SPATIAL AND TEMPORAL DISTRIBUTION CHARACTERISTICS OF CULTURAL RELICS PROTECTION UNITS AND DISASTER RISK ANALYSIS IN BEIJING

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ABSTRACT:

As the ancient capital of the Six Dynasties and the current capital, Beijing has a rich historical and cultural heritage. As a carrier of culture, cultural preservation units have significant historical, artistic, and scientific value in their own right. In this paper, we use the mean nearest neighbor, kernel density analysis, and standard deviation ellipse tools in ArcGIS 10.2 software to analyze the spatial and temporal distribution characteristics of different types and periods of cultural heritage units in Beijing and their potential seismic and meteorological hazard risks, to provide strong data support for the conservation and use of cultural heritage units in Beijing. The results show that the different types of cultural preservation units in Beijing are unevenly distributed, with the two categories of modern important historical sites and representative buildings and ancient buildings being more numerous and concentrated in Dongcheng District, Xicheng District, and Haidian District in central Beijing, and the three categories of ancient tombs, ancient ruins, cave temples, and stone carvings being less numerous and concentrated in the outer administrative districts of Beijing. In recent years, the relative humidity in Beijing has shown a decreasing trend, while the average temperature has shown an increasing trend, and this dry and hot environment is not conducive to the conservation of cultural preservation units. This dry and hot environment is not conducive to the protection of cultural preservation units and is prone to damage such as cracking, collapse, deformation, and discoloration of bamboo, wood, rocks, and other cultural heritage elements. It is concluded that in terms of specific regions, the number of cultural heritage units in central Beijing is high, the period is late and the risk of seismic hazards is high, while the number of cultural heritage units in the outer administrative regions of Beijing is low, the period is early and the risk of seismic hazards is low. In conclusion, to enhance the conservation and use of cultural heritage units in Beijing, the relevant authorities should strengthen the daily management of the three high-density and high-risk areas of cultural heritage units in Dongcheng District, Xicheng District, and Haidian District, while at the same time not relaxing the emergency disaster prevention and mitigation of the smaller number and earlier period of cultural heritage units in the peripheral administrative districts.

1. MANUSCRIPT

Beijing is an ancient capital of the Six Dynasties with a history of over 3,000 years, with the Yan, Liao, Jin, Yuan, Ming, and Qing dynasties all having their capitals here and with a rich historical background and a legacy of valuable cultural heritage. As an important part of cultural heritage, heritage conservation units have witnessed the progress and development of human civilization in many aspects such as history, art, and science (Contributed by the General Office of the Standing Committee of the National People's Congress.,2008). Under the guidance of documents such as the Opinions on Strengthening the Reform of Cultural Heritage Protection and Utilisation, the State Administration of Cultural Heritage has continued to improve the aggregation of information on the various types of cultural heritage units at all levels in China(www.gov.cn). However, this simple basic information is not intuitive to use in the follow-up work, so to better strengthen the conservation and use of cultural relics, this paper uses ArcGIS10.2 software to study the spatial and temporal distribution characteristics and influencing factors of cultural preservation units in Beijing.

The spatial and temporal distribution of cultural heritage units has been studied mainly in terms of geographical areas, ranging from small to large in four dimensions: county, province, region, and nationwide. In terms of the county and urban areas, Tu et al. use the immovable cultural relics in the third national cultural relics census in Fangshan District, Beijing, to explore the spatial patterns of their clustering, distribution, and other influencing factors such as topography, rivers, and traffic. In terms of the scope of the province(Tu et al.,2021), Zhu et al. used the national key cultural heritage units of batches 1-7 and provincial cultural heritage units of Hubei province as of the end of 2015 to explore their spatial distribution center of gravity, distribution types and clustering distribution patterns in different historical periods(Zhu et al.,2016); He et al. used the Ming Great Wall heritage of Beijing from the Third National Cultural Heritage Census to explore its spatial distribution such as density distribution(He et al.,2022), longitudinal distribution and other Wu et al. use national and provincial key cultural heritage units in Yunnan Province to explore their clustering dynamics, density characteristics and influencing factors such as topography and traffic in different historical periods(Wu et al.,2022). On a regional scale, Li et al. take the 8th batch of national key cultural heritage units in the Yellow River Basin as the subject of their study, exploring their balanced distribution, spatial agglomeration, and influencing factors such as elevation, slope, culture, and population (Li et al.,2021). Zhou et al. The national key cultural preservation units in the Yellow River basin are used as the object of study to explore their spatial distribution characteristics such as density, concentration and direction, as well as factors influencing their career funding and river network density (Zhou et al.,2021). On a national scale, Xi et al. explored the density and spatial distribution characteristics of national, provincial, and county-level cultural preservation units from both historical periods and typological perspectives as of the end of 2008(Xi et al.,2013). In summary, however, these studies did not address the spatial and temporal distribution characteristics of

national, provincial, and county-level cultural heritage units in Beijing and the factors influencing them. In terms of disaster risk for cultural heritage units, scholars at home and abroad have mainly analyzed a specific cultural heritage unit or a particular material. For example, Dong studied the effects of temperature and humidity changes on the Maiji Mountain Grottoes (Dong,2000), and Bai et al. studied the effects of temperature changes on the wooden structures of ancient Tibetan buildings (Bai et al.,2017). In summary, however, these studies did not address the analysis of disasters in the wider environment within a particular region.

As the ancient capital of the Six Dynasties and the current capital, Beijing has a rich variety of cultural preservation units and a large period. In this paper, we use national key, provincial and county-level cultural preservation units in Beijing as research data, and investigate their spatial and temporal distribution characteristics and major hazard risks with the help of ArcGIS 10.2 software.

