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# Scenery deconstruction: a new approach to understanding the historical characteristics of Nanjing cultural landscape

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## Abstract

The “Eight Scenic Views Paintings” represent crucial visual materials for investigating the history of cultural landscapes. However, traditional methods of interpreting materials struggle to discern the inherent connections between different landscape elements. This study proposes an approach for deconstructing historical images, taking the example of the Forty Scenic Views in the Late Ming Dynasty in Nanjing, China. To explore the co-occurrence structure, hierarchical clustering, and correlation features among various elements, various digital humanities quantification methods were applied, including spatial analysis of ArcGIS, co-occurrence and clustering of KH Coder, and correlation analysis of SPSS. This study reveals the characteristics of the landscape construction of Nanjing in the Late Ming: natural landscape as the foundation, artificial landscape as the core, and advocating tradition as the fashion. It also uncovers the landscape order: mountains, waters, and scenic views interweaved and coexisted, as well as nature and culture intertwined and clustered. In addition, multiple information graphs of the subordinate and co-occurrence relationships of 20 landscape elements were constructed, 5 landscape paradigms were extracted, and 36 pairs of related relationships were discovered, deepening the historical understanding of the urban landscape construction of Nanjing in the Late Ming. This paper puts forward the idea of analyzing historical images by digital method, which provides some essential and detailed historical basis for explaining the value of cultural landscape heritage and shaping contemporary urban landscape.

**Keywords** Cultural landscape, Forty Scenic Views of Jinling, Culture of eight scenic views, Digital humanities, Landscape elements, Landscape construction, Nanjing in the late Ming dynasty

## Introduction

Cultural landscape, a type of cultural heritage, has received increasing attention in recent years [1–4]. A typical subtype, known as organically evolving landscapes, is explicitly identified in the 2021 edition of the “Operational Guidelines for the Implementation of the World Heritage Convention”, with historicity and

sustainability being its key features. In China, the indigenous style of cultural landscapes is the “poetic and picturesque” oriental aesthetics and ambiance [5], which is determined by traditional culture and is different from other nations. Many historic cities that have persisted for thousands of years have developed their own tradition of landscape construction and cultural landscapes [6]. The Chinese government is committed to transmitting this unique cultural context to the world, as exemplified by the inclusion of the West Lake Cultural Landscape of Hangzhou on the World Heritage List in 2011 [7]. Nonetheless, the rapid urbanization in China in recent years has led to a gradual erosion of traditional landscape culture [8]. Therefore, to preserve the “poetic and pictorial”

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landscape characteristics of urban areas, a retrospective exploration of Chinese ancient history of landscape construction is required. Throughout different dynasties, urban construction always emphasized the harmonious integration of the city with its natural environment and humanity space [9], showing the urban landscape system with the integration of mountains, waters, and cities. Eventually, the "Eight Scenic Views (八景)", a local model of urban and rural residential landscape construction [10], was derived. This model denoted the exceptional landscape assets of a given region, and the "Eight Scenic Views Paintings (八景图)" was an important historical material for studying the scenic features and landscape construction of ancient cities, which was a momentous magic weapon for the successful application of the West Lake for World Heritage in that year.

Current research on traditional landscape construction primarily focuses on three main aspects: landscape systems and construction tradition, the characteristics and evolution of the historical landscape, and the content and significance of the "Eight Scenic Views". Regarding landscape systems and construction tradition, scholars like Mao extracted cultural imagery, site selection patterns, and shaping experiences from the landscape system of the "city and mountain" [11]. Yuan [12] and Zhang [13] explored landscape models of the relationship between cities and their surrounding environment established artificially in plain and mountainous areas, respectively. Regarding the characteristics and evolution of historical landscapes, researchers like Mezcuca [14] and Wang [15] summarized the historical change process of lake-type cultural landscapes by combing historical data. Xiao [16] and Dong [17] conducted studies on the value, evolution, and management of the historical landscape based on accumulation theory. In addition, many scholars explored the historical characteristics of cultural landscapes to find their heritage value and protection methods [18–21]. Concerning the content and significance of the "Eight Scenic Views", scholars such as Zhang [22] and Wang [23] analyzed the composition of the "Eight Scenic Views" paintings and landscape types. Wen [24] and Hu [25] examined the spatial logic, ideological concepts, and political significance inherent in scenic paintings. Li analyzed the differences in artistic expressions of scenic images in different regions [26], and Zhang summarized the local landscape cultural characteristics through a large number of scenic images [27]. The Eight Scenic Views in Japan, Korea, and Vietnam, originating from the "Eight Scenic Views of Xiaoxiang (潇湘八景)" of China, developed distinct differences in their drawing style, compositional characteristics [28] and emotional expression [29] after undergoing localization. However, a commonality was that they were considered significant

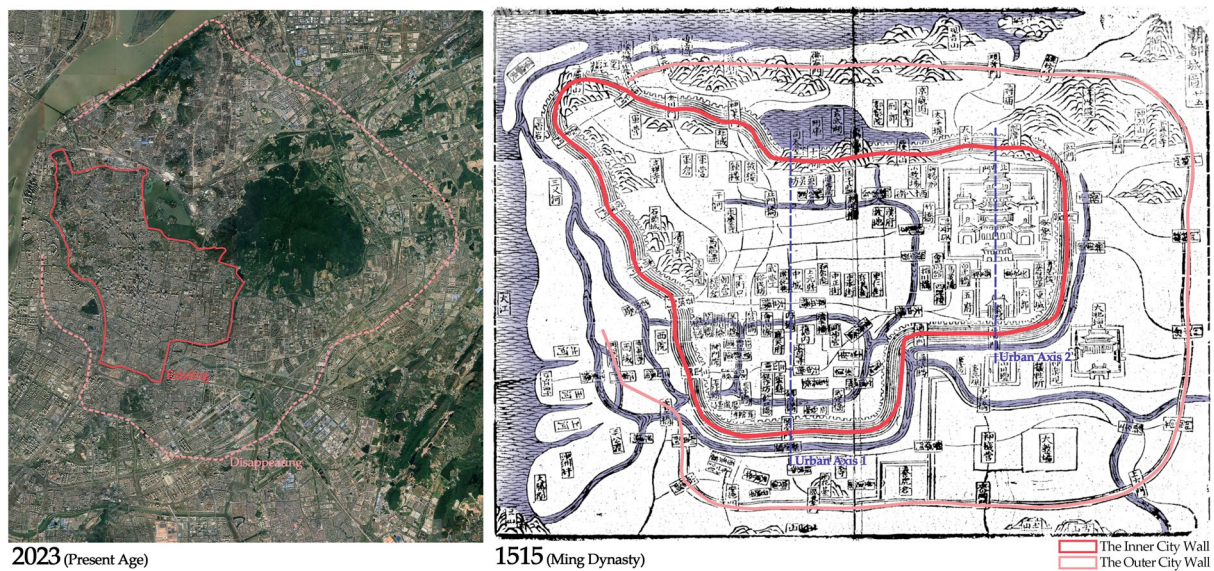
reflections of regional historical landscape features and natives' cultural customs [30].

At the macro scale, existing research mainly emphasized the overall landscape pattern and system characteristics, but failed to analyze the logic of landscape composition, such as why it was the collocation of elements in scenic paintings. At the meso and micro scales, studies on historical landscape imagery using the "Eight Scenic Views Paintings" as data sources relied on direct interpretation methods for materials, making them susceptible to subjective interpretations by scholars. In fact, applying quantitative methods to historical data can help achieve more objective research results. The recent development of digital humanities, spatial humanities theories, and methods [31–33] provided new opportunities for decoding the visual information in these "Eight Scenic Views Paintings". Techniques like word frequency analysis, co-occurrence analysis, social network analysis, and spatial information visualization can be used for digitizing this visual information [34, 35]. Therefore, adopting the mindset of text analysis to translate image information is a vital aspect of this study.

Nanjing, with numerous potential cultural landscape heritages, has a historical landscape system centered around the Ming Dynasty (1368–1644) city wall (Fig. 1). The first emperor of the Ming Dynasty, Zhu Yuanzhang, spent over 20 years building a four-tiered city wall system, connecting the surrounding mountains and water systems with the inner and outer city walls [36]. Although the purpose of constructing this system was to leverage its defensive function, it inadvertently created conditions for the formation of the urban landscape pattern. The right image in Fig. 1 illustrates the urban landscape pattern of the Ming Dynasty: the city, with two axes, was surrounded by mountains, and the inner and outer city walls interconnect them, while a network of water systems weaves through.<sup>1</sup> The Forty Scenic Views of Nanjing (formerly known as Jinling) in the late period of the Ming Dynasty was a reflection of the development of the pattern and a representation of its details.

From the perspective of digital humanities, this study took the "Images and Poems on the Forty Scenic Views of Jinling" finished in the late Ming as the research material. According to the categories of landscape elements, the scenic images will be semantically deconstructed. With the application of a series of digital humanistic analysis methods, the distribution characteristics, network structure, and correlation of historical scenes will be analyzed,

<sup>1</sup> Due to limited spatial awareness at that time, the direction and form of the city were depicted with deviations from reality. However, it is possible to compare the position of the inner and outer city walls with the contemporary urban layout.



**Fig. 1** The urban landscape patterns of the present age and the Ming Dynasty of Nanjing

so as to summarize the characteristics and order of historical landscape construction. The research ideas and methods can optimize the interpretation of heritage information and value, which will bring more possibilities to the historical research of the cultural landscape.

## Materials and methods

### Materials: forty scenic views of Nanjing in the late Ming

The "Eight Scenic Views Paintings", originating from the "Eight Scenic Views of Xiaoxiang" in the Song Dynasty (960–1279), serve as essential visual documentation for understanding local historical landscapes in contemporary times [37]. Its quantity has, with the ongoing exploration and comprehension of landscapes by later literati, resulted in some instances exceeding "eight", such as multiple sets of images in Nanjing, the capital of ten dynasties.

