

Article

Analysis of Spatial and Temporal Distribution Patterns of Traditional Opera Culture along the Beijing–Hangzhou Grand Canal

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Abstract: As an exquisite asset of Chinese traditional culture, traditional opera occupies a place of high esteem within the world’s cultural and artistic treasury. The impact of emerging cultures has threatened the future of traditional opera culture, necessitating a thorough examination of the historical context of the Grand Canal and traditional opera. There is insufficient research on the spatial evolution of the traditional opera culture along the Grand Canal; thus, this study takes ancient opera stages, a representative cultural relic of traditional opera, as an entry point and employs methods such as kernel density analysis and standard deviation ellipse analysis to analyze the spatial and temporal distribution patterns of the traditional opera culture along the Grand Canal. The results showed that: (i) Nationwide, opera stages in the areas along the Grand Canal exhibit a significant clustering characteristic. (ii) The changes in the number and locations of opera stages in the areas along the Grand Canal are closely related to the rise and fall of the Canal. The opera stages emerged along the Canal, gradually prospered with the development of the Canal, and finally clustered in a band-like cluster along the Grand Canal. (iii) From the Ming Dynasty to the founding of the People’s Republic of China, the opera stages in the areas along the Grand Canal spread in the “southeast–northwest” direction, which was consistent with the main direction of the Grand Canal, indicating its driving influence. (iv) On the centennial scale, from the 14th century to the 20th century, the evolution characteristics of the distribution centroid of opera stages in the areas along the Grand Canal were closely related to the key time nodes of Grand Canal construction and basin expansion. This study reveals the relationship between the Grand Canal and the spatial pattern evolution of traditional opera culture, aiming to promote the construction of the Grand Canal cultural belt.

Keywords: Beijing–Hangzhou Grand Canal; spatial and temporal patterns; traditional opera dissemination; historical GIS; Grand Canal cultural belt



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1. Introduction

Traditional opera is an important part of China’s exceptional culture. The Beijing–Hangzhou Grand Canal (hereafter referred to as the Grand Canal), an important north–south transportation route in the Yuan, Ming, and Qing dynasties, flowed through regions with prosperous economies and flourishing cultures. It had a pivotal influence on the emergence, development, and dissemination of traditional opera art [1–3]. In 2019, China issued the Outline of the Planning for the Protection, Inheritance, and Utilization of the Grand Canal Culture, providing important guidance for building the Grand Canal cultural belt. Currently, under the impact of emerging cultures such as online culture, anime, and game culture, the audience of traditional Chinese opera is constantly decreasing, and cultural heritage is facing a major crisis. It is urgent to explore the spatial and temporal

distribution patterns of the Grand Canal's traditional opera culture and promote the construction of the Grand Canal cultural belt according to local conditions.

Currently, the research on the spatial distribution pattern of traditional opera culture can be classified into two categories. The first category is the static study of the spatial pattern of traditional opera (music) culture. Liu et al. [4] mapped the distribution and spreading range of local traditional operas and analyzed the regional distribution characteristics and formation mechanisms of local traditional operas. Fu [5] mapped the distribution of traditional opera genres in the Anhui province and combined historical and theoretical approaches to study the geographical spatial distribution of traditional opera genres in Anhui during the Ming and Qing dynasties. Zhang [6] concluded the characteristics and laws of the main genres of traditional opera in Shaanxi and created a division of traditional opera cultural regions through literature such as local chronicles. Li [7] mapped the distribution of traditional operas in Shandong and analyzed the spatial distribution characteristics of local traditional opera genres in Shandong. Zhang et al. [8] mapped the distribution of intangible cultural heritage of music (ICHM) in Xiangxi and employed methods such as the nearest neighbor index and kernel density estimation to analyze the characteristics and main factors of the ICHM spatial distribution. Fu and Zhang [9] integrated ancient books and materials to summarize the spatial and temporal distribution characteristics of opera stages in Pingyang, Shanxi. Chai [10] arranged and summarized the elevation distribution, regional distribution, and density characteristics of Shanxi opera stages in the Yuan, Ming, and Qing dynasties. Based on music performance activities, Wang and Zou [11] identified the spatial layout pattern of music venues.

The second category is the investigation of the dynamic development of traditional opera cultural regions. Wu [12] proposed a spatial diffusion model for Huai Opera and quantitatively analyzed the evolution and spatial trends of cultural regions based on professional Huai Opera troupes. Tian et al. [13] mapped the distribution of intangible cultural music heritage of the “Yellow River Yangtze civilization Corridor” in different historical periods and analyzed the temporal and spatial distribution characteristics and influencing factors of intangible cultural music heritage in the basin. Fang [14] summarized the types and characteristics of the spatial diffusion and integration of Qin Opera culture and mapped a schematic diagram of the path of Qin Opera culture diffusion. Sun [15] summarized the spatial distribution regions and characteristics of opera types in the Jinji area and discussed the spatial structure and factors of the spatial spread of opera culture. Using professional theater troupes as the basis for zoning, Xia and Huang [16] mapped Huangmei Opera cultural zones and analyzed the evolution characteristics and causes of the cultural zones. Florida et al. [17] summarized and analyzed the agglomeration effect and evolution characteristics of American pop music culture in space from 1970 to 2000. Borowiecki [18] analyzed the spatial clustering distribution and characteristics of the productivity of 116 renowned classical composers based on their life history samples via geographic concentration data. In addition, some scholars proposed the concept of operatic geographies, emphasizing the geographical analysis of opera and establishing the role of spatial patterns in the study of musical development [19–21].

