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SUSTAINABLE GOVERNANCE OF CULTURAL LANDSCAPES: EVOLUTION AND POLICY TRENDS OF LANDSCAPE GENE CONSERVATION IN CHINA (2003–2025)

GOVERNANÇA SUSTENTÁVEL DE PAISAGENS CULTURAIS: EVOLUÇÃO E TENDÊNCIAS POLÍTICAS DA CONSERVAÇÃO GENÉTICA DA PAISAGEM NA CHINA (2003–2025)

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Abstract
Objective: From the perspective of sustainable governance, this study explores the evolutionary trajectory of "landscape gene" research in China to understand how policy frameworks and legal instruments shape the preservation of traditional settlements.Methods: Utilizing bibliometric tool CiteSpace , a quantitative analysis was conducted on literature from the CNKI database (2003–2025), focusing on the intersection of heritage conservation, environmental law, and digital governance.Results: The research reveals that landscape gene studies in China have evolved through three logical dimensions: theoretical ontology construction, multi-scale empirical verification, and methodological innovation driven by strategic policy responses. Since 2017, the field has entered a phase of intensive growth, shifting from qualitative descriptions to digital and intelligent integration.Conclusion: The evolution of landscape gene research is deeply intertwined with China's national strategies, such as "Rural Revitalization" and the "Protection of Traditional Villages," reflecting a transition from spontaneous academic interest to a policy-led governance model. To enhance the sustainable development of cultural landscapes, future research must further integrate legal-spatial

Resumo
Objetivo: Do ponto de vista da governança sustentável, este estudo explora a trajetória evolutiva da pesquisa sobre "genes da paisagem" na China para compreender como as estruturas políticas e os instrumentos jurídicos moldam a preservação dos assentamentos tradicionais. Métodos: Utilizando a ferramenta bibliométrica CiteSpace, foi realizada uma análise quantitativa da literatura da base de dados CNKI (2003-2025), com foco na interseção entre conservação do patrimônio, direito ambiental e governança digital. Resultados: A pesquisa revela que os estudos sobre genes da paisagem na China evoluíram por meio de três dimensões lógicas: construção ontológica teórica, verificação empírica em múltiplas escalas e inovação metodológica impulsionada por respostas políticas estratégicas. Desde 2017, o campo entrou em uma fase de crescimento intensivo, passando de descrições qualitativas para integração digital e inteligente. Conclusão: A evolução da pesquisa sobre genes da paisagem está profundamente entrelaçada com as estratégias nacionais da China, como a "Revitalização Rural" e a "Proteção de Aldeias Tradicionais", refletindo uma transição do interesse acadêmico espontâneo para um modelo de governança

frameworks with digital technology, ensuring that heritage conservation is supported by robust institutional mechanisms and internationalized theoretical standards.

Keywords: Sustainable Governance. Landscape Gene. Heritage Protection Policy. Environmental Law. Knowledge Mapping.

orientado por políticas. Para aprimorar o desenvolvimento sustentável das paisagens culturais, pesquisas futuras devem integrar ainda mais as estruturas jurídicas-espaciais com a tecnologia digital, garantindo que a conservação do patrimônio seja apoiada por mecanismos institucionais robustos e padrões teóricos internacionalizados.

Palavras-chave: *Governança Sustentável. Gene Paisagístico. Política de Proteção do Patrimônio. Direito Ambiental. Mapeamento do Conhecimento.*

1 INTRODUCTION

Against the backdrop of rapid globalization and urbanization, the sustainable governance of cultural landscapes has emerged as a core concern within international legal scholarship and the environmental social sciences. Cultural landscapes are not merely physical spatial entities; they are cultural assets protected under specific legal frameworks and social norms. Precisely identifying and effectively transmitting the irreplaceable cultural characteristics inherent in these landscapes is fundamental to constructing a rule-of-law system for heritage protection. Within this context, the theory of "Landscape Genes" provides a unique cognitive paradigm and technical pathway for the standardized preservation of cultural landscapes.

The concept of the "Landscape Gene" was originally proposed by Chinese scholar Liu Peilin, rooted in a localized context, and defined as "a core factor transmitted across generations that determines the distinctive character of a landscape" [1]. Although this theory draws upon the logic of biological genetics, its essence aligns with the exploration of cultural transmission mechanisms in Western academia. As early as the 1940s, Taylor utilized comparative research to extract stable features of village spaces [2]. In the 1950s, anthropologists Kroeber and Kluckhohn outlined the primitive connotations of "cultural genes," and in 1976, Richard Dawkins' "Meme" theory confirmed the imitation mechanism of cultural units from a multi-disciplinary perspective [3]. These global explorations have laid the theoretical foundation for transitioning landscape genes from a spatial morphological description to a tool for social governance.

In China, the rise and deepening of landscape gene research have demonstrated significant synchronicity with the nation's legal formalization process and the evolution of heritage protection policies. Since 2003, with the promulgation of the Outline for the Protection and Development of Traditional Villages and the Guiding Opinions on Strengthening the Protection and Development of Traditional Villages, the preservation of traditional villages has shifted from sporadic administrative protection to systematic, rule-of-law governance. However, in legal practice, defining the "authenticity" and "integrity" of protected objects often lacks quantitative standards. By providing a logical framework of "identification-extraction-restoration," the landscape gene theory is increasingly becoming a critical scientific basis for the implementation of heritage protection policies and the achievement of sustainable governance for cultural landscapes.

In view of this, the present study utilizes bibliometric methods to systematically examine the evolutionary trajectory of landscape gene research in China from 2003 to 2025. This research focuses not only on the evolution of academic theories but also on how landscape gene research responds to macro-policy demands, such as "Rural Revitalization" and "Heritage Rule of Law." Furthermore, it analyzes future trends in sustainable governance systems empowered by digital technology, aiming to provide a reference for international cultural heritage management and the construction of related legal systems.