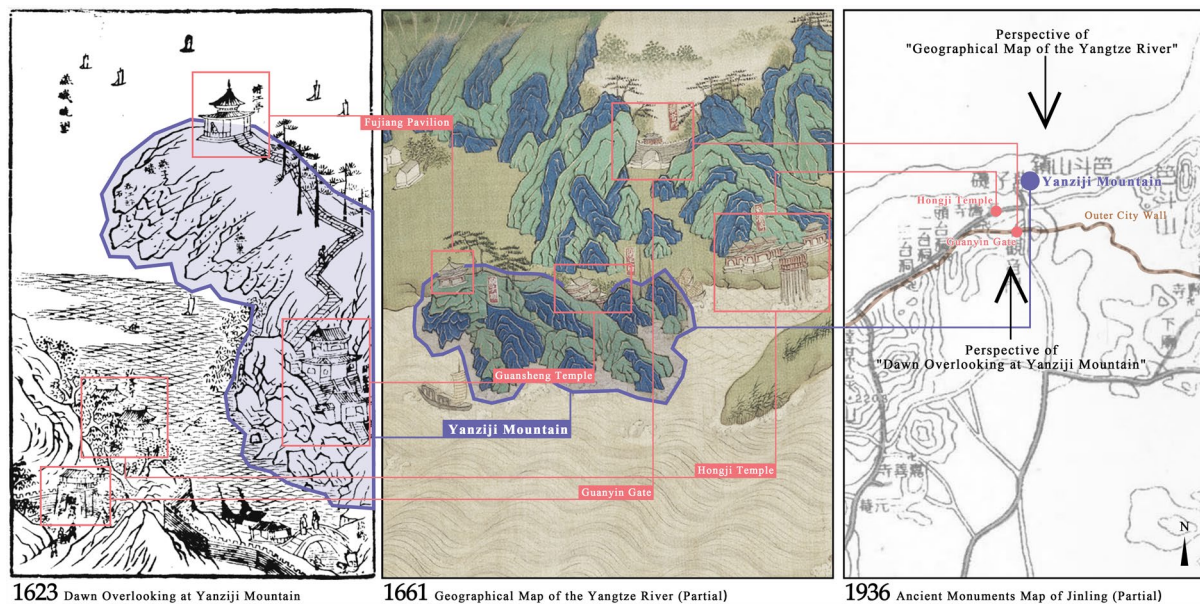
In the mid-Ming period, a trend of appreciating and selecting scenic views gradually emerged in Nanjing, with numerous literati and painters engaging in the creation of landscape poems and paintings. In chronological order, it included works such as the "Eight Scenic Views of Jinling" painted by Huang Kehui, the "Ten Scenic Views Album" painted by Wen Zhengming, the "Eighteen Scenic Views Album" painted by Wen Boren, and "Collection of Elegant Excursions" on twenty scenic views written by Yu Menglin. In the late Ming, Zhu Zhifan, an elite official in the literary community, often regretted the incomplete

coverage of artistic creations by predecessors. Therefore, over many years, Zhu dedicated himself to searching for paintings and exploring landscapes, ultimately expanding the number of the "Eight Scenic Views" to as many as forty [38]. Zhu collaborated with Lu Shoubai to complete the illustrated album named "Images and Poems of the Forty Scenic Views of Jinling"<sup>2</sup> in 1623, featuring a comprehensive selection of scenic views with meticulous illustrations [39]. The album is widely regarded as the most perfect set among the historical landscape compositions of Jinling through the ages, making it one of the most academically valuable visual materials of the urban scenery of Nanjing in the Ming Dynasty.

It is worth noting that, while the scenic images in Zhu's album may not be as precisely accurate as contemporary photographs, they nevertheless reflect the composition and spatial relationships of historical scenes in a relatively truthful and objective manner. Therefore, they can serve as reliable materials for this research. It is exemplified by the 22nd scenic view, "Dawn Overlooking at Yanziji Mountain (燕矶晓望)". Yanziji Mountain in the middle right of the painting serves as the main focus of the landscape. At the top of the mountain, there is the Fujiang Pavilion, while at the bottom, there is Guansheng Temple. Across the river, facing the waterside, there is the Hongji Temple. Closer to the city on this side, there is the Guanyin Gate of the outer city wall (Fig. 2). The composition and spatial relationships depicted in the painting

<sup>2</sup> The forty scenic views in this album each have their own ranking, and each scenery name is composed of four Chinese characters. The initial version of the album was titled "Images and Poems of Jinling".





**Fig. 2** Take the 22nd scenic view as an example to prove the reliability of Zhu's album

correspond closely to the historical map "Geographical Map of the Yangzi River" from a similar period. In 1936, Zhu Xie completed the historical monument investigation work of Nanjing, and his map "Ancient Monument Map of Jinling" marked the geographical locations of monuments in the Yanziji Mountain area. It further confirms the objective recording, rather than subjective creation, of the scene "Dawn Overlooking at Yanziji Mountain". Additionally, other paintings of scenic views have been examined and generally align with historical situations.

#### Data processing: semantic deconstruction of images

Due to the idealized cognitive patterns about landscapes, the elements in these landscape images were presented in a scattered layout, making their interpretation and study challenging. It was essential to summarize and extract the content from the images to facilitate quantitative analysis. Inspired by semantic segmentation thinking [40] and text analysis methods [41], we performed semantic deconstruction of the scenic images. At first, the landscape elements in all images were categorized based on their characteristics, such as form and function. Then, the elements in each image were identified and annotated based on both the image and textual content. Finally, information about the number and importance of elements in each image was compiled into a data table.

Taking the image of "Admiring Entertainers by Long Bridge (长桥艳赏)" as an example, the image contained ten categories of landscape elements (Fig. 3): human activities (feasting and selecting courtesans), bridges

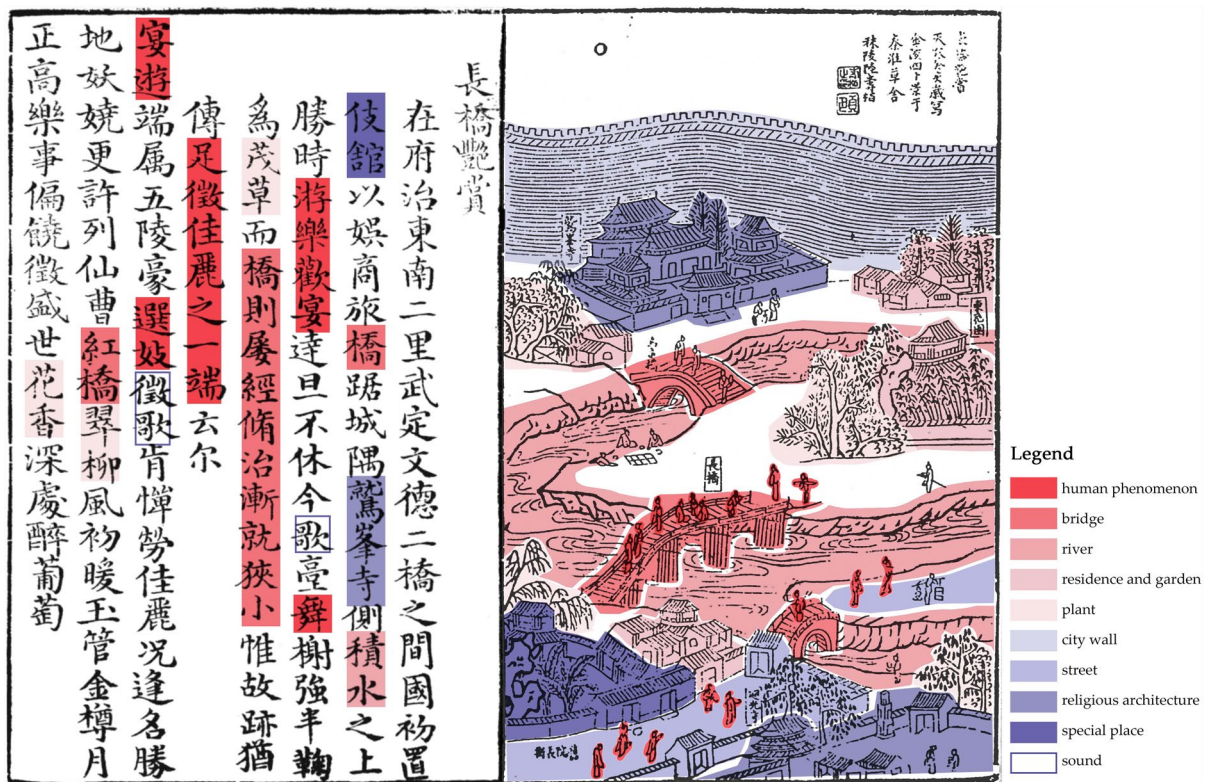
(Chang Bridge, Yuanjia Bridge, Wanyue Bridge), rivers (Little Canal, accumulated water), residential gardens (houses, East Garden), vegetation (green willows, luxuriant grass), city walls, streets (Old Courtyard Street), religious architecture (Jiufeng Temple, Huiguang Temple), special places (Old Courtyard), and sounds (singing). In addition to identifying the position of these elements within the scenic image (foreground, midground, background), style (natural or humanistic), and other information (location, theme), it was also essential to assign values of importance to each landscape element on a scale from 1 to 5. This valuation was determined based on factors such as the proportional representation of elements within the image, their relative significance, and historical influence, as derived from the titles of the images, textual descriptions, and historical records.<sup>3</sup>

#### Research ideas

Distinguished from the direct interpretation of images and texts, this traditional subjective research approach, the study attempts a scientific and quantitative analysis of historical images. It seeks to construct various information graphs of the landscape elements of the Forty Scenic Views of Nanjing in the late Ming, thereby understanding the characteristics and structure of the urban historical landscape. In terms of research ideas, it mainly consists of three sequentially progressive parts (Fig. 4). Firstly,

<sup>3</sup> Importance score is a numerical transformation of text and image information of historical materials, which respects the landscape cognition and aesthetic concept of local literati at that time.





**Fig. 3** Semantic deconstruction of a scenic image

historical materials were processed, as mentioned earlier, carrying out the semantic deconstruction of images. Subsequently, basic data statistics and visualization were conducted, primarily focusing on the spatial distribution of scenic views and the classification of landscape elements. Finally, the correlation of data was analyzed, predominantly encompassing network analysis of landscape elements and the correlation between the importance of elements and the ranking of scenery. The ideas sought to unravel the inherent connections among the various elements in the image, representing an exploration in the field of digitizing historical images.