In summary, most of the existing academic achievements are based on the types of opera (music) and architecture, conducting research on the spatial distribution, evolution, and influencing factors of opera (music) culture. However, the dissemination of traditional opera is closely related to waterway transportation, and the phenomenon of waterway communication of opera needs to be further explored. Moreover, the research scale is mostly in a certain province and city in space, and the time span is short.

As a type of carrier of the Chinese traditional opera culture inheritance, the evolution of opera stages demonstrates synchronous characteristics with the development of traditional opera [22,23]. Therefore, based on the spatial distribution of ancient opera stages, this study carries out quantitative research on the spatial and temporal evolution of the dissemination of traditional opera culture along the Grand Canal. By collecting the construction period and spatial location information of ancient opera stages, this study located the ancient stage

in time and space. Methods such as kernel density analysis and standard deviation ellipse analysis were employed to analyze the distribution pattern of the traditional opera culture along the Grand Canal and its spatial and temporal evolution characteristics. The results reveal the relationship, characteristics, and laws of the Grand Canal and traditional opera dissemination, providing a reference for the development of the Grand Canal cultural belt.

2. Data and Methods

2.1. Data

2.1.1. Data Sources

The national data on traditional opera stages were derived from the Chronicles of Chinese Traditional Opera Cultural Relics: Volume of Opera Stages and the Chronicles of Chinese Traditional Opera (Table 1). Due to the small number of stages in the Yuan Dynasty and before, the Ming Dynasty to the end of the 20th century is chosen as the research period (spanning the Ming Dynasty (1368–1644 AD), the Qing Dynasty (1644–1911 AD), the Republic of China (1912–1949 AD) and after the founding of the People's Republic of China). According to the geographical locations of the national opera stages in the literature, geographic coordinate information was obtained in bulk using the Baidu Map coordinate picking tool. The geospatial data referenced the latest administrative divisions from the official website of the Chinese government, and the base map data were sourced from the standard map online service system of the State Bureau of Surveying and Mapping Information.

Table 1. Source and quantity of stage data.

Data Sources	Number of Stages
The Chronicles of Chinese Traditional Opera Cultural Relics: Volume of Opera Stages	1562
The Chronicles of Chinese Traditional Opera	657

2.1.2. Data Collection and Processing

Excel and ArcGIS were used to convert the latitude and longitude coordinates of the national opera stages into opera stage vector point features to form a distribution map (Figure 1). The attribute data of the stage point features, including the stage name, establishment time, and geographical location (down to the county-level administrative region), were sorted and entered. The opera stages with ambiguous establishment times and locations were marked. For about ten stages without location during the research period, due to the limited data, they were not included in the analysis to ensure the scientific nature of the research results.

2.2. Analysis Method

2.2.1. Kernel Density Analysis

Kernel density analysis uses a given range around any point in space to effectively calculate and represent the spatial characteristics of diverse spatially clustered elements based on the geospatial differences in the area; this information is used to calculate the density of the observed data within that area [24]. In this study, the number of opera stages is used as the weight for kernel density calculation to assess the clustering characteristics of the spatial distribution of opera stages and reflect the spatial distribution differences in traditional opera culture along the Grand Canal. The calculation formula is as follows:

$$f(x) = \frac{1}{nh} \sum_{i=1}^n k\left(\frac{x-x_i}{h}\right) \quad (1)$$

where $\left(\frac{x-x_i}{h}\right)$ is the kernel function, h is the bandwidth, and $x - x_i$ is the distance from the estimated point x to the known stage point x_i .



Figure 1. Distribution of traditional opera stages in China.

2.2.2. Standard Deviation Ellipse Analysis

The standard deviation ellipse method uses visualization to characterize the spatial distribution of a research object in terms of centrality, range, direction, shape of the distribution [25]. By processing point features, an ellipse with three standard parameters (center, major and minor semi-axes, and angle) is output. The major semi-axis of the ellipse represents the distribution direction of point features. The ratio of major to minor semi-axes is called the flattening ratio. A higher flattening ratio indicates a stronger directionality of point feature distribution. The minor semi-axis represents the range of point feature distribution. A shorter minor semi-axis indicates a more clustered distribution of point features, while a longer minor semi-axis indicates a higher degree of dispersion. If the minor semi-axis is equal to the major semi-axis, the point features do not have any specific distribution characteristics. In this study, parameters such as centroid, azimuth, flattening ratio, or major and minor semi-axes are used to quantitatively define the evolution pattern of the spatial distribution of opera stages, so as to reveal the spatial evolution characteristics of the spread of traditional opera culture. The variances of an ellipse are calculated as follows:

$$SDE_x = \sqrt{\frac{\sum_{k=1}^N (x_i - \bar{X})^2}{n}} \quad (2)$$

$$SDE_y = \sqrt{\frac{\sum_{k=1}^N (y_i - \bar{Y})^2}{n}} \quad (3)$$

where x_i and y_i are the spatial position coordinates of each point feature, the sum is the arithmetic mean center, n is the total number of features, and SDE_x and SDE_y are calculated variances of the ellipse.