2. DATA SOURCES

Data on Beijing's national key cultural preservation units are from the National Heritage Administration's comprehensive administrative management platform (ncha.gov.cn); data on Beijing's municipal cultural preservation units are from the Beijing Municipal Bureau of Cultural Heritage (beijing.gov.cn); and data on Beijing's county-level cultural preservation units are from the basic status of China's provincial, municipal and county-level cultural preservation units, as collated and analyzed by the China Institute of Cultural Heritage. The latitude and longitude coordinates of the units were obtained from the Baidu Map system of picking up coordinates (baidu.com). The data on Beijing's administrative divisions were obtained from the 1:1 million public versions of the Basic Geographic Information Data (2021) in the National Geographic Information Resources Catalogue Service (webmap.cn), using the 2000 National Geodetic Coordinate System and the 1985 National Elevation Datum, at a scale of 1:1,000,000. (activefault-datacenter.cn). Relative humidity and temperature data for Beijing were obtained from the National Bureau of Statistics (stats.gov.cn).

3. RESEARCH METHODOLOGY

3.1 Mean Nearest Neighbor

In the ArcGIS software, the tool "Average Nearest Neighbor" is used to determine the spatial distribution pattern of each element. The tool calculates the nearest neighbor index based on the average distance between each element and its nearest neighbor, if the index is less than 1, the element tends to be aggregated in spatial distribution; if the index is greater than 1, it tends to be discrete (https://www.esri.com/). The calculation formula is as follows.

In terms of the specific algorithm, the average nearest neighbor tool first measures the distance between the center of mass of each element and the position of the center of mass of its nearest neighbor element and then calculates the average of all these nearest neighbor distances to derive the average observed

distance; whereas the expected average distance is assumed to be the average distance between neighbors in a random distribution. The formula is as follows:

$$ANN = \frac{\bar{D}_O}{\bar{D}_E} \tag{1}$$

$$\bar{D}_O = \frac{\sum_{i=1}^{n} d_i}{n} \tag{2}$$

$$\bar{D}_E = \frac{0.5}{\sqrt{n/A}} \tag{3}$$

ANN is the nearest neighbor index; $\bar{D}_O$ is the average observed distance; $\bar{D}_E$ is the expected average distance; n is the number of study samples; d_i is the distance between the point i and its nearest neighbor; A is the total study area, i.e. the area of Beijing city of 16,410,010,000 square meters.

3.2 Kernel density analysis

In the ArcGIS software, the kernel density analysis tool is often used to determine the spatial distribution density of each element, that is, the use of kernel functions to calculate the density of each element in its surrounding neighborhood and to fit each point to a smooth surface, the larger the kernel density estimate, the denser the distribution of the study object in the region. The calculation is given by:

$$f_n(x) = \frac{1}{nh} \sum_{i=1}^{n} k\left(\frac{x-x_i}{h}\right) \tag{4}$$

Where $f_n(x)$ is the kernel density estimate; n is the number of study samples; h is the bandwidth, and by default, the minimum value of the width or height of the output range is used divided by 30. The value of h in this study is taken as 6000 in meters; k is the weight function of the kernel, and because each point element in the data represents a cultural preservation unit, the value of k is taken as 1; $x - x_i$ is the distance between the density valuation point x and x_i.

3.3 Mean centers and standard deviation ellipses

In ArcGIS software, the mean center tool and the standard deviation ellipse tool are often used to determine the spatial center and directional distribution of elements. The mean center is the average x and y coordinates of all elements in the study area; the standard deviation ellipse uses the mean center as a starting point and calculates the standard deviation of the x and y coordinates of the elements at each point to determine the long axis, short axis, and direction of the ellipse (the direction represents the rotation of the long axis measured clockwise from the vertex); the number of standard deviations used in this study is 1, which allows the center of mass of approximately 68% of the total of the input elements. The formulae are as follows:

$$\tan \theta = \frac{\sum_{i=1}^{n} \Delta x_i^2 - \sum_{i=1}^{n} \Delta y_i^2 + \sqrt{\left(\sum_{i=1}^{n} \Delta x_i^2 - \sum_{i=1}^{n} \Delta y_i^2\right) + 4\left(\sum_{i=1}^{n} \Delta x_i \Delta y_i\right)^2}}{2 \sum_{i=1}^{n} \Delta x_i \Delta y_i} \tag{5}$$

$$SD_x = \sqrt{\left[\sum_{j=1}^{n} (\Delta x_i \cos \theta - \Delta y_i \sin \theta)^2\right]/n}$$

$$SD_y = \sqrt{\sum_{j=1}^{n} (\Delta y_i \cos \theta - \Delta x_i \sin \theta)^2/n} \tag{6}$$

SD_x and SD_y represent the standard deviation of the x-axes and y-axes respectively; Δx_i and Δy_i represent the deviation of the x and y coordinate points of each punctiform element from their mean centers; θ represents the angle of elliptical rotation; n represents the total number of cultural preservation units.

4. SPATIAL AND TEMPORAL DISTRIBUTION CHARACTERISTICS

Through the analysis of the information on Beijing's cultural preservation units, there are 136 national key cultural preservation units, 255 provincial-level cultural preservation units, and 793 county-level cultural preservation units, making a total of 1,184 units in Beijing. These 1,000 units are located in 16 administrative districts of Beijing, and the spatial distribution of the units is shown in ArcGIS 10.2, using the administrative divisions of Beijing as a base map and overlaying the geographical locations of the units. As can be seen from Figure 1, in general, Beijing's cultural heritage units are unevenly distributed across the administrative districts, and the administrative districts with similar numbers of units are also similarly located. Specifically, the core areas of cultural preservation units are located in Haidian District, Xicheng District, and Dongcheng District; the secondary centers of distribution are in Yanqing District, Changping District, Mentougou District, and Fangshan District; while Huairou District, Shunyi District, Chaoyang District, and Daxing District have the lowest number of units.
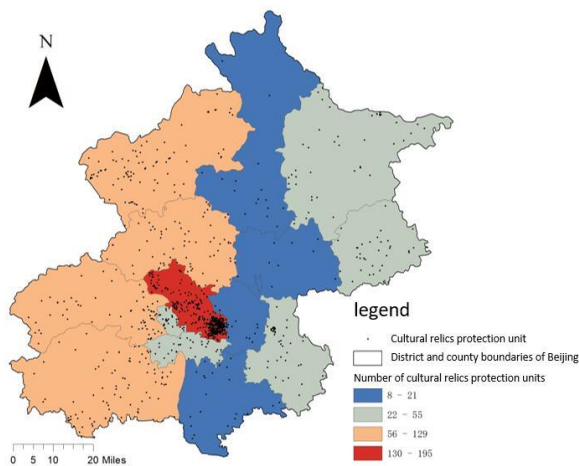

Figure 1. Spatial distribution of cultural preservation units in Beijing.