2 RESEARCH METHODOLOGY AND DATA COLLECTION

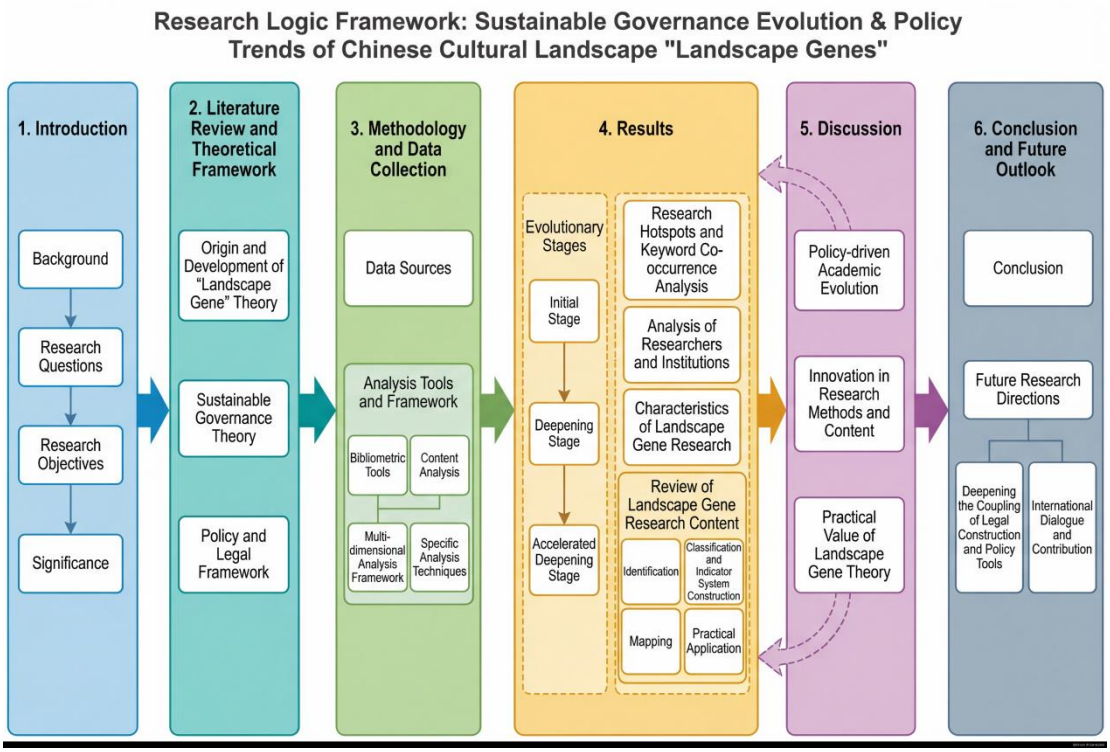
Regarding the selection of data sources, this study adheres to the principles of systematicity and relevance to localized governance. Initial searches were conducted in international databases such as Web of Science and Scopus; however, in-depth identification revealed that 96% of the core author groups originated from Chinese academic institutions. Furthermore, the volume of foreign language literature proved insufficient to support a profound cluster analysis of responses to macro-policies unique to China, such as "Rule-of-Law Protection" and "Rural Revitalization." Given that the "Landscape Gene" theory serves as a critical scientific pillar for China's traditional village protection systems and the legal practice of sustainable cultural heritage

governance, the China National Knowledge Infrastructure (CNKI) academic journal database was ultimately designated as the primary source for metadata accreditation. This ensures that the research sample accurately reflects the interactive logic between policy shifts and academic outputs within China's cultural landscape governance. The observation window spans from 2003 to December 31, 2025. Following a keyword search for "Landscape Gene" and the exclusion of non-academic texts—such as policy briefs, newsletters, and news reports—a refined corpus of 663 high-quality academic papers was established as the fundamental units of analysis.

In terms of analytical tools and frameworks, this study transcends simple software application by deeply integrating the econometric functions of CiteSpace and VOSviewer with the content analysis methods commonly employed in legal sociology. By constructing a multi-dimensional analytical framework comprising "structural mapping, spatio-temporal evolution tracing, and frontier burst detection," this research utilizes co-occurrence and clustering techniques to identify core domains in cultural landscape governance. Furthermore, Timeline and Time-zone visualizations are employed to cross-reference the migration trajectories of academic hotspots with key legal and policy milestones in national heritage protection. This approach reveals how the research paradigm has shifted from early qualitative descriptions toward a policy-driven "identification-monitoring-governance" system empowered by digital technology. This methodological design not only ensures the scientific validity of the conclusions but also strengthens the study's reference value for the institutional construction of sustainable cultural heritage development.The logical framework diagram is detailed as follows Figure 1 .

Figure 1

The logical framework



3 RESEARCH HOTSPOTS AND KEYWORD CO-OCCURRENCE ANALYSIS

The keyword co-occurrence network generated via CiteSpace reveals that landscape gene research in China has evolved into a knowledge map characterized by a typical "core-periphery" structure. Within this network, "Landscape Gene" emerges as the pivotal node with the highest betweenness centrality, forming a stable coupling relationship with core elements such as "Traditional Villages" and "Cultural Landscapes." This confirms a central paradigm focused on deconstructing the cultural connotations of settlements through gene theory (see Figure 2). Cluster analysis, conducted through the g-index algorithm and network topology construction, yielded robust indicators (Modularity Q = 0.797; Mean Silhouette S = 0.872), clearly delineating three highly credible logical pillars within the landscape gene field (see Figure 3).

The first pillar is the Ontological Construction of Theory, centered on clusters "#0 Landscape Gene" and "#2 Cultural Gene." This dimension is dedicated to extracting the core codes of regional cultural transmission from biological metaphors, providing a

jurisprudential and academic foundation for the systematic protection of cultural landscapes.

The second pillar involves Empirical Evidence Across Multi-scale Objects, encompassing clusters "#1 Traditional Villages," "#4 Traditional Settlements," and micro-level cases (e.g., "#12 Nanyue Ancient Town"). This indicates that current Chinese research focuses on empirical studies of traditional villages and settlements at various scales. Through the refined identification of micro-cases like Nanyue Ancient Town, the research has become deeply integrated into the classified governance and planning practices of Chinese traditional villages. Notably, in Table 1, "Traditional Villages" and "Traditional Settlements" immediately follow "Landscape Gene" in frequency, reflecting the close synergy between theory and spatial governance practice.