The angle of the ellipse is calculated as follows:

$$\tan\theta = \frac{A+B}{C} \quad (4)$$

$$A = \left(\sum_{i=1}^n \tilde{x}_i^2 - \frac{\sum_{i=1}^n \tilde{y}_i^2}{1} \right) \quad (5)$$

$$B = \sqrt{\left(\sum_{i=1}^n \tilde{x}_i^2 - \frac{\sum_{i=1}^n \tilde{y}_i^2}{1} \right)^2 + 4 \left(\sum_{i=1}^n \tilde{x}_i \tilde{y}_i \right)} \quad (6)$$

$$C = 2 \sum_{i=1}^n \tilde{x}_i \tilde{y}_i \quad (7)$$

where $\tilde{x}_i$ and $\tilde{y}_i$ are the differences between the mean center and the x and y coordinates. Finally, the standard deviations for x and y axes are determined as follows:

$$\sigma_x = \sqrt{2} \sqrt{\frac{\sum_{i=1}^n (\tilde{x}_i \cos \theta - \tilde{y}_i \sin \theta)^2}{n}} \quad (8)$$

$$\sigma_y = \sqrt{2} \sqrt{\frac{\sum_{i=1}^n (\tilde{x}_i \sin \theta + \tilde{y}_i \cos \theta)^2}{n}} \quad (9)$$

Using the standard deviations, the standard equation of the ellipse can be expressed as

$$\left(\frac{x}{\sigma} \right)^2 + \left(\frac{y}{\sigma} \right)^2 = s \quad (10)$$

where s is the confidence level.

3. Results

3.1. Spatial Distribution

3.1.1. Density Analysis

To study the specific degree of the impact of the Grand Canal on the development of traditional opera culture, a kernel density map was made in ArcMap to analyze the specific distribution pattern of opera stage clusters nationwide, as well as in provinces and cities along the Grand Canal, as shown in Figure 2. The h (bandwidth) in the kernel density analysis is set to 150 km.

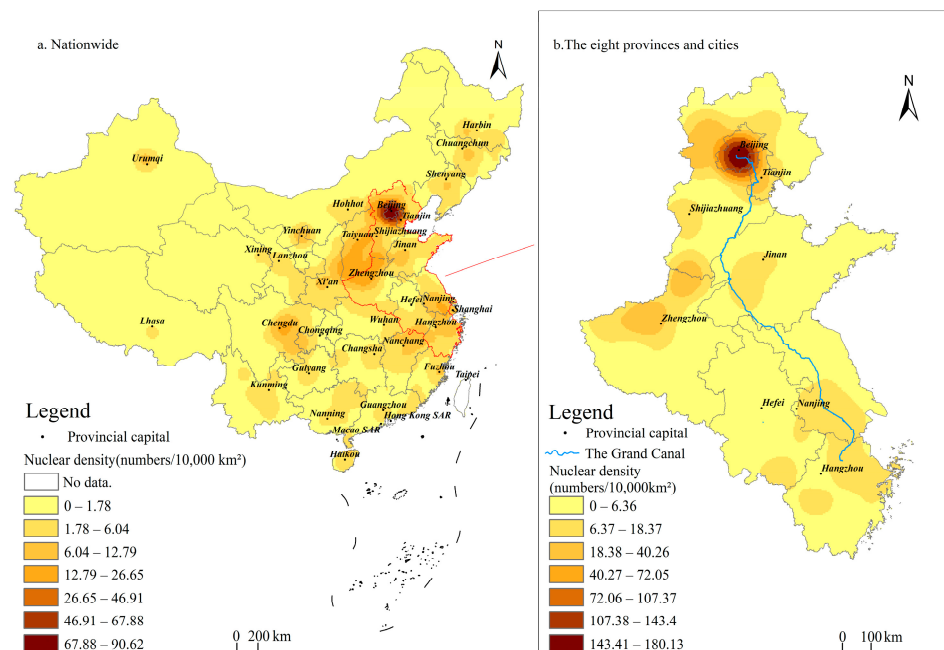


Figure 2. Spatial distribution of opera stages in China and in the eight provinces and cities.

As is shown in Figure 2a, a kernel density analysis of opera stages selected nationwide was conducted. There are four major clusters of opera stages nationwide. The first major cluster is the Beijing–Tianjin area mentioned above, with a kernel density as high as 81–103 stages per 10,000 km². The second major cluster is the Shanxi area, with a kernel density mostly between 34–56 stages per 10,000 km², and centered in Linfen, which has a kernel density as high as 81 stages per 10,000 km². The third major cluster is the Chengdu Plain area, with a kernel density mostly between 18–34 stages per 10,000 km² and with Chengdu as its center, which has a kernel density as high as 34–56 stages per 10,000 km². The fourth major cluster includes the border area of Jiangsu and Shanghai, Zhejiang, as well as the border area of Anhui and Jiangxi, with a kernel density between 18–34 stages per 10,000 km².