## Research method

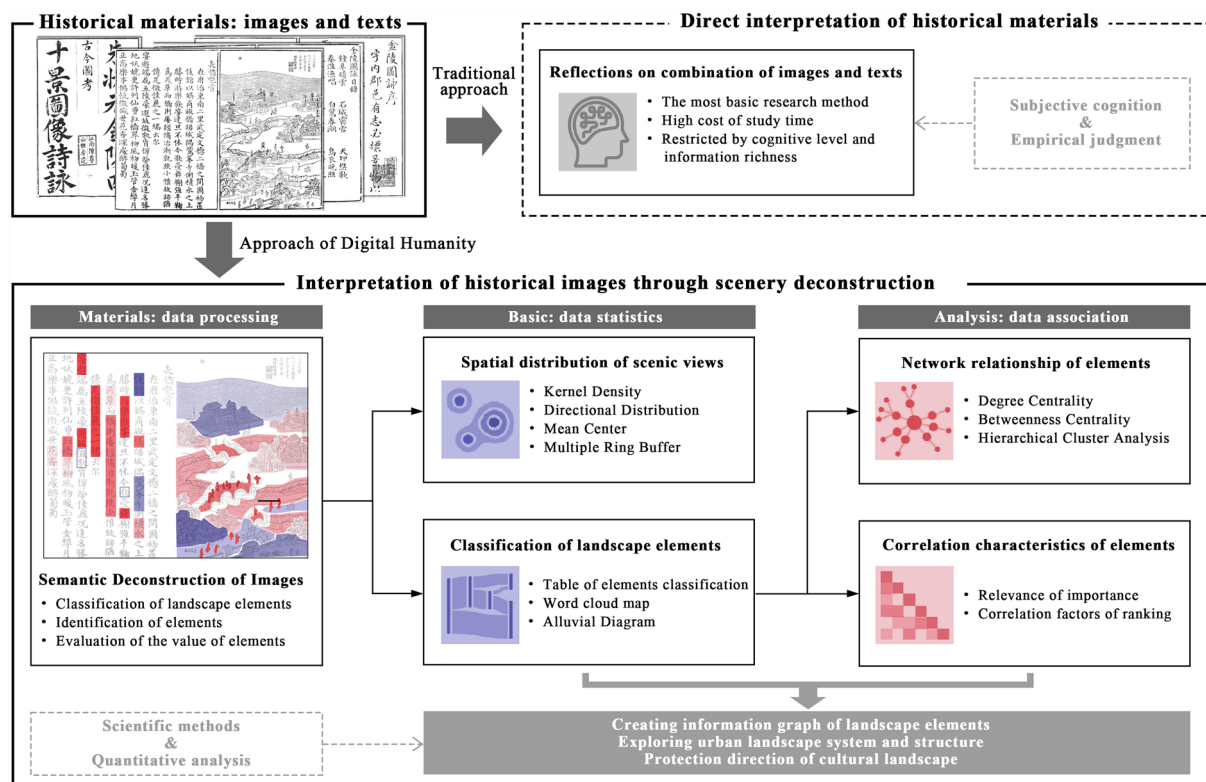
### *Spatial analysis and statistics of ArcGIS*

Utilizing Kernel Density Analysis [42] to depict the hot spots of scenery distribution and thus determine the spatial pattern of scenes. Employing Directional Distribution [43] to analyze the primary direction and dispersion tendencies of scenery distribution. Using the Mean Center to calculate the geometric center of scenery distribution, creating the Multiple Ring Buffer based on this point, and utilizing them to tally the number of scenes at different radii.

### *Co-occurrence and clustering analysis of KH Coder*

In co-occurrence network analysis [44], Degree Centrality, characterizing the centrality of nodes [45], indicated the coreness of various landscape element nodes in the landscape network. Betweenness Centrality, the shortest path where nodes appear between other nodes, was used to portray mediating characteristics and degree of adaptation of each landscape element. The size of the node indicated the frequency of an element, the color depth of the node expressed the centrality of an element, and the size of the coefficient reflected the closeness of the connection between two elements. Furthermore, based on clustering algorithms, Hierarchical Cluster Analysis was used to clarify the combination relationships between various landscape elements at different hierarchical levels by establishing a hierarchical clustering tree according to the similarity. Jaccard coefficient algorithm was adopted in the above analyses, which measured the ratio of elements in the intersection of two sets to the number of elements in their union, and its principle formula was:

$$J(A, B) = |A \cap B| / |A \cup B|.$$



**Fig. 4** Interpretation approach of historical images through Scenery deconstruction

### Correlation analysis of SPSS

Pearson Correlation Coefficient [46] was employed to assess the correlation between the assigned importance values of landscape elements within each scene and between the rankings of scenes and elements. A correlation is considered significant when  $0.01 < P < 0.05$ , highly significant when  $P < 0.01$ , and insignificant otherwise. The correlation coefficient quantifies the degree of association between two elements, with its sign indicating the direction of the correlation (positive or negative). The absolute value of the coefficient can be categorized as follows: 0–0.4 indicates a low degree of correlation, 0.4–0.6 indicates a moderate degree, and 0.6–1.0 indicates a high degree.

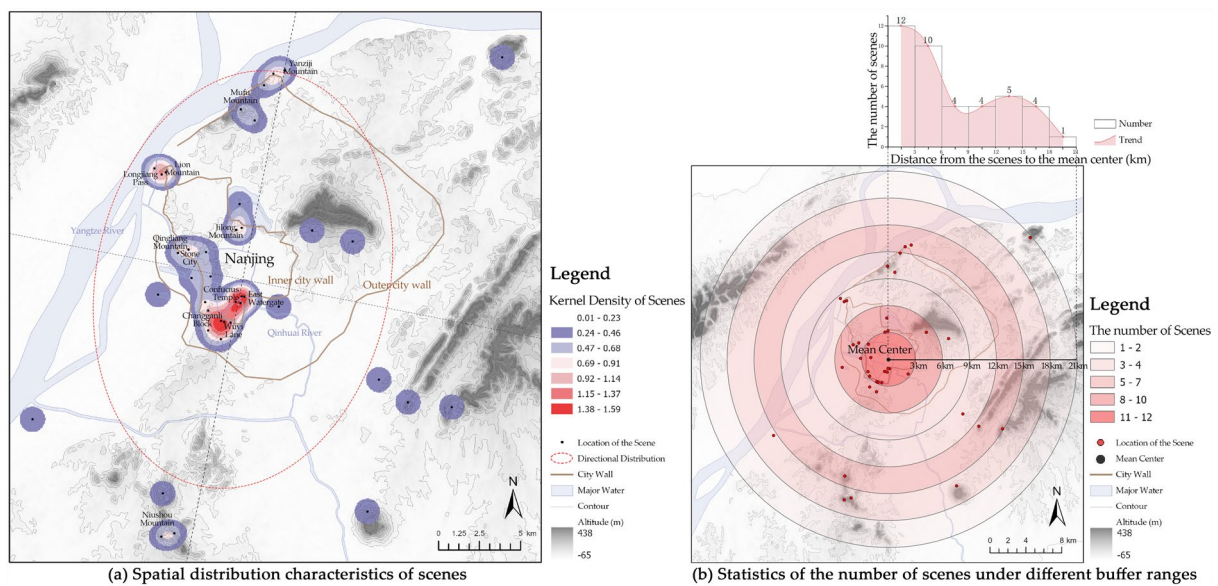
Additionally, statistical and visualization techniques were applied, including word cloud maps, alluvial diagrams, and the creation of correlation heatmaps using programming languages.

## Results and analysis

### Spatial distribution of scenic views

The distribution of scenic views exhibited an overall pattern of "dense south of the inner city wall, sparse near the outer city wall" (Fig. 5a), with obvious radial characteristics. In terms of quantity, the eastern part of the

city had significantly more scenic views than the western part. Two areas, from East Watergate to Confucius Temple and from Changanli Block to Wuyi Lane, were the most densely distributed area of scenes, forming the scenic cores. The core area exhibited a trend extending along the inner city wall towards the western parts of the city, including the areas around Stone City and Qingliang Mountain, eventually forming an L-shaped scenic belt. The area from Lion Mountain to Longjiang Pass, located in the northwest of the inner city, was a sub-dense area of scenes. The areas around Jilong Mountain in the inner city, Mufu Mountain and Yanziji Mountain in the outer city, and Niushou Mountain in the outer suburbs showed specific aggregation. The rest of the scenic views were mainly scattered throughout. The direction of the directional distribution was 11.5 degrees north by east, reflecting the directional characteristics of the urban landscape distribution from the Northeast to the Southwest. This direction roughly formed a scenic axis from Yanziji Mountain to Jilong Mountain to Confucius Temple to Niushou Mountain, which was situated approximately in the central position between the two urban axes of the Ming Dynasty, aligning perfectly with their direction (Fig. 1). It illustrated that while landscape construction was not determined by rulers, it was subtly influenced by



**Fig. 5** The distribution characteristics of scenes

urban planning, reflecting the close connection between them.

The mean center of the scenic views was located just north of the most densely distributed area of scenes (Fig. 5b). The number of scenes exhibited fluctuations with increasing spatial distance from this center. Scenic views were primarily concentrated within a radius of 6 km (the main viewing distance), with a sharp drop in numbers beyond this range. Fluctuations occurred in the range of 12–15 km (distant suburban viewing distance), followed by a gradual decrease beyond that, reaching a minimum at around 21 km (the farthest viewing distance). Based on the contour map, it was observed that the distribution of landscapes in the distant suburbs was primarily influenced by the distribution of mountain ranges, which could be a possible cause for the fluctuations.

#### Classification and subordination of landscape elements

According to the style, form, and functional features of the scenery in the images of Forty Scenic Views, 20 categories of landscape elements were summarized (Table 1). Some of the elements were identified based on the text content, logic of image drawing, and other aspects, including:

- The vast majority of the images contained elements of mountains and plants, but the screening process was essential. Due to the obstruction of the city walls, the view from the inner city could not see distant

mountains outside the city. In such cases, mountain elements were excluded. For plant elements, extraction was conducted by combining visual depictions in the images along with textual records.

- The Yangtze River was often portrayed in the form of blank space when it served as a distant view, with the river surface represented by the simplified boat. In such case, if there was no mention of boats in the accompanying text, boat elements were omitted.
- Temples dedicated to famous officials and generals were classified under ritual architectural elements, while deities and mythological figures related to religious rituals were classified under religious architecture. Pagodas in temples, when depicted as a distant view in a scene, were classified as landscape architecture.
- Human phenomenon elements not only included observable crowds but also phenomena such as fireworks, incense, and lighting.
- Sound elements were identified based on the names of the scenes and textual records.