4.1 Spatial aggregation characteristics of different types of cultural preservation units

There are six types of cultural preservation units in Beijing: ancient buildings, ancient tombs, ancient ruins, cave temples and stone carvings, modern important historical sites, representative buildings, and other types of cultural preservation units. Since the number of other types of cultural preservation units is at least 18, accounting for only 1.52% of the total, and their typological characteristics are not obvious, they are not analyzed for the time being. A total of 1,184 groups of nationally important, municipal, and county-level cultural heritage units in Beijing were analyzed and summarized according to the five main types, and a statistical bar chart of Beijing's cultural heritage units was drawn up (Figure 2). As can be seen from Figure 2, overall, the number of ancient buildings is the highest, with 643; the number of modern important historical sites and representative buildings is the second highest, with 264; these two types alone account for 76.52% of Beijing's cultural preservation units. These two types alone account for 76.52% of Beijing's cultural heritage units. The number of ancient tombs is the lowest, with only 52, accounting for 4.39% of the total. In terms of administrative divisions, Miyun District lacks ancient tombs, Shijingshan District lacks ancient sites, Daxing District lacks important modern historical sites and representative buildings, Chaoyang District lacks cave temples and stone carvings, and Shunyi District lacks ancient tombs, while the other 11 administrative districts have all types of cultural preservation units.
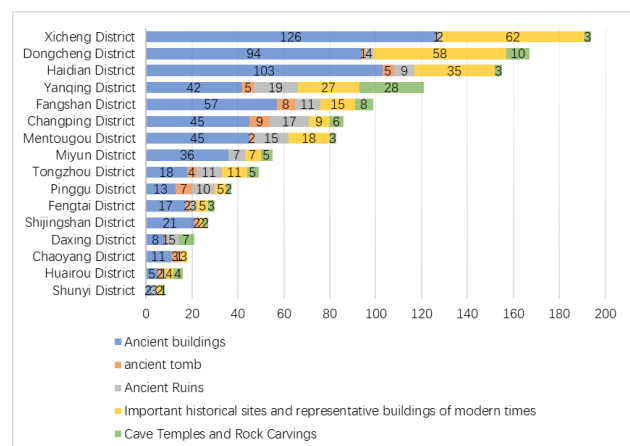

Figure 2. Statistical bar chart of Beijing's cultural preservation units by category.

To explore the spatial distribution of each type of cultural preservation unit, a table of the nearest neighbor indices of Beijing's cultural preservation units (Table 1) and a map of the kernel density of different types of cultural preservation units in Beijing (Figure 3) were calculated using the ArcGIS software tool 'average nearest neighbor. As can be seen from Table 1, in

general, the nearest neighbor indices of the different types of cultural heritage units are all less than one, indicating that they are all clustered, although the degree of clustering varies. The nearest neighbor index for modern important historical sites and representative buildings is the lowest, which means that the degree of agglomeration is the highest, while the nearest neighbor index for cave temples and stone carvings is the highest, indicating that the degree of agglomeration is the least obvious.

Specifically, Figure 3(a) shows that the core areas for the distribution of important modern historical sites and representative buildings are in the Dongcheng and Xicheng districts, where most of the units are former residences of famous people, former school sites, and courtyards with very old Beijing characteristics. There are two secondary distribution areas, the larger one involving the south-eastern part of Haidian District and the periphery of Dongcheng District and Xicheng District, where the tombs of modern celebrities, such as Liang Qichao's tomb and Qi Baishi's tomb, are distributed mainly along Xiangshan Avenue. These cultural preservation units serve as living teaching materials of the anti-Japanese war to educate the nation not to forget the national shame and inspire people to struggle for the revitalization of China (Beijing Yanqing County Cultural Committee. Memories of Guichuan,2012).

As can be seen from Figure 3(b), the ancient buildings are not only the most numerous but also the most extensive, with the core of their distribution located in the Dongcheng and Xicheng districts, mainly because these two administrative districts have been the political, economic and cultural centers of the country since the Ming and Qing dynasties (He,2022). The ancient buildings such as the Huguang Guild Hall, Anhui Guild Hall, and Hunan Guild Hall bear witness to the struggles of the young generation from outside Beijing as places where students from the same country came to Beijing to study and make a living. The secondary distribution of ancient buildings is mainly in the Haidian District, the northern part of Shijingshan District, and the western part of Mentougou District, where Buddhist buildings such as Wanshou Temple and Biyun Temple are located in the mountainous areas of Xishan and Xiangshan. The northern part of Tongzhou District, the northern part of Miyun District, and the southwestern part of Fangshan District are also mostly religious buildings such as temples, monasteries, and Taoist temples.

From Figure 3(c), it can be seen that the most concentrated area for the distribution of ancient tombs is the northwestern part of Changping District, where a total of nine tombs from the Ming and Qing dynasties are located, with the higher ranking being the Thirteen Tombs of the Royal Tombs of the Ming Dynasty and the Family Cemetery of Prince Qingxi of the Royal Tombs of the Qing Dynasty. The earliest ancient tombs in Beijing are concentrated in the south-central part of Pinggu District, such as the bronze ritual objects excavated from the Shang dynasty tombs in Liujiahe, which provide useful clues for the study of the relationship between the cultures of the Central Plains and the north, and the large area of urns in the Heng Yuan Tomb Group in the east of Mentougou District. Unlike the two types of cultural preservation units, namely modern important historical sites and representative buildings and ancient buildings, which are mainly located in the Dongcheng District and Xicheng District, there are only two ancient tombs in the central area of Beijing, namely Yuan Chonghuan's tomb and ancestral hall in the Xicheng District and the tombs of Matteo Ricci and foreign missionaries in the Dongcheng District. It can be seen that the majority of ancient burial sites are located in the peripheral areas of Beijing, away from the city center.