As is shown in Figure 2b, the kernel density analysis was carried out on the number of opera stages in the eight provinces and cities along the Grand Canal to identify regions with concentrated spatial distribution of opera stages as well as flourishing growth and development of traditional opera. Based on the kernel density values, the core areas of opera stage distribution are classified into three levels. Within the eight provinces and cities along the Grand Canal, the spatial distribution of opera stages can be divided into one primary core area, two secondary core areas, and five tertiary core areas. The primary core area is located in the Beijing–Tianjin area. The kernel density of opera stages in this area ranges from 144 to 180 stages per 10,000 km², and the opera stages are in large quantities, widely distributed around Beijing, which is the core of the primary core area. The secondary core areas have a kernel density in the range of 19 to 40 stages per 10,000 km², including Luoyang in Northwest Henan Province and Anyang and Handan at the junction of Henan and Hebei, with the surrounding areas forming a dumbbell-shaped region with a relatively high kernel density of opera stages. The tertiary core areas have a kernel density ranging from 7 to 18 stages per 10,000 km² and include Suzhou, Wuxi, Changzhou, Zhenjiang, Nanjing–Hangzhou area, Qiandao Lake area and Mount Huang area in Southern China, as well as Tai’an–Jining area in Western Shandong and Shijiazhuang in Western Hebei in Northern China. In Southern China, the opera stages are distributed in a band-like manner along the Grand Canal in the core areas in Jiangsu and Zhejiang and in patches in the Southern Anhui area and the Qiandao Lake area.

3.1.2. Centroid and Direction Analysis

To analyze the directional characteristics of the spatial distribution of opera stages in the provinces and cities along the Grand Canal from a comprehensive perspective, the standard deviation ellipse method was used to analyze the opera stages in China as well as in the eight provinces and cities along the Grand Canal in different periods, so as to reveal the center, dispersion, and directional trend of the spatial distribution of opera stages. The results are shown in Figure 3 and Tables 2–4.

Table 2. The coordinates of the centers of standard deviation ellipses for the distribution of opera stages in different regions and different periods.

Region and Period	Ming Dynasty	Qing Dynasty	After the Founding of the Republic of China and then the People’s Republic of China
Eight provinces and cities	(35.53° N, 117.37° E)	(37.00° N, 116.42° E)	(36.35° N, 117.73° E)
Nationwide	(34.28° N, 113.89° E)	(34.98° N, 113.10° E)	(36.38° N, 113.02° E)

Table 3. The azimuths of standard deviation ellipses for the distribution of opera stages in different regions and different periods (unit: °).

Region and Period	Ming Dynasty	Qing Dynasty	After the Founding of the Republic of China and then the People’s Republic of China
Eight provinces and cities	156.18	160.26	156.86
Nationwide	156.85	25.76	49.82

Table 4. The major and minor semi-axes of standard deviation ellipses for the distribution of opera stages in different regions and different periods (unit: km).

Region and Period	Ming Dynasty		Qing Dynasty		After the Founding of the Republic of China and then the People’s Republic of China	
	Minor Semi-Axis	Major Semi-Axis	Minor Semi-Axis	Major Semi-Axis	Minor Semi-Axis	Major Semi-Axis
Eight provinces and cities	245.22	684.27	281.82	616.23	174.41	686.95
Nationwide	615.73	758.02	630.58	909.29	1205.36	1352.11

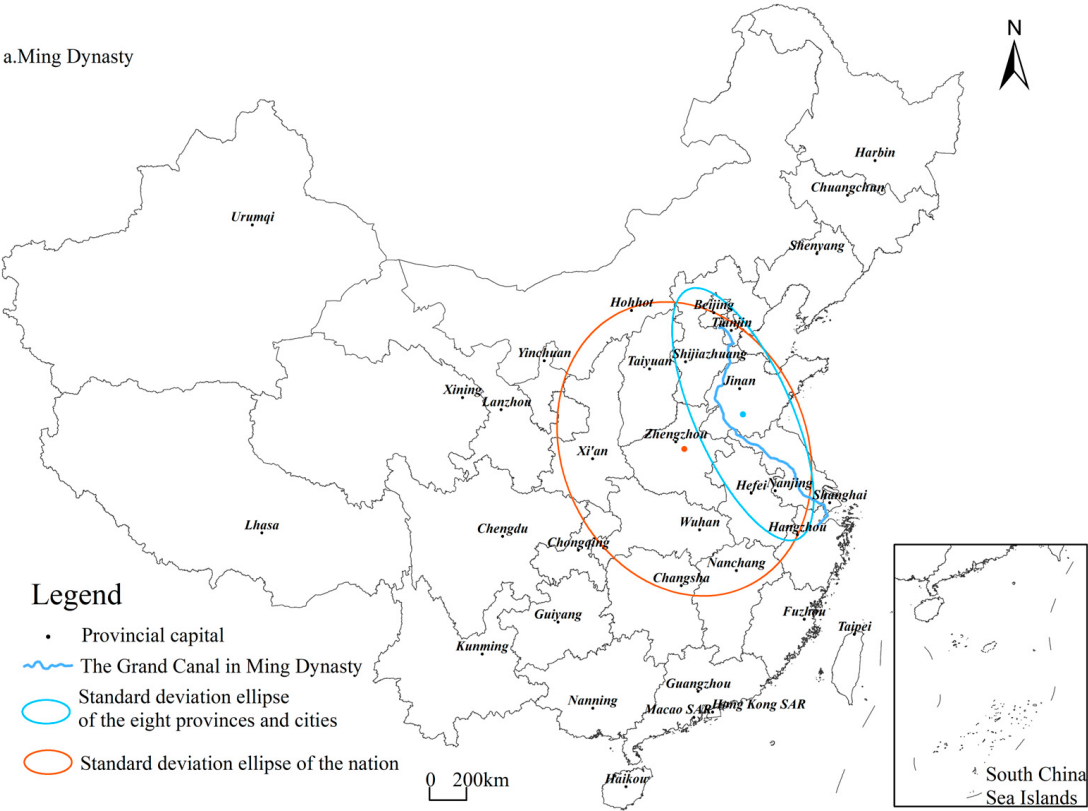


Figure 3. Cont.