The third pillar represents Methodological Innovation and Policy Response, extending to "#5 Gene Map" and "#8 Rural Revitalization" strategies. This explains the underlying drivers for the global dominance of Chinese scholars in this field and reveals how landscape gene research—facilitated by digital technology—has transitioned from pure morphological description to dynamic monitoring and long-term protection mechanisms serving national sustainable governance strategies. This evolutionary shift from qualitative identification toward quantitative and digital governance constitutes the core blueprint for the future trends of China’s landscape gene protection policies.

Table 1

Top 20 High-Frequency Keywords in Landscape Gene Research

Keyword	Frequency	Year
Landscape Gene	275	2008
Traditional Village	177	2012
Traditional Settlement	61	2006
Cultural Landscape	59	2003
Cultural Gene	59	2003
Gene Mapping	31	2009
Gene Identification	27	2010
Spatial Gene	21	2020
Mapping Construction	18	2018
Rural Revitalization	15	2021
Landscape Character	14	2012
Landscape Design	13	2020
Rural Landscape	12	2017
Vernacular Landscape	12	2018
Identification	11	2012

Conservation Strategy	10	2017
Landscape Architecture	10	2021
Conservation	9	2014
Ancient Village	9	2003
Atlas	7	2017

Figure 2

Keyword Co-occurrence Network Map

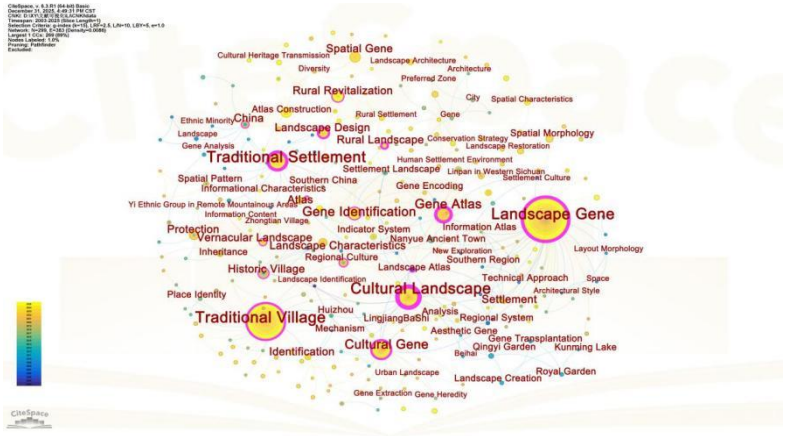


Figure 3

Keyword Clustering Map

Figure 4

Timeline Visualization

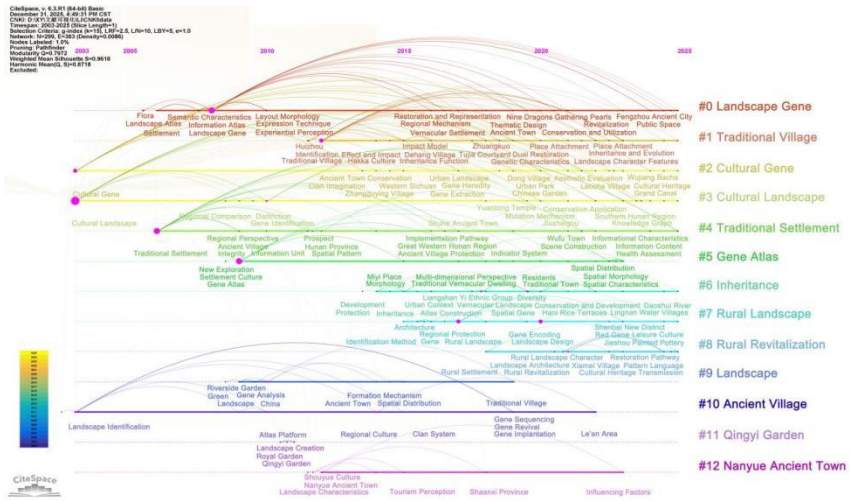


Figure 5

Keyword Burst Detection

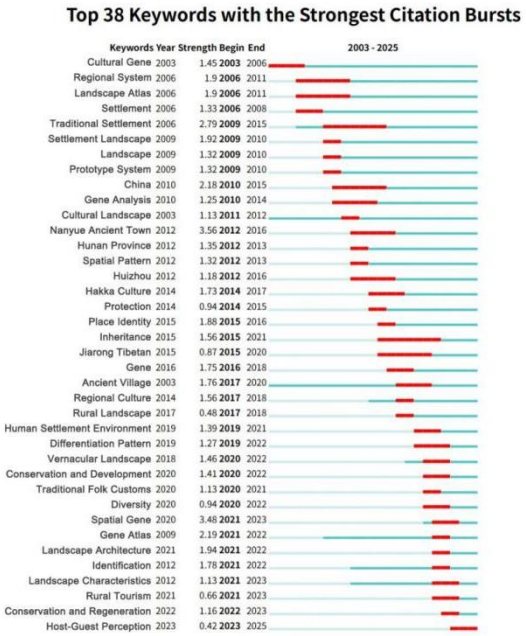
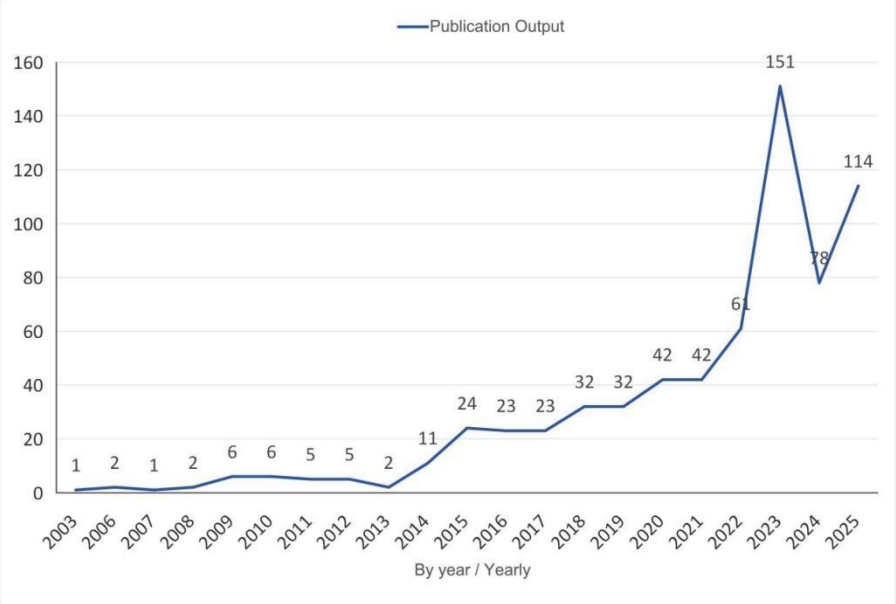