From Figure 3 (d) can be seen: the core area of the distribution of ancient sites is located in the northeast of Haidian District and the southwest of Changping District border area, Changping southwest of the Taihang Mountains remnants from the Beijing West Xiang Mountain to the north, in a small area of memory there are five major sites of the Qing Dynasty Bao Yun Temple, Che Yun Temple, Qing Qing Qing Yun Temple, Shi Yun Temple and Danyun Temple, plus the site of the Temple above Haidian District, folk have "five temples hold above "The ancient sites in the western core distribution area of Yanqing District have a much longer history, with the Hujiaying site being the largest Eastern Zhou settlement site found in Beijing, providing new material for exploring the cultural affiliation of the area and the exchange between northern and southern cultures; while the secondary distribution areas of ancient sites in Dongcheng District and Xicheng District are larger in area but their historical phasing is more backward.

As can be seen from Figure 3(e), there are two main core areas of cave temples and rock carvings, one near the city center in the Dongcheng and Xicheng Districts and more in the Dongcheng District, mainly because the Beijing Rock Carving Art Museum is located in the Dongcheng District and some of the scattered and difficult to protect rock carvings are found there. The other core area is located at the border between Yanqing and Changping and has been developed largely since the Song dynasty, mainly involving waterfront rock carvings, cliff statues, stone carvings within temples, merit monuments, and boundary markers.

type	the average observed distance(km)	the expected average distance(km)	the number of study samples	z	the total study area(K ㎡)	Spatial distribution type	Clustering degree sorting
modern important historical sites, representative buildings	1.88	4.17	0.4498	-17.07	18295.74	gather	1
ncient buildings	1.41	2.9	0.4845	-25.01	21652.22	gather	2
ancient tombs	5.44	7.9	0.6884	-4.3	12967.66	gather	3
ancient ruins	4.27	6.2	0.6887	-6.47	18133.92	gather	4
cave temples and stone carvings	4.84	6.97	0.694	-5.55	17500.5	gather	5

Table 1. Nearest Neighbor Index for Beijing's Cultural Heritage Units.
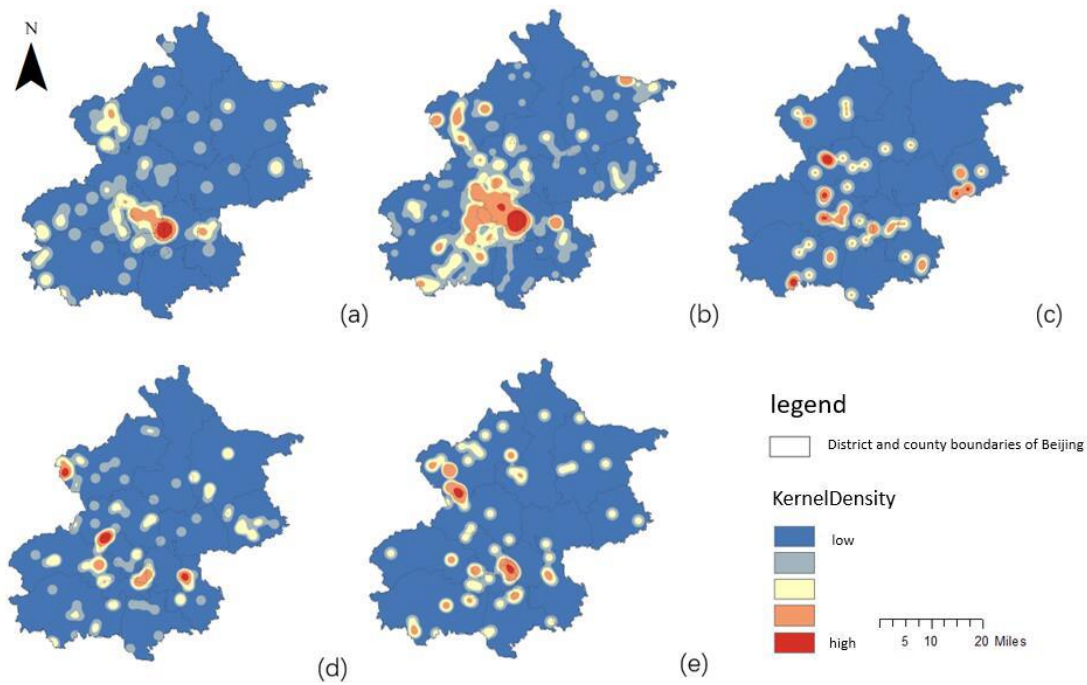
Figure 3. Kernel density map of different types of cultural preservation units in Beijing.

4.2 Spatial orientation characteristics of cultural preservation units in different periods

According to the period of Beijing's cultural preservation units and their historical background, the time dimension of the study is divided into five historical periods: the pre-Qin period, the Qin and Han periods, the Sui and Tang periods, the Song, Yuan, Liao and Jin periods, the Ming and Qing periods, and the modern period, and the historical periods.