According to the word cloud analysis (Fig. 6), mountains (33 times) appeared most frequently, accounting for 83% of the total scenic images. This result aligned with the topographical characteristics of Nanjing, which was a group of mountains surrounding. Religious architecture (30 times) was the second most frequent category, accounting for 75% of the total scenes, indicating the once prosperous Buddhist culture continues, just as a Tang poem said, "Four hundred eighty splendid temples



**Table 1** Categories and classification ranges of landscape elements

Style	Element category	Classification range
Natural	Mountain	Mountain range, hill, outcrop
	River	River, stream, moat
	Lake	Lake, wetland
	Plant	Clearly described characteristic plants such as trees and flowers
	Natural phenomenon	Observable natural phenomena such as clouds, rain, snow, and sunset
Artificial	Religious architecture	Buddhist and Taoist architecture such as temples, nunnerys
	Ritual architecture	Mausoleum, ancestral hall, altar, Confucius temple, martial temple, memorial archway
	Landscape architecture	Building tower, platform tower, tower attic, pavilion, waterside pavilion, distant view pagoda
	City wall	City gate, city tower, city wall, water gate
	Residence and garden	Private residences such as residential houses and gardens
	Street	Streets and alleys with named or clearly described feature
	Trail	Clearly delineated tourist trails such as mountain roads and causeways
	Bridge	Wooden bridge, stone bridge, sluice bridge
	Boat	Detailed depictions of ship, fishing boat and gaily-painted pleasure boat
	Farmland	Farmland, vegetable field
	Special place	Official or restricted places
	Human phenomenon	Behavior that can be viewed and phenomena such as artificially generated light and smoke
Compound	Rock and cave	Natural or artificial rock, cliff, cave
	Wellspring	Ancient well, the mouth of a spring
	Sound	Sound with outstanding landscape value or characteristics

still remain, of Southern Dynasties (420–589) in the mist and rain (南朝四百八十寺, 多少楼台烟雨中)". Plants (25 times), rivers (22 times), landscape architecture (19 times), ritual architecture (16 times), city walls (15 times), and others also appeared frequently. Through the above information, it was inferred that the main features of the landscape construction of Nanjing in the Late Ming included mountains and rivers as the foundation, complemented by plants, connected by city walls, interspersed with religious architecture, and adorned by landscape architecture and ritual architecture.

In terms of the information graph on the category and relationship of landscape elements (Fig. 7), concerning the position of landscape elements in the images of the Forty Views, mountains (64%), religious architecture (80%), plants (96%), rivers (60%), landscape architecture (79%), sounds (67%), trails (63%), residences and gardens (64%), and rocks and caves (91%) were primarily presented in the middle ground of the scenery (62%), served as the main viewing objects. The proportion of cultural and natural elements in the middle was approximately 3:2, indicating a slight preference for cultural elements among Nanjing literati. In the background, the proportion of natural and cultural elements was more balanced, with mountains, city walls, and rivers being the main contributing factors, accounting for 20%, 17%, and 13% of the elements of the background, respectively. Combined with the

above, city walls primarily served as a background to highlight other landscape elements, but mountains and rivers held prominent positions as main or background features. In the foreground, most categories of elements were humanistic styles, with many categories occupying a place, especially wellsprings, streets, and ritual architecture, while mountains, plants, and lakes were less prominent. Overall, the ratio of cultural to natural elements was approximately 16:9, reflecting that in the Forty Views, there was a focus on emphasizing the cultural or artificial environment. It suggested that, in the minds of the literati, the preference was not solely for admiring pure natural landscapes but for exploring historical landmarks and the cultural roots of Jinling, showing their aesthetic preferences and motivation for sightseeing.

According to the main viewing elements represented in the names of the scenes, the scenic views were categorized into four themes: mountains or rocks, rivers or lakes, Buddhist or Taoist temples, and streets or lanes (Fig. 4). Among these, mountain or rock landscapes had the highest proportion (47%), with a relatively even distribution in the city, suburbs, and outer suburbs. River or lake landscapes come next (23%), mainly located in the city and suburbs. Buddhist or Taoist temple landscapes (21%) were predominantly located in the suburbs and outer suburbs. Street or lane landscapes had the lowest proportion (9%) and were only found in the

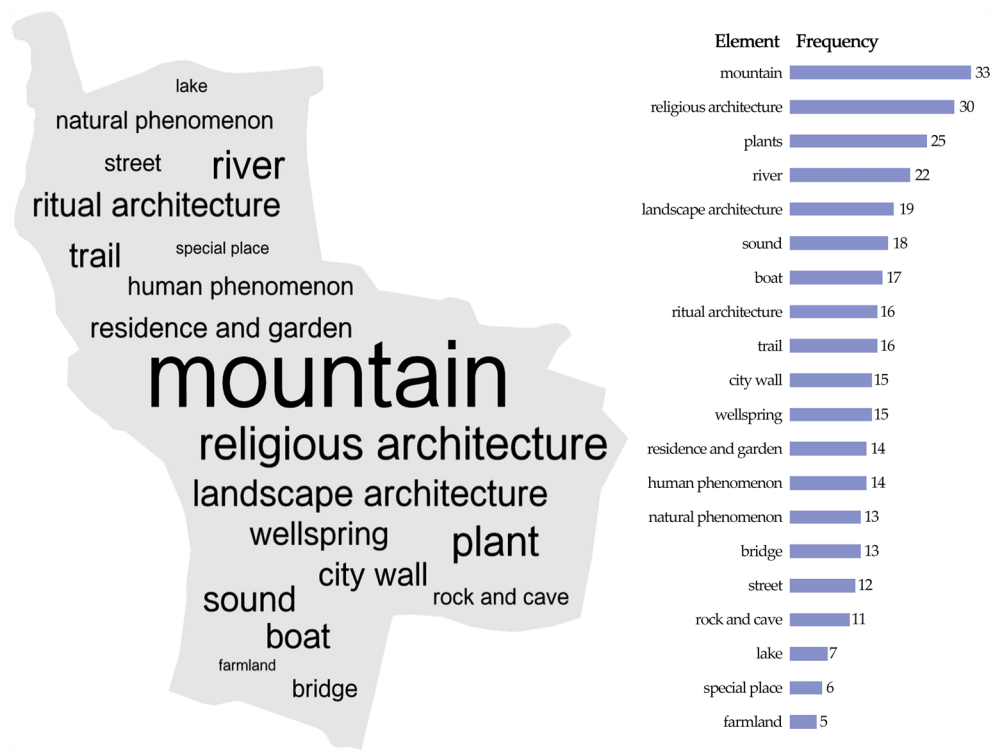


Fig. 6 Word cloud map of the categories of landscape elements

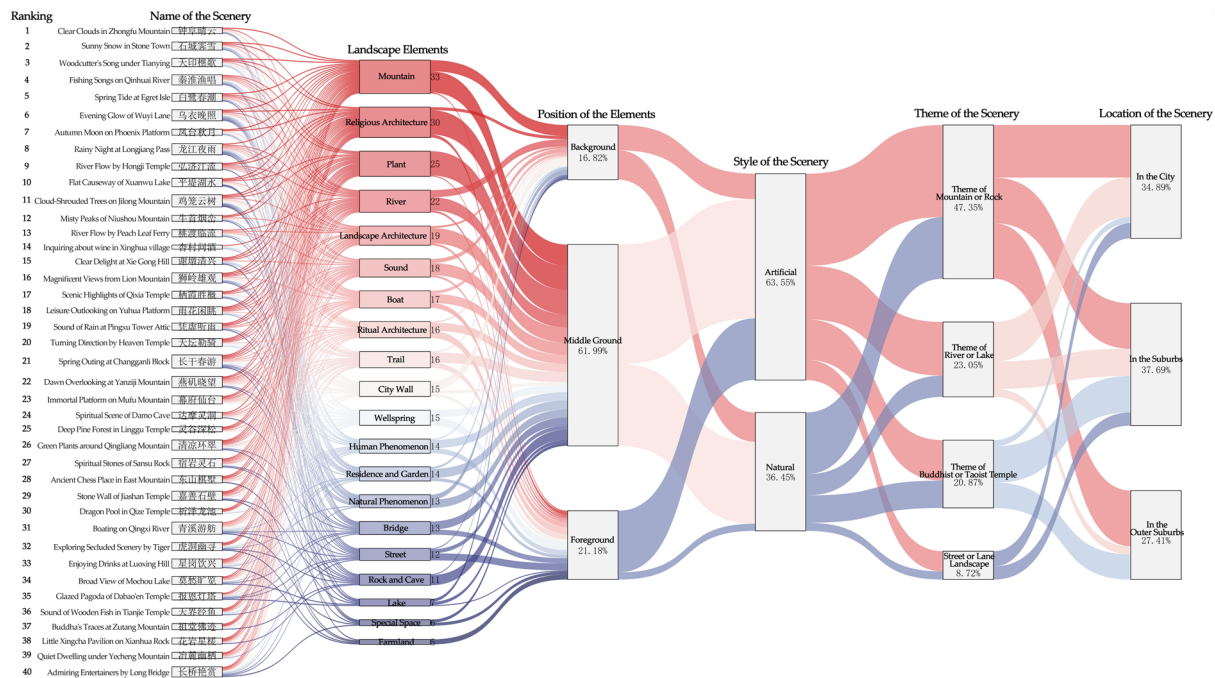
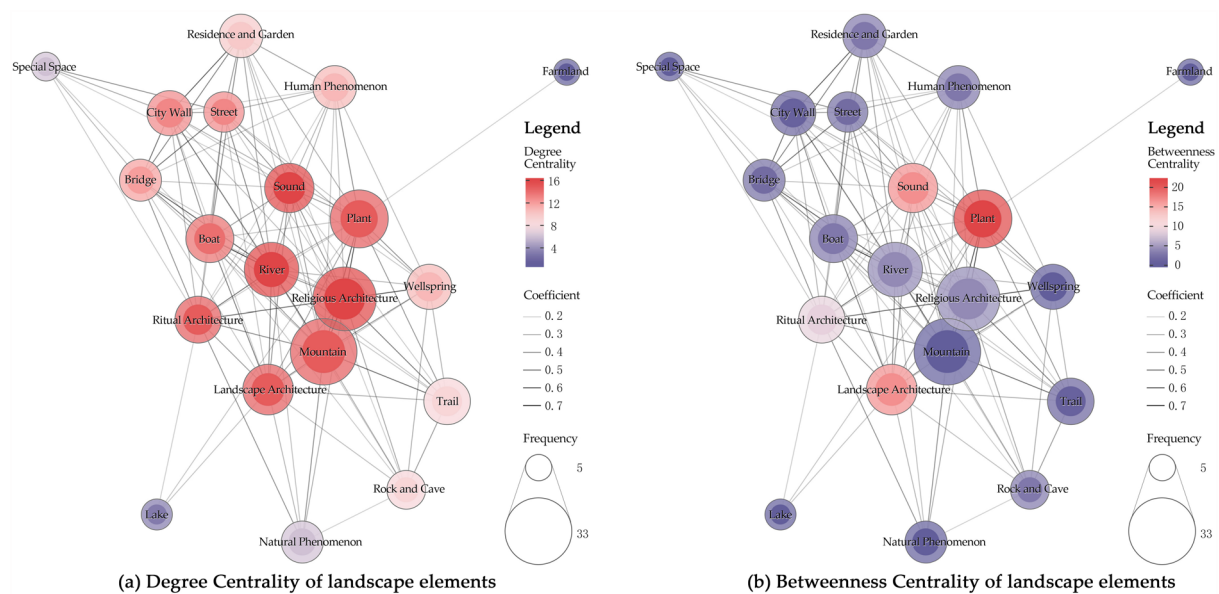


Fig. 7 Information graph reflecting the types and subordination of landscape elements



**Fig. 8** Degree Centrality and Betweenness Centrality of landscape elements

city and suburbs. For mountain or rock landscapes as well as Buddhist or Taoist temple landscapes, the ratio of cultural to natural elements was about 3:2. It suggested that when primarily appreciating natural elements like mountains or rocks, there was still a need for accompanying cultural elements, and vice versa. Landscapes of rivers or lakes and streets or lanes were often dominated by cultural elements.