Figure 6

Annual Publication Output



4 THE EVOLUTIONARY PROCESS OF LANDSCAPE GENE RESEARCH

Based on the diachronic analysis of the CiteSpace timeline visualization (Figure 4) and keyword bursts (Figure 5), the trajectory of "Landscape Gene" research in China can be clearly delineated into three evolutionary stages, transitioning from theoretical foundations to deepened practical applications. The specific stages are as follows:

4.1 (1) Phase I: the incipient stage (2003–2009)

This period marked the embryonic stage and framework construction of China’s landscape gene theory, with its developmental trajectory closely intertwined with the establishment of early protection systems for historical and cultural towns and villages. In 2003, Chinese scholar Liu Peilin published the seminal paper proposing the concept and principles of landscape genes, aiming to uncover the intrinsic characteristics of settlements through genetic logic [1]. That same year, the Ministry of Construction and the State Administration of Cultural Heritage released the first list of "National Historical and Cultural Villages." This landmark administrative action formally initiated the legal

process for protecting traditional settlements at the national level, directly prompting academia to focus on the internal genetic composition of traditional villages.

In 2006, the theory was integrated for the first time with the tourism development of ancient villages and towns [6]. Concurrently, the research team at Hengyang Normal University pioneered the concept of the "Landscape Gene Map," achieving a holistic study of regional settlement landscape zoning and series within Chinese academia [7-10]. While outputs during this phase remained primarily within the realm of theoretical exploration, the nascent awakening of cultural heritage protection awareness within national legal and policy frameworks laid a solid institutional foundation for landscape gene research.

4.2 (2) Phase II: the deepening stage (2010–2016)

During this phase, the research focus shifted from pure theoretical discourse toward practical application and systematic governance, accompanied by a steady increase in publication volume. This transition was profoundly influenced by the systematic intensification of national efforts to protect traditional villages. Notably, the 2012 Notice on Carrying Out the Investigation of Traditional Villages, issued by four departments including the Ministry of Housing and Urban-Rural Development, formally established a mechanism for the census and identification of traditional villages.

Driven by these legal and policy dividends, research directions aligned closely with policy demands, focusing on methodological innovations such as landscape regionalization and gene identification elements [12], the "Cell-Chain-Shape" (C-C-S) identification method (Table 2) [11], environmental-spatial compatibility [13], platform system design [14-15], the OOCPLG landscape gene classification model [16], and coding and derivation models [17]. Scholars began exploring multi-dimensional intersections, such as deconstructing the urban image genes of Xi'an [18] or examining the translation and reorganization mechanisms of artistic conception in royal gardens [19].

With the 2014 release of the Guiding Opinions on Effectively Strengthening the Protection of Chinese Traditional Villages, protection efforts shifted from case-by-case development to systematic governance. This prompted the academic community to

achieve quantitative identification of regional landscape genes through multi-level evaluation index systems [20-21] and to innovatively apply K-modes clustering algorithms for spatial regionalization visualization [22]. These efforts provided scientific support for constructing a rule-of-law governance framework spanning from macro-strategy to concrete implementation.

Table 2

The "Cell-Chain-Configuration" Analytical Framework

Component	Constitutes
Cell	Fundamental landscape units, such as individual buildings and ancestral halls.
Chain	Landscape connectors and corridors, including water systems and pathways.
Configuration	The overall two-dimensional spatial pattern or layout of the landscape.

4.3 (3) Phase III: accelerated advancement and comprehensive deepening (2017–2025)

With the introduction of the "Rural Revitalization" strategy and the formal implementation of the Rural Revitalization Promotion Law of the People's Republic of China in 2021, landscape gene research entered a period of explosive growth in both output and scale. During this stage, the legal and policy framework expanded from mere "cultural preservation" to grand narratives involving "sustainable governance," "cultural security," and "digital heritage." Notably, following the release of advanced generative AI models such as ChatGPT-4.0 Turbo in late 2023, the leap in artificial intelligence technology provided new productive tools for landscape gene research. Guided by policies such as rural environment remediation, Chinese scholars have deeply integrated digital technologies to innovate research pathways.

Recent studies have moved from analyzing the regional mechanisms of Hakka cultural landscape genes to integrating digital technologies for cultural protection and heritage development [23]. These efforts encompass the use of space syntax for morphological analysis [24], 4D GIS for scene digitalization and virtual tourism management [25], systematic reviews of genetic attributes [26], and research into digital programming algorithms [27]. At the level of township construction, scholars have taken the Southern Hunan region as a case study to construct a complete chain of landscape

gene applications, integrating them into modern rural planning [28]. The scope of research has gradually expanded to the regional scale, forming a cyclical systemic framework of "development–restoration–protection–development" [29-30] while shifting toward a jurisprudential examination of regional and cultural alienation [31-32].