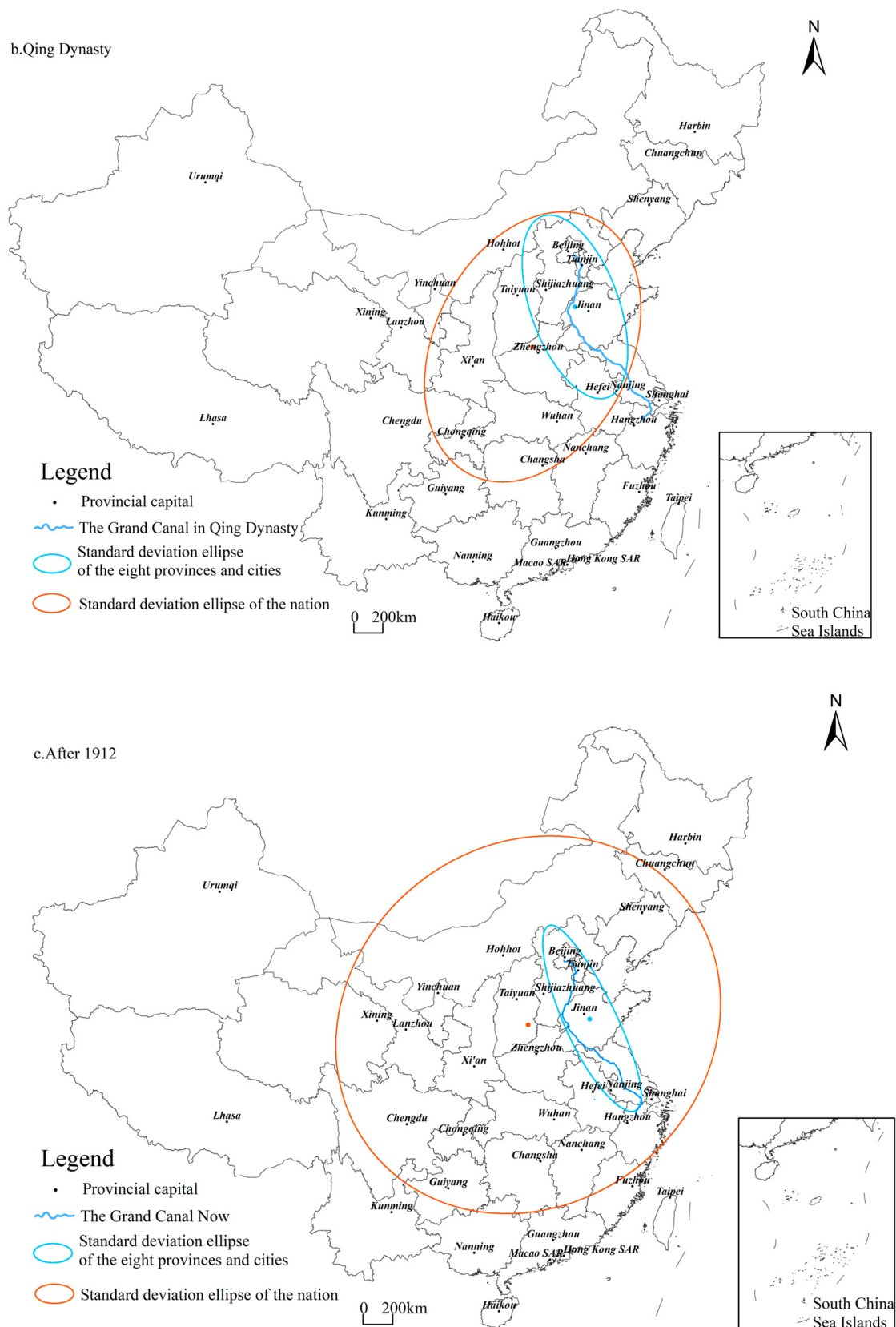


Figure 3. Standard deviation ellipses for different regions during different periods.

In terms of the centroid, during the Ming Dynasty, the centroid of opera stages in the eight provinces and cities was located in the southern part of Sishui County in Jining

City, Shandong Province, while the centroid of opera stages nationwide was located in the northern part of Changge City in Xuchang City, Henan Province. During the Qing Dynasty, the centroid of opera stages in the eight provinces and cities was located at the border of Dezhou, Shandong Province, along the Grand Canal, while the centroid of opera stages nationwide was located in Jiaozuo, Henan. After the establishment of the Republic of China and later the founding of the People's Republic of China, the centroid of opera stages in the eight provinces and cities was located in the Jinan area, Shandong Province, which is the central part of Shandong Province, while the centroid of opera stages nationwide was located in Changzhi City, Shanxi Province. In summary, from the Ming Dynasty to the founding of the People's Republic of China, the centroid of opera stages in the eight provinces and cities has been located in the central and western part of Shandong Province, adjacent to the east bank of the Grand Canal, while the centroid of opera stages nationwide has been located on the west bank of the Grand Canal and runs approximately parallel to the Grand Canal from central Henan to southeastern Shanxi. Therefore, the centroid of opera stages nationwide has been driven by the Grand Canal.