The 33 cultural preservation units listed as pending were not analyzed for the time being. A total of 1184 groups of nationally important, municipal, and county-level cultural heritage units in Beijing were analyzed and summarised according to six main historical periods, and a bar chart of the historical periods of Beijing's cultural heritage units was drawn up (Figure 4). Figure 3 shows that, overall, the largest number of units in Beijing is from the Ming and Qing dynasties, with 754 units; the next largest number of units from the modern era is 232 units; these two periods alone account for 82.28% of the total number of units, while the Sui and Tang dynasties have the lowest number of units, with only 19 units accounting for 1.6% of the total number. In terms of administrative districts, Yanqing District has the largest number of cultural preservation units from the pre-Qin period and Fangshan District has the largest number of units from before the Ming Dynasty, indicating that these two districts have a relatively long history and deeper cultural heritage; Xicheng District and Dongcheng District have a larger number of cultural preservation units but are of a later period, having developed basically from the Song Dynasty onwards; while Shunyi District, Huairou District, Chaoyang District and Daxing District Shunyi, Huairou, Chaoyang and Daxing Districts are in the category of districts with a small number of units and a later historical period.
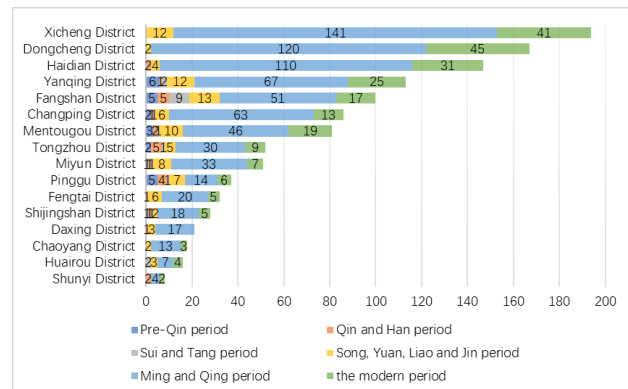

Figure 4. Bar Chart of Historical Stages of Cultural Preservation Units in Beijing.

To further illustrate the spatial distribution of cultural heritage units in each historical period, a line graph of the nearest neighbor index of Beijing's cultural heritage units was obtained using the average nearest neighbor tool in the ArcGIS software (Figure 5). The nearest neighbor indices for the most historical periods before the Qin Dynasty and after the Tang Dynasty are all less than 1, i.e. they are all clustered; while the nearest neighbor indices between the Qin and Tang Dynasties are all greater than 1, i.e. they tend to be more discrete. In general, although the degree of agglomeration fluctuates from one period to the next, the overall agglomeration of the units is increasing.
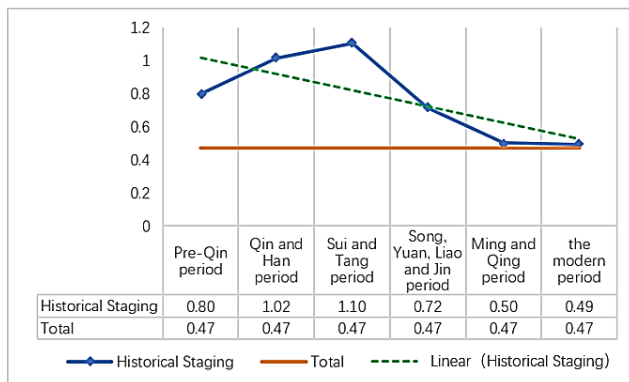
Figure 5. Nearest Neighbor Index for Beijing's Cultural Heritage Units.

To represent the spatial orientation of Beijing's cultural heritage units in each historical period, the mean center and standard deviation ellipse tools in the ArcGIS software were used to obtain the standard deviation ellipse distribution of Beijing's cultural heritage units (Figure 6), and the standard deviation ellipse analysis table of Beijing's cultural heritage units (Table 2). The ellipse analysis table (Table 2), the eccentricity of the standard deviation ellipse of Beijing's cultural conservation units (Figure 7), and the mean center of Beijing's cultural conservation units (Figure 8). From Figure 6, Table 2, Figure 7, and Figure 8, it can be seen that the standard deviation ellipse of Beijing's cultural preservation units has a rotation angle of 42.44° and an eccentricity of 0.6, indicating a narrow northeast-southwest distribution, with the overall center located in the eastern part of Haidian District. Xicheng District and Dongcheng District, most of Changping District and Shunyi District, and a small part of Mentougou District, Fangshan District, Daxing District, Tongzhou District, and Huairou District, but not Miyun District and Pinggu District in northeastern Beijing and Yanqing District in the northwest.

In terms of specific phases, the standard deviation ellipse of the pre-Qin period is not only the largest in the area but also has the longest length and shortest axes, indicating that the distribution of cultural preservation units in this period is closest to the periphery of Beijing, with the largest number of units in Yanqing District being six, followed by five in Pinggu District and five in Fangshan District. The first of these are the ruins of Lujiahe and Cai Mugou, both of which date from the Palaeolithic period, but the ranking of the units in this district is county level.

The largest angle of rotation of the standard deviation ellipse during the Qin, Han, and Three Kingdoms periods indicates a distribution closer to the east-west direction, with Fangshan District and Tongzhou District in the south of Beijing being the most numerous, followed by Pinggu District in the east. After the destruction of the Six Kingdoms by the Qin Dynasty, Jicheng, the new capital of the State of Yan, became the capital of Guangyang County, and during the Han Dynasty, it was the seat of three separate feudal states. In this context, the short reign of the Qin dynasty and the warfare that began with the fall of the Han dynasty led to the greatest number of cultural and conservation units remaining from this period, most of them from the Han

dynasty. As a result, many cultural and conservation units remain from the Han dynasty, including the ruins of Guangyangcheng, Changgou Tucheng, and Doudian Tucheng, which are of great value for understanding the social life and political and economic development of the area during the Han dynasty.

The eccentricity of the standard deviation ellipse is highest during the Sui and Tang dynasties, indicating the narrowest spatial distribution of the units, with the core of their distribution located in Fangshan District in the south-west and Huairou District in the north-east of Beijing. During the Sui and Tang dynasties, Youzhou was a major multi-ethnic city in the northern part of the city, under the control of the unified Chinese dynasty, as it was a necessary route for the emperor to conquer the Goguryeo kingdom to the north-west and a military town to defend against the encroachment of northern tribes, mainly the Khitan. Against the backdrop of the intermingling of cultures, 12 of the 19 cultural preservation units in Beijing from this period are Buddhist-related relics such as pagodas, statues, and temples, such as the Yunju Temple in Fangshan and the cliff statues at Dayugou and the Hongluo Temple in Huairou, showing the prevalence and prosperity of Buddhist culture during the Sui and Tang dynasties.