In terms of methodology, recent research emphasizes the transmission of "genetic information chains" [33]. By integrating GeoDesign with traditional settlement landscape gene frameworks, scholars have developed an identification paradigm based on the three-dimensional coupling of "Time-Space-Culture." This includes the creation of cultural landscape morphological gene coding sequence maps relying on computer programming logic [34-35]. Ultimately, through the combination of landscape gene programming maps and deep learning, researchers have achieved AI-driven 3D digital scene rendering, effectively dismantling the technical barriers of digital landscape gene research in the era of human-computer interaction [35-37].

4.4 (4) Policy-driven governance logic

From a macro-legal and policy perspective, the evolutionary logic of landscape gene research in China is highly consistent with the sustained commitments of the "No. 1 Central Document" issued annually. This hierarchical framework, extending from central macro-strategies to local regulations, has not only provided continuous administrative investment and institutional momentum for landscape gene research but has also established the legal status of traditional villages as "rule-of-law resources."

From the initial historical village protection system to the current Rural Revitalization Promotion Law, policy drivers have determined the shift in research hotspots. Moreover, through legal enforceability, they have ensured the mandatory application and scientific transmission of landscape gene theory in urban-rural planning, tourism design, and heritage conservation. This has culminated in a trinity-based sustainable governance paradigm characterized by policy guidance, legal safeguards, and academic support.

5 ANALYSIS OF RESEARCHERS AND RESEARCH INSTITUTIONS

Within the dimensions of academic social structure and knowledge governance, contributing authors and research institutions serve not only as the core drivers of disciplinary evolution but also as the "think tank" force promoting the implementation of landscape gene protection policies and sustainable governance.

Analysis of the author co-occurrence map (Figure 7) reveals a data set of N=277 and E=174, indicating that the field has formed a cohesive academic community centered around scholars such as Liu Peilin, Hu Zui, Deng Yunyuan, Li Bohua, and Shen Xiuying. These leading figures, through their high-output academic achievements and frequent scholarly collaborations, have established a stable research paradigm and played a critical guiding role. Although there are numerous peripheral nodes, most appear as scattered points, and the overall network density remains relatively low (Density = 0.0046). This suggests that beyond the core teams, there is significant potential for expanding broader cross-institutional collaborative networks.

Simultaneously, the institutional co-occurrence map (Figure 8) exhibits distinct clustering characteristics (N=201, E=205) and regional centrality. Research platforms represented by Hengyang Normal University, its affiliated colleges, and the National-Local Joint Engineering Laboratory occupy the central position of the research landscape, forming a powerful cluster advantage. While research efforts currently show strong regional concentration—primarily distributed in regions such as Hunan Province—the collaborative links with top-tier domestic institutions like Peking University and Tongji University foreshadow the emergence of a cross-regional research pattern characterized by "one leading institution with multi-point radiation." This organizational foundation is crucial for constructing a more internationally influential theoretical system for the sustainable governance of landscape genes in the future.

Figure 7

Author Co-occurrence Network

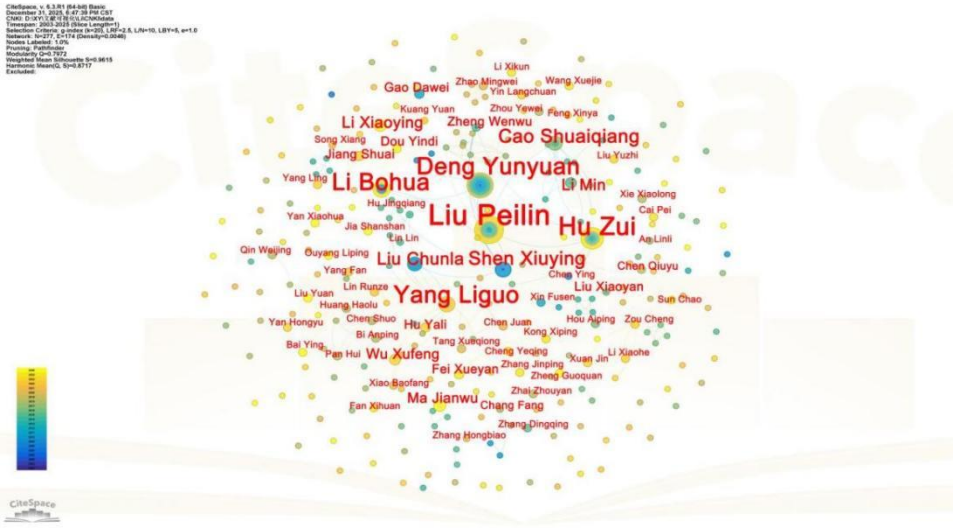


Figure 8

Institutional Co-occurrence Network

6 CHARACTERISTICS OF LANDSCAPE GENE RESEARCH

Landscape gene theory offers a novel methodological framework for observing the culture of Chinese traditional settlements from a natural science perspective [1, 38]. This theoretical framework integrates methodologies from various disciplines, including settlement geography, architecture, biological genetics, landscape morphology,

settlement typology, and historical geography [11]. By systematically synthesizing the core tenets of these related disciplines, landscape gene theory has evolved into a sophisticated and independent theoretical system.

Specifically, landscape morphology provides the foundation for morphological description and measurement; biological genetics inspires the analogical logic for cultural analysis; settlement typology guides systematic classification; historical geography offers analytical pathways for evolutionary processes; and architecture contributes specific perspectives for the analysis of physical spatial structures. Consequently, landscape gene theory represents the culmination of multidisciplinary intersection and fusion. Furthermore, the principles of landscape gene theory primarily rely on the construction of an indicator system [7, 15]. It employs quantitative analysis to decode the cultural characteristics of Chinese traditional settlements [18], providing valuable references for the protection and inheritance of traditional settlements as well as contemporary urban-rural construction. At the 2010 Annual Conference of the Geographical Society of China, Professor Xie Juemin, a tenured professor at the University of Pittsburgh, identified landscape gene theory as a "model for the localization of Chinese human geography research" [39].