In terms of direction, from the Ming Dynasty to the founding of the People's Republic of China, the distribution of opera stages in the eight provinces and cities was always in the southeast–northwest direction, while the distribution of opera stages nationwide was in the southeast–northwest direction during the Ming Dynasty and in the southwest–northeast direction from the Qing Dynasty to the founding of the People's Republic of China. Therefore, the distribution of opera stages in the eight provinces and cities in the north–south direction has been greatly affected by the direction of the Grand Canal.

3.2. Temporal Variation

3.2.1. Density Variation Analysis

To study the specific distribution of opera stages along the Grand Canal during different periods, a kernel density map was created in ArcMap to conduct a kernel density analysis on the number of opera stages along the Grand Canal in the eight provinces and cities during the Ming Dynasty, Qing Dynasty, and the modern era, in order to compare the changes in regions with a concentrated distribution of opera stages and widespread dissemination and development of traditional opera in different periods. The results are shown in Figure 4.

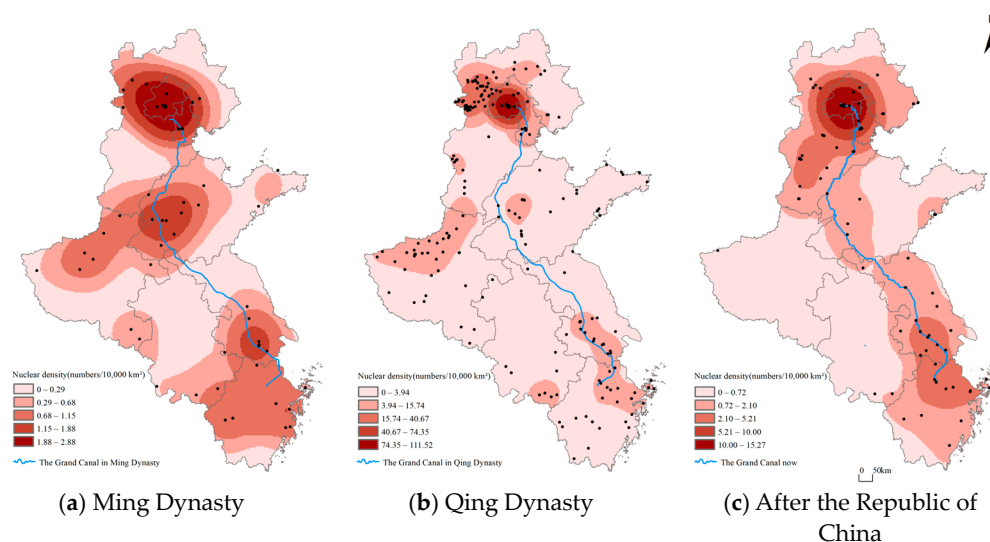


Figure 4. The kernel density distribution of opera stages in the eight provinces and cities along the Grand Canal in different periods.

In Figure 4, darker colors indicate a higher number of opera stages per unit area. There was a continuous increase in the number of opera stages in the eight provinces

and cities along the Grand Canal from the Ming to Qing dynasties. During the Ming Dynasty, there were only a considerable number of opera stages at the beginning, end, and middle sections of the Grand Canal: most opera stages were located in regions such as Beijing, Shandong, Henan, Jiangsu, and Zhejiang. Following the Ming Dynasty, with the continuous development of the Grand Canal during the Qing Dynasty, the number of stages reached its peak; this period was the most prosperous for the development of the Grand Canal. During this period, opera stages were clearly distributed along the route of the Grand Canal, with the highest concentration at the starting and ending parts of the canal. Especially in the Beijing area, the density of opera stages reached as high as 100 per 10,000 km². After the establishment of the Republic of China, the Grand Canal was no longer fully navigable, and hence its function as a means of communication between the north and the south declined. Consequently, the number of opera stages dropped sharply.

In terms of the distribution characteristics of opera stages in the eight provinces and cities along the Grand Canal in the Ming and Qing dynasties, in the Ming Dynasty, opera stages were distributed within a primary core area in the Beijing area and within two secondary core areas in the Henan and Shandong border area and the Jiangsu and Zhejiang border area along the Grand Canal. During this period, the opera stages were mainly distributed at the important nodes of the Grand Canal. In the Qing Dynasty, the opera culture flourished exceptionally in the vicinity of Beijing, and the primary core area of opera stages remained clearly concentrated in this area. In other areas along the Grand Canal, the opera stages gradually formed a band-like cluster. In modern times, as shown in Figure 4, the dark areas, that is, the dense core areas, have almost overlapped with the route of the Grand Canal, with the highest distribution in the Beijing area and at the border area of Jiangsu and Zhejiang, and the opera stages in the eight provinces and cities have roughly formed a band-like dense area along both sides of the Grand Canal.