Regarding the location, urban landscapes should be primarily composed of residences and streets. However, according to the statistical results, mountain or rock landscapes (46%) and river or lake landscapes (35%) dominated in the city. It suggested that in the eyes of the literati in the Late Ming, the low mountains that were easy to ascend and the rivers that were suitable for boating were more highly regarded than the living environment with scattered and orderly buildings. Additionally, the proportion of scenes in the city, suburbs, and outer suburbs was 35:38:27. The differences in quantity between these three areas were not significant. However, this distribution reflected that the suburban areas were more developed for their beauty, which had a higher proportion of mountain or rock landscapes, river or lake landscapes, and Buddhist or Taoist temple landscapes. Although more distant, the outer suburbs still offered impressive scenery, with mountain or rock landscapes being predominant.

In summary, the construction of the information graph illustrated the quantitative flow of six pieces of information in Forty Scenic Views of Nanjing: the name of the scenery, landscape elements, position of the elements,

style of the elements, theme of scenery, and location of the scenery, which indicated a preliminary understanding of the composition and characteristics of the prominent landscapes of Nanjing as well as the literati's aesthetic preferences for scenery appreciation activities during the late Ming period. The statistics of information of these elements provided data support for further research into their network relationship and correlations.

#### Network relationship of landscape elements

The results of degree centrality analysis (Fig. 8a) show that river, religious architecture, and sound elements had the highest values, indicating that they occupied a central position in the landscape network with the most extensive direct connections to other elements. From the perspective of spatial distribution, Nanjing was endowed with numerous river tributaries and a wide drainage area that seamlessly connected urban, mountainous, pastoral, and lacustrine environments, establishing the river as a central element in the landscape network. Religious architecture, which appeared in 75% of the scenic images, was distributed in different locations and was featured in various themes of scenes, contributing to its high degree centrality. Sounds, despite not having as high an occurrence rate as the previous two, maintain close connections with various elements due to their widespread sources. For instance, in terms of location, there were woodcutters' songs in the distant suburban forests and the sound of waves in the rivers, the noises of carriages and horses on the streets in the near suburbs, and the bells of temples in the city. The elements of mountains,



plants, landscape architecture, ritual architecture, and boats comprise the second tier of degree centrality. When considering the reasons for these elements having the second level and similar values, in the case of the mountain element, its frequency of appearance (33 times) was significantly higher than the other four elements. However, it exhibited relatively weak co-occurrence relationships with some elements, such as residences and gardens, and streets. Plants were found in various scenes, playing an important role in enhancing the ambiance of views. Elements of landscape architecture and ritual architecture were highly adaptable, distributed in various locations, whether among mountains, by the water, or along the streets. The Boat element mainly relied on rivers and lakes, and its centrality was influenced by the river elements located on the first level. Conversely, the degree centrality of farmland and lakes was low, as these elements appear infrequently and had limited co-occurrences with other elements. Farmland never appeared in the middle ground of scenic images, reflecting that pastoral scenery was not mainstream aesthetics.

Regarding betweenness centrality (Fig. 8b), the plant element exhibited the highest value, significantly surpassing all other elements. It signified its pivotal role in organizing and witnessing diverse combinations of other landscape elements, enhancing the richness and variety of landscape styles and imagery. For instance, the plant element witnessed the combination of mountain and rock elements with various other elements. In the scene of "Spring Tide at Egret Isle (白鹭春潮)", rushes and reeds connected mountains (Three Mountains) with ritual architecture (Yan Gong Temple). In "Woodcutter's Song under Tianyin Mountain (天印樵歌)", creepers highlighted the combinations of mountains (Tianyin Mountain) with wellsprings (Gexian Gong Well). In "Magnificent Views from Lion Mountain (狮岭雄观)", old cypresses and young pines complemented the combinations of mountains (Lion Mountain) with city walls (Yifeng Gate). Furthermore, landscape architecture and sound elements also exhibited relatively high betweenness centrality, indicating their compatibility in combining with other elements. However, elements with a high degree centrality, such as rivers, mountains, religious architecture, and boats, displayed low betweenness centrality. It suggested that these elements had relatively fixed, clearly defined combinations with other elements, lacking significant bridging roles.

According to the results of hierarchical cluster analysis, the landscape elements were classified into five clusters (Fig. 9): "Streets+ Bridges+ City Walls+ Residences and Gardens+ Special Places" (Cluster 1), "Boats+ Rivers+ Landscape Architecture+ Sounds" (Cluster 2), "Natural Phenomena+ Ritual Architecture+ Lakes" (Cluster 3),

"Human Phenomena+ Farmland" (Cluster 4), and "Mountains+ Religious Architecture+ Plants+ Trails+ Wellsprings+ Rocks and Caves" (Cluster 5).

Cluster 1 represented scenes like "Boating on Qingxi River (青溪游舫)", "Spring Outing at Changganli Block (长干春游)" and "Admiring Entertainers by Long Bridge" (Fig. 10), primarily showcasing the landscape of human settlements with crisscrossing traffic and houses, against the backdrop of city walls. This cluster implicitly included the element of rivers (such as the Qinhuai River and Qingxi River). The spatial coupling of rivers and city walls reflected the historical interaction between the urban defense system and the water system in Nanjing (the artificial moat dug along the city walls influenced by the concept of "ramparts of metals and a moat of boiling water 金城汤池", the natural river Qinhuai flowing through the city).

Cluster 2 featured scenes like "Rainy Night at Longjiang Pass (龙江夜雨)", "River Flow by Hongji Temple (弘济江流)", "Dawn Overlooking at Yanziji Mountain" and "Spiritual Stones of Sansu Rock (宿岩灵石)", which were near the large river, as well as those distributed along riverbanks like "Fishing Songs on Qinhuai River (秦淮渔唱)", "River Flow by Peach Leaf Ferry (桃渡临流)" and "Boating on Qingxi River". The former group included landscape architecture elements like building towers, tower attics, and pavilions that offered distant views of the river with glimpses of sails and the sound of waves crashing on the shore. The latter group featured waterside pavilions where you could sit and admire the passing boats while listening to fishermen's songs.

Cluster 3 was represented by scenes like "Spring Tide at Egret Isle" and "Cloud-Shrouded Trees on Jilong Mountain (鸡笼云树)". In this cluster, the ritual architecture represented the literati's ideology of the ritual system, the culture of rites and music, and the worship of the sages. The clustering of ritual architecture with natural phenomena reflected the ancients' pursuit of ideals such as "unity between heaven and humanity (天人合一)" and "the principle of modeling heaven and earth (法天象地)". The geographical environment of lakes contributed to enhancing spiritual perception through dialogues with nature.

Cluster 4 was represented by scenes like "Clear Delight at Xie Gong Hill (谢墩清兴)", "Exploring Secluded Scenery by Tiger Cave (虎洞幽寻)" and "Enjoying Drinks at Luoxing Hill (星岗饮兴)", showcasing the activities of citizens in the fields, growing vegetables, chopping wood, herding livestock and drinking in a wild tavern.

Cluster 5 was represented by scenes like "Stone Wall of Jiashan Temple (嘉善石壁)" and "Buddha's Traces at Zutang Mountain (祖堂佛迹)". The combination of mountains and religious architecture was most