From the perspective of research subjects, landscape gene theory is deeply rooted in the fertile empirical ground of Chinese traditional villages. Its research scope focuses on ancient village regions that possess a long history and retain significant cultural characteristics and relatively intact traditional appearances. The term "settlement" originates from the German word Siedlung, referring to small-scale or relatively independent communities and villages. Systematic exploration of settlements by foreign scholars began in the late 19th century, with definitions varying across disciplines. Geographers such as Dutta, Giunchiglia, and Maltese (2011) define a settlement as a city, town, village, or other built-up area where humans live and work [40].

Traditional settlements are defined as ancient villages, towns, and cities formed during historical periods that preserve prominent historical-cultural traits and a relatively complete historical character [41]. Research on Chinese traditional settlements can be traced back to the 1930s, emerging from the context of the "rural crisis" and the introduction of international theories in sociology, anthropology, and architecture. In his seminal work From the Soil: The Foundations of Chinese Society (Xiangtu Zhongguo),

Fei Xiaotong (2013) first systematically explored the characteristics and development of Chinese traditional settlements [42]. Furthermore, in April 2012, relevant departments of the State Council of China jointly issued the "Notice on Carrying Out the Investigation of Traditional Villages" (Guanyu Kaizhan Chuantong Cunluo Diaocha de Tongzhi). This document standardized various terms such as "ancient villages" (gucunluo) and "historical villages" (lishi cunluo) into the unified term "Traditional Villages" (Chuantong cunluo). The document explicitly defined traditional villages as those formed in early historical periods, possessing rich traditional resources, and holding significant historical, cultural, scientific, artistic, social, and economic value that warrants protection [43]. Therefore, the "Chinese traditional settlements" discussed in this research primarily refer to the regions of China's traditional villages.

China's splendid agrarian civilization has endowed its villages with integrated ecological and cultural systems, rendering them not only repositories for the preservation of material heritage but also the primordial contexts for intangible cultural heritage. Diverse physiographic conditions have nurtured an authentic "cultural gene pool" with distinctive ethnic characteristics, providing a rare systematic sample for the identification and theoretical construction of landscape genes. As research deepens, the role of landscape gene theory in the sustainable governance of cultural landscapes has become increasingly prominent. It offers a unique analytical lens and provides a scientific basis for management within a legal framework. Through the precise identification and transmission of these genes, research ensures that cultural heritage avoids the risks of blind development and cultural homogenization, thereby achieving synergy between economic growth and cultural preservation. This trajectory aligns closely with international legal concepts regarding cultural heritage law and sustainable development law, providing legitimacy and efficacy for local governments in formulating protection regulations and governance schemes.

Viewed from a diachronic evolutionary perspective, landscape gene research in China exhibits distinct staged shifts and significant policy orientation. The research trajectory has transitioned from an early exploratory phase—centered on the conceptual analysis of "ancient villages" and "regionalization"—to a methodological deepening phase focusing on "identification indicators" and "atlas construction." In particular, the explosion of burst keywords such as "Rural Revitalization," "Spatial Gene," and "Digital

Technology" signifies the discipline's transition from single-element qualitative description to multi-dimensional quantitative characterization and strategic national response.

The fluctuation in publication volume is intrinsically linked to China's rural development and protection directives (as shown in Figure 9); the policy terminology listed in Table 3 has also become pivotal keywords in the evolution of landscape gene research. In 2002, the institutionalization of the selection process for "National Famous Historical and Cultural Villages" began. Following the announcement of the first list in 2003, traditional settlements—as comprehensive heritage types bridging physical form and cultural connotation—gradually entered the core focus of academic inquiry. Against this backdrop, research on the protection and tourism utilization of historical and cultural settlements, framed by cultural landscape theory, intensified. Analysis shifted from isolated elements to the holistic exploration of landscape structures and generative mechanisms.

In 2006, the "No. 1 Central Document" explicitly stipulated for the first time that the protection of ancient villages and traditional dwellings with historical and cultural value must be strengthened during village governance and rural construction. Subsequently, successive No. 1 Central Documents deepened these requirements, proposing the establishment of a "Protection List of Traditional Villages and Traditional Dwellings" to transition from ad-hoc, rescue-based protection to systematic, categorized, and graded management. In 2014, a series of technical standards and policy documents were issued, including the "Several Opinions on Comprehensively Deepening Rural Reform and Accelerating Agricultural Modernization" and the "Guiding Opinions on Effectively Strengthening the Protection of Chinese Traditional Villages." These provided a clear institutional framework and methodological guidance for rural research and practice in China.

Driven by these policies, research on traditional settlement protection and tourism development based on "landscape gene" theory emerged as a focal point (Figure 9). Simultaneously, for the vast number of non-ancient villages not included in official lists, academia has expanded its focus to the holistic cognition and design translation of vernacular and regional cultural landscapes. Recent studies utilize the landscape gene perspective to decode implicit regional landscape traits and cultural information

structures in atypical traditional villages, providing a theoretical basis for local continuity in contemporary rural landscape design and renewal practices.

Table 3

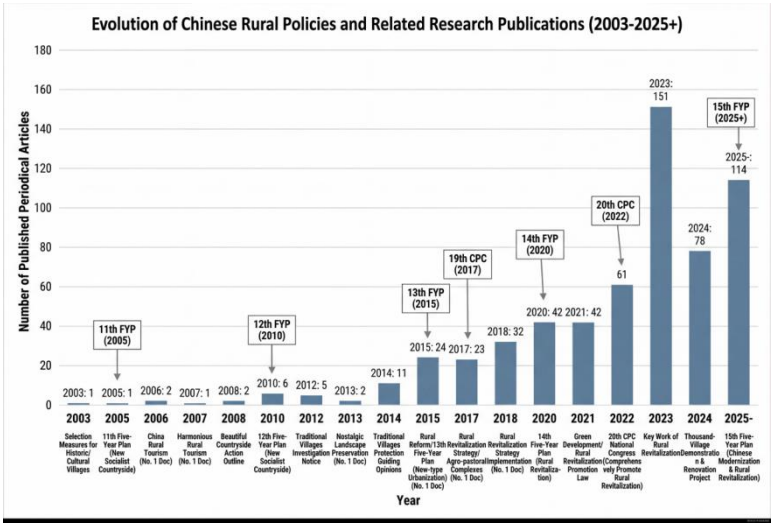
Key Policies Related to Rural Development in China