The Song, Yuan, Liao, and Jin periods were important periods in the transformation of the distribution area of Beijing's cultural preservation units from the periphery to the center, and from this period onwards the extent and direction of the standard deviation oval of each dynasty ceased to change significantly. In terms of historical development, the Liao, Jin, and Yuan dynasties were all minority regimes, with the Liao using Youzhou as the accompanying capital as a center for the integration and cohesion of the Khitan and Han peoples, and at this time the main cultural heritage units in Beijing were Buddhist temples and pagodas. After the Yuan dynasty destroyed the Southern Song Dynasty, China once again became a unified, prosperous, and powerful country, and since then Beijing has been used as the capital of the Ming, Qing, and Republican Dynasties.

The standard deviation ellipse of the Ming and Qing dynasties was similar to that of the Song, Yuan, Liao, and Jin dynasties when feudal centralization reached its peak and the eccentricity of the standard deviation ellipse was at its lowest. In recent times, the standard deviation ellipse has increased in extent and its eccentricity has risen, mainly because with economic development and population growth, the area around the imperial city could no longer meet the resources needed for social progress, so the city naturally developed outwards, and the cultural heritage units expanded accordingly.

The average distribution of the centers in the various historical periods shows that the trajectory of the centers has been alternately east-west and north-south, except for the three states of the Qin and Han dynasties, when they were located in Changping District, the three states of the Qin and Han dynasties, when they were located in Chaoyang District, and the Sui and Tang dynasties, when they were located in Mentougou District. This is mainly because from the Sui and Tang dynasties onwards Beijing was mainly a major town the dynasties, while from the Yuan dynasty onwards the political, economic, and cultural center of China was located in Beijing.
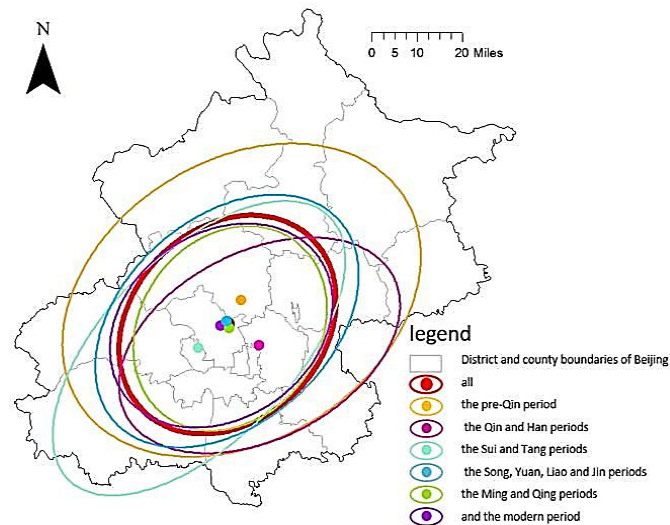
Figure 6. Oval distribution of standard deviations of cultural preservation units in Beijing.

period	Central coordinates	District and county of the center	area (km²)	major axis (km)	minor axis (km)	rotation angle（°）
Pre-Qin period	116°21′38.41″E, 40°06′49.33″N	Changping	10857.73	50.24	68.80	56.75
Qin and Han period	116°26′09.78″E, 39°58′00.16″N	Chaoyang	5669.34	33.58	53.74	62.13
Sui and Tang period	116°11′05.42″E, 39°57′23.62″N	Shijingshan	6985.48	33.51	66.36	44.06
Song, Yuan, Liao and Jin period	116°18′00.13″E, 40°02′43.34″N	Haidian	6251.50	36.84	54.03	47.26
Ming and Qing period	116°18′46.44″E, 40°01′18.66″N	Haidian	3915.19	31.88	39.09	35.25
the modern period	116°16′33.20″E, 40°01′48.98″N	Haidian	4449.21	33.25	42.59	53.93
Total	116°18′11.49″E, 40°01′59.23″N	Haidian	4664.99	34.39	43.18	42.44

Table 2. Standard deviation ellipse analysis of Beijing's cultural preservation units.

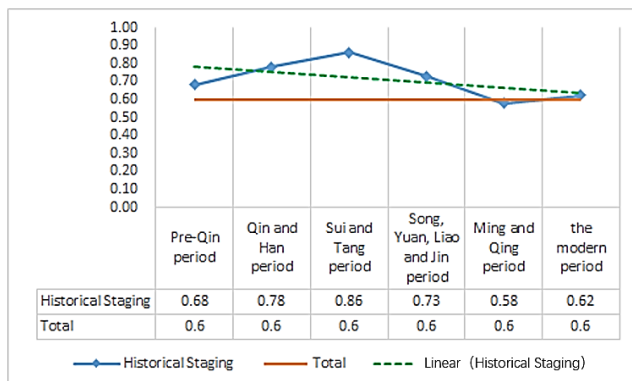|	Pre-Qin period	Qin and Han period	Sui and Tang period	Song, Yuan, Liao and Jin period	Ming and Qing period	the modern period
Historical Staging	0.68	0.78	0.86	0.73	0.58	0.62
Total	0.6	0.6	0.6	0.6	0.6	0.6

Figure 7. Standard deviation ellipse eccentricity of Beijing's cultural heritage units.
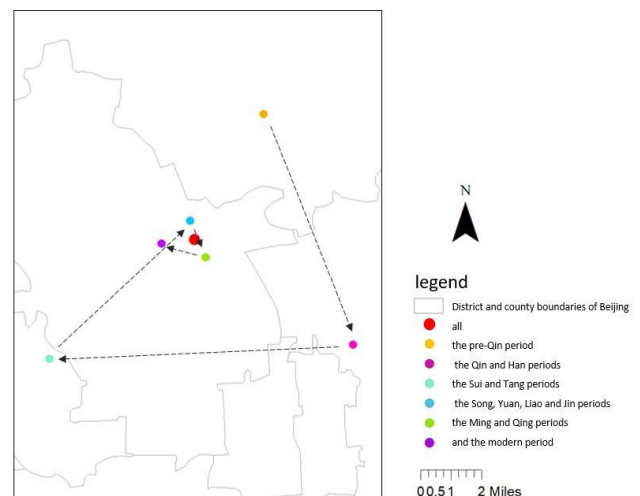

Figure 8. Shifting center of gravity of the distribution of cultural preservation units in Beijing.