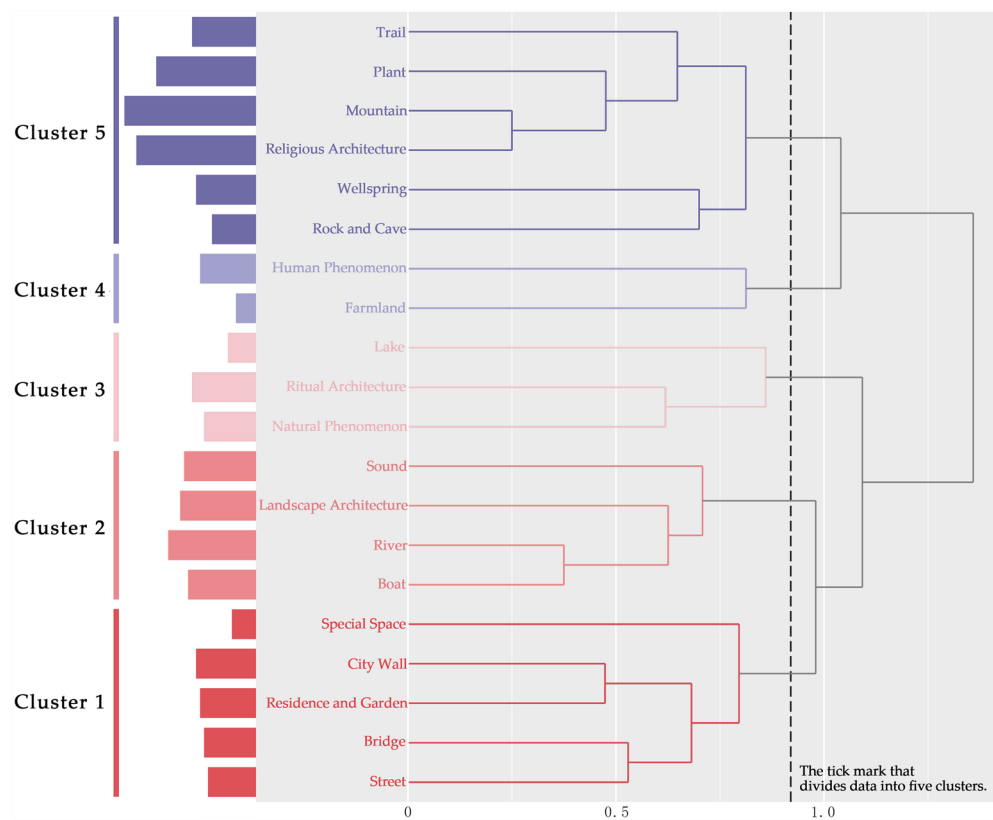


Fig. 9 Five clusters of hierarchical cluster analysis

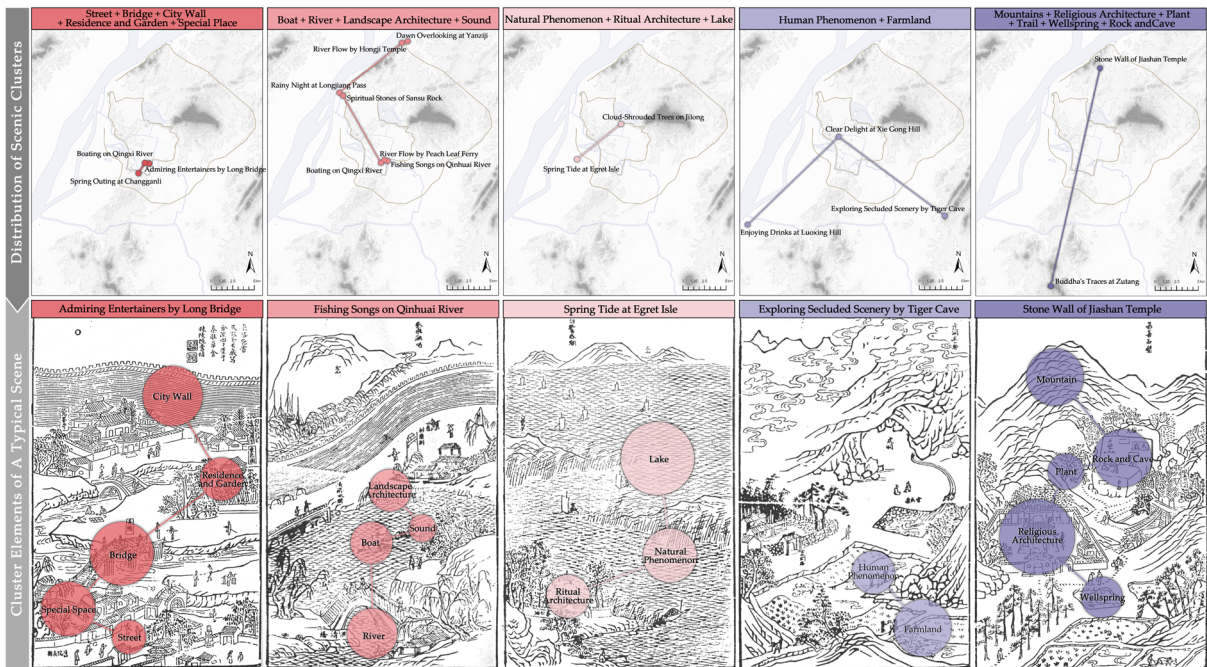
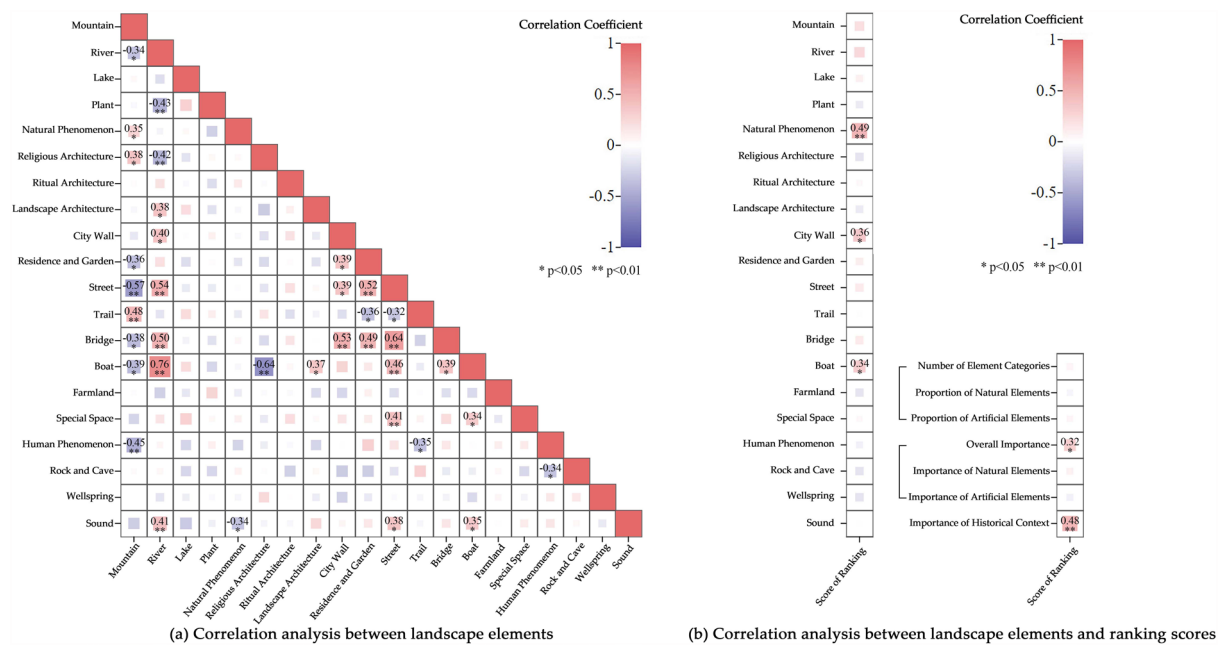


Fig. 10 Analysis of landscape distribution and cluster elements corresponding to five clusters



**Fig. 11** Heat map of correlation between landscape elements

prominent in this cluster. It indicated that most temples were constructed in mountainous areas. Subsequently, plants and pathways were incorporated into this combination, highlighting the prominent feature of old trees among mountain temples, and the trails were subtly integrated with the mountains. Later, as rocks and caves, and wellsprings were included, the group of the landscape reflected the traces of the monks' lives. As seen in the scene of "Stone Wall of Jiashan Temple", there was a pond in front of Jiashan Temple, and to the right of the temple was a massive rocky wall, and in "Buddha's Traces at Zutang Mountain", there were two springs in front of the temple and the Patriarch Cave on the cliff to the right. It fully embodied the Buddhist architectural tradition and belief culture: the location of springs reflected the ancient belief in geomantic omen. It serves as a means of purification (used for washing hands and faces and purifying the soul), and it can also be used to put out fires. The excavation of the Buddha cave is for meditation and worship, and the rocky wall is a crucial carrier of the beliefs, culture, and Buddhist art.

Through the above analysis, the inherent structural relationships of the landscape elements, serving as historical landmarks, have been dissected, revealing different statuses of various elements of the Nanjing landscape system in the late Ming. The clustering relationships among landscape elements reflected the stable and fixed landscape intentions formed during the spontaneous development of the urban landscape.

### Correlation characteristics of landscape elements

Different landscape elements varied in their importance for composing the scene. To further investigate whether there were correlated features in the importance of each two elements, we revealed it through a correlation analysis (Fig. 11a). In terms of importance (low correlation degree was not marked.):

- Mountains had a positive correlation with natural phenomena, religious architecture, and trails (moderate) and a negative correlation with rivers, residences and gardens, streets (moderate), bridges, boats, and human phenomena (moderate).
- Rivers had a positive correlation with landscape architecture, city walls (moderate), streets (moderate), bridges (moderate), boats (high), and sounds (moderate), and a negative correlation with plants (moderate) and religious architecture (moderate).
- Natural phenomena were negatively correlated with sounds.
- Religious architecture was negatively correlated with boats (high).
- Landscape architecture had a positive correlation with boats.
- City walls had a positive correlation with residences and gardens, streets, and bridges (moderate).
- Residences and gardens had a positive correlation with streets (moderate), and bridges (moderate), and a negative correlation with trails.



- Streets had a positive correlation with bridges (high), boats (moderate), special places (moderate), and sounds, and a negative correlation with trails.
- Trails had a negative correlation with human phenomena.
- Bridges had a positive correlation with boats.
- Boats had a positive correlation with special places and sounds.
- Human phenomena had a negative correlation with rocks and caves.

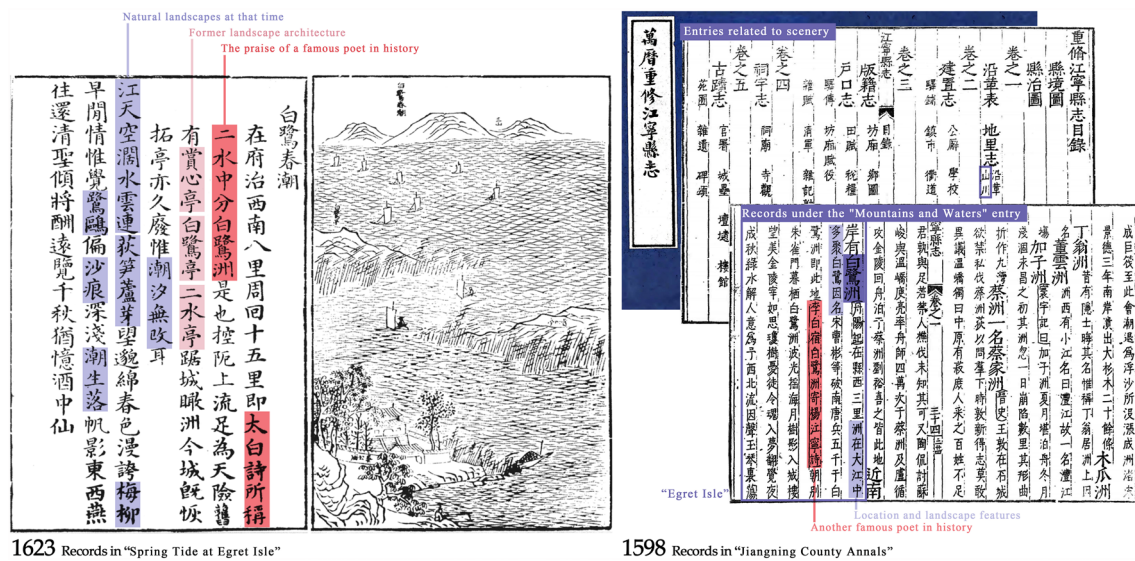
The results of the correlation analysis above could be understood as thirty-six pairs of interactive relationships among landscape elements, including synergy or antagonism, reflecting the combination law of landscape elements hidden in the forty scenic images. For example, in the scenic depictions emphasizing famous mountains, there was a certain restraint in portraying water environments, human habitats, and human activities. Instead, the focus was on ancient and famous temples in the mountains, as exemplified in "Scenic Highlights of Qixia Temple (栖霞胜概)", which expressed the architectural layout of Qixia Temple, along with a rich network of trails and various natural phenomena like the mist enveloping the peak of Zhongfu Mountain in "Clear Clouds in Zhongfu Mountain (钟阜晴云)". When emphasizing the significance of important rivers, it often accompanied landscape architecture like pavilions and towers (as seen in "Dawn Overlooking at Yanziji Mountain", where one could view the Yangtze River from the Fujiang Pavilion), historical streets and lanes (such as "Evening Glow of Wuyi Lane (乌衣晚照)", there was Wuyi Lane located alongside the Qinhuai River.), and various sections of the city wall. However, these scenes tended to provide fewer depictions of renowned temples and botanical landscapes. In the case of city walls, they often appeared alongside significant residences and gardens, bridges, and streets, as observed in "Admiring Entertainers by Long Bridge". In this scene, the city wall served as the background, the middle ground included the East Garden and Long Bridge, and the foreground featured Old Courtyard Street. In the scenes that emphasized the historical essence of streets, the focus was on historic rivers, bridges, boats, special places, and sounds. For instance, these elements existed in the scene of "Boating on Qingxi River" around the Qinhuai River and Qingxi River, which together convey and continue the prosperity of the distant Southern Dynasties.