Year	Policies and Regulations
2003	Ministry of Construction and National Cultural Heritage Administration Release the "Selection Measures for Historic and Cultural Villages of China"
2005	Proposals of the CPC Central Committee for Formulating the 11th Five-Year Plan for National Economic and Social Development (Proposed the construction of a "New Socialist Countryside"); The 5th Plenary Session of the 16th CPC Central Committee first proposed "Beautiful Villages".
2006	The China National Tourism Administration (CNTA) proposed the theme for 2006 China Tourism: "China Rural Tourism"; Several Opinions of the CPC Central Committee and the State Council on Promoting the Construction of a New Socialist Countryside.
2007	CNTA proposed the theme for 2007 China Tourism: "Harmonious Rural Tourism"; Several Opinions of the CPC Central Committee and the State Council on Actively Developing Modern Agriculture and Solidly Promoting the Construction of a New Socialist Countryside (No. 1 Central Document).
2008	Action Outline for Building "Beautiful Countryside" in China.
2010	Proposals for Formulating the 12th Five-Year Plan for National Economic and Social Development (Proposed accelerating the construction of a New Socialist Countryside).
2012	Notice on Carrying out the Investigation of Traditional Villages.
2013	Several Opinions on Accelerating the Development of Modern Agriculture and Further Strengthening the Vitality of Rural Development (No. 1 Central Document); Emphasis on "allowing people to see the mountains and water, and remember their nostalgia" (Nostalgic landscape preservation).
2014	Guiding Opinions on Strengthening the Protection of Chinese Traditional Villages; Proposed increasing protection efforts for traditional villages to implement the spirit of the CPC Central Committee and State Council on protecting and carrying forward excellent traditional culture.
2015	Several Opinions on Effectively Deepening Rural Reform and Accelerating the Pace of Agricultural Modernization (No. 1 Central Document); Proposals for Formulating the 13th Five-Year Plan (Proposed promoting "New-type Urbanization").
2017	The Report to the 19th CPC National Congress proposed the "Rural Revitalization Strategy"; Several Opinions on Deepening the Reform of Agricultural Supply-side Structure and Cultivating New Drivers of Agricultural and Rural Development (No. 1 Central Document); Proposed developing the rural leisure tourism industry and building "Agro-pastoral Complexes" (Tian Yuan Zong He Ti).
2018	Opinions on Implementing the Rural Revitalization Strategy (No. 1 Central Document).
2020	The 14th Five-Year Plan (2021-2025) for National Economic and Social Development and the Long-Range Objectives Through the Year 2035 (Proposed comprehensively promoting rural revitalization).
2021	Opinions on Promoting Green Development in Urban and Rural Construction (Proposed building green and livable beautiful villages); The Rural Revitalization Promotion Law of the People's Republic of China officially came into effect.
2022	The Report to the 20th CPC National Congress proposed to "Comprehensively Promote Rural Revitalization" and prioritized the development of agriculture and rural areas; Opinions of the CPC Central Committee and the State Council on Comprehensively Promoting the Key Work of Rural Revitalization in 2022.
2023	Opinions of the CPC Central Committee and the State Council on Comprehensively Promoting the Key Work of Rural Revitalization in 2023.

2024	Opinions on Learning and Applying the Experience of the "Thousand-Village Demonstration and Ten-Thousand-Village Renovation" Project to Effectively Promote Comprehensive Rural Revitalization.
2025 -	The 15th Five-Year Plan (2026-2030): Accelerating agricultural and rural modernization and elevating the comprehensive promotion of rural revitalization to a strategic height concerning the overall situation and color of Chinese modernization.

Figure 9

Evolution of Chinese Rural Policies and Related Research Publications(2003-2025)



7 REVIEW OF LANDSCAPE GENE RESEARCH CONTENT

A comprehensive synthesis of existing literature and knowledge mapping visualizations reveals that research on the landscape genes of Chinese traditional settlements has established a rigorous logical closed-loop, extending from theoretical ontology identification to governance practice. The core mission of this framework is to decode the cultural genetic code that constitutes the uniqueness of traditional villages, maintain the fragile bonds of cultural diversity, and profoundly elucidate the dialectical isomorphic relationship between material landscape carriers and immaterial cultural connotations. From the academic dimension of sustainable governance, existing research primarily follows a four-stage progressive path that evolves from external forms to internal essence and from abstract concepts to concrete applications.

First, Landscape Gene Identification serves as the foundational premise. It emphasizes the systematic collection of natural environmental elements (e.g., geoclimate, vegetation, and landforms) and humanistic elements (e.g., historical context and social

structures) based on rigorous empirical field surveys. This process strictly adheres to the "Four Principles" [44] to accurately extract the core characteristics of villages (see Table 4).

Second, Gene Classification and the Construction of Indicator Systems constitute the pivotal stage of theoretical deepening. Existing studies have established diversified classification criteria based on different dimensions (see Table 5), marking the maturation of the theory and the laying of a foundation for rule-of-law-based management. Researchers have translated discrete physical information into a structured knowledge system, providing a standardized reference framework for subsequent policy formulation.

Building upon this, the Construction of Landscape Gene Atlases (see Table 6) serves as a critical spatial parsing tool. It facilitates the precise spatialization and graphic representation of abstract cultural traits, thereby intuitively revealing the evolutionary laws and internal logic of landscape genes across long historical trajectories. This cartographic representation is not merely a technical innovation but a strategic effort to delineate clear cultural protection redlines within territorial spatial planning, ensuring that the uniqueness of cultural landscapes remains resilient against the impacts of modernization.