5. DISASTER RISK ANALYSIS

5.1 The impact of earthquakes on heritage conservation units

Earthquakes often cause serious casualties and can cause secondary disasters such as fires, floods, landslides, cave-ins, and fissures (ZHU et al.,2010). Beijing is located in the North China Plain seismic zone, which ranks second in the country in terms of earthquake intensity and frequency, and is a key earthquake defense area (Zhu,2019). As far as cultural preservation units are concerned, earthquakes are prone to damage such as cracking of building beams and collapse of walls, subsidence of ancient tombs, the burial of ancient sites, and tipping and falling of cave temples and stone carving elements (An et al.,2022). To illustrate the spatial seismic safety assessment of different levels of cultural heritage units in Beijing, a seismic intensity distribution map of Beijing's cultural heritage units (Figure 9) and a seismic fault distribution map of Beijing's cultural heritage units (Figure 10) were drawn up and used to analyze the different levels of seismic damage to cultural heritage units, thus providing the most basic reference for future disaster risk management and prevention (Li,2021).
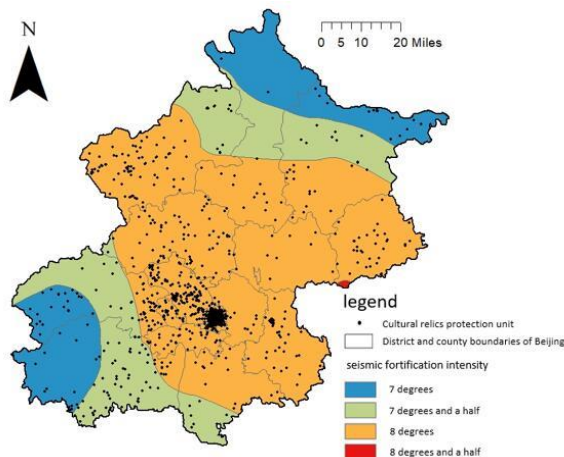

Figure 9. Seismic Intensity and Seismic Fault Distribution of Beijing's Cultural Heritage Units.
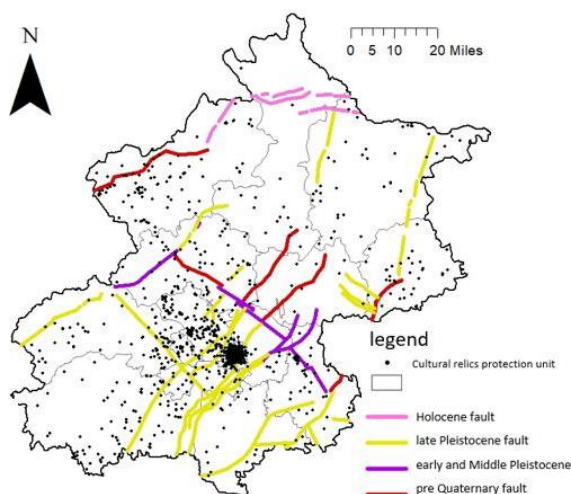

Figure 10. Distribution of seismic faults in cultural heritage units in Beijing.

In terms of seismic intensity, Figure 9 shows that the overall seismic intensity in Beijing is low in the north and low in the south, and high in the center (Zhao et al.,2020). The seismic intensity indicates the degree of impact and damage to the ground and engineering buildings and is graded from 1 to 12 degrees, with the higher the degree the greater the damage. The first three levels have 75, 104, and 1005 cultural heritage sites, accounting for 6%, 9%, and 85% of the total number of cultural heritage sites in the region, while there are no cultural heritage sites within the 8.5-degree range. It is evident that the most devastated areas of the city do not need to spend a lot of money and resources on the protection of cultural heritage units, while the central region, with the largest area and the largest number of cultural heritage units at 8 degrees, is a key area for seismic protection.

In terms of seismic faults, Figure 9 shows that the distribution of seismic faults in Beijing is uneven, with a general pattern of fewer faults in the north and more in the west and earlier in the north and later in the center. Seismic faults are a type of rupture structure in the crustal rocks that are significantly displaced along the rupture surface (Gan,2020). Faults that have been active since 120,000 years ago are called active faults, including Late Pleistocene faults and Holocene faults, which have a high seismic hazard. In all major earthquakes, houses collapsed and casualties were severe in the earthquake fault zone, but the situation outside the earthquake fault zone is much better (Yuan et al.,2022). In accordance with the Urban Seismic Disaster Prevention Standards, it is absolutely forbidden to construct buildings within 50m of an earthquake fault zone, and for active fault zones where the location cannot be determined, buildings are required to stay 200m away, while evacuation buildings should be at least 500m away from the active fault zone (Mou,2020). Using this as a criterion, the spatial distribution map of cultural preservation units in Beijing was overlaid with the earthquake fault map for buffer zone analysis, and the number of cultural preservation units within the 50m, 200m, and 500m buffer zones were 15, 41 and 95 respectively, accounting for 1%, 3% and 8% of the total number of cultural relics in the region. Further analysis shows that there are 13 seismic faults in Beijing with cultural preservation units within the 500m buffer zone, with the Shunyi-Liangxiang fault zone having the highest number of units, followed by the Nankou-Sunhe fault zone, as shown in Figure 10, which provides a strong reference for more accurate identification of which faults are more threatening to cultural preservation units.
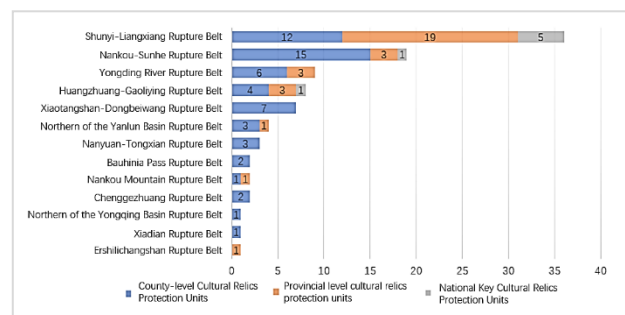