The ranking of scenery reflected the landscape preferences of ancient literati in Nanjing. This study investigated the influencing factors of these rankings and conducted a correlation analysis between the ranking and various indicators such as the importance of individual

elements, the number of element categories, the overall importance, and the importance of historical context (Fig. 11b). Surprisingly, the ranking of the scenery was not correlated with elements such as mountains and religious architecture, which significantly deviated from traditional beliefs. For example, the scene of "River Flow by Hongji Temple", depicting the scenery of the famous Hongji Temple, was ranked 9th, while the image of "Glazed Pagoda of Dabao'en Temple (报恩灯塔)", drawing the figure of the more famous Dabao'en Temple, was ranked 35th, and this contrast was not an isolated case. It suggested that for Nanjing in the Late Ming, famous mountains or temples were not the key factors determining the ranking of scenery.

In terms of individual landscape elements, the ranking was positively correlated with the importance of natural phenomena (moderate), city walls, and wellsprings. It implied that natural occurrences like rain, snow, clouds, sunsets, and tidal surges had a significant impact on the hierarchy and ambiance of the landscapes, reflecting the ancients' reverence and worship of nature and celestial phenomena. Scenes featuring city walls, including city towers, gates, and watertowers, mostly ranked highly. It illustrated that, although they served as defensive military structures, they played a significant role in urban landscape construction, strengthening the relationship between the foreground and background of the scenery, as well as serving as objects for public appreciation. Furthermore, Nanjing prospered in trade by leveraging the transportation function of the Yangtze River, and it thrived in poetic culture by relying on the leisure function of the Qinhuai River. Therefore, the element of boats played a pivotal role in various aspects of society, from its development to the daily lives of its citizens.

From a holistic perspective, the overall importance (the sum of the importance of individual elements) was positively correlated with the ranking of scenery, but the correlation was relatively weak (correlation coefficient of 0.32), indicating that it was not the primary influencing factor. In contrast, the significance of historical context showed a moderate positive correlation with the ranking of landscapes (correlation coefficient of 0.48). Scenes with higher historical significance tended to rank higher. For example, the 1st scene, "Clear Clouds in Zhongfu Mountain", had historical roots dating back to the Three Kingdoms period (220–280) and was associated with imperial tombs. In contrast, the 34th scene, "Broad View of Mochou Lake (莫愁旷览)", had a historical background from the Southern Dynasties and was linked to a legend about a famous courtesan. This kind of historical background information, such as historical eras, figures, events, and legends, was extensively marked in the captions of the forty scenes (35 in total). It reflected the



**Fig. 12** The records of "Egret Isle" in Zhu's album and county annals of the same period

significant place of historical context in the minds of literati and the crucial role of cultural scenery in shaping these landscapes.

The above analysis indicated a more detailed understanding of the composition or formation reasons of the landscape of Nanjing, further advancing the study of landscape network relationships mentioned earlier.

## Discussion

### Enhancement of understanding of the historical landscape of Nanjing

"Images and Poems on the Forty Scenic Views of Jinling" depicted forty independent and distinctive scenic views in the late Ming. According to textual descriptions, their formation was traced back to human efforts in harnessing nature with cultural significance during previous dynasties, and some of these were later praised by literati through poetry [38]. For instance, in the 5th view, "Spring Tide at Egret Isle", the accompanying text elaborated on the composition of this scenery, including the poetic praises from a renowned historical poet (Li Bai), former landscape architecture (three historic pavilions), and the natural landscape at that time (sandbars, tidal waves, waterfowl, etc.). During the same period, the local records named "Jiangning County Annals" systematically documented various subjects. The entry on "Mountains and Waters", specifically the description of Egret Isle, included information about its geographical location, landscape, historical events, and renowned poems (Fig. 12). From the above recording method, it was evident that the ancients of that time perceived landscapes as individual entities, lacking a comprehensive

understanding of urban scenery as a system. Influenced by these records, after interpreting them, contemporary scholars regarded these scenic views as historical landmarks [25]. Regarding the overall characteristics of the urban landscape system, scholars tended to direct their attention to the most significant landscapes and the overall geographical environment, summarizing them as "Zhongfu Mountain is like a coiled dragon, and Stone Mountain is like a crouching tiger (钟山龙盘, 石头虎踞)" and "mountains, waters, city, and forests, blending seamlessly into one entity" [47].

After the analysis, scholars' summaries seemed to be incomplete. In comparison, this study, through a deconstructive method of scenery, dissected the composition of various elements within each scene. Moreover, it went beyond the individual level to analyze the relationships among components at the overall level. For instance, in the section "Network relationship of landscape elements", we employed "Degree Centrality" and "Betweenness Centrality" as metrics to assess the roles played by different landscape elements in the overall urban environment. Additionally, we identified five significant clusters of elements by using clustering algorithms, and they could be summarized as "leisure living under the city walls", "listening to various sounds by the rivers", "respecting for heaven, earth, and nature", "exploring human traces in the fields" and "visiting famous temples by mountain climbing". Based on these five clustering results, we could discover the landscape patterns and lifestyles favored by literati in the late Ming Dynasty. These patterns were not evident in the traditional research perspective of the landscape system of Nanjing. Furthermore, in the section

"Correlation characteristics of landscape elements", we found the correlation between landscape elements, identifying phenomena where significant elements combine to create a particular scenery. We also observed that if a scenic view was praised, it typically involved not only the prominence of the main scene but also the overlay and coordination of other elements of varying importance. Hence, this study respected each component of every landscape element, rather than focusing solely on the most significant one.

### **Differences in perception compared to the traditional "Eight Scenic Views"**

In the traditional Chinese concept of the "Eight Scenic Views", the creation process typically involved literati combining natural landscapes with inner emotions, expressing them through poetry and painting. The "Eight Scenic Views of Xiaoxiang" in the Song Dynasty were considered the most influential, where creators prioritized poetic and expansive themes over realistic depictions, using fewer landscape elements to shape the composition. This approach reflected a pursuit of a poetic style and a profound atmosphere, subtly intertwined with a nuanced political stance [48]. Scholars in China, Japan, and South Korea shared remarkably similar interpretations of the "Eight Scenic Views", considering them as assessments and aspirations of traditional aesthetic concepts and ideal human habitats from ancient times [30]. However, due to the limitations imposed by the traditional selection of a limited number of scenic views, only one or two could be chosen from each category. For contemporary scholars, only fragmented urban historical landscapes can be seen from the eight images, lacking statistical significance.

The "Forty Scenic Views of Nanjing", with an ample number of illustrations, depicted a diverse array of landscape elements, facilitating data collection and correlation calculations and thereby enabling a possibility for a more profound and nuanced interpretation of landscape characteristics. In the composition of the scenery of Nanjing in the Late Ming, artificial elements were notably more prevalent than natural elements, and the middle ground, which served as the primary focus of scenery, also predominantly comprised human-related features. It reflected that in the landscape construction, natural elements like mountains, rivers, and plants were not typically placed in the primary position. Instead, these elements served as the foundation to showcase the local culture of Nanjing, which is completely opposite to the Eight Scenic Views in the Song Dynasty. The great prominence of artificial elements was a major feature of the scenery of Nanjing, with a particular emphasis on the depiction of religious architecture, especially represented by temples. It reflected the profound

influence of Buddhist culture from the Southern Dynasties period on the Late Ming. In these scenic images, there was an emphasis on the distinctive landscape features of these temples, a de-emphasis on their belief feature, and a highlighting of their appeal for recreational purposes. It underscored the secularization and popularization trends in the development of temples. Ritual architecture and city walls were very rare in the Eight Scenic Views Paintings of other cities, but they were more commonly found in the scenic images of Nanjing. Among them, Ritual architecture symbolized reverence for heaven, earth, the ancients, rites, and regulations [49], showcasing the qualities of the ancients who were disciplined and adhered to propriety and rituals. The element of city walls was more prominently featured in the scenic images of Nanjing, reflecting the elevated status of the "matchless city walls" constructed by the founding emperor in the minds of local residents. City walls played a crucial role in landscape construction, particularly in the correlation between the water gates and gate towers and the renowned residences and gardens, bridges, and streets, showcasing the composition and texture characteristics of the urban living environment of Nanjing. Furthermore, Some special places reflected the distinctiveness of Nanjing's urban space function and public perception, such as the Imperial College in the scenes of "Cloud-Shrouded Trees on Jilong Mountain", the Examination Halls in "Boating on Qingxi River", and the Old Courtyard in "Admiring Entertainers by Long Bridge". They reflected the Confucian consciousness and elegance [50] of the local literati, showcasing the iconic buildings of Nanjing as the "Cultural Hub of China (天下文枢)" at that time.

Therefore, the perspectives and methodologies of digital humanities are particularly applicable to the quantitative analysis of cultural landscapes with extensive image records. It is especially advantageous in exploring the relationships among constituent elements. To a certain extent, they can mitigate the potential limitations of previous conclusions drawn from scattered examples, contributing to a more comprehensive understanding. This approach aids contemporary scholars in approaching a more accurate portrayal of historical contexts, facilitating the holistic and intrinsic preservation of the historical features of heritage.