Finally, all theoretical inquiries culminate in the practical application of Landscape Gene Protection, Restoration, and Transmission. These studies aim to explore mechanisms for the sustainable governance of traditional villages through the "activated utilization" of genes, simultaneously preserving local context and promoting national traditional culture. This research paradigm—transitioning from micro-gene extraction to macro-governance policy response—not only enriches indigenous Chinese geographical research but also provides valuable "China Experience" for cultural landscape protection within the global perspective of International Heritage Law and Sustainable Development Law. It reflects a profound evolutionary trend from scientific identification to governance based on the rule of law.

Table 4

The Four Principles for Landscape Gene Identification

Principle	**Description**
IntrinsicUniqueness	The formative cause or origin is not found in other settlements.
Extrinsic Uniqueness	The external landscape manifestation is not found in other settlements.

Local Uniqueness	A specific, localized yet crucial element is not found in other settlements.

Table 5

Classification Criteria and Outcomes for Landscape Genes

No.	Classification Criterion	Classification Outcome
1	Importance&Composition	Dominant genes, Attached genes, Mixed genes, Variant genes [45]
2	Formof External Expression	Dominant (Explicit) genes, Recessive (Implicit) genes [15]
3	Deconstructionof TraditionalSettlement Landscape Features	Architecture, Culture, Environment, Layout [15]
4	Spatial Scale	Dwelling, Street/Block, Single Settlement, Local Settlements, Regional Settlements, Settlement Group/Lineage [15]
5	Mode of Gene Expression & Description	Symbolic, Graphic, Textual [16]
6	Mode of Expressing Spatial Form Features of a Settlement Unit	Two-dimensional Plan, Three-dimensional Front Elevation, Three-dimensional Side Elevation [16]
7	Difficulty Level in the Extraction Process	Directly extracted genes, Indirectly extracted genes [15]

Table 6

Classification of Landscape Gene Atlases

Category	Primary Content
Plan&Elevation Atlases	Depict settlements and dwellings in horizontal (plan) and vertical (elevation) dimensions.
Temporal&Spatial Atlases	Emphasize the relationship between historical development and geographical evolution.
Form&Perception Atlases	Present the physical appearance of settlements and their associated emotional/intrinsic values.
Front&SideView Atlases	Provide multiple viewing angles for a comprehensive understanding of settlement features.
Holistic&Partial Atlases	Display the overall pattern of settlements and their detailed constituent elements.

8 CONCLUSION

As a core instrument for the excavation and innovation of traditional village culture, landscape gene theory provides a unique interdisciplinary perspective for the study of Chinese traditional settlements. Based on the knowledge mapping analysis of landscape gene research from 2003 to 2025, the following conclusions can be drawn:

(1) The field exhibits distinct staged evolutionary characteristics with a significant policy-driven effect. The developmental trajectory displays a dynamic progression from

early theoretical inception to mid-term deepening and, finally, to recent accelerated advancement. This process is driven not only by academic logic but also by a highly pronounced policy-driven effect; the fluctuation in publication volume aligns closely with the implementation of the National Rural Revitalization Strategy and traditional village protection policies. While the research force has formed a pattern led by specific core teams, the rising demands for governance have shifted the academic focus from pure morphological description toward the more complex domain of sustainable governance of cultural landscapes. Particularly at the intersection of policy and the rule of law, landscape genes are no longer merely analytical indicators for geography or architecture; they have evolved into critical scientific evidence supporting decision-making for cultural heritage protection, reflecting a logical transition from academic ontology to deep integration with national strategic governance.

(2) At the level of research methodology and content, landscape gene research has achieved a leap from qualitative identification to digital integration and empirical application. Relying on identification rules such as the "Cell-Chain-Shape" (Ce-Ch-Sh) model, research methods have continuously integrated advanced technologies including GIS spatial analysis, spatial syntax, and machine learning, enabling the automated identification and quantitative expression of gene atlases. Simultaneously, the research scope has expanded from micro-level case studies to macro-regional scales, forming a systematic framework encompassing theoretical construction, multi-scale empirical studies, and strategic responses. Within the current context of global sustainable development, this research shift not only enhances the precision of cultural landscape identification but also provides an objective data foundation for cultural heritage protection under a legal framework. Landscape gene theory demonstrates powerful explanatory force and practical value in addressing the alienation of traditional character and cultural fragmentation during urbanization, laying a solid foundation for the construction of a "Identification-Restoration-Protection-Development" governance cycle.

9 FUTURE OUTLOOK

Looking forward, landscape gene research should prioritize deepening the coupling path between legal construction and policy instruments, grounded in digital transformation and national strategic needs.On one hand, research should actively embrace Artificial Intelligence (AI) and immersive technologies. By constructing high-precision landscape gene knowledge graphs, the discipline can achieve the digital immortality and intelligent management of cultural heritage.On the other hand, future research urgently needs to translate the results of landscape gene identification into actionable legal provisions, exploring their application in the legislation, enforcement, and judicial practice of cultural heritage protection. By integrating gene identification standards into heritage site management regulations and mandatory standards for urban and rural planning, the integrity and authenticity of landscape genes can be safeguarded through legal means.Furthermore, attention should be paid to the dialogue and contribution of Chinese landscape gene research within the fields of International Heritage Law and Sustainable Development Law. Promoting multidisciplinary synergy and cross-regional cooperation through legal mechanisms will address the complex challenges facing cultural landscape protection globally, thereby facilitating the widespread dissemination of the "China Experience" on the international academic and legal stage.

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AUTHOR CONTRIBUTIONS

Conceptualization, prepared data curation, figures 2-8and table2-6,C.P.; writing—review and editing, S.Y.S.prepared table1.and prepared figures1 A.F.B; All authors have read and agreed to the published version of the manuscript.software,Z.Y.J;validation,H.M.Q.

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Not applicable.

DATA AVAILABILITY STATEMENT

The data used in this study are available from the first author upon request (E-mail: caipp0605@gzist.edu.cn).

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Authors' Contribution

All authors contributed equally to the development of this article.

Data availability

All datasets relevant to this study's findings are fully available within the article.

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