3.2.2. Analysis of Centroid and Direction Changes

To reveal the changes in the spatial and temporal patterns of the geographical features of opera stages, this study used the standard deviation ellipse analysis to examine the evolutionary characteristics of the distribution centroid of opera stages in the eight provinces and cities along the Grand Canal from before the 14th century to the 20th century. A comparative analysis of the key time nodes of the construction and development of the Grand Canal showed that the distribution of opera stages had a certain correlation with the construction of the Grand Canal and the direction of the basin expansion.

The changes in the centroid in Figure 5 and the data in Table 5 show that, from the 14th century to the 20th century, six time nodes were important in the change in the centroid of the opera stages in the eight provinces and cities along the Grand Canal. In the ninth year of the Yongle's reign (1411), the Huitong River was expanded and renovated. With the opening of the Huitong River, Linqing gradually developed from an ordinary small county town to the largest commercial city in northern China. Along with this development, the Grand Canal culture flourished, and Dongping on the banks of the Huitong River once became the center for Zaju (poetic drama) creation, leading to a northward shift in the centroid of the opera stages from 1411 to 1527, compared to that in the pre-14th century period until 1411. To protect the Grand Canal from flooding by the Yellow River and avoid a 180 km journey along the Yellow River, two separate canal construction projects took place during the Ming Dynasty. The first project occurred from the seventh year of the Jiajing reign to the first year of the Longqing reign (1528 to 1567), and the second project took place from the twenty-third to the thirty-third year of the Wanli reign (1595 to 1605). These projects involved the construction of a canal that extended 220 km from the eastern part of the present-day Nansihu Lake in the south of Nanyang Town in Jining, Shandong. This diverted the original route of the Grand Canal, which used to pass through Peixian and Xuzhou before reaching the Yellow River (known as the Sishui Canal). Instead, the new route went through Xiazhen, Hanzhuang, and Taierzhuang, connecting to the eastern part of the present-day Nansihu Lake. As a result of these changes, the centroid of opera

stages shifted southward during the period of 1528 to 1680 compared to the period of 1411 to 1527; however, it shifted northward during the period of 1681 to 1854 compared to the period of 1528 to 1680. In the fifth year of the Xianfeng reign (1855), the Yellow River changed its course northward after breaching its banks at Tongwaxiang in Henan Province and appropriated the Daqing River to enter the sea in Shandong Province, leading to the complete disruption of the north–south navigation on the Grand Canal. Consequently, the centroid of opera stages shifted southward again during the period of 1854 to 1952, compared to the period of 1681 to 1854. The overall trajectory of this movement can be summarized as a process of “shifting northward—southward—northward—southward”. The centroid of opera stages, which was previously situated around the areas of Suzhou and Suqian at the border of Anhui and Jiangsu provinces before 1411, shifted during the past six centuries of the Ming and Qing dynasties to the areas of Jinan, Tai’an, Zibo, and Weifang in Shandong Province in the 20th century. The centroid moved progressively northward during this period, reaching as far south as the Huainan and Bengbu areas along the Yangtze River in Anhui Province, and as far north as the Dezhou and Hengshui areas in Hebei Province.

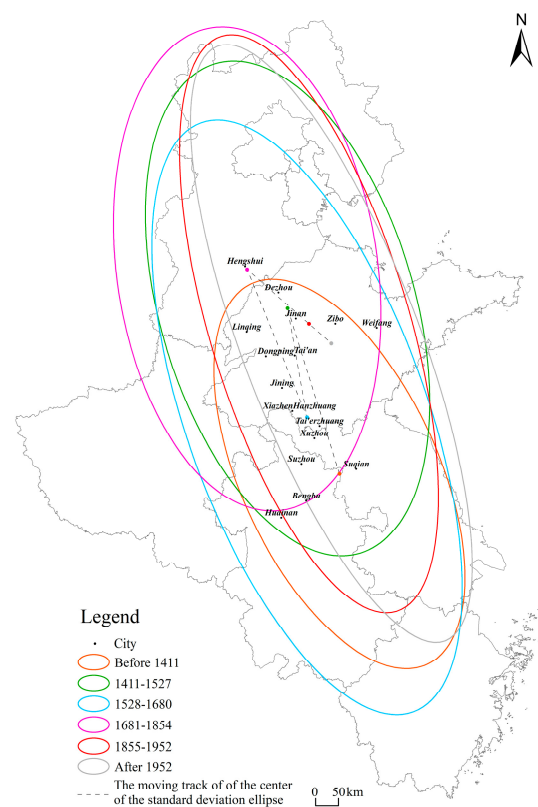


Figure 5. Standard deviation ellipses of important time nodes from before the 14th century to the 20th century.

Table 5. The main parameters of the standard deviation ellipse of the stage distribution at important time nodes in eight provinces and cities from the 14th century to the 20th century.

Time	Centroid Coordinates	Size (km ²)	Azimuth (°)	Flattening Ratio	Minor Semi-Axis (km)	Major Semi-Axis (km)
Before 1411	(33.63° N, 118.09° E)	313,636.50	155.18	0.5293	216.78	460.57
1411–1527	(36.92° N, 116.86° E)	493,494.50	163.45	0.5008	280.04	560.98
1528–1680	(34.76° N, 117.33° E)	571,415.13	160.19	0.6159	264.33	688.20
1681–1854	(37.69° N, 115.85° E)	482,322.03	171.73	0.4653	286.54	535.84

Table 5. Cont.

