBE) and the Law of Comparative Judgement (LCJ). SBE, which uses photographs for evaluation, is straightforward and accessible but susceptible to subjective emotional biases [22]. In contrast, LCJ, which involves paired comparisons of landscapes, offers greater accuracy but requires complex computations and a more extensive evaluation process [65,66].

c. Cognitive Paradigm
Based on evolutionary theory and focuses on human survival and functional needs. This paradigm emphasises cognitive and emotional responses to landscapes [67]. It examines how landscapes fulfil human survival and functional needs, integrating psychological and behavioural perspectives [68].
d. Experimental Paradigm
This paradigm prioritises personal perception, interpreting landscape aesthetics through cultural, historical, and individual experiences [69]. Relying on artistic and literary analysis, it offers insight into subjective interpretations but lacks systematic evaluation frameworks [49].
A comprehensive assessment of landscape visual quality may benefit from integrating multiple paradigms to capture both objective and subjective dimensions.

5. TRENDS AND KEY RESEARCH AREAS IN LANDSCAPE VISUAL QUALITY ASSESSMENT

Over the past half-century, research on landscape visual quality assessment has been characterised by the interplay between two contrasting yet interconnected approaches: expert-based quantitative evaluation (the objective school) and public perception-based evaluation (the subjective school). The former primarily employs Environmental Metrics to facilitate landscape visual assessments, while the latter focuses on collecting public perception data through more practice-oriented evaluation theories and methodologies. Among these, the subjective approach has been predominant in the field.
Two primary dimensions have garnered significant attention in landscape visual quality research: the physical characteristics of the environment and human sensory experience. In recent years, research has increasingly embraced a hybrid approach that integrates both subjective and objective methodologies. This typically involves constructing models and indicator systems to assess visual quality, followed by validation through survey data from respondents to refine and corroborate the findings.
With advancements in modern technology, the proliferation of computational tools, and the maturation of visual quality assessment theories, a growing number of innovative techniques and tools have been incorporated into landscape visual quality studies. Beyond traditional methods such as photographs, slides, and photomontages, technologies such as Virtual Reality (VR) [70,71], Augmented Reality (AR) [72], and 3S technologies (Remote Sensing, Global Positioning System, and Geographical Information System) [73,74] have been applied. Additionally, visual perception simulations, landscape visualisation models, and digital landscape technologies [75,76] are increasingly utilised in landscape visual assessments. These advancements indicate a clear research trend towards digitalisation, precision, and intelligence in landscape visual quality evaluation.
However, several critical issues remain unresolved. These include the integration of landscape elements into environmental management strategies, effective communication of landscape characteristics to facilitate accurate public perception, and the complex interactions between the physical environment and human perception.
Since the beginning of the 21st century, research priorities in landscape visual assessment have gradually shifted from comprehensive aesthetic evaluations and landscape characteristics analysis towards a more multidimensional approach that integrates social and ecological values. Currently, most studies rely on the construction or adaptation of evaluation indicator systems, with an emphasis on objective assessment complemented by subjective evaluation. The prevailing methodology involves a combination of qualitative and quantitative techniques to analyse specific factors, refine assessment models, and optimise evaluation frameworks. Despite ongoing innovations in evaluation techniques and systems, landscape characteristics and respondents' psychological states are dynamic, making it challenging to capture and interpret these complexities using existing technologies. Consequently, many assessment conclusions tend to have a limited temporal validity.
At present, landscape visual quality assessment research exhibits a multidisciplinary and integrative trajectory, with various schools of thought converging. Over decades of theoretical evolution, the focus of visual assessments has expanded-from addressing conflicts between forestry activities (such as logging and planting) and aesthetic considerations to enhancing people's overall experience in specific environments. The evaluation perspective has evolved from aesthetic appraisal alone to a broader framework encompassing ecological, social, and psychological dimensions.

Early theoretical contributions to environmental visual research stem from frameworks such as the Visual Management System (VMS) in the United States [77] and the Proactive Design Approach (PDA) in the United Kingdom [78]. However, these systems are not readily adaptable to most regional landscape visual quality assessments. Currently, many areas-especially in developing countries-lack systematic and universally applicable evaluation standards and management frameworks. This further underscores the complexity of visual quality assessments and the limitations of existing methodologies.

6 CONCLUSION

This study conducted a scientometric analysis of literature on landscape visual quality assessment indexed in the Web of Science (WoS) database up to February 2025. Using CiteSpace 6.4 R1 for data processing and visualisation, it systematically reviewed the development trajectory, research hotspots, and emerging trends in this field. The key findings can be summarised as follows:

a. Publication Trends: Since 2021, there has been an explosive increase in research publications, largely driven by advancements in data collection and analysis technologies. The integration of 3S (Remote Sensing, GIS, GPS) and computer-assisted analysis has become a major technical focus.

b. Scope of Research: There has been a clear progression from natural areas to rural and suburban environments, and eventually to urban contexts. Compared to natural settings, urban visual components are more complex and difficult to categorise. However, technological advancements have enabled this shift in focus.

c. Research Focus: Early studies primarily emphasised the aesthetic value of landscapes. Since the 21st century, there has been a gradual shift towards social, cultural, and ecological values. The focus has also expanded from examining the impact of the environment on people to exploring the dynamic interactions between the two.

d. Research Institutions and International Collaboration: Early visual quality assessments were mainly conducted for government agencies and environmental management departments, resulting in limited international collaboration. In recent years, academic networks between international authors and institutions have become increasingly interconnected.

e. Methodological Development: Research has evolved from single-disciplinary approaches to multidisciplinary integration, incorporating techniques from ecology, computer science, and other related fields.

Assessing landscape visual quality is of significant importance for ecological restoration, aesthetic enhancement, and cultural heritage preservation. Currently, this field is closely intertwined with psychology, behavioural sciences, ecology, and sociology, making it highly interdisciplinary but also more challenging. Several key issues remain unresolved:

a. Understanding the underlying mechanisms of human-environment interactions: While the mutual influence between landscapes and human perception is widely acknowledged, the complex mechanisms underlying this relationship remain difficult to define.

b. Generalisation and Sustainability of Findings: As both landscapes and their audiences are dynamic-subject to ecological and social changes-many research findings are questioned for their long-term applicability. Greater attention should be given to ensuring the generalisability and sustainability of assessment methods and conclusions.

c. Bridging Research and Practice: Advances in technology have enabled more efficient and fine-grained assessments. However, a critical challenge lies in integrating research findings into landscape and urban management practices to enhance practical outcomes.

Addressing these challenges will be crucial in advancing the field of landscape visual quality assessment and improving its real-world applications.

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