Figure 11. Number of cultural preservation units within the 500m buffer zone of seismic faults in Beijing.

5.2 The impact of temperature and humidity on heritage conservation units

Unlike museums, where movable cultural objects are kept at a constant temperature and humidity, cultural heritage units are

more exposed to the outside world due to their size and size, which makes them more susceptible to damage due to climate change (Liu et al.,2020). In the case of wooden buildings, changes in temperature and humidity can cause cracking and decay, while stone buildings are prone to corrosion and loosening (Ning et al.,2019). If wood and stone are damaged by changes in temperature and humidity over the years, these color materials are more susceptible to fading, discoloration, and peeling caused by subtle changes in temperature and humidity (Wang et al.,2009).

Beijing's climate is typical of a warm temperate semi-humid continental monsoon climate, with hot and rainy summers, cold and dry winters, and short springs and autumns. From a microscopic point of view, combining the monthly average relative humidity and average temperature data in Beijing for the twenty-three years from 1998 to 2020, the lowest monthly average humidity in Beijing occurred in March 2011 at 25%; the highest monthly average humidity occurred in July 1998 at 79%; the relative humidity difference was 54%. The monthly average minimum temperature in Beijing occurred in January 2010 at -6.4°C; the monthly average maximum humidity occurred in July 2020 at 29.6°C, with an average temperature difference of 36°C. On a macro level, in order to more accurately measure the changes in temperature and humidity in Beijing over a longer period of time, a discounted annual average relative humidity and annual average temperature for Beijing from 1998 to 2020 were plotted (Figure 11). As can be seen from Figure 11: the annual average humidity in Beijing ranges from 48% to 62% and the annual average temperature ranges from 12.6°C to 14.2°C, both of which fluctuate relatively little. However, in general terms, there is a trend toward lower relative humidity and higher temperatures in Beijing in general.
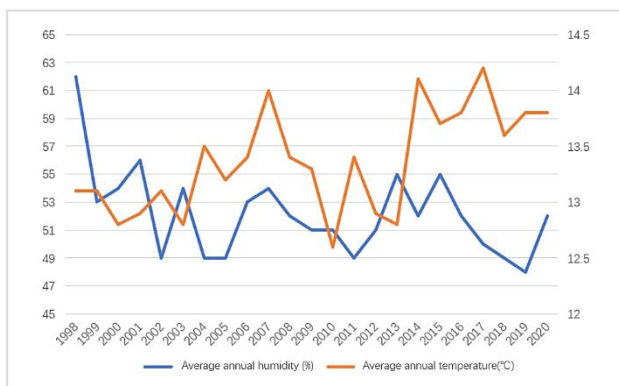

Figure 12. Discounted annual average relative humidity and annual average temperature from 1998 to 2020.

The better preservation conditions for cultural relics of different materials vary: stone tools, inscriptions, petroglyphs, painted clay sculptures, and other rock materials should be stored at a humidity of between 40% and 50% and a temperature of around 20°C; lacquerware, wood, bamboo, furniture, prints and other bamboo and wood materials should be stored at a humidity of between 50% and 60% and a temperature of around 20°C. So, all things considered, a climate with a relative humidity of 40%-60% and a temperature of around 20°C is more suitable for the preservation and protection of cultural relics (Dai,2021). Over the past five years, the average relative humidity in Beijing has been 50.2% and is still on the decline, which is good for the conservation of stone artifacts, but less so for bamboo and wood artifacts. The reduction in humidity leads to a reduction in the water content of bamboo and wood, which is an important factor

in the cracking and deformation of bamboo and wood. In terms of temperature, the average temperature in Beijing over the last five years is 13.84°C. Although there is still a trend towards higher temperatures, there is still a large gap between 20°C and 20°C, which is suitable for heritage conservation, and this can easily lead to cracking of masonry and aging of bamboo and wood. The thermal expansion and contraction caused by the 30-degree temperature difference between winter and summer in Beijing can easily cause the material to lose its elasticity and loosen its bonds.

6. CONCLUSIONS

1. Different types of cultural preservation units in Beijing are clustered, with five types of units, namely modern important historical sites and representative buildings, ancient buildings, ancient tombs, ancient ruins, cave temples, and stone carvings, decreasing in degree of clustering and spreading from central Beijing to the periphery of the core area.

2. The distribution of cultural preservation units in Beijing is also uneven from one period to the next, with the peripheral period being earlier and the central period later, but the distribution direction is northeast and southwest.

3. Beijing's cultural preservation units intersect more with seismic hazard areas, and those located in areas of high seismic hazard are mainly concentrated in Dongcheng District, Xicheng District, Haidian District, and Mentougou District.

4. The average relative humidity in Beijing over the years is 52.17%, which is good for preserving units of different materials; its average temperature over the years is 13.36°C, which is much lower than its best preservation temperature. However, in recent years, the relative humidity in Beijing has shown a downward trend, while the temperature has shown an upward trend, which is not conducive to the conservation of cultural preservation units. Therefore, the authorities should carry out long-term and careful climate monitoring of the units to avoid irreparable damage.

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