Time	Centroid Coordinates	Size (km ²)	Azimuth (°)	Flattening Ratio	Minor Semi-Axis (km)	Major Semi-Axis (km)
1855–1952	(36.61° N, 117.38° E)	454,672.09	163.09	0.6683	219.12	660.61
After 1952	(36.22° N, 117.93° E)	428,236.20	159.02	0.7215	194.86	699.71

4. Conclusions and Discussion

4.1. Conclusions

The development, spread, and evolution of traditional opera culture in China possess a dual nature of regional and historical dimensions, representing an artistic phenomenon existing within geographical space. As an important geographical venue for the dissemination and transfer of traditional opera culture, opera stages are situated within the coordinates of time. By utilizing GIS spatial analysis based on data of opera stages nationwide since the Ming Dynasty, we investigated the spatial and temporal evolution processes and patterns of the spread of opera stages along the Grand Canal and throughout the entire country and analyzed the spatial and temporal distribution patterns of traditional opera culture. The following conclusions are drawn.

- (i) The spatial distribution of traditional opera culture has clear characteristics of clustering. The opera stages are mainly distributed in patches. They are represented by one primary core area, two secondary core areas, and five tertiary core areas within the eight provinces and cities along the Grand Canal and by four major clusters at the national level.
- (ii) From a temporal perspective, the changes in the number and locations of opera stages are closely related to the rise and fall of the Grand Canal. The analysis between different dynasties showed that during the Ming Dynasty, opera stages were distributed along the beginning, middle, and end sections of the Grand Canal; in the Qing Dynasty, as the Grand Canal thrived and developed, the number of opera stages gradually increased, ultimately forming a dense concentration of opera stages in a band-like cluster along both sides of the Grand Canal; and after the establishment of the Republic of China and later the founding of the People's Republic of China, the number of opera stages gradually declined, but they remained distributed in a band-like cluster along the Grand Canal. Overall, traditional opera culture originated along the Grand Canal, gradually prospered with the development of the Grand Canal, and eventually became concentrated in a band-like cluster along the Grand Canal.
- (iii) From the Ming Dynasty to the founding of the People's Republic of China, the spread of traditional opera culture in the eight provinces and cities along the Grand Canal followed a "southeast–northwest" trajectory, with opera stages mainly located in the "Zhangjiakou–Hangzhou" area, aligning with the main direction of the Grand Canal, and driven by it as well. In terms of the distribution centroid, since the Ming Dynasty, the centroid of traditional opera culture in the eight provinces and cities has been located in the central and western parts of Shandong Province on the eastern bank of the Grand Canal and in proximity to the waterway. At the national level, the center shifted to the western bank of the Grand Canal, approximately parallel to the Grand Canal's waterway, spanning from the central part of Henan to the southeastern part of Shanxi, with its spatial pattern driven by the Grand Canal. Regarding the distribution direction, the spread in the north–south direction covered a broader area than in the east–west direction and the spatial distribution pattern of traditional opera culture had a close relationship with the north–south spatial characteristics of the Grand Canal.
- (iv) On the centennial scale, the evolution characteristics of the distribution centroid of traditional opera culture in the eight provinces and cities along the Grand Canal from before the 14th century to the 20th century are closely related to the key time

nodes of the construction of the Grand Canal and the expansion of its basin. Since the Ming Dynasty, the direction of the movement of the centroid of traditional opera has shown a trend of shifting between the northern and southern regions, following the flow direction of the Grand Canal. Overall, the direction of the spread of traditional opera culture changed in accordance with the direction of the construction of the Grand Canal.

4.2. Discussion

In the existing research on the Grand Canal culture, scholars have mostly used methods such as analyses of the historical literature and combinations of historical and theoretical approaches to qualitatively investigate the spread of traditional opera along the waterway. In our study, using opera stages as an indicator, we used methods such as kernel density analysis and standard deviation ellipse analysis to achieve a certain level of quantitative analysis. Additionally, macro- and meso-scale research were combined to cover the whole country as well as eight provinces and cities along the Grand Canal, spanning over 600 years from the Ming Dynasty to the modern era. This spatial and temporal analysis approach allows for a more direct comparison of the spread of traditional operas in different times and spaces in the eight provinces and cities along the Grand Canal, providing more quantitative references for future cultural studies along the Grand Canal.

In addition, in the investigation of the relationship between the Grand Canal and the dissemination of traditional opera, this study took opera stage-related data as an indicator to reflect the dissemination of traditional opera culture and established a spatial and temporal pattern based on the opera stage data. The spatial and temporal pattern reveals the law between the stage and the Grand Canal. The changes in the location and number of the stage are related to the rise and fall of the Grand Canal, which is also confirmed in the Yongji Canal section of the Grand Canal. In the future, multiple indicators reflecting the spread of traditional opera culture will be selected for comparative analysis. Through a multi-scale analysis, the correlation between the Grand Canal and the dissemination of opera culture will be studied, and the spatial and temporal dynamic characteristics of the dissemination of opera culture along the Grand Canal will be examined, providing valuable insights for the construction of the Grand Canal cultural belt.

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