### **Reflections on the conservation of the contemporary cultural landscape**

Contemporary preservation policies in Nanjing for cultural heritage included an important aspect of establishing a list of heritage conservation units and ranking them [51] based on an assessment of their heritage value. There was a particular emphasis on safeguarding individual architectural heritage that had been





**Fig. 13** The current situation of a preserved scenic view and a disappearing scenic view

preserved, while the protection efforts for cultural landscapes, representing regional heritage, were insufficient. Historical cultural landscapes, represented by the Forty Scenic Views, were complex entities composed of different elements of architecture and the environment. Therefore, comprehensive protection measures should be implemented based on the information contained in paintings. The primary task at present is to conduct surveys and establish archives for the existing conditions of the Forty Scenic Views. Subsequently, preservation or restoration designs could be developed in accordance with historical records. For well-preserved scenic views, such as "Cloud-Shrouded Trees on Jilong Mountain", protection measures should be implemented based on the standards of regional cultural landscapes rather than as multiple independent heritage entities (Fig. 13). It should include demarcating heritage and buffer zone boundaries, with a particular emphasis on preserving the authenticity and integrity of the heritage and controlling the height of surrounding buildings and overall landscape features [39]. As for disappeared views, such as "Spring Outing at Changganli Block", restoration research and design could be conducted based on image and textual materials. This effort could be coordinated with urban renewal policies

to restore and continue the historical context. For urban renewal in other non-typical historical areas, the five clusters summarized in the section "Network relationship of landscape elements" could be utilized for controlling the historical landscape character to ensure the continuity of traditional landscape patterns. The conclusions drawn from the section "Correlation characteristics of landscape elements" could provide a basis for the collaborative protection of high-importance historical landmarks. Furthermore, the government could even apply for world heritage in the whole ancient city with 40 scenic views as the core of cultural landscape, learning from the experience of West Lake in Hangzhou (with the culture of eight scenic views and oriental aesthetics), as well as Quanzhou (the whole city as a heritage).

Moreover, it is recommended to strengthen the connection between the urban green space system and cultural landscapes. Specifically, the fully protected and restored Forty Scenic Views can be incorporated into the green space system as core green space nodes. It will allow citizens to savor historical heritage during daily recreation, achieving an organic integration of "protection, cognition, and incorporation" on three levels.

## Conclusion

The "Eight Scenic Views", as an essential component of the regional traditional landscape construction system, serve as a crucial foundation for contemporary comprehension of cultural landscapes and the interpretation of their heritage value. However, interpretations of the "Eight Scenic Views" in fields such as architecture, history, and art were still in the stage of direct interpretation of historical materials. To advance the research, this study attempted to introduce digital humanities research methods. It involved the semantic deconstruction of the images of the "Forty Scenic Views", statistical analysis of various landscape elements using visualization tools, and the application of research methods like spatial analysis of ArcGIS, co-occurrence and clustering of KH Coder, and correlation analysis of SPSS. These approaches aimed to explore quantitative relationships, such as co-occurrence structures, hierarchical clustering, and correlations among various elements. The comprehensive analysis sought a deeper understanding of the historical significance and cultural meaning of the "Eight Scenic Views", thus enhancing our historical knowledge of the urban landscape construction of Nanjing in the Late Ming. The main findings of this study are as follows:

1. The distribution of scenic views was most concentrated in the area south of the Qinhuai River, extending westward to form a concentrated distribution belt in an L-shape. The axis of the scenery aligned with the city axis, and the quantity of scenery distribution fluctuated outward from the mean center in a wave-like decreasing pattern.
2. An information graph reflecting 20 types of landscape elements was constructed, revealing quantitative relationships in terms of the name of the scenery, landscape elements, position of the elements, style of the elements, theme of scenery, and location of the scenery. Compared to the "Eight Scenic Views" in other regions, scenic views of Nanjing placed a greater emphasis on humanistic styles, particularly the historical significance. Distinctive element types included ritual architecture, city walls, residences and gardens, and rocks and caves.
3. Network relationship graphs of landscape elements were constructed. The elements of the rivers, religious architecture, and sound ranked in the top three for Degree Centrality, holding a core position. The elements of the plants, sound, and landscape architecture ranked in the top three for Betweenness Centrality, serving as pivotal points. 5 landscape paradigms identified through cluster analysis showcased

the distinctive regional features of landscape order and spatial patterns of Nanjing.

4. The correlational factors of landscape elements and their ranking were calculated. 36 pairs of interactive relationships (synergy or antagonism) among landscape elements were found, which were based on the dimension of importance. For instance, around a well-known river with rich culture and history, the landscape architecture as the landmark was often constructed, providing further depth to the summarization of landscape paradigms in (3). Additionally, it was observed that factors influencing the ranking of scenic views include historical context and the overall importance of elements.
5. A research approach for the digital analysis of historical images, termed landscape deconstruction, was proposed. The approach involved dissecting the internal "associations" by analyzing the surface-level "composition" of images. It represented a new exploration into the ways of dissecting and understanding historical and cultural landscapes.

The obtained results indicated the feasibility of the research approach. We aim to attempt the deciphering of historical information using digital methods in the information age, providing more ideas and enlightenment for urban development and cultural inheritance. Through the exploration in this paper, more scientifically informed decision-making support can be provided for the historical inheritance and preservation of the urban landscape of Nanjing. Furthermore, these research methods are expected to serve as a positive reference and promotion in the studies of historical landscape construction in other cities.

In terms of future prospects, overcoming the variations among different historical images, if artificial intelligence can be employed to automatically identify the constituent elements of images, it holds the potential to analyze more extensive and complex image datasets. Then, it may enable the deciphering of the genetic composition of historical landscapes in diverse countries and regions, thereby contributing to the historical heritage of future urban landscape planning.

## Figure source

Figure 1: The right part is from the "Textual research on ancient and modern maps of Jinling" written by Chen Yi in the Ming Dynasty.

Figure 2: The middle part is from the "Geographical Map of the Yangzi River" in the Qing Dynasty collected by the Taipei Palace Museum. The right part



is from the "Textual research on ancient Monument Map of Jinling" written by Zhu Xie in the Republic of China.

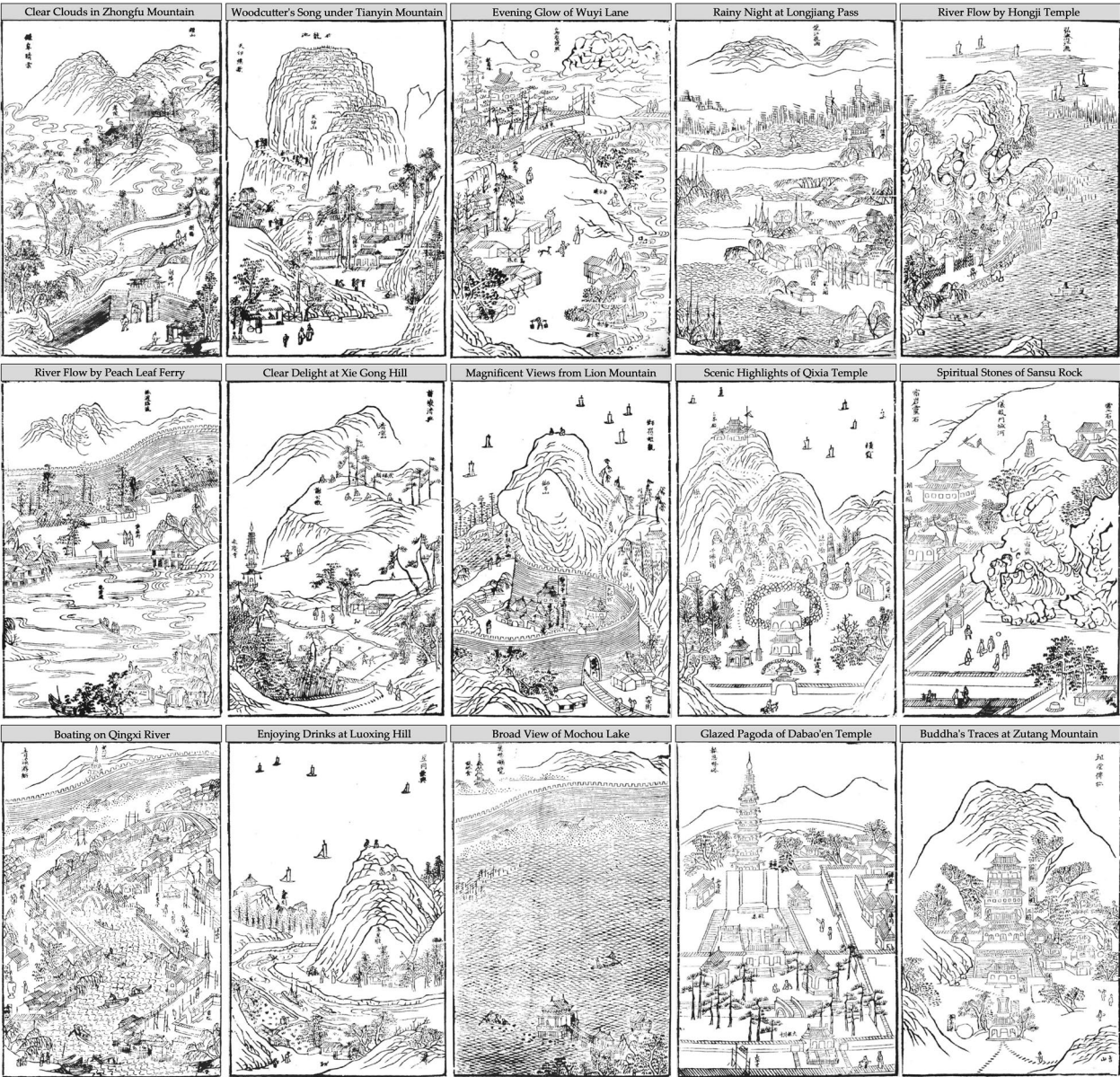
Figure 12: The right part is from the "Jiangning County Annals" in the Wanli period of the Ming Dynasty.

Figure 13: The two photos in the middle part are from open photos in Google Earth.

The rest of the historical scenic images, including appendix images, are from the "Images and Poems

on the Forty Scenic Views of Jinling" written by Zhu Zhifan and Lu Shoubai in the Ming Dynasty. The rest are all drawn by the authors of this paper.

**Appendix**  
23 of the 40 scenes are mentioned in this paper. Except for 8 in Figs. 2, 3, 10, 12, and 13, the remaining 15 scenic images are listed here for reference when reading.





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**Author contributions**

Conceptualization, methodology, research ideas, data collection and analysis, drawing of Figures and Tables, major writing, WZ; optimization of research content, suggestions for research results, language polishing, YW; discussion and optimization of research methods and ideas, revision suggestion, LF; guidance and supervision of data processing, sponsor, YH. All authors have read and agreed to the published version of the manuscript.

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The authors declare no competing interests.

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